FISHERIES RESOURCES PROFILES:
PAPUA NEW GUINEA

Prepared by

Patricia J. Kailola

with support from
Joel Opnai, Augustine Mobiha, Cathy Hair, Molean Chapau,
Philip Polon, Ursula Kolkolo, Chris Evans and Petrus Sagom[1]
and
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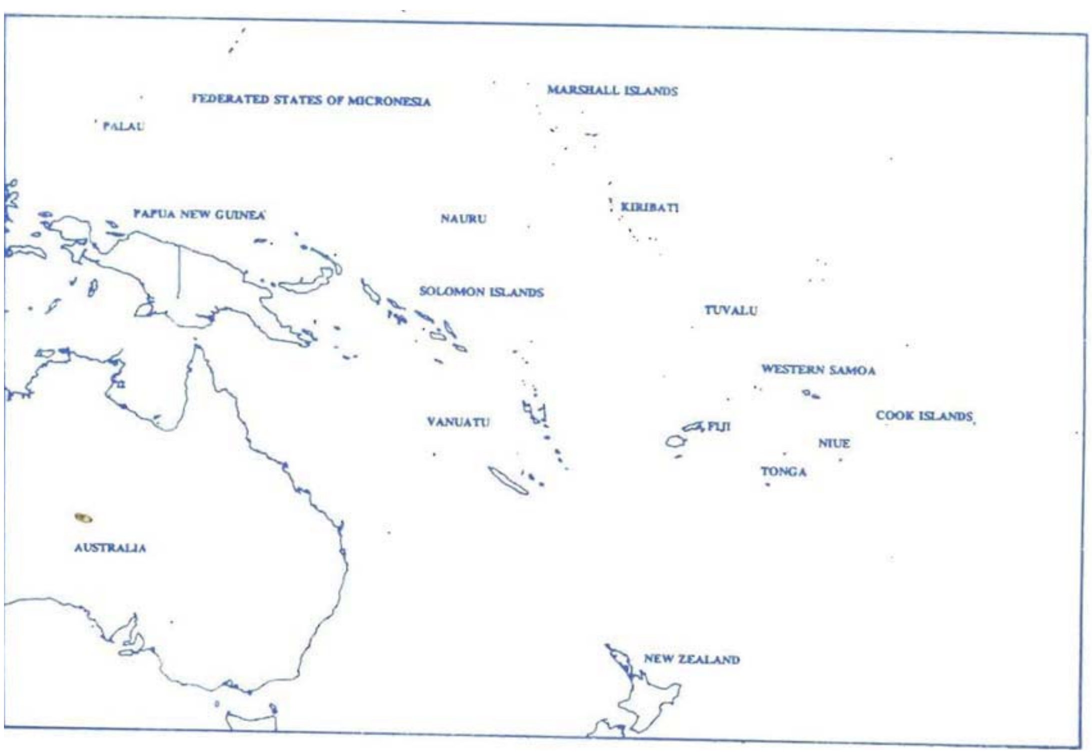
FFA Report No.95/45



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PREFACE

The Government of Papua New Guinea (PNG) requested assistance from the South Pacific Forum Fisheries Agency (FFA) in compiling a set of fisheries resources profiles. These profiles were to provide an overview of the fisheries and marine resources identified as being of importance to the commercial, artisanal and subsistence fisheries sectors in PNG. The main purpose was to provide the basic information required to assess the current levels of exploitation, and to identify the research and management requirements for future developments.

The Terms of Reference adopted were similar to those used for resources profiles already completed for other FFA member countries:

1. With assistance from national fisheries staff and FFA Research Co-ordination Unit staff, examine closed and current files pertaining to fisheries resources matters in PNG, including aquaculture and inland fisheries stock enhancement;
2. Assess, collate and compile written matter, data, etc., which provides information relating to resource abundance, distribution, exploitation, etc., in PNG;
3. Review existing legislation controlling the exploitation of living marine and freshwater resources in PNG, and advise on appropriate regulations for controlling the existing fisheries for those resources currently not protected;
4. Based on the information examined, produce a comprehensive set of resource profiles for the fisheries and marine resources of PNG, including riverine fisheries and aquaculture.

The present report was prepared over several months following two-month's of field work in PNG during July and August 1994. In consultation with Research and Surveys staff of the Department of Fisheries and Marine Resources and Mr Andrew Richards of FFA, 49 groups of fisheries resources were identified as important to either or all subsistence, artisanal or commercial fisheries sectors in PNG. These resources span marine, estuarine and fresh waters. Some of the identified resources (e.g. threadfin salmon, sponges, seaweed, Fly River herring, nearshore pelagics) have potential importance. Time and resource restraints precluded preparation of profiles on turtles, crocodiles and dugongs, even though I recognise them as important resources, mainly for the subsistence and artisanal fishing communities.

The format for each profile is composed of five sections -

(i) a brief description of the resource (species present, their distribution, biology and ecology);

(ii) an overview of the existing fishery (utilisation, production, marketing);

(iii) the status of the stocks;

(iv) management (current legislation, policies regarding exploitation, recommended management options); and

(v) references.

The preparation and documentation of this report was funded by the United Nations Development Programme (UNDP) under the FFA/South Pacific Commission (SPC) Regional Fisheries Support and National Capacity Building Programme and the Government of Canada through the Canadian International Development Assistance (CIDA) under FFA's Research Co-ordination Unit. The assistance provided by Mr Joseph Gabut, Secretary of the Department of Fisheries and Marine Resources, and his staff, is greatly appreciated. Support was also provided in PNG by:

Port Moresby - Maurice Brownjohn, George Habib, Barry Shackles, Papena Gamini, members of the Port Moresby Gamefishing Club (particularly Terry Priest) and the Port Moresby Recreational Fishermens' Club (particularly Dale McCarthy).

Madang - Theo Visser of SRFSEP, and Hubert Bingeli and Alois Koyo.

Lae - Peter Jacob, Alberta Tumonde and other staff at MOMASE fisheries, and members of the Lae Gamefishing Club (particularly Darryl Goile and Jan Hardy).

Rabaul - Gisa Komaneng of DFMR

In Solomon Islands, Noel Omeri and other FFA staff, and Johann Bell and staff of ICLARM gave assistance. Paul Dalzell (SPC, Noumea) provided information. Several former colleagues in Australia provided support and reviews, including Mike King, John Stevens, Cathy Colgan, Warwick Nash, Stewart Frusher, Albert Caton, Richard Tilzey, Phil Cadwallader, Marc Wilson, Grant West, Felicia Kow, Mike Potter, Julie Lloyd, Allan Haines, Mike Cappo, Dean Butler, Gustaaf Hallegraeff, Geoff Williams, Shirley Slack-Smith, Clive Keenan, Loisette Marsh, Chan Lee, David (Dos) O'Sullivan, Clive Jones, Nick Ruello and Shirley Sorokin. The Bureau of Resource Sciences (Canberra) and the Australian Maritime College (Launceston) generously provided support facilities.

However, I, Patricia Kailola assume full responsibility for the contents of this report. Opinions expressed are mine alone and in no way reflect the policy of the FFA, the PNG National Fisheries Authority, the PNG Government or any other institution or individual.

LIST OF ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AIDAB	Australian International Development and Assistance Bureau (now AusAID)
C.I.F.	Cost, insurance and freight inclusive quotation
CITES	Convention on International Trade in Endangered Species of Wildlife
CL	Carapace length
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DFMR	Department of Fisheries and Marine Resources
DFZ	Declared Fishing Zone
DWFN	Distant Water Fishing Nation
EEZ	Exclusive Economic Zone
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organisation of the United Nations
FFA	South Pacific Forum Fisheries Agency
FL	Fork length
F.O.B.	Free on board
FSM	Federated States of Micronesia
GDP	Gross Domestic Product
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
ICLARM	International Center for Living Aquatic Resource Management
IPA	Investment Promotion Authority
IUCN	International Union for the Conservation of Nature
JICA	Japanese International Cooperation Agency
MEY	Maximum economic yield
MOMASE	Morobe, Madang and East Sepik
MSY	Maximum sustainable yield
NFA	National Fisheries Authority
NZ	New Zealand
PNG	Papua New Guinea
SCUBA	Self Contained Underwater Breathing Apparatus
SRFSEP	Sepik River Fish Stock Enhancement Programme
SPC	South Pacific Commission
TBAP	Tuna and Billfish Assessment Programme
TL	Total length
TSPZ	Torres Strait Protected Zone
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
USA	United States of America
UVC	Underwater Visual Census

TABLE OF CONTENTS

SUMMARY

Papua New Guinea (PNG) comprises the eastern half of the island of New Guinea, located in the western Pacific, between the Equator and 12° South, and 141° - 160° East. It has a total land area (mainland and more than 600 islands) of approximately 463,000 km^2. Its Declared Fishing Zone (DFZ) has an area of approximately 2.3 million km^2.

It is estimated that the population at the end of 1995 totaled 4.1 million, with an annual population growth rate of approximately 2.3 per cent. PNG is culturally diverse with between 700-800 different languages and dialects. Nearly 40 per cent of the population live in the densely-inhabited Highlands provinces and only about 13 per cent in coastal rural areas.

Approximately 85 per cent of the population is engaged in subsistence agriculture which is undertaken in association with subsistence fishing, primarily in coastal areas. Fishing is the dominant activity where land is in short supply, e.g. the outer islands. Freshwater fish stocks are increasingly being fished as sources of protein, particularly in Highlands areas, and there have been attempts to increase production in freshwaters through aquaculture and species introductions.

PNG is an independent state within the Commonwealth. The nation is governed under a Westminster system based on a written constitution and a single legislative house known as the National Parliament, with national elections every five years. Until July 1995, the country was divided into 19 administrative provinces, each with its own elected government. A new provincial government system has now been established.

Although PNG has an abundance of natural resources, with heavy dependence on the exports of gold, copper and petroleum, and tree crops and forestry products, the standard of living of most Papua New Guineans has declined in real terms over the last decade. The contribution of fisheries resources to the national economy has fluctuated markedly over the past 20 years, with fisheries products, principally trochus and bêche-de-mer, now contributing less than one per cent of national exports. Steps are being taken by the national government to encourage the exploitation of PNG's substantial tuna stocks. The careful management of these and other fisheries resources may set the stage for increasing significance of fisheries exports in the national economy.

Responsibility for fisheries matters lies with the National Fisheries Authority (previously the Department of Fisheries and Marine Resources) under the Minister for Fisheries and Marine Resources. The Executive Director of the National Fisheries Authority (NFA) is responsible to a board composed of government and private sector appointed representatives, and oversees the work of the Authority which has its headquarters at Port Moresby on the southern coast of the mainland. It is planned that the NFA will also have regional offices in Kavieng, Madang and the Highlands.

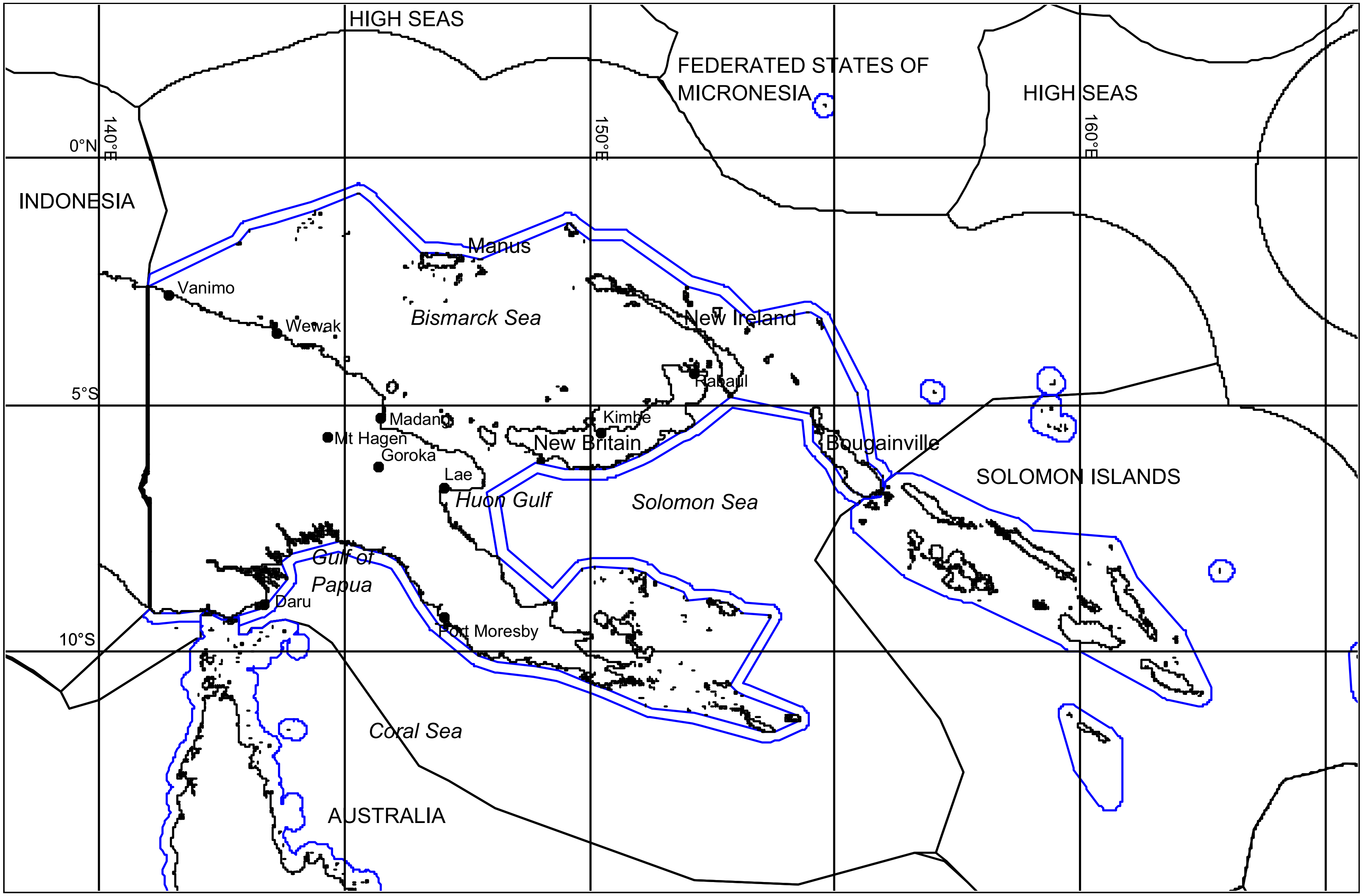
The key programmes to be undertaken by the NFA include the development of a local tuna industry, enablement of artisanal fisheries development, augmentation of the production capacity of inland river systems through stocking, maximisation of the rent from distant water tuna fisheries and strengthening of the institutional capacity of the NFA to make it more client-supportive.

Papua New Guinea has a fisheries college which for the past 18 years has provided education and training in fisheries technology at Certificate level. The University of PNG offers fisheries-orientated material in its Science (biology) degree course.

The laws relating to marine resources in PNG are enshrined in a new Fisheries Act passed in 1994. This fisheries legislation goes considerably further than that of other Pacific countries in that it combines management of domestic fisheries with regionally integrated control of the Pacific distant water tuna fishing industry. There are several other Acts related to fisheries matters.

The three main categories of fishing in PNG are subsistence, artisanal and commercial/industrial, with recreational fishing being of minor importance. Whereas resources such as sea cucumber, trochus, green snail and penaeid prawns are being harvested at or near maximum sustainable yield, many other marine resources are considerably under-utilised. There are several constraining factors to this situation, all of which need to be addressed if fisheries resources are to significantly contribute to the nation's development.

Papua New Guinea has actively contributed towards the development of several regional and international agreements relating to fisheries, and discharges its obligations under these to the fullest possible extent, as befits its status as the largest of the Pacific Island countries.


HIGH SEAS
FEDERATED STATES OF
MICRONESIA
HIGH SEAS
0°N
140°E
150°E
160°E
INDONESIA
Manus
Vanimo
Wewak
Bismarck Sea
New Ireland
Rabaul
5°S
Madang
Kimbe
Mt Hagen
New Britain
Bougainville
Goroka
Lae
SOLOMON ISLANDS
Huon Gulf
Solomon Sea
Gulf of
Papua
Daru
Port Moresby
10°S
Coral Sea
AUSTRALIA

A. BACKGROUND

A.1 THE COUNTRY

Papua New Guinea (PNG) is located in the Western Pacific between the Equator and 12° South, and 141° - 160°E, comprising the eastern half of the island of New Guinea. It is the largest of the Pacific Island countries, having a total land area (mainland and islands) of about 463,000 km^2. PNG comprises more than 600 islands.

The main island of New Guinea, New Britain, New Ireland and Bougainville have rugged mountains occupying their central areas. Whereas on the mainland the river systems have formed extensive lowland areas and delta systems, the rivers on other islands are short and fast-flowing, and there are limited coastal lowlands. Remaining islands are either coralliform or rugged. There are extensive island groups in the Milne Bay and Manus Provinces.

There are an estimated 40,000 km^2 of coral reefs to a depth of 30 m (Dalzell and Wright, 1986). Along with Indonesia and the Philippines, PNG lies in the Indo-West Pacific biogeographic centre of coral diversity, and PNG's reefs are among the most diverse in the world.

On mainland PNG, the main river systems are the Sepik-Ramu in the north, the Fly-Strickland in the south-west and the extensive Kikori-Purari flowing into the Gulf of Papua. There are over 150,000 ha of mangrove habitat in the Gulf of Papua coastal and delta area. The Markham River in the east and rivers in the south-east are significant in terms of outflow.

The country shares a land border with Indonesia (West Irian) and sea borders with Australia, the Federated States of Micronesia (FSM) and Solomon Islands. PNG's 200 nautical mile Declared Fishing Zone (DFZ) has an area of 2.3 million km^2 of ocean.

A.2 THE PEOPLE

It has been established that man was in the New Guinea highlands at least by 8,000 BC, and it is probable that the first arrival of man in New Guinea was as early as 30,000 years ago. There appear to have been several migrations from Asia by way of Indonesia over a great length of time. Modern day Papua New Guineans are generally Melanesian, although the eastern islands populations have been influenced by Polynesian stocks. There is considerable phenotypic diversity among the people, a product of their origin and separations caused by the rugged topography and stretches of sea between some island groups.

Cultural diversity is remarkable as well. There are an estimated (1995) 4.1 million inhabitants of PNG (with an annual population growth rate of approximately 2.3 per cent) and between 700 - 800 different languages and dialects. The *lingua franca* is Pidgin with Police Motu spoken extensively in southern areas. English is the language of commerce and educational systems.

Nearly 40 per cent of the population live in the densely-inhabited Highlands provinces (Eastern Highlands, Simbu, Western Highlands, Southern Highlands and Enga) and only about 13 per cent in coastal rural areas. There are large populations drawn from all provinces in the main towns, particularly Port Moresby (> 200,000) and Lae.

Much of the population, approximately 85 per cent, is engaged in subsistence agriculture and this is undertaken in association with subsistence fishing, primarily in coastal areas. Fishing is the dominant activity where land is in short supply - e.g. on small islands. However, freshwater fish stocks are being increasingly fished as sources of protein - particularly in

Highlands areas - and there have been attempts to increase production in freshwaters through aquaculture and species introductions.

A.3 THE GOVERNMENT

Prior to achieving full independence in 1975, Papua was an external territory of Australia and New Guinea was administered by Australia as a UN trust territory. PNG is an independent state within the Commonwealth with Queen Elizabeth II as Head of State. She is represented in PNG by a Governor-General who is appointed by the Queen acting with the National Executive Council, which consists of all the the Ministers with the Prime Minister acting as chairman.

The nation is governed under a Westminster system based on a written constitution and a single legislative house known as the National Parliament. There are 109 seats in the National Parliament. Elections are held normally every five years and voting is compulsory. The national capital is located at Port Moresby on the southern coast.

Until 1995, the country was divided into 19 administrative provinces, each with its own elected government. There was also a developing system of Local-level Governments. With the passing of a new Organic Law on Provincial Governments and Local-level Governments in July 1995, a new provincial government system was established. The new bill has essentially changed the composition of provincial governments whereby national ministers have given themselves seats in provincial governments along with other elected representatives from the local-level governments and other community interest groups such as women. The regional member has the option of taking up the governorship of the province while the deputy governor is elected from amoung the local government and area authority representatives (Temu *et al*., 1995).

A.4 THE ECONOMY

A.4.1 Recent Economic Performance

Papua New Guinea has an abundance of natural resources. The national economy is heavily dependent on exports of minerals, principally gold, copper and petroleum and, to a certain extent, tree crops (coffee, cocoa, copra and palm oil) and forestry products (Table 1) (Campbell and Owen, 1994).

Table 1 Value of exports from Papua New Guinea, 1980-1993 (in millions of Kina)

	1980	1983	1987	1990	1993
Minerals	500.0	425.3	714.9	757.5	1997.0
Coffee	183.8	108.0	134.7	103.5	105.4
Cocoa	72.1	47.2	56.2	29.9	37.9
Forestry products	71.0	62.4	110.9	79.6	112.8
Copra products	38.0	27.4	29.7	20.3	26.9
Palm oil	25.7	22.8	23.9	32.7	60.1
Fisheries products	52.5	10.9	11.0	8.2	18.7
Other exports	129.2	79.6	41.9	90.9	75.6
Total	1072.3	783.6	1123.2	1122.4	2434.4

(Source: Papua New Guinea Bureau of Statistics)

Mining and oil output increased substantially in the 1990s and international development assistance has been maintained at levels well above that in comparable countries. Despite these factors, the standard of living of most Papua New Guineans has declined over the last decade. In 1990, real Gross Domestic Product (GDP) per capita was 2 per cent lower than in 1980.

Substantial increases in real GDP were recorded in the early 1990s due to an increase in gold and oil output. But importantly, non-mining real output grew on average by only 1 per cent in the period 1989-1993. Private sector formal employment declined by approximately 8 per cent over these years which has resulted in a substantial increase in unemployment. The investment share of GDP is on a downward trend, and both labour and capital productivity are low.

Poor economic performance has been accompanied by disappointing progress in social indicators. Although improvements have been made, Papua New Guinea still has a long way to go in terms of measures such as life expectancy at birth, calorie intake, access to doctors, access to safe water and primary school enrolment (Anon., 1994).

A.4.2 Role of fisheries in the economy

Fisheries resources have fluctuated in their contribution to the national economy (Table 1), the high point being in the late-1970s - early-1980s when pole-and-line tuna fishing contributed as much as USD37.3 million to fisheries exports (Doulman and Wright, 1983). Fisheries products comprised four per cent of the national exports during that period, comprising mainly tunas (three per cent), barramundi, prawns and ornate rock lobsters. However, with the demise of the pole-and-line tuna fishery in the early 1980s, the significant reduction in barramundi stocks over the past ten years and the levelling-out of yield in the Gulf of Papua prawn fishery, the contribution fisheries products make to national exports has fallen to less than one per cent. In 1987, export earnings from fisheries were K11.7 million (Fishery Sector Review, 1989) and the value has declined further. Fisheries exports now almost consist of a new suite of resources, dominated by sedentary organisms such as trochus and bêche-de-mer (their combined export value in 1992 was more than K6.5 million, f.o.b.).

Japan is the main recipient of fisheries exports, in 1989 accepting 75 per cent of exports by value including 92 per cent of prawn exports. In 1989 Australia was the second most important export destination; however I suspect that South-east Asia is now the leading importer of PNG fisheries products after Japan because of PNG's increased exports of trochus and bêche-de-mer.

Recent studies of tuna resources in PNG by the South Pacific Commission (prime among others) have indicated the existence of substantial stocks of tunas in the PNG DFZ. The national government is taking steps to encourage the exploitation of these resources and is being aided in its endeavour by the building of a large privately owned cannery in the Madang Province. With careful management of this and other fisheries resources, the stage may be set for fisheries exports to again be significant to PNG and thereby assist in the nation's development.

Formal employment in the fisheries sector is provided by industrial fisheries, national and provincial institutions and artisanal fisheries (perhaps more than 4,000 fishers). At the end of 1993 measures to assist the fishing industry were proposed, including taxation, reforms in licensing and fisheries management, provision of credit to the fishing industry and a review of harbours and associated charges imposed on fishing vessels.

A.5 FISHERIES AND MARINE RESOURCES

PNG lies between the Indian and Pacific Oceans, close to perhaps the epicentre of marine species diversity - Indonesia and the Philippines. It is also located on the pathways of three equatorial current systems. The general low productivity of tropical oceanic waters is countered in the PNG DFZ by processes including localised upwelling around islands, offshore reefs and seamounts, upwelling along the PNG north coast during the November-March monsoon season, major rainfall inputs (especially immense run-off from mainland rivers), trade wind patterns and current movements between islands.

PNG's geographic location combined with its extensive deltaic systems has produced some of the richest marine, coral reef and estuarine faunas on earth. In contrast to these, the PNG freshwater fauna is low in family diversity although unique suites of species have developed. This poor freshwater fauna is a reflection of continental drift and PNG's palaeohistoric association with Australia on the Sahul Shelf and its separation by 'Wallace's Line' from the rich freshwater faunas of South-east Asia.

A.5.1 Institutions

The Department of Fisheries and Marine Resources (DFMR), established in December 1986, has overall responsibility for national fisheries. The gazettal notice which formally established DFMR listed a range of departmental functions covering legislation, development, research, resource management and liaison requirements. At the time of DFMR's establishment, each provincial government had provincial fisheries divisions with programmes concurrent with those of DFMR.

In 1993, the government approved the establishment of the National Fisheries Authority (NFA), to take over the existing functions of DFMR. In the second half of 1995, DFMR was abolished and all functions transferred to the newly established NFA. The key programmes to be undertaken by the NFA include the development of a local tuna industry, enabling artisanal fisheries development, augmenting the production capacity of inland river systems through stocking, maximising the rent from distant water tuna fisheries and strengthening the institutional capacity of DFMR to make it more client-supportive (Buraik and Yule, 1995).

DFMR's only fisheries college, which provides education and training in fisheries technology at Certificate level, has been in existence for 18 years. The college is located at Kavieng, New Ireland Province. The University of PNG offers fisheries-orientated material in its Science (biology) degree course. There is a research centre affiliated with the University at Motupore Island (Central Province). In addition, fisheries research is conducted at the privately owned Christensen Research Centre in the Madang Province.

Some overlap of responsibility for the marine and freshwater environments and their fauna is borne by the Department of Environment and Conservation, primarily for 'non-fish' such as turtles, dugong and crocodile. Permits for the movement of wildlife out of the country, including fish, are issued by this department.

A.5.2 Fisheries Legislation and Management

Most of the maritime zones of PNG are established by or under the National Seas Act 1977. This act defines the archipelagic waters, as well as baselines from which the 12 nautical mile territorial sea is measured. The offshore seas are defined in the Offshore Seas Proclamation made under the National Seas Act in 1977, and they plus the territorial sea have an areas equivalent to an exclusive economic zone. The offshore seas are declared to be the 'Declared Fishing Zone' under the Fisheries Act 1974 (amended 1978, 1982, 1984). A new Fisheries Act was passed in 1994 which established the National Fisheries Authority. The DFZ was declared at the end of March 1978. The continental shelf is defined in the Continental Shelf (Living Natural Resources) Act 1984.

The 1994 PNG fisheries legislation goes considerably further than that of other Pacific countries in that it combines management of domestic fisheries with regionally integrated control of the Pacific distant water tuna fishing industry.

Other Acts are the:

- Export (Fish) Regulations (1982), made under the Customs Act and the Commerce Act;
- Fisheries (Torres Strait Protected Zone) Act 1984;
- Offshore Seas Proclamation 1978;
- Tuna Resources Management Act 1973; and
- Whaling Act.

The Public Investment Programme 1988-1992 (Fishery Sector Review, 1989) stated that it is the policy of the Government to:

'Promote the utilisation of the fisheries and marine resources to accrue optimum benefits for Papua New Guineas and to know, conserve, and ensure the resources are available for future generations of Papua New Guineans.'

The PNG Government's broad objectives for the development of fisheries were to:

- develop renewable fisheries resources, within the limits of sustainable yields; and
- invest public sector resources in economically viable smallholder fisheries acitivies which lead to the expansion of exports and import substitutes and which will expand local food supplies and give small-holders increased access to the cash economy.

A.5.3 The Fisheries

There are three main categories of fishing in PNG with a fourth - recreational - being of minor importance.

Subsistence fishing occupies the bulk of people engaged in fishing activities. Harvesting is done by traditional or low-technology means. Although most fishers are engaged in this activity, each has rather small catches.

Artisanal fishing is where the harvest is sold for cash income, generally at local markets. Some post-harvest technology may be employed - e.g. smoking for preservation. Artisanal fishing involves the catching of barramundi, lobsters, shallow-water reef fish, nearshore pelagic fish, mangrove crabs, freshwater prawns and a range of other reef and coastal fishes.

Commercial/industrial fishing are larger operations requiring more gear and capital and are usually aimed at export markets (although gathering of sedentary products rely on simple techniques and low technology). Commercial fishing also includes tuna fishing by foreign fleets under access licences with PNG.

Whereas some resources (sea cucumber, trochus, green snail, penaeid prawns) are being harvested at or near maximum sustainable yield (MSY), there is considerable underutilisation of other resources. Several constraining factors contribute to this situation, including:

- the lack of timely and inexpensive transport;
- the lack of refrigeration and quality control;
- the barriers imposed by customary ownership, especially with regard to nearshore pelagic species;
- insufficient guidance in marketing and post-harvest technology available in PNG;
- the lack of access to domestic and external markets;
- the lack of infrastructure;

- poorly developed services (such as inspection and policing);
- the lack of capital, including domestic equity; and
- the lack of a 'capitalist approach' among many artisanal fishers.

A.5.4 Regional and international agreements relating to fisheries

PNG is a member of the South Pacific Forum and accordingly is also a member of the Forum Fisheries Agency. It is also an ACP state of the European Community, a member of the South Pacific Commission and the FAO of the United Nations. PNG is a party to the Nauru Agreement Concerning Co-operation in the Management of Fisheries of Common Concern (Nauru Agreement) and the Multilateral Tuna Fishing Treaty between the Governments of Certain Pacific Island States and the Government of the United States of America (US Multilateral Treaty) both formed primarily to address issues in tuna resource exploitation and management in the far western Pacific. PNG has signed the 1982 Convention on the Law of the Sea and is also signatory to the:

- Palau Arrangement for the Management of the Western Pacific Purse Seine Fishery; the
- Federated States of Micronesia Arrangement for Regional Fisheries Access; the
- Niue Treaty on Co-operation in Fisheries Surveillance and Law Enforcement in the South Pacific Region; and the
- Convention on International Trade in Endangered Species of Wildlife (CITES).

PNG and Australia have reached understanding over their common border in the Torres Strait. The Torres Strait Treaty contains a Fisheries (Torres Strait Protected Zone) Act 1984 which covers fishing in areas of PNG jurisdiction in the Torres Strait Protected Zone (TSPZ). Fisheries management and exploitation in the TSPZ are shared between the two countries under the treaty.

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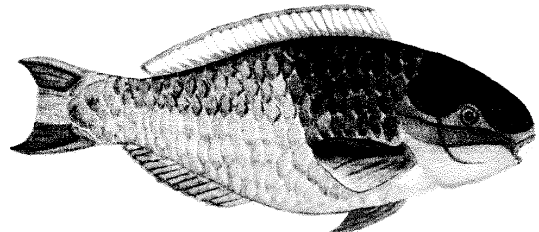
1.1 SHALLOW-WATER REEF FISH

1.1.1 The Resource



Scarus gibbus

Species present: The food fishes characteristically found on coral reefs include wrasse (Labridae), groupers (Serranidae), emperors (Lethrinidae), bream (Sparidae), sea perch and fusiliers (Lutjanidae), parrotfish (Scaridae), sweetlips (Haemulidae), butterflybream and monocle bream (Nemipteridae), squirrelfish (Holocentridae), drummers (Kyphosidae), eels (Muraenidae), triggerfish (Balistidae), rabbitfish (Siganidae), surgeonfish and unicornfish (Acanthuridae) and goatfish (Mullidae). Trevallies (Carangidae), mullet (Mugilidae) and barracuda (Sphyraenidae) are frequent pelagic reef inhabitants. Some of these groups have been profiled elsewhere (profiles 1.2, 1.5, 1.6, 1.7, 1.12, 1.13 and 1.17) and hence there may be unavoidable overlap of information in those profiles and this one.

More than 300 species of finfish have been recorded from reef-associated fisheries throughout the Pacific (Wright, 1993). These species fall into about 50 families. In a 13 month study of finfish resources of the Tigak Islands (New Ireland Province), Wright and Richards (1983a; 1985) recorded 253 finfish species belonging to 43 families which were represented in the artisanal and subsistence fish harvests there.

Distribution: PNG contains some of the highest diversity of reef-associated fishes in the Indo-Pacific. The geographical distribution of many of the fishes inhabiting shallow water coral reefs in PNG extends throughout the Indo-Pacific, although the number of species in families decreases west to east because of the Pacific Plate boundary (Springer, 1982), a decrease in available habitats and inter-islands distances (see also Wright, 1993). Although this phenomenon is noticeable in central Pacific countries, there is likely to be a decrease in species diversity between (e.g.) the Milne Bay Province and New Ireland and North Solomons Provinces within PNG.

Biology and Ecology: Coral reefs provide habitats for the most diverse of fish communities found in marine environments (Wright, 1993). Coral reefs are often closely associated with mangroves and seagrass beds; and the reefs themselves offer a range of habitats - from shallow flats to drop-offs into deep water. Many species are transients between these habitats. The numerous species associating with shallow water coral reefs have very different life histories and biological parameters.

Many studies have been and are being performed on the diets of reef-associated fishes. Food preferences of these fishes are possibly as diverse as the fishes themselves which are generally categorised as either piscivore, herbivore or omnivore. Herbivorous food-fishes can be partitioned into those feeding on unicellular algae (e.g. mugilids), grazers on algae close to the substrate (e.g. siganids, labrids, acanthuriids, balistids), browsers on algal fronds (e.g. some siganids and acanthurids, drummers, balistids) and incidental algal ingesters (e.g. labrids, scarids) (Hiatt and Strasburg, 1960, in Wright, 1993). Parrotfish also feed on coral and young shells. Some mullids feed on detritus; lethrinids and nemipterids are scavengers. The piscivorous fishes are categorised as those feeding on animals within and on the substrate or in midwater, and 'roving' carnivores that are either largely demersal and reef-attached or are more pelagic in nature and frequent reefs to feed (Hiatt and Strasburg, 1960, in Wright, 1993). Carnivorous food fishes include lutjanids, mullids, labrids, eels, holocentrids, lethrinids, serranids, carangids, balistids, sphyraenids and scombrids. Studies of trophic relationships on reefs have shown either that herbivores predominate (e.g. at Enewetak Atoll) or that piscivores predominate (up to 54 per cent on some reefs: Parrish *et al.,* 1986, in Wright, 1993).

Most reef associated fishes have separate sexes, among them the haemulids, mullids and siganids. On the other hand, many fishes change sex through their life - either from female to male (e.g. scarids, serranids, nemipterids, lethrinids and labrids) or male to female (e.g. sparids, muraenids). A wide variety of reproductive strategies are employed by reef fishes. Many undertake spawning migrations to certain reef sections while others are site attached; schooling prior to spawning (e.g. acanthurids); pair spawning or group spawning (e.g. serranids); spawning on a lunar rhythm (e.g. scarids); aggregating to spawn over several days; and territorial defence and pair formation have all been recognised. An overview of reproductive strategies in coral reef fishes is provided by Robertson (1991).

In tropical waters, individual members of fish populations are sexually active at any time of year, although spawning peaks occur at certain times. In a study of 19 reef-associated fish species in the Tigak Islands (New Ireland Province), Mobiha (1993a) found that most of them spawned throughout the year yet also exhibited one or two spawning peaks - usually between February and March and between August and November. Species included in his study were five species of lethrinid, three lutjanids, two acanthurids, the drummer, *Kyphosus cinerascens*, two siganids, two haemulids, *Valamugil seheli* and two serranids. Mobiha found that length at first maturity varied, from serranids which matured at c.59 per cent of their hypothetical maximum length to siganids maturing at 87 per cent of it. Fecundity increased with increasing length, and a haemulid, *Valamugil* and the two siganids were estimated to have the highest fecundities (serranids not assessed).

Most reef-associated food fish produce pelagic eggs and these eggs and subsequent larvae drift in ocean currents for various lengths of time prior to settlement. Most siganids, tetraodontids and balistids however, lay their eggs in nests (Wright, 1993). Many larvae disperse widely although a measure of self-recruitment (to the spawning site) does take place. There has been significant recent research on the timing and extent of settlement of larvae in tropical systems (Doherty, 1991; Wright, 1993). Because spawning by reef fishes throughout the year is not uncommon, recruits to the reef system (and fisheries targeting reef fish) also happen throughout the year.

Mobiha (1993b) used readings of daily growth increments on otoliths to estimate age in *Lethrinus semicinctus* in Tigak Islands populations. Some fish species (e.g. *Lutjanus bohar, Lethrinus miniata*) inhabit reefal areas as juveniles and young adults then migrate to deeper water as they grow larger (Wright and Richards, 1985).

Groupers are reported to be slow-growing and long-lived (10 years or more) (Shapiro, 1987). Size at maturity ranges from 25 cm total length in *E. fuscoguttatus* to 34 cm total length in *E. microdon*. Fecundity falls generally in the range of 100,000-500,000 eggs per female (Shapiro, 1987). Mature siganids form large schools and aggregate to spawn. Spawning is said to take place throughout the year with peaks from March to June and in November (Myers, 1991). Siganids probably have a rapid growth rate and mature at 1-2 years of age.

1.1.2 The Fishery

Utilisation: Shallow water reef fishes are harvested in subsistence, artisanal and commercial (including live reef fish export) fisheries in PNG.

The main fishing methods used in artisanal and subsistence fishing are handlining and gillnetting. Spearing, trolling are less often used. Poisoning and trapping are employed for subsistence harvest as well. Unfortunately, dynamiting (generally using unexploded World War II bombs) is used in many northern PNG coastal areas although its use is illegal. Frielink (1983) documented some of the change-over between traditional and modern fishing gears used to catch shallow water reef fishes in PNG. There are full time, part time and subsistence fishers, and a range of vessels are used - from dugout canoes to very large canoes to dories.

Lock (1986a, 1986b) and Wright and Richards (1985) pointed out that the wide mix of fishing methods in the Port Moresby and Tigak Islands artisanal fisheries has resulted in an efficient utilisation of the reef resource. Handlining takes large and small reef-associated carnivores, underwater spearing takes large reef fish, surface spearing takes the pelagic carnivores, and netting exploits nearly all sections of the reef community, from large carnivores to small herbivores. Hence, a high species diversity is characteristic of the catches of fishers using a variety of fishing gears to harvest coral reef fishes.

The harvest of species in PNGs shallow reef fisheries is nowhere similar because of factors such as habitat variety, seasonal presence or absence of fish and fish catchability. Hence, in none of the fisheries do the same fish species dominate landings.

Table 2 Catch composition of some artisanal reef fisheries in PNG (only families comprising more than 2 per cent of the catch). Sources: Tigak Islands - Wright and Richards, 1985; Port Moresby - Lock, 1986a (first value), 1986c (second value); Huon Gulf - Hermes, 1992; NIP 1994 - DFMR Kavieng database)

Family	% Tigak Islands catch	% Port Moresby catch	% NIP 1994 catch	% Huon Gulf catch
Mugilidae	21.2	4.0-4.4	-	-
Carangidae	14.0	8.3-7.8	5.6	23.0
Lutjanidae	13.3	4.7-5.1	18.3	19.0-23.24
Lethrinidae	10.4	29.3-31.8	4.9	6.4-11.13
Serranidae	9.1	2.5-2.7	4.6	5.1-8
Scaridae	8.1	5.2-5.6	6.5	1.9
Acanthuridae	4.7	6.8-7.3	-	-
Haemulidae	3.3	3.9-4.2	3.2	2.5
Scombridae	2.7	10.1-4.0	-	-
Chanidae	2.3	<1.0	-	-
Siganidae	1.3	5.5-6.0	-	-
Belonidae	<1.0	5.2-5.4	-	-
Mullidae	<1.0	4.5-4.8	-	3.4

(Notes: 1) Huon Gulf catch sampled in March 1992 and October-December 1992; 2) NIP = New Ireland Province)

Of the 253 species recorded in the Tigak Island fishery, 42 species contributed 84.3 per cent by weight to the total catch (in the 13 month study) (Wright and Richards, 1985). The dominant species by weight were the mullets *Valamugil seheli* and *Chelon vaigiensis* (contributing 25.1 per cent of the catch), trevallies *Caranx sexfasciatus* (5.5 per cent) and *C. melampygus* (4.8 per cent) and the double-headed parrotfish *Bolbometopon muricatus* (6.3 per cent). *Lutjanus gibbus* contributed 5.2 per cent. The remaining harvest comprised serranids, lethrinids, lutjanids, *Chanos, Kyphosus*, scarids and tuna-like fishes (Scombridae), all comprising between 2 per cent and 3.9 per cent of landings. Netted (surround nets) fish comprised 35.2 per cent of the catch, handlining contributed 21.6 per cent, spearfishing contributed 6.1 per cent (better catch rates at night), a combination of all three contributed 37.1 per cent and trolling contributed 5.9 per cent to the catch.

Calculations of yield from the different fishing methods in the Port Moresby artisanal fishery (also covering some of the Central Province) (Lock, 1986a) are: underwater spearing - 5.7 per cent; surface spearing - 4.8 per cent; handlining - 5.7 per cent; various surround netting - 33.7 per cent; drive netting - 28.1 per cent; gillnetting - 11.6 per cent; barrier netting - 2.3 per cent; and trolling - 8 per cent. Of the 23 families recorded in the Port Moresby fishery, seven contributed more than 5 per cent to the total annual catch.

In the Huon Gulf fishery (Morobe Province), handlines (hook and line) are used to catch serranids, lutjanids, haemulids, lethrinids and mullids (Hermes, 1992). Serranids caught range in size from less than 100 g to more than 10 kg. All red sea perch (lutjanids) are targeted, especially *Lutjanus sebae*. Juvenile lutjanids are frequently included in surplus landings and are probably more common in the subsistence catch. *Plectorhinchus* species (Haemulidae) are also caught with seine nets and spears, while grunts (*Pomadasys* species) are caught with beach seines and encircling gillnets. Large and small lethrinids are dominant in landings. These fish (including large *Monotaxis* species and *Gymnocranius* species) are speared, handlined and seined. Mullid landings mostly comprise *Parupeneus* species of less than 30 cm length. Adults of *Bolbometopon muricatum* are occasionally present in spear fishing catches.

In a handline survey of some reefs in the Warrior Reefs complex, Western Province, Mobiha *et al.* (unpublished) found that lethrinids, the wrasse *Choerodon schoenleinii,* and *Lutjanus carponotatus* were predominant in catches. Serranids (*Epinephelus* species) were also common. In a spearfishing survey in the same area, the dominant species in the catch were *Plectorhinchus flavomaculatus, P. nigrus, Siganus lineatus, L. carponotatus* and *Plectropoma leopardus*.

From a survey of subsistence fishing effort in five bays on the west coast of Manus Island, Chapau and Lokani (1986) recorded the following dominant species by fishing method:

Spearfishing - *Siganus fuscescens* (27 per cent by number), *Acanthurus nigricans* (10 per cent), *Scarus ghobban* (9 per cent) and *S. niger* (8 per cent);

Shallow-water handlining - *Nemipterus peronii* (50 per cent) and *Lethrinus lentjan* (25 per cent);

Trolling - *Euthynnus affinis* (71 per cent) and rainbow runner, *Elegatis bipinnulatus* (25 per cent).

In a survey of islands off Aitape, West Sepik Province in late 1986, lutjanids, *Scomberomorus commerson* and *Caranx tille* dominated handline catches; and *S. commerson, E. affinis* and *Caranx papuensis* dominated the troll catches (Fisheries Research annual report 1985-1991).

Another fishery targeting reef fish which has developed in PNG in recent years is that supplying the 'live fish trade' in Hong Kong, Singapore and other Asian capitals. Companies supplying this market largely target serranids (e.g. malabar cod, *Epinephelus malabaricus*, camouflage cod, *E. polyphekadion* and coral trout, *Plectropoma* species), labrids (e.g. the maori wrasse, *Cheilinus undulatus*), certain lutjanids, lethrinids and stonefish (*Synanceia* species). The fish are caught with the aid of hook-and-line and by divers using hooked sticks and supported by hookah gear. Caught fish of acceptable size and variety are kept in holding ponds until sufficient have been collected for shipment. While in the pens they are fed on bycatch from the fishing operations. The fish are exported by sea (circulating sea water in the ships' hold) or by air. Live reef fish individually fetch K60-70 at retail outlets in Asia (R. Vonole: DFMR memorandum, 18/11/93) or as much as K100/kg for rarer fish (Richards, 1993b). The declared f.o.b. export value in PNG is about one tenth of the market value. The fishery in PNG has been described by Richards (1993a; 1993b).

The live reef fish fishery commenced in the Hermit Islands of the Manus Province in 1991. Live reef fish operations were/are/may be in operation in the Central, East New Britain and New Ireland provinces.

Table 3 The prospectus of the company operating in the Hermit Islands listed the following species as the target group (the company's names):

English name	scientific name	English name	scientific name
flag-tail grouper	*Cephalopholis urodela*	coral trout	*Plectropomus leopardus*
brown-spot grouper	*Epinephelus chlorostigma*	peacock grouper	*P. leopardus*
brown-stripe grouper	*E. morrhua*	lunar-tailed rock cod	*Variola louti*
blue-tailed grouper	*E. microdon*	polkadot grouper	*Cromileptes altivelis*
giant grouper	*E. magniscuttis*	hump-head wrasse	*Cheilinus undulatus*
brown-marbled gouper	*E. fuscoguttatus*	black-spot tuskfish	*Choerodon schoenleinii*
honeycomb rock cod	*E. merra*	orange-dotted tuskfish	*Choerodon anchorago*

The fishery initially looked attractive to provincial governments as it was seen as a means whereby cash income could be generated in remote areas. However, the fishery has many ill-effects and/or operators have not followed licence conditions. These problems are now recognised by most fisheries authorities and relevant government bodies.

Issues include:

1. foreign crews are engaged in fishing, contrary to licence conditions;
2. in order to make the fishery economic, the cpue's of preferred species have to be high. To meet this, spawning aggregations (especially of serranids) are targeted. Over even a short time, the numbers and average weight of target fish in the areas of operation decline substantially. The companies then move onto unfished reefs;
3. cyanide is used to stun fish making them easy to catch (R. Vonole, DFMR memorandum, 18/11/93). The effects of the chemical has been marked on some reefs;
4. there is substantial bycatch (about ten times the target catch) which is often wasted;
5. the overall mortality of fish waiting in pens for shipment ranges over 5-50 per cent;
6. the PNG fishers working for the operation are paid a meagre price for target fish (they are not paid for unwanted bycatch); and
7. scarcely trained PNG fishers are encouraged to use hookah gear to catch deeper living species - a practice identified as dangerous.

Production and marketing: After the event, the composition of the category "fish" in fisheries catch statistics and export quantities cannot be determined. How much of it is of "shallow-water reef fish"? Wright (1986) stated that the term "fish" generally refers to whole fish and fish fillets from fish caught near coral reefs or to whole fish taken as a by-product of the industrial fisheries for prawns or the gillnet fishery for shark. It could also include inshore pelagic fish. But in the end, "fish" catches are what I cannot avoid quoting in this section.

Table 4 DFMR export figures of (mixed reef) fish from 1982 to 1993

Year	quantity (kg)	value (K)	Year	quantity (kg)	value (K)
1982	68,060	23,652	1988	-	-
1983	10,856	22,620	1989	-	-
1984	100,448	144,854	1990	28,960	-
1985	38,206	71,765	1991	966,000	-
1986	71,736	89,825	1992	-	-
1987	16,570	53,059	1993	5,295	35,148

Live fish were recorded in export figures for 1991 (est. 8,000 kg), 1992 (est. 11,202 kg @ K67,215 fob) and 1993 (est. 1,800 kg @ K9,120; all stone fish). These records *must be incomplete* - see Richards (1993b), where 23.9 mt of fish were exported from the Hermit Islands in the first 18 months of a company's operations.

On the whole, the DFMR figures above are very different to the DFMR figures given by Wright (1986) for PNG exports of mixed fish between 1982 and May, 1986.

Table 5 Wright (1986) said that most product listed below consisted of fish caught near coral reefs. This product was exported to Australia, Guam and Hong Kong.

Year	1982	1983	1984	1985	1986 (to May)
quantity (kg)	14,113	856	33,348	39,206	15,000
value (K)	28,112	2,241	124,854	69,149	19,800

Figures for the broad category of 'reef fish' can be guestimated however, based on a combination of Frielink (1983), Munro (1976, in Frielink, 1983), Wright and Richards (1983b) and the DFMR database at Kavieng as follows:

- It is more likely that more 'reef' fish are represented in 'fish' catches from the provinces with extensive reef systems; and these - according to Munro (1976) - are only the Central, Milne Bay, Bougainville, New Ireland and Manus provinces.
- The improved recording* of fish landings (as species group) by the Manus Fishing Authority enables a calculation of the percentage reef-associated fish make to the total fish landings in the province. I did this for the period 1990-93; they averaged 85 per cent. [* For example, whereas in 1989 there was one figure for (all) fin fish landings, in 1990 there were 15 species groups (and 15 figures), swelling to 26 species groups in 1993.]
- The 85 per cent figure was then applied to pre-1990 Manus Province 'fish' landings, and subsequently to available 'fish' statistics for New Ireland and Milne Bay provinces - i.e. provinces with extensive reef systems.
- Using Wright and Richards' (1983b, in Frielink, 1983) estimates of PNG reef areas shallower than 30 m, I then calculated the average yield of reef fish in kg/ha/year for those three provinces. The average yield for New Ireland is 0.12 kg/ha/year over 16 years, for Manus it is 0.06 kg/ha/year over 10 years, and for Milne Bay it is 0.008 kg/ha/year (but only over 2 years).

Table 6 Calculated artisanal landings of reef fish for three PNG provinces:

Year	NIP, catch (kg)	NIP, kg/ha/yr	Manus, catch (kg)	Manus, kg/ha/yr	MBP, catch (kg)	MBP, kg/ha/yr
1979	14,459	0.1	-	-	-	-
1980	19,809	0.14	-	-	-	-
1981	41,742	0.3	-	-	-	-
1982	27,752	0.2	-	-	-	-
1983	37,368	0.3	-	-	-	-
1984	14,511	0.1	630	0.003	-	-
1985	14,524	0.1	13,875	0.06	-	-
1986	5,314	0.04	31,347	0.14	-	-
1987	10,108	0.07	17,477	0.08	-	-
1988	9,642	0.07	28,986	0.13	-	-
1989	9,974	0.07	14,907	0.06	-	-
1990	11,570	0.08	10,978	0.05	-	-
1991	8,659	0.06	7,555	0.03	-	-
1992	22,228	0.16	5,461	0.02	9,530	0.007
1993	11,673	0.08	8,392	0.04	12,177	0.009
1994	4,720	0.03	-	-	-	-

(NIP = New Ireland Province; MBP = Milne Bay Province)

In the Western Province, landings of reef fish in Daru between 1986 and 1992 are provided by DFMR Daru and by Mobiha *et al.* (unpublished). Their information can be expanded to provide estimates of harvest rate (kg/ha/year) based on the estimated area of 1,042,000 ha of shallow reef in the Torres Strait region of Western Province (Frielink, 1983; Dalzell and Wright, 1986).

Table 7 DFMR Daru figures

Year	1986	1987	1988	1989	1990	1991	1992
quantity (kg)	18,786	19,860	5,944	nil record	3,079	1,702	1,560
kg/ha/yr	0.02	0.02	0.006	-	0.003	0.002	0.001

Table 8 Mobiha *et al.* (unpublished) recorded different and extended figures, covering the period 1990-93

Year	1990	1991	1992	1993
no. days fished	-	153.5	167.5	137
quantity (kg)	3,352.7	3,379.8	21,739.7	13,546.7
kg/ha/yr	0.003	0.003	0.02	0.01

Even with the added subsistence catch it is apparent that shallow reef systems in these four provinces are VERY lightly fished. The subsistence catch has been calculated for the Tigak Islands and New Ireland Province fisheries by Wright and Richards (1985), for the Port Moresby fishery by Josephides (1982, in Lock, 1986a), in the west coast of Manus Island fishery by Chapau and Lokani (1986) and by Frielink (1983) for all of coastal PNG. The results differ widely; however the Fishery Sector review (1989) suggested that the subsistence catch in shallow-reef coastal areas of PNG would represent less than 25 per cent of the total catch.

Some fishing grounds are more heavily fished than others - generally those near urban centres, those where landing and marketing facilities are not far distant and those adjacent to settlements where there is little arable land. This matter is discussed further below.

Catches of reef-associated fishes in the Madang area for recent years have been calculated similarly as a percentage of the total of all fish. Most reef associated fishes are included in the categories 3 and 4 of the MOMASE project. In 1992, c. 1,993 kg of reef fish were landed, and in 1993, the amount was c. 1,307 kg.

Table 9 Recorded landings of 'fish' at coastal provinces bordering reef areas for the 1980s, in mt, are (sources: Frielink, 1983; Dalzell and Wright, 1986; Alu, 1989; Fisheries Research annual report 1980 & 1981; Sector Review, 1989. *Figures differed in every source*. The highest figures were used to construct this table.)

Station	1980	1981	1982	1983	1984	1985	1986	1987
Samarai (MBP)	-	49	90	209	236	265	275	301
Kimbe (WNBP)	31	58	36	55	72	71	61	32
Kupiano (CP)	15	14	14	19	32	30	26	24
Tufi (NP)	-	17	38	54	35	35	28	40
Lorengau (MnsP)	-	-	-	16	10	20	38	19
Madang (MdgP)	-	6	13	15	18	20	5	9
Lae (MrbP)	13.2	14	23	35	49	73	87	64
Kavieng* (NIP)	-	48	34	36	40	40	7	11
Kieta (NSP)	-	-	16.5	30	56	82	90	55

(Notes: 1) The province names have been abbreviated in the table. 2) A comparison with New Ireland Province and Manus Province figures tabulated earlier reveals sometimes major discrepancies between both sets of figures for some years.)

(*Between 1970 and 1982 the mean annual production figure for Kavieng was 23.2 mt: Fisheries Research annual report 1984)

The Morobe, Madang and Sepik (MOMASE) project aims at facilitating the development of inshore fisheries along the northern and eastern coasts of the PNG mainland. At the Voco Point landing site in Lae and at the Madang landing site, freezer, ice, purchasing and distribution facilities are available. The landing sites purchase fish from the fishers and onsell it. The MOMASE project groups mainly finfish into five categories - category 1 (large pelagics), category 2 (mainly inshore fish and small pelagics), category 3 (mainly demersal hardbottom fish), category 4 (reef fish) and category 5 ('special' fish - red emperor (*L. sebae, L. timorensis, L. malabaricus*) and Spanish mackerel, also squid, prawns, cuttlefish and rock lobsters). Prices paid to fishers at Voco Point in 1994 ranged from K1.50-2/kg for fish in categories 1 and 2 to K3.50-4/kg for components of category 5 (the non-finfish receiving up to K6/kg).

Prices paid for fish in PNG markets vary. The prices paid to fishers at the Madang branch of the MOMASE project in 1994 ranged from K0.70/kg to K2.50/kg (non-finfish receiving up to K4.00/kg). The average purchase price of the 52,500 kg of fish bought by the Kavieng fish depot in 1981 was K0.60/kg (from Wright and Richards, 1985) although individual fish were more highly valued. Some fishers prefer to sell direct to consumers in order to receive a slightly higher price/kg. At Koki market in Port Moresby in 1985, retail prices ranged from K2.61/kg for large reef fish sold singly to K1.51/kg for small reef fish (Lock, 1986d). Prices were generally 34 per cent higher at Gordon's market in Port Moresby. Prices at Koki and Gordon's markets rise considerably on government pay-day: in 1985 they were 60 per cent higher at Koki and 14 per cent higher at Gordon's (Lock, 1986d). Supply and demand at Koki are also evident seasonally. In periods of rough weather, a string of small, ungutted fish sells for K7-8 (P. Gamini, pers. comm.); and there are seasonal drops in prices for tunas and long-toms (Belonidae - profile 1.5).

Based on available f.o.b. prices for PNG exports, returns on finfish have ranged from K1.32/kg in 1986 to K6.64/kg in 1993 (DFMR figures; Wright, 1986).

There are several estimates of coastal production in PNG waters. The reef and coastal lagoon artisanal fisheries in PNG were estimated to yield 15,000 mt of finfish in 1978 (Pernetta and Hill, 1981, in Lock, 1986d). For the reefal area of 40,000 km^2 (4 millon hectares), this gives an overall average yield of 0.38 mt/km^2/year (Lock, 1986b).

The exception to this is the Port Moresby area. The Port Moresby artisanal reef fishery produced 577 mt of fish in 1985 (Lock, 1986a; 1986d) [*or 524 mt (Lock (1986c; 1986b)*] from its 116 km^2 area. However, because the proportion of fish sold in the Port Moresby fishery amounted to 80 per cent of the total catch (20 per cent being given away or eaten in the subsistence diet) (Lock, 1986a, 1986c) the total catch in 1985 was therefore c. 721 mt (on 577 mt). Yields for seven fishing grounds in the Port Moresby artisanal fishery in 1985 ranged from 3.54 kg/ha to 82.52 kg/ha with an average of 50 kg/ha/year (Lock, 1986b; 1986c).

In 1981, the subsistence + artisanal finfish catch in the Tigak Islands' shallow coral reef area of 20,765 ha, averaged 4.2kg/ha/year (Wright and Richards, 1985). The subsistence component of the total catch was 15 per cent - i.e. 0.63 kg/ha/year. These authors also calculated that the estimated annual finfish harvest for all of the New Ireland Province in 1981 was 2.1 kg/ha/yr.

Chapau and Lokani (1986) estimated that 174 mt/year was harvested from the shallow reef area of five bays on the west coast of Manus Island, totalling 6,106 ha. All of this harvest, of 28.5kg/ha, is used in the subsistence diet.

The overall artisanal exploitation rate of reefs in the Western Province is low. Based on landings at the Daru market and fish plants on Daru over the period 1991-93, the cpue (kg/day) for the Daru reef fishery was 22.02 kg (1.8 kg/hour, per hour based on a 12-hour day: Mobiha *et al.,* unpublished) in 1991, 129.8 kg (10.8 kg/hour) in 1992 and 99 kg (8.3 kg/hour) in 1993.

In 1979, the national government committed itself to encouraging the harvest of the country's substantial fisheries resources available in its shallow reef and coastal waters, spurred on by the need to increase protein intake in inland areas as well as to generate income. The national and provincial governments established fisheries stations in each of 12 coastal provinces. The stations were to assist in and increase the harvest and marketing of coastal fishes. They provided cold storage, ice, fish collection boats and other services. Although landings increased at some provincial centres in the early 1980s, they gradually dropped off. By 1984 only 592 mt were landed at these stations (Lock, 1986a). The stations were being heavily subsidised and were not economically viable (Alu, 1989). In 1984 for example, subsidies for three stations amounted to K184,000 whereas production from those stations totalled only 128 mt. In general, the coastal stations have high operating expenses and the frozen product does not receive as high prices.

The Port Moresby artisanal market is a contrast to other fisheries landings places. It enjoys no government assistance and has almost no shore-based infrastructure yet produces approximately K1 million worth of marine products annually (Lock, 1986a). Reasons for this and the situation in other fisheries landings depots in the country are suggested below.

- The people employed in the Port Moresby fishery are highly motivated, the large market can afford to pay high prices for fish, the supplying communities all have a strong tradition of fishing and have little agricultural land, there is strong local demand and the price for fish obtained at the market is high, so enabling the fishers to earn a reasonable salary (Lock, 1986d). Unlike many other coastal centres [in PNG], fishing provides full-time employment for many villagers, with fishers spending up to 5-6 days each week at sea. Fishing in the Port Moresby area is probably the most intensive undertaken anywhere in Papua New Guinea's coastal waters (Fisheries Research annual report 1983).
- The further away is a fishing area from the government landing place (or the market), the less is the production from the area. Villages close to the landing place have a much higher production than those further away. This is because the effort and cost (e.g. fuel, icebox, ice, time) involved in selling the catch increases with distance. This phenomenon has been demonstrated in the Tigak Islands - New Ireland fishery (Wright and Richards, 1985), the villages feeding to the MOMASE depots in Madang and Lae (station records and pers. comm.'s) and the East Sepik fishery feeding the Wame depot (Chapau and Dalzell, 1991). The costs away from main areas are also greater because services cost more (e.g. fuel, outboards) yet the price received for fish is lower.
- In the Tigak Islands, fishers continually enter and leave the artisanal fishery as immediate cash needs are satisfied. As in most PNG communities, large quantities of cash are only required for specific purposes (e.g. payment of school fees) and this occasional need is reflected in coastal areas by the intermittent production of fish for sale (Wright and Richards, 1985).
- Correlations can be made between fish production and copra price (or the price of some other commodity) and these correlations highlight the point that most coastal fishers fish part-time and have alternative occupations. The overall prevailing economy therefore, affects the extent of fishing activity. People generally prefer to garden than fish. Villages with little or poor land available for gardening have a higher dependence on fish as a source of income. This was demonstrated by Lock (1986d) for some of the fishing communities supplying the Port Moresby market, for one of six Tigak Islands villages studied by Wright and Richards (1985, who found that this village had the highest harvest of 5.5 kg/ha/yr during 1981) and by Chapau and Lokani (1986) for some villages on the west coast of Manus Island (coincidentally, these villages also had the largest populations).
- Many coastal villagers eat only small amounts of fresh fish and - unless a market is handy or they have a need for extra cash (above) - see little need to go fishing. Many prefer to eat tinned fish, beef or pork to satisfy their daily protein needs (situation of the Tabar, Tanga and Green Island groups north of New Ireland and North Solomons, reported in the Fisheries Research annual report 1979).

1.1.3 Stock status

From a surplus production model of the Port Moresby artisanal fishery of 1985, Lock (1986b) estimated an msy for the fishery of 76 kg/ha/year (an area of 11,600 ha). Accordingly, Lock recognised that one ground (catch rate 82.52 kg/ha) was being fished beyond the msy while another two were being fished near the msy. Access to less fished, distant grounds was hampered by sea conditions during the South East Monsoon period. For the whole area, Lock (1986b) calculated a theoretical msy under the 1985 fishing conditions of 881 mt/year (although in another paper he stated 858 mt).

Table 10 Catch per unit of effort for handline, spear, net and troll fishing from surveys in PNG waters. (Sources are: Tigak Island - Wright and Richards, 1985; Bougainville - Ito, 1984; Port Moresby - Lock, 1986a, 1986c; Warrior Reefs, Western Province - Mobiha *et al.,* unpublished; west coast of Manus Island - Chapau and Lokani, 1986; off Aitape, West Sepik - Fisheries Research annual report 1985-1991).

Location	Handline (kg/line/hr)	Troll (kg/line/hr)	Spear (kg/man/hr)	Net (kg/man/hr)
Tigak Islands	1.2-3.9	4.0	2.4*	3.6
Bougainville	1.8	4.2	-	-
Port Moresby	2.5	6.9	2.4	2.5
Warrior Reefs	1.24	-	1.02	-
Manus Island	0.57	8.4	1.1*	-**
West Sepik	1.6	2.7	-	-

(* mean of the day rate and the night rate. Night spearing yields catches 2-3 times greater; ** catches from gillnetting were 0.4-12.84 kg/net night.)

Overall cpue for the Port Moresby artisanal fishery ranged from 1.04 kg/man hour to 4.58 kg/man hour (Lock, 1986b;1986c).

CPUE is a valuable tool for estimating stock size and for ascertaining the health of a fishery over time. However, cpue's of different fisheries (e.g. as above) should not be compared as vessel size, gear, seasonal catch rates, fish type and catchability vary, and the skills of the fishermen impact heavily on the results.

Russ (1991) pointed out that yield is a function of fishing intensity and the actual area of reef fished; and Lock (1986b) added that levels of sustainable yield estimates for reef fisheries depend largely on the fishing methods used. Where a wide range of fishing techniques are employed, higher yields are attainable; but in a handline fishery (where only predators would be caught) lower yields would be achieved. Lock (1986b) developed a surplus yield curve for the multi-species Port Moresby artisanal fishery. Problems associated with application of this model were discussed in Wright (1993).

The implications and effect of the live fish trade fishery on fish populations and reef habitats were discussed by Russ (1991). He cited two examples (Great Barrier Reef, Australia and central Philippines) where serranid, lutjanid and lethrinid populations were dramatically depleted after a short time of intensive fishing. Richards (1993b) showed that in only a 10 month period of fishing in the Hermit Islands (Manus Province), the average number and average weight of a targeted species, *Epinephelus polyphekadion*, had dropped substantially, as had the average weight of the wrasse, *C. undulatus.* This phenomenon is an example of 'growth overfishing' (Russ, 1991). 'Recruitment overfishing' - where fishing reduces the size of the adult stock to a point where production of larvae and subsequent recruitment are impaired - is possibly also happening on reefs which have been fished for the live fish trade. Richards (1993a; 1993b) reported high catches of serranids and wrasse at periods concurrent with periods when spawning aggregations are known to take place.

Lock (1986b) estimated that 30,000 km^2 of the 40,000 km^2 of reef in PNG less than 30 m deep (Frielink, 1983) could be shallower that 7.5 m - the depth to which most fishing effort in the Port Moresby fishery is concentrated. Accordingly, at a msy of 7.6mt/km^2 a theoretical harvest of 228,000 mt is obtainable from these shallower PNG reefs - cf the late 1970s-early 1980s estimate of 15,000 mt (and the later estimate of 10,000 mt; below) (76 kg/ha/year). However, Lock conceded that factors such as low market price, alternative incomes and activities, high operating costs and absence of netting as a harvesting method (see above), would prevent much of PNG's total reef area being exploited to a level comparable to the Port Moresby area.

Harvests of 40-75 kg/ha/year of finfish are considered obtainable from most coralline areas (Gulland, 1972; Marshall, 1980; Munro, 1978, all in Wright *et al.,* 1983) but much higher harvests (160-237 kg/ha/year) have been recorded in American Samoa and the Philippines (reported in Wright and Richards, 1985). At very modest exploitation levels (20 kg/ha/year: Munro, 1976, in Frielink, 1983) a potential yield of 80,000 mt is projected from shallow reef areas in PNG. Production from reef and lagoon areas in PNG shallower than 30 m was estimated at 10,000 mt/year in 1983 (Frielink, 1983) and 1989 (Sector Review, 1989) - or 2.5 kg/ha/year (0.25 mt/km^2/year). Compared with other tropical shallow reef systems, where harvest levels range from 5 mt/km^2 to 21 mt/km^2 (Munro and Williams, 1985, in Lock, 1986b), PNG's coastal fish stocks are considerably underexploited.

Despite this overall view, fishing pressure near centres of population has had an effect on the size of fish and the species composition being caught. Lock (1986c) found that in the Port Moresby artisanal fishery, large reef fish were giving way to small ones and the cpue was declining. In the Western Province, both B. Shackles (pers. comm.) and Mobiha *et al.* (unpublished) suggested that the subsistence catch from the reefs in the Western Province has probably increased significantly and that there is moderately heavy local exploitation of the shallow reefs and coastal lagoons. People from the Fly River delta had joined the traditional coast dwellers in fishing the reefs since the decline of the barramundi fishery and the advent of the bêche-de-mer fishery (their study and figures presented were from the period before the moratorium on that fishery), and 'sardi' is being used extensively and gillnets are constantly set. In the Huon Gulf fishery, there is evidence that constantly fished reefs are yielding smaller fish compared to irregularly fished, more distant reefs.

In summary - PNG's fish resources themselves are not a limiting factor to development. Lock (1986a) observed that where factors such as motivation, high fish price and demand are lacking, "it is likely that fisheries will not develop beyond the subsistence level, or at best only attract part-time fishermen. The provision of services and facilities ... does not in itself appear to be a sufficient stimulus to promote fisheries." (p.54). However, Wright *et al.,* 1983 were more euphemistic when they stated that problems associated with increasing yield include the lack of facilities and services in isolated areas and the need to rely on only local fishers to increase production in traditionally owned areas.

1.1.4 Management

Current legislation/Policy regarding exploitation: Fisheries development in PNG is mainly the responsibility of provincial governments, as it was one of the central government's functions decentralised when provincial governments were established. However, the DFMR Research and Surveys Branch provides financial and technical assistance for the assessment of marine fisheries resources in the provinces (Fisheries Research annual report 1985-1991).

The government prohibits the use of non-sustainable fishing methods - e.g. the use of cyanide and other poisons in the reef fish trade.

No regulations on the live fish trade have yet been gazetted.

Recommended legislation/Policy regarding exploitation: There appear to be two aspects which require attention. One is the need to safeguard the resources, the other is to develop those resources.

SECURING THE RESOURCE.

Catch rates decline rapidly with increased fishing pressure in handline, spear and net fisheries and the catch composition changes. In the light-moderate phase of fishing pressure, catches include a greater proportion of large fish (predators and herbivores). In the heavy phase of fishing pressure catch rates decline steeply due to the removal of those large fish, and the catches are dominated by small predatory fish (e.g. lethrinids). When the resource is fully- to over-exploited, catches by netting are dominated by small herbivores (e.g. siganids). In intensively fished reefs, average fish weight declines significantly and the species composition changes.

Lock (1986c) demonstrated this phenomenon in his study of the Port Moresby area artisanal reef fishery. Lock showed that reefs subject to less fishing pressure yielded more large fish and fewer small herbivores than did reefs heavily fished. The inverse occurs on reefs subject to heavy fishing pressure. Lock warned that estimates of the viability of an artisanal fishery (in PNG) should only be based on the middle-phase of the fishery - i.e. after the 'fish-down' period. Maintaining fishing pressure at a low level would give the best financial returns however - because of high catch rates of the predominantly higher value fish.

Determining the effects of fishing on coral reef fishes is a very difficult and complicated enquiry. Russ (1991) presented an excellent and very relevant overview of known effects on population levels and community levels of fishing which is direct (catch, mortality, age structure, behaviour, biomass, etc) and indirect (habitat modification).

Recommendations

- Shallow reef and inshore fisheries servicing larger population centres in PNG should be *monitored* at landing depots. Monitoring will pick up drops in fish size and catch, cpue changes and prevalence of fishing methods.
- *Management control to restrict fishing effort* could be implemented in areas subject to high fishing pressure. Lock (1986d) suggested a *limited entry system* whereby all vessels would be licenced (licences transferrable). Management zones for different licenced vessels would be needed and the system could largely be policed through village courts. Such a system could be introduced to the Port Moresby and Daru areas with support of the fishing communities.
- *Diverting fishing effort* off the reefs can assist the recovery of reef fish stocks. Deepwater handlining and trolling are examples. The troll fishery in the Tigak Islands, Port Moresby and some other areas has been facilitated by the siting of FADs [see other profiles.] Development of suitable craft and use of handreels are also needed.
- An adjunct to the above, is the need to encourage more *consumer acceptance of reef fishes lower in the food chain* (e.g. through fisheries extension workers), the better to ensure all trophic levels were maintained on the reef systems (although Lock (1986c) noted that Port Moresby consumers did not appear to be particular about eating large carnivores instead of small herbivores). Multi-gear fisheries affect the population structure of targeted reefs.
- *Community support* for maintaining traditional conservation techniques (such as closed seasons or reefs) should be re-established through village awareness extension work.

Recommendations for control of the live fish trade fishery were given by Richards (1993b). They include:

1. monitoring the trade. This includes ensuring that catch data forms are completed and submitted;
2. advise provincial authorities on the biological, social and economic costs and benefits of permitting such companies to operate in PNG's coastal waters;

3. fisheries officers should regularly inspect the operations of existing live fish trade fisheries in PNG waters. This includes enforcing national labour laws applicable to operations within 12 nautical miles (e.g. work permits; no use of hookah gear).
4. where joint ventures operate, ensure that there is no superfluous "crew" (who actually fish) on the carrier vessel;
5. investigate mechanisms for compensating fishers for 'bycatch' fish. This would involve having access to real prices in the receptive markets;
6. prohibit the use of underwater breathing apparatus for the taking of live reef fish;
7. encourage the application of traditional bans on fishing spawning aggregations. Applying closed seasons on fishing operations (based on traditional knowledge) should be encouraged and supporting legislatively (if this can be done. Does the baitfish fishery set a precedent here?)
8. restrict the number of live reef fish fishery operations in PNG waters to 2-3. This measure would enable better policing of the fishery.
9. maintain the annual review and renewal of licences
10. ensure no double licences are issued, i.e. that fish trade fishery operators do NOT have a concurrent licence to take marine aquarium fish.
11. apply access fees to the operations. The fees should be substantial and re-routed to the provincial governments who should dispense them to the communities in areas where fishing has taken place.

DEVELOPING THE RESOURCE

Many constraints to developing the resource have been discussed already. The Fishery Sector Review (1989) added a few more [from the aspect of commercial development]: the diversity of species, the marked variation in fish size, variation in the catchability of species between areas, conflicting community obligations, distance from markets, high domestic and international transport costs, limited extension work and follow-up, the low status of fish as a consumer item in coastal areas combined with competition from processed fish imports, strong market preference for fresh fish over frozen fish shipped from distant locations, inadequate marketing and distribution networks, and the reluctance of the private sector to become involved.

Recommendations

- Whilst recognising the need for assistance (especially to defray high transport, fuel and gear costs) I am wary of suggesting that the PNG government again embark on heavy subsidy support for the development of coastal fisheries. The price received for the product does not cover the cost of collector boats, subsidised freight, cold storage plants and so on. However, I do think that a provision of fisheries support through *training* and the *encouragement of private enterprise ethics in coastal communities* towards regular supply of fish to nearby towns should be undertaken much more positively than it appears to have been in the past. I encourage the IPA, DFMR and provincial government fisheries planners give high priority to developing and implementing these measures of support.
- *Quality of product* is worth attending. Ice can be purchased at the Lae, Madang and(?) Kavieng landing depots[1]. At the busiest markets - in Port Moresby - ice is not available and moreover, fish are generally sold ungutted. Some product would have been transported considerable distances to the market from villages (e.g. GaboGabo: P. Gamini, pers. comm.) and considerable time would have elapsed since the capture of many fishes. *Extension services* by the government (Department of Health, DFMR) *should be increased*

[1] I am uninformed whether there are other fisheries ice plants in PNG

to encourage better post-harvest handling practices by fishers in the interest of health and reduced resource wastage. [Does 'Women-in-Fisheries' do any of this? If not, why not?]

- *Proper training* (e.g. in species identification, record keeping, fish quality) should be provided *for the managers* of landings depots.
- Fishers should be obliged to bring their *catch to registered premises* (e.g. fish landing depots, a market office) *for weighing*, identification (? into broad categories) and *quality checking*. They need not sell to those premises however. Adapting some of the monitoring practices of the MOMASE project wouldn't go astray.
- The IPA and the DFMR could investigate the possibility of assisting *small national companies undertake the preparation of* '*convenience packs' of filleted reef fish* for sale in stores, to hotels and restaurants. Quality and cleanliness would have to be maintained; but fish in this form would incur only low freight costs, and the packs may swing some of the consumers away from imported product. Down the line, differently prepared packs could be developed (e.g. spiced fish; fish and onions). [The 'Women-in-Fisheries' group may already be involved in this kind of thing, but I am not singling out women here.]
- The prevalence of *ciguatera* in reef fish is something to be mindful of when planning expansion of fishing effort and catch. Ciguatera is not evenly distributed however: whereas in Samarai red bass (*L. gibbus, L. bohar*) are avoided because of their ciguateric reputation (Fisheries Research annual report 1980 & 1981), these same species are targeted in the Huon Gulf just to the north. Lewis (1985) considered that 'blanket bans' on the sale of certain species because of ciguatera fears unfairly penalises the fisher and results in wastage. *DFMR should seek information from experts in this field* before advocating a policy.
- The DFMR should *make greater efforts to provide* the provincial governments and fishing communities with:
- FEEDBACK on fishery catch reports;
- copies of reports on relevant fisheries resources;
- feedback on information provided to them by fishers;
- the reasons why management steps are advocated (village awareness). These kinds of 'little things' encourage respect for the resource by the resource users, respect for the resource users by the resource minders, and - in the long run - cooperative resource development and protection.

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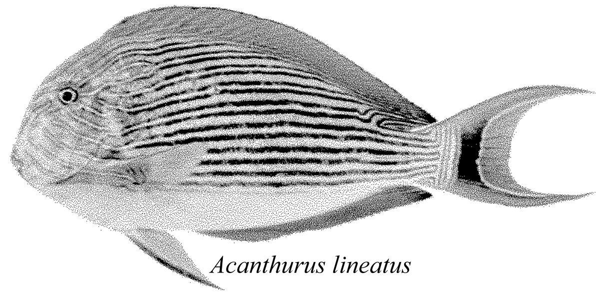
1.2 SURGEONFISH

1.2.1 The Resource


Acanthurus lineatus

Species present: Twenty nine members of the family were recorded from PNG by Kailola (1991) although some of these - such as *Ctenochaetus* and *Zebrasoma* are too small to feature in subsistence and artisanal fisheries. Seven members of *Naso* (unicornfish) and 15 species of *Acanthurus* (surgeonfish) are recorded from PNG.

Distribution: The species have a tropical and subtropical distribution, most of the species inhabiting PNG waters also occuring throughout the Indo-Pacific.

Biology and Ecology: Surgeonfish and unicornfish live mainly in shallow water around reefs, often forming schools. They are herbivorous, scraping substrate and benthic algae with their fine teeth (Munro, 1967; Dalzell, 1989).

Information on the biology of six species of surgeonfish

can be obtained from Dalzell (1985; 1989). There are sexual differences in length-weight relationships for two species *A. nigricauda* and *A. xanthopterus*. *A. nigricauda* has a L_∞ of 24.3 cm and lives for 4-5 years, while *A. xanthopterus* has a L_∞ of 48.3 cm and lives for up to 20 years.

Spawning appears to take place throughout the year. Six species studied in the Tigak Islands Mobiha (1993) observed that *A. lineatus* spawns throughout the year with peaks in reproductive activity during June and November, while *A. olivaceus* also spawns throughout the year yet displays beaks between January and February and June and July. *A. nigricauda* and *A. xanthopterus* also spawn year-round in the same area but exhibit broad spawning peaks during the middle of the year (Dalzell, 1989) when sea surface temperatures are coolest and salinity is high. *A. pyroferus* exhibits a peak in spawning activity between March and October (Dalzell, 1989). In the Tigak Islands, *A. lineatus* attains maturity on average at 14.2 cm total length and *A. olivaceus* at 13.3 cm total length (Mobiha, 1993); *A. nigricauda* at 13-14 cm total length and *A. xanthopterus* at 25-19 cm total length (Dalzell, 1989). Spawning may take place on outer reef areas and nursery areas are reef flats where there is little water movement (Mobiha, unpublished). Mobiha (1993) calculated fecundity and sex ratios of these two species.

Naso species attain at least 60 cm total length, *Acanthurus* species somewhat smaller.

1.2.2 The Fishery

Utilisation: Surgeonfish and unicornfish are important artisanal fisheries. They comprise one of the major group of fish harvested from offshore reefs.

On the west coast of Manus Island, surgeonfish are commonly caught by surround gillnets. Fishing is conducted during the day at low tide and targets schools of fish (Chapau and Lokani, 1986). In the1986 survey, it was found that *A. nigricauda* (as *A. nigricans* in Chapau and Lokani, 1986) comprised 10 per cent of the catch from underwater spearfishing.

Surgeonfish are also caught by spearing and netting in the Tigak Islands (Wright *et al.,* 1983) and by handlining from canoes in most areas. They are also collected illegally by bombing.

In trials using two different types of fish traps on coral reefs off Kavieng, surgeonfish dominated the catches (Dalzell and Aini, 1992) - *A. nigricauda* in the dollar traps and *A. xanthopterus* in the arrowhead traps. Surgeonfishes comprised about 40 per cent of the total catch in the dollar traps, of which *A. nigricauda* constituted about 60 per cent of all the surgeonfish caught. In the arrowhead traps, *A. xanthopterus* was the only species caught in those laid along the Kavieng shoreline and comprised 95 per cent of catches in those set on nearby reefs (Dalzell and Aini,1992). In contrast, surgeonfish caught by nets, spears and handlines comprise only 5 per cent of artisanal reef fish catches in the Kavieng area (Wright and Richards, 1985).

In reefs near Port Moresby (e.g. Daugo Island reef complex) unicornfish are caught mainly by underwater spearing, forming 16.8 per cent of the catch by this method (Lock, 1986a). By surround netting they comprised 12 per cent of catches.

Production and Marketing: Surgeonfish and unicornfish are generally sold whole - often ungutted - in coastal markets. They are highly esteemed as food fish throughout PNG coastal areas.

Surgeonfish comprise nearly 17 per cent of fish landed by surround netting in western Manus Island (Chapau and Lokani, 1986). *Acanthurus xanthopterus* was the 6th most common fish (3.9 per cent of total) brought to the Kavieng fish depot in the year from November 1980 (Wright *et al.,* 1983). Surgeonfish and unicornfish are classed a category 4 fish in the MOMA fish marketing scheme (Lae and Madang), fetching about $1.80/kg in 1994.

In the Port Moresby area in 1985, it was estimated that unicornfish captured by underwater spearing made up 5.6 t of artisanal fishery landings (Lock, 1986a) and nearly 30 t by surround netting. By drive netting they made up about 3 t and 1 t by gillnetting (Lock, 1986a). Their total landings (unicornfish only)[1] were estimated at 39.5 t (or between 5 per cent and 8 per cent of the total: Lock, 1986c). Prices obtained for unicornfish at Koki market in 1985 averaged K2.61/kg (Lock, 1986c).

There are no production figures for PNG (apart from a small quantity of *Naso* recorded by the Manus fishing authority in 1993 - DFMR Kavieng database).

1.2.3 Stock status

Mobiha (unpublished) reported on the occurrence of surgeonfish in the Madang Province. The areas he surveyed were reefal (Bagabag and Karkar islands areas), part reefal and estuarine/river influenced (Bogia coast), lagoons and reefal (Madang area) and sandy (Saidor coast). He found that surgeonfish and unicornfish were the dominant fish group in all areas.

There are no comprehensive stock assessments for surgeonfish and unicornfish in PNG waters. As a result of their trapping survey near Kavieng, Dalzell and Aini (1992) pointed out that these fish may be more abundant than previously realised, but remained lightly exploited due to the inefficiency of local fishing methods.

Lock (1986b) observed that unicornfish (*Naso unicornis* and *N. brevirostris*) are very susceptible to fishing pressure in a multi-gear reef fishery. Their catch rates decrease sharply after an applied effort of more than 2,000 man-hours/sq km. At an effort of 2,000-6,000 man-hours/sq km their abundance declines to very low levels.

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[1] Lock (1986 papers) does not mention surgeonfish, yet these fish are just as common in Koki market as are unicornfish.

1.2.4 Management

Current Legislation/Policy Regarding Exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Lock (1986) suggested that management measure suitable to a multi-species reef fishery should be considered. This would appear most appropriate where the reefs are adjacent to large population centres (e.g. Port Moresby; Lae) and are utilised to supply fish to the local artisanal markets. Munro and Williams (in Lock, 1986c) stated that measures such as catch quotas, seasonal quotas and limited entry may be employed. In the case of the Port Moresby artisanal reef fishery (and possible others in PNG), a licence-limited entry fishery seems most appropriate (Lock, 1986c).

The deployment of a fish aggregation device (FAD) off Daugo Island in 1992 has alleviated pressure on reef fish stocks and has therefore become (?by default) an effective management tool. By its very nature it supplies a different type of fish to the Port Moresby artisanal markets - open water pelagic rather than reef fish. No study has been conducted on which type of fish consumers prefer, whether sales indicate their preference or can influence the composition of fish offered for sale, whether the prices of the two types of fish are comparable and so on.

In lieu of stock assessments and biological studies, no recommendations on exploitation levels and management measures can be made. In the interim, implementation of a monitoring program for artisanal fisheries supplying larger population centres in PNG would be an advantage.

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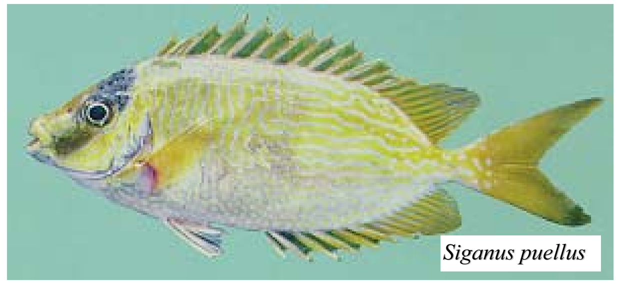
1.3 RABBITFISH

1.3.1 The Resource



Siganus puellus

Species present: *Siganus* species. About 14 species are present in PNG waters (Kailola, 1991).

Distribution: Rabbitfish are distributed in tropical Indo-Pacific waters from East Africa to Polynesia.

Biology and Ecology: Rabbitfish live in shallow coastal waters, including mangroves, estuaries, brackish lagoons and seagrass beds, also coral reefs (Hermes, 1992). Some species form schools. Rabbitfish are herbivorous grazers on seagrass and algae, but they also consume small animals on the plant material. In the Tigak Islands, New Ireland Province, *S. lineatus* and *S. doliatus* spawn throughout the year, although *S. lineatus* appeas to have a single spawning peak from November through to March and *S. doliatus* has a spawning peak in August (Mobiha, 1993). In the same area, *S. doliatus* matures on average at 14.5 cm total length and *S. lineatus* matures at 22 cm total length (Mobiha, 1993). The fecundity and sex ratios of these two species have also been calculated (Mobiha, 1993). They can attain lengths around 45 cm total length (Munro, 1967).

1.3.2 The Fishery

Utilisation: Rabbitfish are valued as food by many coastal people in PNG. Their flesh is of excellent flavour though slightly weedy. They are harvested for both subsistence and artisanal purposes.

On the west coast of Manus Island, rabbitfish are caught by gillnets set overnight in shallow water near mangroves or deep channels between reefs (Chapau and Lokani, 1986). In a 1986 survey, *S. fuscescens* was the most common fish in catches made by underwater spearfishing, comprising 27 per cent of landings. *S. fuscescens* is also caught by surface spearing with multi-pronged spear and comprised 13 per cent of landings by that method (Chapau and Lokani, 1986).

Rabbitfish are often the subject of bombing expeditions on reefs, e.g. in the Tigak Islands, *Siganus lineatus* is the most common catch from such a fishing method (Wright and Richards, 1983).

In Sissano Lagoon, West Sepik Province, rabbitfish (*S. fuscescens, S. guttatus*) are caught with surround gillnetting (Ulaiwi, 1992).

In the Huon Gulf, Morobe Province, rabbitfish are caught with spears and encircling gillnets, also with hook and line (Hermes, 1992).

In the Port Moresby (Central Province and National Capital District) artisanal fishery in 1985, rabbitfish comprised about 31 per cent of total catches by surround netting (Lock, 1986a), 7.9 per cent of drive netting catches and 16 per cent of total catches from barrier netting.

In the Daru area, Western Province, rabbitfish are commonly caught by 'sardi' (*Derris* species) root poisoning on the reefs at low tide (Mobiha *et al.,* unpublished).

Production and Marketing: There is little information on quantities harvested in PNG, although rabbitfish have been found to constitute up to 60 per cent of marketable-sized fished of shallow reef flats (Hermes, 1992).

Several species of rabbitfish are represented in landings at Voco Point, Lae (Morobe Province). The group is estimated to comprise 3.6 per cent of annual total landings there (Hermes, 1992).

Rabbitfish (*S. lineatus*) caught on reef complexes south of Daru are occasionally sold in the Daru market, Western Province (Mobiha *et al.,* unpublished).

In the Port Moresby artisanal fishery, rabbitfish comprised an annual catch of about 17 mt from surround netting, 12.8 mt from drive netting and 2 mt from barrier netting (Lock, 1986a). Their total 1985 landings (all methods) were estimated at 1.1 mt (or between 5 per cent and 8 per cent of the total: Lock, 1986c).

1.3.3 Stock status

There are no estimates of stock status nor structure in PNG waters.

Mobiha (unpublished) reported on the occurrence of rabbitfish in the Madang Province. The areas he surveyed were reefal (Bagabag and Karkar islands areas), part reefal and estuarine/river influenced (Bogia coast), lagoons and reefal (Madang area) and sandy (Saidor coast). He found that rabbitfish were the most dominant fish family after surgeonfish in the Bogia and Madang areas.

In a study of fishing pressure on fish resources in the Port Moresby area, Lock (1986b) found that rabbitfish catches were largest when fishing pressure was high. He suggested that this was a result of the heavier fishing pressure removing larger predators such as sea perch (Lutjanidae) emperors (Lethrinidae), rock cod (Serranidae) and unicornfish. Lock considered rabbitfish domination in catches from a reef fishery as indicating that the finfish resources were over-exploited - in the case of the Port Moresby artisanal fishery, when fishing intensity exceeded 6,000 man-hours/km^2.

1.3.4 Management

Current legislation/Policy regarding exploitation: There is none, although bombing of fishes is banned by gazettal and under police laws regarding possession of explosives.

Recommended legislation/Policy regarding exploitation: From available information, it appears that rabbitfish stocks are not affected by fishing pressure. However, a regular monitoring system of landing centres and artisanal markets should be implemented with catches identified by species groupings.

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1.4 MULLET

1.4.1 The Resource

Crenimugil crenilabis

Species present: Kailola (1987) recorded 18 species belonging to seven genera of mullet (family Mugilidae) from PNG waters. They are: Goldie River mullet (*Cestraeus plicatilis*), wart-lipped mullet (*Crenimugil crenilabis*), fringe-lipped mullet (*C. heterocheilus*), basket mullet (*L. alata*), large-scaled mullet (*L. macrolepis*), cream mullet (*L. melinoptera*), giant-scaled mullet (*L. parmata*), flat-tailed mullet (*L. subviridis*), rock mullet (*L. tade*), diamond-scaled mullet (*Liza vaigiensis*), sea mullet (*Mugil cephalus*), hornlip mullet (*Oedalechilus labiosus*), shark or mud mullet (*Rhinomugil nasutus*), bluetail mullet (*Valamugil buchanani*), round-headed mullet (*V. cunnesius*), Engel's mullet (*V. engeli*), blue-spot mullet (*V. seheli*) and Speigler's mullet (*V. speigleri*).

Distribution: Mullets occur in all tropical and temperate seas, usually near shore, frequently in brackish estuaries and fresh water. Within PNG, *L. vaigiensis* and *V. seheli* are common in the New Guinea Islands (Wright and Richards, 1985), *L. macrolepis* and *V. seheli* are common in Sissano Lagoon on the north coast of the mainland (Ulaiwi, 1992) and *Liza* species and *Mugil* species are common on the south coast (Lock, 1986). In the Purari River system, different species of mullet replace each other upstream and downstream: *L. parmata* and *V. buchanani* in the Purari River are replaced downstream respectively by *L. vaigiensis, L. dussumieri, L. tade*, and *V. seheli* (Haines, 1983). Haines also deduced that small juveniles of the freshwater species *Crenimugil labiosus* migrate upstream (in the Purari River) against a powerful current.

Biology and Ecology: Mullets are algal grazers and detrital feeders on the surface of bottom sediments. Much of the inorganic sediment is expelled through the gill chambers, while some of it passes with the organic material through a thick-walled, gizzard-like stomach and long intestine. In sea mullet, the inorganic material passing to the stomach is thought to assist in the grinding of food in that organ (Thompson, 1951, in Kailola *et al.,* 1993). Mullets may also consume insects, fish eggs and plankton (Myers, 1991).

Mullets are pelagic fish, usually found in association with shallow sand or reef habitats. Most species can tolerate a wide range of salinities, some inhabiting purely fresh water while a few species are found on coral reefs (Myers, 1991). *L. vaigiensis* forms large schools, frequently in mangrove areas while *C. crenilabis* occurs in schools, in sandy lagoons and on shallow seaward reef flats. The species is reported to spawn in large aggregations after dark (Randall *et al.,*1990).

A study by Mobiha (1991) of the reproductive biology of selected reef fish species in the Tigak Islands, New Ireland Province, showed that individual *V. seheli* were reproductively active all year round, with peaks in reproductive activity occurring in November and February. Goldie River mullet (*Cestraeus plicatilis*) spawn in the Vailala River (Papua) in March-April (Haines, 1978-79). In the rivers feeding into the Gulf of Papua, *C. plicatilis* migrates downstream to breed in the estuary-delta in April-May. In the Fly River, the freshwater *L. diadema* also migrates downstream to breed in estuaries (Haines, 1979). While the breeding localities and seasons of *Rhinomugil nasutus* and *Crenimugil labiosus* are unknown, juveniles are found in the estuary-delta and freshwaters, respectively (Haines, 1979). Freshwater-marine breeding migrations of *V. buchanani* and *L. parmata* also take place in the Gulf Province. Mullets in Tongan waters - principally *M. cephalus* and *Liza* species - are reproductively active between July and September, with spawning commencing in the third quarter of the year, during the cooler months.

Female *V. seheli* in PNG measuring 28-35 cm in length have been estimated by Mobiha (1991) to produce between 321,000 and 535,000 eggs. Length at first maturity was 30 cm. In

Australian waters, female *M. cephalus,* depending on size, produce between 1.6 million and 4.8 million eggs. The eggs are pelagic and average 0.6 mm in diameter (Grant and Spain, 1975, in Kailola *et al.,* 1993). Knowledge of larval biology in *M. cephalus* is limited to laboratory studies.

Postlarval *M. cephalus* first enter Australian estuaries when 2-3 cm long (Chubb *et al.,* 1981). After entering the estuaries, the fish form schools of a few hundred individuals and move to shallow nursery areas, which may be located from the lower estuaries to the freshwater reaches of tidal creeks (Thompson, 1955, in Kailola *et al.,* 1993). In Australian waters, juvenile *M. cephalus* reach an average size of 15 cm fork length at an age of 1 year, 24 cm at 2 years and 33 cm at 3 years. They reach maturity at the end of their third year, at sizes between 30 cm and 35 cm. *M. cephalus* in Australian waters are reported to reach a total length of 76 cm and a weight of 8 kg (Thompson, 1951, and Grant, 1982, in Kailola *et al.,* 1993). Langi *et al*.(1992) reported that in Tonga, both *M. cephalus* and *Liza* species exhibit sexual size dimorphism, with females growing larger than males.

1.4.2 The Fishery

Utilisation: Mullet comprise subsistence and artisanal fisheries in PNG. They are caught with a variety of seines and nets (including encircling gillnets, barrier nets, drive-in nets and scoop nets (Wright *et al.,* 1983; Hermes, 1992). They are seasonally important in some areas: e.g. ripe *Cestraeus plicatilis* are dip-netted from numerous canoes in rivers close to the sea during the mullets' spawning run in the Vailala River and other southern river systems (Haines, 1978-79) and a similar phenomenon has been observed in the middle(?) Fly River system with *L. vaigiensis* (A. Haines, pers. comm.). Large, commercial-size catches of mullet can be taken in the wet season in freshwaters of rivers draining into the Gulf of Papua (Haines, 1979).

Encircling seine nets, traditionally made from buch materials, are used in the Manus Province to capture mullet (Kubohojam, 1985, in Dalzell, 1993). In the Sepik provinces, mullet are common in artisanal fisheries in the Murik Lakes, Sissano Lagoon and Tumelo Islands (Chapau, 1991; Ulaiwi,1992; Chapau, undated). *L. vaigiensis* and *V. seheli* are the main species harvested (Ulaiwi, 1992). In Morobe Province, mullet are frequently targeted by net fishermen. Spawning aggregations are especially targeted (Hermes, 1992). In the Port Moresby area, mullet are caught by drive netting and barrier netting (Lock, 1986).

Production and Marketing: There are few separate figures available for artisanal or subsistence catches of mullet.

- In a November-December survey of the Sissano Lagoon, West Sepik Province, mullet were the dominant group in surround gillnet fishing, comprising 24.5 per cent of the catch by number (Ulaiwi, 1992).
- In contrast, mullet only comprised 11 per cent of the gillnet harvest from the Murik Lakes, East Sepik Province, during a February-March survey (Chapau, 1991).
- In the Madang Province, mullet are a very minor component of landings (DFMR Kavieng figures).
- In Manus Province, 189 kg were landed in 1990, 16 kg in 1991 and 108 kg in 1992 (DFMR Kavieng database).
- At the Kokopo Fish Market (East New Britain Province) 98 kg were sold in 1990, 54 kg in 1991, 101 kg in 1992 and 5 kg in 1993 (DFMR Kavieng database).
- In 1984, mullet comprised only 0.1 per cent of landed fish in the North Solomons (69 kg). Both fresh and smoked mullet are sold in local markets (Ito and Selemet, 1985).
- Mullet comprised 21.2-25.1 per cent of the artisanal catch of fishermen in the Tigak Islands (New Ireland Province) reef fishery in 1980-81 (Wright *et al.,* 1983). *V. seheli* was

far more abundant in landings than was the second-ranked mullet, *L. vaigiensis*. Catches by mainland coastal dwellers generally contain fewer pelagic fish such as mullet (Wright *et al.,* 1983).

- Several species form 3.4 per cent of total landings from the Huon Gulf at the Voco Point fish plant in Lae (Morobe Province) during the October-December 1991 period. Juvenile mullet are frequently present in landings throughout the year.
- Mullet ranked only 11th in importance in landings from the Port Moresby reef fishery (National Capital District) and comprised only 4.4 per cent of the artisanal catch (Dalzell and Wright, 1986). In the Port Moresby area, mullet comprise 10.7 per cent of catches taken by drive netting and 37.6 per cent of catches taken by barrier netting (Lock, 1986).

Mullet are usually sold fresh, but in some areas - such as the Gulf Province - preservation techniques such as smoking, salting and sun-drying are implemented. The market price of such-treated fish is often only marginally higher than the fresh product.

1.4.3 Stock status

There is no information on the stock status of mullet species in PNG; however, stocks are probably underutilised. For example, catch rates for mullet in the upper Purari River (Wai Creek below Hathor Gorge) are high. In a January one hour set of a monofilament gillnet, 88 mullet averaging 1 kg each were caught. Haines (1979) believed that a similar catch rate could be repeated in other suitable habitats as large schools of mullet approximating that size were observed in all clear water creeks.

1.4.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: There does not appear to be a need for legislation. Mullet are harvested mainly for subsistence and are sold in markets when seasonally abundant. As with other fish resources however, artisanal catches should be monitored and information such as quantity, price, harvest locality and harvesting method recorded.

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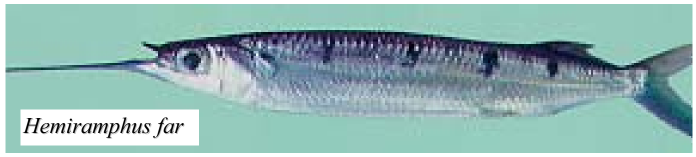
1.5/1.6 GARFISH and LONG-TOMS

1.5/6.1 The Resource


Hemiramphus far

Species present: Fourteen species of marine garfish (Hemiramphidae) were recorded from PNG waters by Kailola (1987) of which probably six are more common (e.g. *Hyporhamphus quoyi, Hemiramphus far, Hy. dussumieri, Hy. balinensis*). (The freshwater species, belonging to *Zenarchopterus,* are small fish). Of long-toms (Belonidae), there are five marine species (*Tylosurus, Ablennes, Platybelone*) and five freshwater species (*Strongylura*).

Distribution: Garfish and long-toms are tropical and subtropical fish, some garfish species also inhabiting temperate waters. The fished species in PNG waters are generally distributed in the Indo-Pacific region.

Biology and Ecology: Garfish are pelagic and very abundant, forming schools in open and inshore coastal waters, the brackish water of estuaries and freshwaters. They school near the surface during the day and over seagrass beds at night. Garfish are mainly herbivorous, feeding on small particles of vegetable matter including green algae and seagrass. They also consume small invertebrates. Garfish breed mainly in quiet regions of estuaries, laying eggs which adhere to plants by means of sticky threads. They can attain 50 cm total length (*Hemiramphus far*). Garfish are in the same group as small pelagics such as *Selar*, *Decapterus* and *Rastrelliger* species (profile 1.15), characterised by having restricted spawning seasons, low batch fecundities (400-600 oocytes/g of fish) and a 2-5 year life span (Dalzell, 1993).

Long-toms inhabit coastal waters and some live always in freshwater. They often congregate in large surface schools and are fast swimmers. Long-toms are pelagic surface predators, mainly feeding on small fishes such as sardines and hardyheads (Atherinidae), and they are generally voracious feeders. They can attain 1.5 m total length (Munro, 1967).

It is possible that long-toms aggregate for spawning at certain seasons. For example, shoals of them appear during July-August in the Finschhafen area (Alberta Tumonde pers comm) and the Huon Gulf. In the Port Moresby area they aggregate to spawn in open water during September-October (Papena Gamini pers comm). Alu (1989) reported that they school with the southeasterly monsoon throughout PNG waters.

1.5/6.2 The Fishery

Utilisation: Garfish are one of the major groups of fish caught from mangrove areas during the year.[1]

Garfish are often caught by spearing from a canoe using a multi-pronged spear tied to a bamboo pole. On the west coast of Manus Island *He. far* (as *H. commersoni* in the report) comprises 13 per cent of the catch caught by that method (Chapau and Lokani, 1986). Encircling seine nets, made traditionally from buch materials, are also used in Manus Province to capture garfish (Kubohojam, 1985, in Dalzell, 1993). Experiments with gillnets in the Sissano Lagoon, West Sepik Province, showed that juvenile garfish (mainly *He. far*) are caught in 2" (5.1 cm) mesh surround gillnets (Ulaiwi, 1992). In the Port Moresby artisanal fishery garfish comprise a small amount (3.7 per cent of the total catch) from barrier

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[1] There is no information in PNG fisheries literature, from PNG catch records, nor from the DFMR about the utility of garfish and long-toms in the Gulf Province and the Western Province - areas where mangroves and other suitable habitats exist.

netting (Lock, 1986a). In the Daru area (Western Province), garfish - mainly *Hy. dussumieri* - are caught by gillnetting over the reefs, and sometimes by spearing (Mobiha *et al.,* unpublished). At the Daru local market garfish comprise much of the catch of pelagic fishes caught over reef complexes.

As in many areas of the western Pacific, garfish are used as lures when trolling for larger pelagics - as they are in the Tigak Islands, New Ireland Province (Wright *et al.,* 1983).

In the Milne Bay Province, long-toms are traditionally caught by fixing a silvery cobweb pad on the tail of kites pulled along above the water surface. The cobweb becomes entangled in the long-tom's teeth (Wright, 1983). Fish are also taken at night when thay are attracted to shallow water by lights. A variety of nets and traps used throughout PNG to catch garfish in inshore waters (Wright, 1983). In Central Province, the fish were caught at night with spears from outboard canoes with the aid of lamps (Alu, 1989).

In the Port Moresby area, long-toms are caught by (surface) spear fishing over reefs and seagrass beds. It has been estimated (Lock, 1986a) that they comprised 94.8 per cent of the catch taken by that method. A major proportion of the catch is made between June and October (Lock, 1986a). The long-tom fishing season is September-October when the fish aggregate for spawning (Papena Gamini, pers. comm.).

In the Huon Gulf fisheries, long-toms are caught with castnets or by trolling with surface lures. They are also caught at night by attracting them to lights. In the Finschafen area long-toms are caught seasonally (July-August).

The fish are eaten fresh or smoked. They are said to be particularly good to east when smoked. The smoking is done using hardwood (not mangrove wood).

Production and Marketing: In the Port Moresby area in 1985, an estimated 26.4 mt of long-toms were landed in the artisanal fishery from surface spearing and another 2 mt by surround netting (Lock, 1986a). Total estimated landings of long-toms for the year (all methods) were estimated at 29.8 mt (5-8 per cent of total landings: Lock, 1986b), and for garfish about 6 mt.

In 1985 garfish sold for an average K2.36/kg in Koki market (Port Moresby) and log-toms fetch an average K1.76/kg (Lock, 1986b) (K1.50/kg when they are seasonally abundant).

At Voco Point (Lae), long-toms comprise only a small amount of total landings - for example, about 1 per cent in 1992 (Hermes, 1992).

1.5/6.3 Stock status

There is no information on stock structure. Stock assessment studies have not been performed.

Alu (1989) considered that the use of modern fishing vessels and spotlights has had a profound effect on the quantity of long-toms caught in the Port Moresby area. He considered that catches were 3-4 times greater than catches made using small outrigger canoes and lamps.

1.5/6.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: In lieu of adequate information on the fisheries, stock levels and so on, it would be premature to propose management measures. The seasonal nature of the fisheries may be their own best managers at present. However, an appropriate monitoring system of artisanal catches throughout PNG - including records of catches and identification by species groupings and fishing methods - should be implemented.

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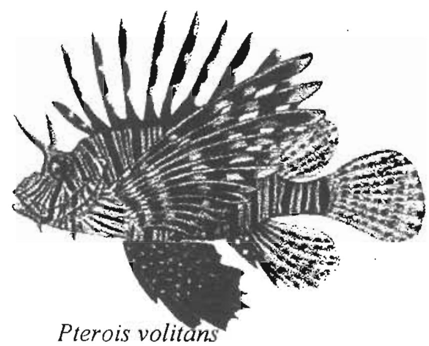
1.7 AQUARIUM FISH

1.7.1 The Resource



Pterois volitans

Species present: The main groups of marine aquarium fishes are coralfish and butterflyfish (Chaetodontidae), anemonefish and damselfish (Pomacentridae), surgeonfish, tangs and Moorish idols (Acanthuridae), wrasse (Labridae), angelfish (Pomacanthidae), triggerfish (Balistidae), gobies (Gobiidae), blennies (Blenniidae), basslets and small groupers (Serranidae), pufferfish (Tetraodontidae), rabbitfish (Siganidae), hawkfish (Cirrhitidae), cardinalfish (Apogonidae), boxfish (Ostraciontidae) and leatherjackets (Aluteridae). The central Indo-Pacific location of PNG suggests that the variety of species in its waters of potential interest to the marine aquarium fish trade is probably one of the highest in the world.

Because of the limited development of the aquarium fish industry in PNG, endemic species potentially valuable to the aquarium fish trade in PNG waters have yet to be identified. It has proven economically beneficial for countries entering the marine aquarium fish industry to be able to offer species not available from other countries. As much as 80 per cent of income may come from just a few species which are abundant enough to be regularly collected in high numbers (Pyle, 1993). For example, the viability of the Cook Islands aquarium fish industry relies on two main species - flame angels (*Centropyge loriculus*) and red hawks (*Neocirrhites armatus*) (Richards, 1993) and the Sri Lanka industry relies heavily on powder blue tangs (*Acanthurus leucopareius*?).

PNG also possesses colourful freshwater fishes sought after by the aquarium fish hobby trade. Most of these fish are rainbowfish (Melanotaeniidae) yet small gudgeons (Eleotrididae) are also traded.

Distribution: The groups of species used in the marine aquarium fish trade are widely distributed in the Indo-Pacific and PNG has more than a fair share. For example, 46 species of coralfish, 23 species of angelfish and 105 species of damselfish alone inhabit PNG waters (Kailola, 1987). I suggest that approximately 20 per cent of the c. 2,400 species recorded from PNG waters could be of interest to the international marine aquarium fish trade. Some species with a limited distribution or endemic to PNG may be among them. Aquarium fish collectors on the neighbouring Great Barrier Reef (Queensland, Australia) target species in 35 families (Couchman and Beumer, 1992) and representatives of 45 families are permitted import to Australia (Commonwealth of Australia Gazette no.GN 33, 19 August 1992).

There is no information on the distribution of individual marine aquarium fish species in PNG waters. In the Western Pacific generally, many of the more valuable species of aquarium fish inhabit deeper water and tend to be found in outer reef areas (Pyle, 1993).

Biology and Ecology: Due to their vast diversity, it is difficult to make generalisations about the biology and ecology of tropical marine aquarium fishes as a whole (Pyle, 1993). Aquarium fish inhabit waters from near the surface to depths of up to 70 m, and may be located in a variety of habitats, depending on the species' preference. Many are associated with coral reefs and fish such as cardinalfish, small groupers and rabbitfish also live in mangrove areas. Clownfish (*Amphiprion* species) are unusual, preferring to live among the tentacles of sea anemones.

Feeding strategies for these fishes vary from herbivore (surgeonfishes and tangs) through omnivore (wrasses) and planktivore (damselfish, serranid) to carnivore (hawkfishes) (Pyle, 1993).

Reproductive activities are various, including mated pairs, polygamous harems and temporary mass aggregations of individual fish for spawning. The fish either spawn pelagic eggs or brood their larvae. Butterflyfish and wrasse are among the many groups of indiscriminate spawners whose eggs hatch into planktonic larvae. Up to 90 per cent of aquarium fish species spawn this way. Larvae drift in the ocean currents for a length of time, depending on the particular species and the current duration. The larvae may travel thousands of kilometres from their origin before settling on a suitable reef habitat. Shortly thereafter the larvae metamorphose into juvenile fish.

Brooding fish (e.g. damselfish, gobies, cardinalfish) lay their eggs on the sea floor and usually defend them from predators until they hatch. The newly hatched larvae hide in the reef or vegetation while growing into juveniles.

1.7.2 The Fishery

Utilisation: Small, colourful fishes are collected as pets by thousands of individuals in countries all over the world. The aquarium fish trade is extremely valuable. Bassleer (1994) estimated that the total wholesale trade value of live ornamental fish is US$900 million, of which marine fish comprise 10 per cent. Because tropical species are more diverse and generally more colourful than are temperate species, much of the aquarium fish trade (98 per cent: Bassleer, 1994) is conducted on tropical species. Juveniles are sought after by the trade as they are often more colourful than are adults and generally easier to handle. They are generally not more than 6 months old and 10 cm long. Colourful fish which attain a small size as adults are also sought by collectors. Very few of the desirable aquarium species are juveniles of commercial food fishes (Lewis, 1985).

The major importers of aquarium fishes are the United States of America, Europe and Japan, and the main suppliers are Singapore, Thailand, Indonesia and the Philippines (Bassleer, 1994). The United States of America is the largest importer of tropical marine aquarium fish in the world and obtains about 80 per cent of its supplies from the Philippines (Wells and Hanna, 1992). The Philippines is the main global supplier of marine aquarium fish, followed by Indonesia and Sri Lanka.

Marine aquarium fish have been collected and traded from Rabaul (East New Britain Province) for some years. Operations appear to have ceased some time ago, but DFMR is currently considering a proposal for a company called Taklam to carry out marine aquarium fish collecting. I also understand that there are exports of marine aquarium fish from Wewak (East Sepik Province) but information about the trade there was not available. I do not know of other past or present aquarium fish industry operations in PNG.

The trade in PNG freshwater rainbowfish and gudgeons is generally met by breeders in Singapore (Perino, 1990) because of problems in locating and capturing fish in PNG itself and transporting them to markets.

The aquarium fish industry in the Western Pacific consists of three elements. These are collecting, transport to in-country warehousing and holding facilities, and exporting.

Collecting

Most collecting is carried out by nationals of the countries involved. Collectors are paid by the fish and prices paid depend on the demand for each species and the size and condition of the fish. Craft used by the collectors vary from canoes to 5-8 m long outboard-powered boats.

There are two main ways of collecting marine aquarium fish, differentiated on their ecological soundness. The one is by the use of chemicals and breaking up of habitat, the other is by the use of nets and hand.

The most popular chemical used in collecting fish for the aquarium trade is sodium cyanide, and it has been used extensively in the Philippines since the 1960s. Sodium cyanide damages the internal organs of the fish and up to 80 per cent die within weeks or months after collection (Wells and Hanna, 1992). The chemical is also toxic to corals, invertebrates and other organisms on the reef, and can cause long-term damage to the reef itself (Randall, 1987 in Couchman and Beumer, 1992; Pyle, 1993). Bleach (sodium hypochlorite) is another chemical frequently used to collect aquarium fishes.

Tranquilizing chemicals such as quinaldine and rotenone apparently have no adverse impacts on the ecosystem and fish collected through their use do not suffer ill effects (Perino, 1990).

Fish which hide between the branches of coral heads can be flushed out into barrier nets by breaking the coral ('notching'). This practice is performed only by experienced collectors who are said to break the coral such that it has the best chance for re-growth (Passfield and Evans, 1991, in Richards, 1993). However, there is no information on whether regrowth occurs or - if it does - over what time period.

Although some aquarium fish are collected by snorkellers, they are usually collected by divers aided by scuba or hookah gear. The divers work between 7 m and 70 m and mainly use small-mesh barrier nets and hand-held scoop nets to collect fish (often used in conjunction with a short rod or pole ('poker') to insert into coral to scare fish into the net). Barrier nets are bottom-set gillnets and vary in length from 1 m to more than 20 m. They are set at strategic locations and target fish are herded into the net by divers. From there, the fish are picked out by hand. Handlines with barbless hooks are also used for taking certain species, such as wrasse (Couchman and Beumer, 1992). In general, collecting healthy fishes for the aquarium trade requires much skill and experience (Pyle, 1993).

Some marine fish (notably anemonefish) can be bred in captivity to supply the aquarium fish trade (Pyle, 1993).

In-country transport, holding and warehousing

Collected fish are placed in a small holding bucket until the dive is finished. Fish collected from deeper water (more than about 10 m) must be decompressed by either bringing them slowly to the surface or by puncturing their swimbladder with a hypodermic needle (done by experienced collectors). On board each dive boat are special tanks or large plastic containers for keeping the fish alive and as unstressed as possible. Some collectors use pumps to re-circulate the sea water in the tanks. Once ashore, the fish are despatched to a warehouse.

An aquarium system at a warehouse/holding facility keeps the fish alive until they are shipped to the wholesaler overseas. Aquarium fish warehouse facilities in the Pacific region vary in size from about 50 m^2 to 200 m^2, averaging about 100 m^2 (Pyle, 1993). The location of the warehouse is important: near the ocean where clean seawater may be taken; where there is easy access to roads; close to an airport; close to boat ramps and protective harbours in cases of inclement weather; close to good collecting areas; and with access to reliable supplies of electricity and other utilities.

Fishes are maintained in large tanks, although aggressive species - such as angelfish - are isolated from one another to prevent their fighting (Pyle, 1993). The tanks are fed with fresh seawater pumped directly from the ocean or recirculated seawater. At the first sign of any disease problem in the facility, the water is treated with antibiotics. Great care is taken with water quality, all incoming water being filtered and water and oxygen content being controlled (Passfield and Evans, 1991, in Richards, 1993; Pyle, 1993).

Production and Marketing:

Exporting

Fish are kept for several days in holding tanks prior to shipment. For this they are packed individually into doubled polythene bags separated by a liner of newspaper. The bags are one quarter filled with seawater, inflated with pure oxygen, sealed, and packed tightly in lined cardboard boxes prior to being air-freighted overseas.

Freight costs are high because of the need to despatch fish in individual bags (weight of water), even though in many countries it is more economic to send large volumes at a time because of available minimum freight rates. The peak selling season for aquarium fish in the United States of America and Europe is from June to August (Richards, 1993).

An export industry for aquarium fish relies on access to regular, frequent and reliable flights to international destinations. Most fish collected in the Pacific are exported direct to America. Transhipping fish to secondary destinations is commonplace. PNG could supply Asia (Japan) and Australia - where more than 500,000 fish are imported annually (Couchman and Beumer, 1992).

Mortality rates of marine aquarium fish after collection depend on the manner of collection. Improper decompression, damage during handling (e.g. overcrowding, poor aeration) and poor water quality have been implicated (Pyle, 1993). Higher pre-export mortalities occur when fish have to be transported a long distance from point of collection to export holding facilities. Shipping mortalities average 5-10 per cent for shipments from the Pacific region (Pyle, 1993) (only 0.5 per cent in Fiji: Hanna and Wells, 1992). Some fish are prone to dying when removed from their environment, and should not be collected. These fish include certain anemonefish, obligate coral-feeding butterflyfish and cleaner wrasse (*Labroides* species).

Collection by chemicals generates high mortalities. Perino (1990) reported that 5-25 per cent of fish collected by chemicals die within hours of capture, and comprise 20-40 per cent more after that.

I have no information on the production and marketing of aquarium fish in PNG. Perino (1990) provided optimal estimates of possible aquarium fish exports over a five-year term (culminating in an export value of K1 million by the year 2000). These are presented in Table 11.

Table 11 Optimal estimates of possible aquarium fish exports from PNG over a five-year term (Source: Perino, 1990).

year of operation	no. of boxes (fob volume)	value in kina (@ 1990 rate)
year one	1,000	38,000
year two	1,800	68,400
year three	2,200	83,600
year four	4,400	167,200
year five	7,200	273,600

The industrial chain which 'constructs' the price is explained as follows (Bassleer, 1994):

fisher -> exporter -> airline -> importer/wholesaler -> retailer -> hobbyist.

According to Perino (1990) the prices paid to the collectors by the buyer (exporter) are between 10 per cent and 50 per cent of the export price. The importer adds 100 per cent to the CIF price of fish and then the retailer adds 100 per cent to the price he pays to the importer. For example, for a fish bought for $100 by a hobbyist, the retailer paid $50 to the importer, the importer paid $25 to the exporter, who paid between $2.50 and $12.50 to the collector. If the exporter has to buy from a middleman, the price to the collector will be less. Prices paid to the collectors also depend on supply and demand. According to Richards (1993) the average return to the exporter (ex Rarotonga, Cook Islands) is about $NZ7.00 per fish.

1.7.3 Stock status

There is no information on the population status of species in PNG used in the marine aquarium fish trade. However, because of the minimal trade (if any) in PNG and the abundance of coral reefs in PNG waters, aquarium fish stocks are probably greatly underexploited.

An idea of the abundance of aquarium fish species in PNG can be made by comparison with Fiji's projected stocks. In 1985, c. 40,000 fish were exported from Fiji (Lewis, 1985), a country with 90 per cent more reef area than has Hawaii - which in turn exports more than 150,000 fish each year on a sustainable basis. PNG's reef area is considerably greater than is Fiji's. Perino (1990) reported that in Fiji there had been no noticeable depletion of aquarium fish stocks in a six year period from a harvesting area of about 70 square miles.

Effects on reef communities from aquarium fish collection by hand or net are believed to be very small (Lewis, 1985) and very few - if any - species of reef fishes are in danger of becoming extinct as a result of aquarium fish collecting (Wells and Hanna, 1992; Pyle, 1993). This is because

- many of the popular species are abundant on reefs,
- recruitment rates and natural mortality rates of reef juveniles are very high,
- local depletion is only temporary because of the constant influx of settling larvae and juveniles moving in from adjacent reefs,
- because the spawning stock (adults) are generally not targeted, recruitment overfishing does not occur (**beware: live fish trade),
- because collection is labour intensive it not effective (low cpue) in habitats providing cover for target species, and
- many rare species generally occur in localities (including depths) where collection is not commercially viable.

The effect on reef fish populations of habitat destruction from collecting techniques (broken coral; use of poisons such as sodium cyanide and bleach) is discussed by Pyle (1993).

Stock assessments provide the only reasonable measure of sustainability, but monitoring of catches and exports plus estimates of species abundance over time are required before they can be made. Calculation of cpue from operators' returns is the only means available to PNG in the short term, with special note being made of exports of rare or endemic species demanded by the trade. Underwater visual censusing and transect techniques are probably the most accurate methods to assess species abundance.

Note that fluctuations in catches may <u>not</u> indicate reduction in stocks. Fluctuations may be caused by market requirements (where demand for certain previously popular species has dropped), natural population changes, variable catchability of particular species, collectors' experience and site access during periods of inclement weather.

1.7.4 Management

Current legislation/Policy regarding exploitation: In 1993 the DFMR recognised the potential value of an export marine aquarium fish industry to PNG. The DFMR pointed out that the industry would be assisted by a) access to major international air services, b) management, c) the prohibition of deleterious collecting methods and d) the use of foreigners to train PNG nationals in species identification and handling and transport techniques.

Recommended legislation/Policy regarding exploitation: A marine aquarium fish industry *could* provide a good alternative source of income for coastal villagers in PNG. The most important things to consider when determining the feasibility of extablishing an aquarium fish industry in the tropics are - according to Pyle (1993):

1. local wage rates;
2. the abundance of accessible coral reefs;
3. the regularity and reliability of airline connections to market destinations (and from sources of supply within the country);
4. competitive freight rates; and
5. the availability and cost of land for facilities.

How does PNG rate? The only 'positive' is the abundance of coral reefs. On the negatives: the high value of the kina and wage structure in PNG mean that *labor is not inexpensive*; *airline connections* to market destinations (Europe, USA, Japan) are *few* or only exist via circuitous routes; both overseas and domestic *freight rates are high* (more than in any other country participating in the industry) and mean that shipments of aquarium fish from PNG would not be competitive anywhere in the world; and *access to land* for facilities could be *prohibitive* - depending on the operational structure of the industry (i.e. amount of national participation). That marine aquarium fish are difficult to breed in captivity may well be the only factor preventing a trade in PNG marine aquarium fish following the same path as did the trade in the country's freshwater aquarium fish (see earlier).

Several factors besides abundance of favourable habitat *could* support the development of a marine aquarium fish industry however. These are:

- physical access to collecting areas is easy (*cf* for freshwater fishes);
- the high number and diversity of species in PNG provides a new source of fish for the world market;
- advantage could be taken of the existing international airlines services to Asia (Japan) and Australia. These are markets where a young PNG marine aquarium fish trade could easily become established - to Asia, through being able to supply quality fish collected without the use of chemicals (*cf* Philippine supplies, which are mostly collected with the aid of chemicals), and to Australia, which is sensitive to the risk of importing diseases and parasites with imported aquarium fish. PNG shares a common border and similar zoogeography to tropical Australia. A fledgling PNG aquarium fish industry could benefit by pursuading Australia that the risk of importing exotic diseases with its imported marines would be reduced considerably if Australia were to obtain its marine aquarium fish from PNG rather than further afield. Approximately 95 per cent of the marine aquarium fish species imported by Australia naturally occur there (Couchman and Beumer, 1992).

Industry involvement is required to develop the fishery in PNG, as the expertise of collecting and maintaining is not available in government ranks. Industry involvement also would facilitate establishing markets and operator links in importing countries. Government assistance - in the short term - would also be an advantage. I suggest that PNG (DFMR and the Investment Promotion Authority, IPA)

1. establish guidelines for the industry; then
2. invite expressions of interest;
3. assess applicants against the guidelines;
4. license one operator initially;
5. monitor the operation against the guidelines - with an option to revoke the licence if conditions are not being met; and
6. provide government assistance in the form of: assisted freight rates (domestic and international), involvement in land and traditional fishing rights negotiations and a cooperative and efficient Customs service (for clearance of shipments).

Exploitation guidelines for a future PNG marine aquarium fish export industry should include the following:

- Operators should have a high international reputation with a proven record in the trade. The operator should also provide some equity into the business.
- Exporters should be licenced. Conditions for issuing a licence to exporters should include:

  - training staff,

  - a minimum number of national staff will be employed,

  - acceptance of observer and inspection status,

  - an undertaking to take appropriate measures to control and conserve stock.

  The licence should be issued for short period initially (e.g. 12 months) and renewed annually depending on the advice of the DFMR and the licencee meeting all licence conditions. Licensing ensures that collectors and exporters are competent in capturing and caring for fish. Their expertise means that fish mortality will be minimal (Pyle, 1993) - e.g. as low as 0.5-2 per cent (Perino, 1990).

  The operator must specify on his licence the varieties of fish he is targeting.

- Fish may not be collected with the use of toxic chemicals, local poisonous plants, electricity and explosives, and destructive methods of collecting (e.g. crushing stony coral for the purpose of getting fish out) should also be prohibited.
- Conversely, approved collection methods have also to be stated. For example, only certain types of nets (without knots) and a specified length of barrier netting.
- Operators are to keep records of the numbers and variety of fish collected, their source, the price paid to collectors, date of collection and of export, numbers and varieties exported, destination, price received and mortality at all stages. Records may be inspected upon request and/or submitted on a monthly basis. Collectors are to be given receipts for fish bought. Similarly, export permits should be required for each shipment, with quantities and species recorded.
- Reefs in the area of operations should be set aside as reserves, and protected areas should be established in which fish capture is partially or totally banned for prescribed periods. Collecting may only be performed in permitted areas. Randall (1987, in Pyle, 1993) argued that permanent marine sanctuaries or marine parks should be established wherein ALL fishing is prohibited. These sanctuaries would provide areas where breeding

populations would be sustained. They would also support the tourism industry in ensuring undisturbed habitat for diving and viewing.

- Collection activities should not interfere with other fishing/recreational activities (e.g. diving, food fishing, tourism).
- Species unsuitable for aquaria should not be collected. This means that collectors must be able to accurately identify fish.
- Conservation guidelines should be agreed between the operator and the government. There is an option to set a quota on the number of fish exported per year based on the area of operation, but these would be arbitrary as there is no information on stock size, nor the long-term effect of removal of fish from a reef system. Should preferred and/or endemic species be identified, consideration should be given to placing quotas on them however. In Queensland, there are no limits on the size of fish and numbers collected.
- The owners of the resource should be involved in the industry to the maximum extent practicable with a minimum national participation being agreed. Every encouragement should be provided (e.g. through the IPA) to secure local investment, with a projected major shareholding or ownership in the future. Perino (1990) suggested that the government itself could enter the trade as a shareholder.

  Further on the economic side, local involvement in the industry is also a security for resources. Payments for customary fishing rights owners for access to the reefs could be a major economic drawback to the industry, and aquarium fish are caught in inshore areas. The government (DFMR and IPA) could assist the operator to negotiate for fishing rights - ideally over a medium term of 3-10 years (Perino, 1990).
- Nationals involved in the industry should receive training in all aspects of the industry. They must be experienced in the use of SCUBA gear, be able to identify fish (at least, into categories), care effectively for fish, practise good and environmentally safe collecting methods. Because of difficulties in identifying fishes + allocation of different common names in separate regions, it may be better for the national collectors to group the fish into categories. (This is common practice in Queensland, where 14 categories are recognised: Couchman and Beumer, 1992). Closer identifications would be required if certain species were targeted, or if quotas were brought in.
- A joint licence for aquarium fish collecting + the live fish trade - nor for any other harvesting activity (e.g. ornamental corals, sea cucumbers, trochus, mother-of-pearl) should not be issued. The live fish trade will remove the spawning stock of certain species (certain serranids, wrasse and rabbitfish) and engender recruitment overfishing. Licensed aquarium fish collecting and harvesting of live fish for human consumption by the one or several companies may not be performed in the same geographic area.

Additional comments

A developing marine aquarium fish industry in PNG should aim at quality in its product. The maintenance of quality in exported aquarium fish ensures high price and sound reputation. Quality generally can be *seen*, as the products are *alive*. The extra cost of quality control in a fish house with good water management and trained staff adds to the value of the fish (Bassleer, 1994). Short transport and holding times, correct care of fish and good water maintenance are some of the factors which ensure quality is achieved and good prices are received.

As well as maintaining quality warehousing and maintenance, enforcement is necessary to prevent illegal collecting practices (e.g. the use of chemicals) (Couchman and Beumer, 1992) and a 'black market' trade by unlicenced operators. In embarking on a new, international industry, PNG cannot afford to wait for the market to detect and respond to poor collection practices, as it would then have to input a lot of time and resources to clear its name and re-establish itself on the global market. Therefore, enforcement of correct collection practices is needed (NB: Pyle (1993) reported that there is now a test for detecting sodium cyanide in aquarium fishes).

Long-term monitoring and regular assessments of stocks of target species should be performed in the areas of operation. These practices would provide a measure of the effect (if any) fish collecting has on the reef ecosystem as well as an indication of abundance of target species. (*This information could also be useful in assessing the live fish and reef fish trade*)

A PNG marine aquarium fish industry would be in a good position if it were able to export fish unique to PNG. I suggest that one of the first steps the operator should undertake therefore, is an analysis of the composition of PNG marine fish fauna and an appraisal of the availability of 'unique' fish. An attractive prospectus could then be prepared to send to importers.

The operation should be based in Port Moresby, with branches in other provinces. Perino (1990) suggested Kavieng, Madang and Daru (although Daru has a limited variety of species). Perino also suggested that fish from each of these centres should be sent to Port Moresby already packed for export (i.e. saves time -> quality product). Difficulties which could be experienced by collectors in minor towns and villages would include the availability of reliable electricity supplies (batteries?) and the availability of transport.

With more collectors and areas of operation, supplies are more consistent, are plentiful, and there is a good variety and sizes of fish. More fish also ensures consistent pricing. The capital cost of boats and outboards, SCUBA gear, collecting equipment, pumps, buckets, nets, aerators, and so on could be prohibitive however. Perino (1990) suggested that the collectors could share the costs through forming cooperatives, and/or that the IPA could provide financial aid.

No export duty should apply to product, as it will make the fish products non-competitive. PNG's high freight rates have already been identified as an impediment to the industry. Government assistance should be sought to negotiating more competitive rates.

Is there some provision whereby the industry can pay for management costs? In Queensland a collecting permit fee is paid each year and monies from that are channelled back to support the industry (Couchman and Beumer, 1992). PNG should consider whether application of a licence fee for its single operator would benefit a fledgling industry. In any case, the DFMR should conduct *independent price checks* of marine aquarium fish on the global market, if only to ensure that the village collectors are receiving the correct percentage payment.

Perino (1990) suggested that the feasibility of establishing a captive breeding program for marine aquarium fish be investigated. Such a program would - he said - reduce disturbance and damage to reefs, relieve pressure on wild populations and assure a constant supply of fish for export. However, whereas much of the global freshwater aquarium fish trade is supplied from captive breeding programs, attempts at commercial-scale captive breeding of marine fish species have met with only limited success. Hence I consider it prudent for PNG to wait for other countries to spearhead research in this area, as it would be expensive and the necessary expertise in not available in PNG. In any case, most of the problems of wild harvest identified by Perino are unlikely to face a PNG marine aquarium fish industry.

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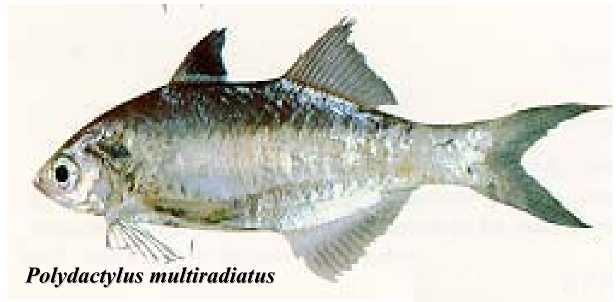
1.8 THREADFIN SALMON

1.8.1 The Resource


Polydactylus multiradiatus

Species present: Blue or giant threadfin, *Eleutheronema tetradactylum,* and king threadfin, *Polydactylus sheridani*, are the main species harvested in PNG. Nine other, smaller species in the family Polynemidae are present in PNG waters (Kailola,1987), including seven-fingered threadfin (*P. heptadactylus*), small-mouthed threadfin (*P. microstoma*), black-spot threadfin (*P. sextarius*) and many-rayed threadfin (*P. multiradiatus*).

Distribution: Threadfin salmon are widely distributed in the Indo-Pacific, from India to the Hawaiian, Marquesan and Tuamotu Islands. In PNG, their range is uncertain. *E. tetradactylum* are distributed from West Irian border to Marshall Lagoon (Central Province) (Kailola, 1975) and *P. sheridani* are distributed from western Papua eastwards to perhaps Yule Island (Central Province). Members of the family have been recorded from the East Sepik, Madang, West New Britain, Morobe and Milne Bay Provinces.

Biology and Ecology: Threadfin salmon live in tropical, inshore (to about 25 m) waters, estuaries and tidal reaches of rivers, including sandbanks and mud substrates. They are more common in the Gulf of Papua than in western Papua, as they prefer turbid (silty) waters. *E. tetradactylum* appears to be the most abundant of the two larger species. Both species are abundant in coastal waters. *E. tetradactylum* rarely enters the coastal to brackish zones of the Kikori, Era, Purari and Vailala river systems, while *P. sheridani* is more common in those habitats, being occasionally found in the freshwater zones of the deltas (Haines, 1979). There is little information on the life cycle movements of threadfin salmon, although they are known to move ong distances along a coastline.

Threadfin salmon usually form loose schools; larger fish may be single or in pairs. They are protandrous hermaphrodites - i.e. they mature first as males, and after some years, change into females. Most *P. sheridani* above 95 cm fork length are females (Kailola *et al.,* 1993), and probably most *E. tetradactylum* above 100 cm fork length are females (Griffin, 1993). Opnai (1983) recorded an average length at first maturity of 65-70 cm fork length (although he did not state the sex) for *P. sheridani* in the northern Gulf of Papua.

In northern Australia, *P. sheridani* spawn from October to March, spawning peaking about December. *E. tetradactylum* appear to spawn earlier. There is limited information on the fecundity and reproductive cycle of either species (Kailola *et al.,*. 1993). In the Gulf of Papua, *E. tetradactylum* spawns in August (Haines, 1979) and *P. sheridani* spawns between about October and February: mature and spent males and females appear in catches during this period. Peak spawning of *P. sheridani* takes place in December and also in February (Opnai, 1983). The fish move out of the river systems into the sea to spawn (Haines, 1979; Opnai, 1983).

Threadfin salmon eggs are planktonic, and nursery areas are inshore, shallow and of low salinity. Juveniles occur in estuaries and foreshores during and just after the wet season (Haines, 1979; Kailola *et al.,* 1993). In the Gulf of Papua, juveniles 7-164 mm fork length are caught in mangrove areas and nipa palm areas (Opnai, 1983).

In Australian waters, *P. sheridani* reach 150 cm fork length and *E. tetradactylum* reach 82 cm (in other areas of their distribution *E. tetradactylum* have been recorded at 2 m length and 145 kg). Haines (1979) calculated a length-weight relationship for *P. sheridani* - from a predicted of 20 g at 10 cm length to 10.3 kg at 100 cm length. Threadfin salmon are carnivores, feeding on fish, small sharks, crustaceans such as prawns, crabs, lobsters, and molluscs such as octopus and bivalves. Opnai (1983) observed that penaeid prawns, crabs and freshwater prawns (*Macrobrachium* species) comprised 67 per cent of the *P. sheridani* diet around Baimuru, although Haines (1979) found that penaeid prawns and fish comprised most of the diet of both species.

1.8.2 The Fishery

Utilisation: Threadfin salmon are not targeted by commercial fishers. However, *P. sheridani* are the second most important commercial/artisanal species in the Gulf of Papua after barramundi to which they are largely a bycatch. This is the case also in northern Australia (Kailola *et al.*,. 1993). Threadfin salmon produce fillets of good flavour: in Australia, *P. sheridani* particularly fetches high prices (and has been used as a very acceptable barramundi substitute). In the Gulf of Papua, threadfin salmon are salted and sundried in villages for sale in Kerema and the PNG Highlands (Haines, 1979), and successful marketing trials of frozen gilled-and-gutted threadfin sawn into cutlets were made from the Baimuru Fish Plant (Haines and Stevens, 1983).

Threadfin salmon are caught mainly with coastal set gillnets. Although a usual bycatch of the barramundi fishery, there are reports that in western Papua they could be caught along the coast at an alternative season to the coastal barramundi fishery which runs from September into late December. In other words, the commercial barramundi fishery along the coast only operates during the spawning run, yet threadfin move along the coast all year.[1] Both species of threadfin salmon exhibit higher catch rates during the dry season in northern Australia - while barramundi dominate catches during the wet season (Kailola *et al.,* 1993). Catches in the northern Gulf of Papua fluctuate (possibly an artifact of non-targeting and of the movement of the populations).

Threadfin salmon are highly valued by recreational sports fishermen in several countries - such as Australia and Hawaii - because of their 'fighting ability'.

Production and Marketing:

Table 12 Landings (not catch, which includes subsistence) (kg whole weight) of threadfin salmon (both species) at Baimuru for the period 1979-1983 are (sources: DFMR files and Opnai, 1984)

year	1979	1980	1981	1982	1983
kg (whole wt)	1,200	3,544	4,421	5,575	24,238

(1979, 1980 and 1981 figures calculated on a yield of 12.34 per cent of the total monthly landings: DFMR file 3-3-11, plus database printout)

Table 13 Threadfin salmon landings (kg whole weight) at the Baimuru Fish Plant, 1984-89 (source: DFMR files)

year	1984	1985	1986	1987	1988	1989
king threadfin	6,734	no record	23,524	33,238	19,372	17,824
blue threadfin	369	no record	327	280	316	384

[1] I have not been advised by DFMR that the situation is different to this.

Table 14 Threadfin salmon landings (both species) (kg whole weight) at Daru (source: DFMR database)

1986	1987	1988	1989	1990	1991
1,702	3,275	317	nil	nil	nil

Despite the absence of reported catches for three years, there are reports that *E. tetradactylum* is being increasingly targeted around Daru - as evidenced by turnover at 'Daru Trading'.

1.8.3 Stock status

There is no information on threadfin salmon stocks. The cpue ranges from1.1 to 10.1 fish per net set (Opnai, 1984) and in 1984 was highest in the period January-June. Haines (1979) recorded catch rates of threadfin salmon in deltas of the Purari and Era rivers up to 62 per cent (weight/hour/net) during the day and 100 per cent (weight/hour/net) during the night, using a monofilament net.

1.8.4 Management

Current legislation/Policy regarding exploitation: No management regulations are in place.

Recommended legislation/Policy regarding exploitation: Threadfin salmon stocks are worthy of investigation. Primary studies need to be performed on the movement of the population and the species' spawning period(s), leading to stock assessments. Along with shark and Spanish mackerel, they could be the basis of a sound domestic (and potentially) export supply of good quality fish. Haines (1979) held this opinion too, and catch rates he secured in the delta regions of the Gulf were very promising. Monitoring of the resources would give an indication of the stock sizes and their distribution throughout the year: e.g. are they always 'available' in the coastal zones?

In Australia, threadfin salmon catches have averaged about 600 mt/year since 1980 (Kailola *et al.,* 1993). There is every reason the believe that the PNG resources could support a much higher harvest than its current(?) figure of less than 30 mt/year.

In Australia, threadfin salmon are caught by coastal set gillnets, tidal traps, beach seines and ring nets. I have recently been informed that one fisherman operating off the mouth of the Daly River (Northern Territory) targets threadfin salmon (and catches very few barramundi) by using a drifting gillnet on the seafloor. This technique could be trialled in PNG.

There is potential for threadfin salmon aquaculture (CTSA Regional Notes, 1994). In Hawaii, where Pacific threadfin (*Polydactylus sexfilis)* commands a high market price, a collaborative series of rearing trials between three institutions are being conducted. The same species also inhabits PNG waters. The development of a successful farming technology in Pacific threadfin should be transferable to other species.

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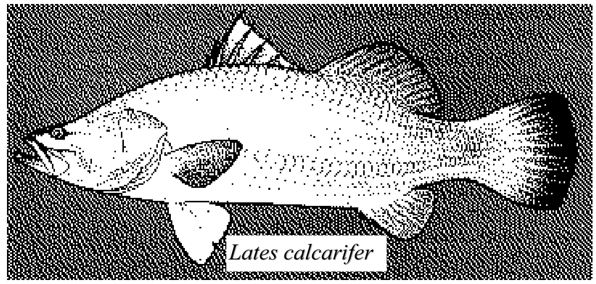
1.9 BARRAMUNDI

1.9.1 The resource



Species present: *Lates calcarifer* (Bloch)

Distribution: In PNG, barramundi are distributed from the West Irian border to Mullins Harbour in eastern Papua. They are only present on the south coast. They are most abundant in rivers with substantial lake and swamp systems and those forming extensive deltas (Moore, 1982). Elsewhere, barramundi are widely distributed in South East Asia, India and Australia. Barramundi are abundant in the delta system of the Gulf of Papua (but not the Vailala River, which lacks a delta: Haines, 1979) the middle Fly River and the coastal regions west of the Fly River and east of the Gulf of Papua. Adult barramundi are most abundant in the freshwater lakes and swamps of the middle Fly; also in the less extensive but similar habitats in the Bensbach and Aramia rivers.

Biology and Ecology: *Lates calcarifer* is a protandrous hermaphrodite (Moore, 1979); that is, it matures first as a male and later changes to a female. Males mature at 3-5 years of age and females generally mature at 8-9 years of age (Opnai and Tenakanai, 1987), but some females mature as young as 6 years of age (Moore, 1979). Barramundi generally become female when they attain 7 kg or more. Fish less than 75 cm total length are usually male and fish more than 100 cm total length are usually female. However, some fish do not change into females, or they mature initially as female (Moore, 1979).

Fecundity in barramundi increases as weight increases, and within the weight range 7.7-20.8 kg, fecundity ranges from 2.3 million to 32.2 million eggs per fish (Moore, 1982; Davis, 1984).

Barramundi are catadromous and undertake substantial migrations to specific spawning grounds. The fish generally move from freshwater streams, lakes and rivers to the sea where they spawn in inshore coastal waters in the intertidal zone of mangrove areas. The fish tend to enter coastal waters in groups of a single sex with a tendency for male fish to arrive before the females. Moore's study (1982) showed that there is only one major spawning ground in western Papua - between Sigabaduru and Jarai - with smaller grounds in the Fly River estuary (e.g. Kiwai Island) but probably none in the Gulf of Papua. In addition, there are probably some spawning grounds in eastern Papua. The actual location of the spawning area varies year to year depending on water salinity. Peak movement of adult fish into coastal waters occurs during spring tides. There is a possible relationship between spawning and the start of the wet season. Barramundi prefer to spawn in areas of high salinity.

Barramundi have a single annual spawning period, peaking in November and January (and extending from October to February). The spawning period for individual fish is relatively short. Usually no fish with gonads past half maturity stage are caught in the freshwater systems. In western Papua the spawning period is generally extended because of differential arrival of fish on the spawning grounds. Some barramundi from the Fly River delta take part in the spawning migration into the Daru area (and there is recruitment of juveniles back to the delta region). Adults also move from the Gulf of Papua to grounds west of Daru. In addition, there is a to and fro movement of barramundi between the Daru area and the Bamu-Aramia river system. After spawning, fish return to the same general area from which they migrated (Moore and Reynolds, 1982).

The eggs hatch in coastal waters between the months of November and February. The larvae migrate through drainage channels into neighbouring swamps during spring tides. They remain there until they are about 20-30 cm long, then they migrate back to coastal waters.

This return movement takes place towards the end of the wet season (in March-July) when the swamps are beginning to dry out (Moore, 1982; Opnai and Tenakanai, 1987).

These 0+ fish tend to congregate around the mouths of small creeks and rivers until they are 6-12 months old. Most fish of 1+ age migrate into inland waters; yet some 1+ fish remain in coastal waters and migrate when they are 2+ or even 3+ years of age. The migration usually commences in March-April, and accompanies the return movement of adult fish to inland waters at the end of the wet season (Moore and Reynolds, 1982; Opnai and Tenakanai, 1987).

Some fish of all age groups remain in coastal waters (Moore and Reynolds, 1982). Coastal barramundi numbers increase markedly in October-November, corresponding with the commencement of the spawning season. Movement of adults from inland waters usually occurs during September-October, the end of the dry season, and most fish taking part in this migration are at least 3-4 years old. Inland movement of barramundi into swamps and out of them appears to be in response to water levels.

Barramundi in fresh water have a much higher condition factor than those in salt water and are thus more likely to grow faster (Reynolds and Moore, 1982). Barramundi generally have a rapid growth. Reynolds and Moore (1982) found the mode for 0+ fish at 33.5 cm TL, 1+ fish at 45.5 cm, 2+ fish at 54.4 cm, 5+ fish at 64.5 cm and 4+ fish at 74 cm. The growth coefficient, K, was calculated to be 0.128, the L_∞ at 138 cm and t_o at -1.12 years. The largest barramundi weighed by Ray Moore in 4 year's of sampling in western Papua weighed 25.6 kg, and Allan Haines recorded a fish 1.2 m fork length from the Purari River system (1979). Barramundi are carnivorous, consuming crustaceans (crabs, prawns) and fish.

1.9.2 The Fishery

Utilisation: Barramundi comprises the major resource of villages where fish and other aquatic resources represent the major cash income. The barramundi are mainly fished on their spawning migration, using 5-8 inch (12.7-20.3 cm) gillnets.

The history of the barramundi fishery in PNG is given by Opnai and Tenakanai (1987). By 1979, there were three operations in the Western Province: a Daru-based coastal fishery; a refrigerated fishing vessel fishery; and a fishery based on village freezers. The village freezer fishery ended in about 1986.

Daru based fishery. Fishing is carried out by local fishers and the catch is either taken directly to processing plants at Daru, or sold to freezer boats anchored near the fishing grounds which on-sell to the Daru processing plants, or the catch is landed at processing plants in the upper Fly River then transported by freezer vessels to Daru. From 1986 to 1991 there were two main factories on Daru Island receiving catches, but since then only Arimina Seafoods operates (I have no information about earlier processing plants).

This fishery exploits barramundi stocks from along the coast between the Fly River mouth and the Binaturi River (the Coastal Fishery) and from the Fly River-Lake Murray system (the Inland Fishery). Village fishers near Daru land their product directly at the Daru processing plant, some fishers operating up to 65 km away. Licensed freezer 'mother boats' service the distant fishers along the coast and in the Inland Fishery: they buy fish from them and land it in Daru. Depending on supply, frozen fillets are then distributed to the PNG domestic market or to the export market. The Inland Fishery catches are landed mainly from Lake Murray at Boboa[1], Obo village, Kuvaviva, Lake Boset and Manda. Fishers sell their catches either to the land-based fish factories or to the freezer boats. Fishers in the Inland fishery set nets in the lower Lake Murray to take advantage of the spawning migration via the Herbert River and also set nets in the upper Lake Murray, convenient to the land-based processing plants. This upper area is not normally serviced by freezer vessels.

[1] At time of printing, information on landing places had not been confirmed for Boboa and Kuvaviva.

The catches sold to the fish factory are highest during the dry season months (August-September) and when no freezer boats are purchasing fish in the lake. In the absence of freezer boats, catches are sold to the factory at Boboa (Mobiha and Murri, 1993) and - presumably - to the other inland land-based factories.

Between 1986 and September 1994, about 54 per cent of Western Province barramundi landings were made direct to the Daru-based plants and 36 per cent were landed there by freezer vessels. Six per cent of the province's barramundi landings for 1992 and 1993 were made to the upper Fly River-based freezers (R. Lari, pers. comm.).

Refrigerated fishing vessels. These 14-16 m vessels fish near the Fly River mouth and along the coast to the west during the spawning run and later move into the Middle Fly and Lake Murray areas. They take on catch throughout the year. The number of vessels has fluctuated between one and eight, and has been low in recent years. These vessels are equipped with nets and have processing facilities, and in the Inland Fishery these vessels may either fish themselves or issue nets to national fishers (in the Coastal Fishery the vessels do not fish). The vessels carry about nine barramundi nets each: as well as being used by the vessels, the nets are loaned to local fishers if their own nets are damaged or unavailable. The net loaning also enables the boat owner to negotiate with the fishers for a lower purchase price for the fish (Mobiha and Murri, 1993).

The quality of fish brought to the Daru fish plant and the annual catch have been continually influenced by the number of freezer vessels, their area of operation and the distance from the plant that national fishers fish. When freezer vessels do not service an area, local fishers have to transport their catch to Daru themselves and rejection (wastage) rates are high depending on the distance travelled from the fishing grounds: when freezer boat service is adequate fishers only have to transport their catch 2-4 km, but when it is not, fishers have to travel 16-45 km by canoe to the shore based processing factory at Daru. This is a major problem for the fishery.

Village freezers. These were established at Boset (Middle Fly) and on Kiwai Island. Fishers supplied these freezers from outboard-powered dinghies and canoes. The filleted fish were stored in the freezers and sold to freezer vessels or the Daru store. This village freezer system was not operating by 1986.

The village freezer system also operated in the Gulf Province and supported the Kikori processing plant with an average of 12 mt of barramundi a year during the 1970s (Anon., 1976, in Haines, 1979). The fishery was expanded in 1979 with small but increasing catches coming from the estuarine region of the Gulf Province around Baimuru. The Baimuru fish plant and the Kikori processing plant operations were[2] village based fishery operating without freezer boats but using a limited iced fish collection system. The catch was either brought into Baimuru or Kikori directly or via dories from collecting stations. The 3.5 mt freezer owned by the Kikori Local Government Council continued to receive fish at least until 1983, with production reaching about 1 mt of barramundi fillets per month (Haines and Stevens, 1983). Barramundi was frozen head off and gutted, or as fillets in 10 kg blocks, or 1 kg retail packs. There was[3] one freezer vessel-system servicing the Kikori River. It operated in the usual way - purchased fish from the village people who were netting them, would gill and gut and often fillet. This operator supplied quantities of barramundi to the mining company caterer, Poon Catering.

In Western Province, 63-91 per cent of catch is taken from October to January when the fish are migrating (Moore, 1982). For the remainder of the year, barramundi are caught in the

[2] At time of printing, I have not been provided with information on whether the Baimuru and Kikori fish plants still operate.

[3] This operation appears to have ceased early in 1994, although information is unclear.

Middle Fly (Inland) fishery. Commercial catches normally drop sharply towards the end of December in western Papua, when most of the fish have spawned and migrated from coastal waters. Furthermore, if inland water levels remain high, the catch in coastal regions is reduced - i.e. a reduced migration takes place (Moore and Reynolds, 1982). Not all mature barramundi migrate each year, and there is always a residual population on the inland fishing grounds in the Fly River and Lake Murray systems.

During early 1982 an extensive market developed for juvenile barramundi and large numbers were caught in the sea and sold in and through Daru (Fisheries Research annual report 1982). These would have been 0+ to 2+ fish. Since then, juvenile and undersized barramundi have become a common item at the market at Daru. Between 20 and 60 undersized barramundi are sold daily there, representing an annual harvest of 15,000 fish (Mobiha, 1993). Apart from the non-policing of regulations banning the sale of juvenile barramundi, and the unrestricted use of small-mesh gillnets in the area, Mobiha suggested that an increase in the population of unemployed people who settle around Daru has also contributed to increased catches of juvenile barramundi.

Production and Marketing: In 1969 and 1970, 207 mt and 134 mt of whole barramundi were produced in the coastal fishery based at Daru (Opnai and Tenakanai, 1987).

Table 15 Production figures for barramundi in the Fly-Lake Murray ('inland'), coast near Daru ('coastal') and Baimuru ('estuarine') fisheries, combined, between 1971 and 1983 (mt whole weight) are given below. (Sources: DFMR files and fisheries research annual reports from 1978 through to 1984.)

Season	Total	Inland	Coastal	Estuarine
1971-72	394	146	248	-
1972-73	241	56	185	-
1973-74	284	96	187	-
1974-75	352	31	321	-
1975-76	179	28	151	-
1976-77	210	26	184	-
1977-78	170	55	115	-
1978-79	212	34	173	*5
1979-80	243	70	151	22
1980-81	329	117	191	21
1981-82	347	121	207	19
1982-83	219	49	138	32
1983-84[4]	-	107	32	-
1985	85	-	-	-

(* = estimate). The barramundi 'year' (= season) runs from 1 September to 31 August.

Somewhat overlapping or extending catch information is provided in landings data from Daru and Baimuru, below. More recent figures than 1991 are not available.

[4] There should be clarification of the nominal annular break between (e.g.) 1983-84 and 1985, 1986, etc.

Table 16 Landings of barramundi at Daru for the period 1986 to 1994 (kg whole weight) (source: DFMR database, Daru)

Year	quantity (kg)	Year	quantity (kg)
1986	91,268	1991	62,499
1987	130,376	1992	45,804
1988	28,213	1993	44,124
1989	29,733	*1994	*5,422
1990	5,318		

(*: to end of September)

Table 17 Landings of barramundi at the Baimuru Fish Plant for the period 1979 to 1989 (kg whole weight) (sources: 1979-81, 1984-89 from DFMR files plus DFMR database; 1982-83 from Opnai, 1984).

Year	Quantity (kg)	Year	Quantity (kg)
1979	6,851	1985	**140,000
1980	20,171	1986	143,817
1981	25,160	1987	89,656
1982	*7,525/19,000	1988	31,078
1983	27,881	1989	36,164
1984	38,728		

(Notes: 1979-81 figures are based on barramundi comprising 70.23 per cent of the average monthly landings at Baimuru; * alternative 1982 figure from Fisheries Research annual report 1982; ** figure from DFMR files, c.1986 report)

Table 18 The cpue in the Daru-based fishery from 1980 to 1986 was given by Opnai and Tenakanai (1987)

year	1980	1981	1982	1983	1984	1985
cpue (kg/100 m net days)	51	24.5	23.7	25	21.9	25.6

At the Baimuru Fish Plant, highest landings were recorded from July to November. The *cpue* increased from 5.1kg/100 m net day in 1982 to 27.8 kg/100 m net day in 1986 (Opnai and Tenakanai, 1987). Haines (1979) recorded the *abundance* of barramundi at different times of the year in the Kikori and Purari rivers and deltas as their relative percentage in sets. In the rivers, barramundi were present in 6-100 per cent of night sets and 9-100 per cent of day sets; and in the deltas of these rivers, barramundi were present in 14-100 per cent of night sets and 69-100 per cent of day sets.

Historically, product from Baimuru was sold to Goroka Seafoods Marketing, then channelled through DFMR and then Gulf Investments. Because of an erratic transport system supply of product from Baimuru to the Highlands and Port Moresby (e.g.) has[5] been difficult to maintain.

In 1990, 1991 and 1993 there was no separate export category in the DFMR database for barramundi (i.e. it was included with 'fish'). No export figures were available for 1988 and 1989.

[5] At time of printing, there is no information on whether this marketing arrangement still exists.

Barramundi skins were exported in 1991 (2 mt) and 1993 (288.4 kg). It is not stated whether these are dried or fresh - but they are probably fresh, for tanning. This quantity of skins must represent a large number of fish; and I assume the skins are from filleted fish to be consumed.[6]

Historically, the main markets for barramundi were:

1) the largely Australian export market; and

2) the domestic market of large towns (e.g. Port Moresby) and the Highlands.

In recent years, the market has changed to be:

1) the domestic market; and

2) the mining and drilling companies (e.g. Ok Tedi Mining and Chevron Oil). For example, Poon Catering, the suppliers to Porgera Goldfield (Placer), Ok Tedi Mining Company at Tabubil, Misima mine and Chevron oilfield are contracted to supply fish to workers so that there is a choice on the menu of fish each day. There are currently about 12,000 staff to be catered, so they require about 2 mt of fish each month. Some of this supply is secured from Lake Murray land-based freezers at Obo and Bosset (Timperley, 1994).

Table 19 Exports of barramundi from PNG for the period 1977 to 1993. (Sources: A: DFMR file and the National Statistics Office; B: DFMR fisheries research annual reports and the DFMR database.). Values are stated in PGK'000

year	A. (mt)	A. (value, '000 K)	B. (mt)	B. (value, '000 K)
1977	26	77	-	-
1978	23	83	-	-
1979	57	234	16.69	66,433
1980	99	414	62.45	257,900
1981	116	491	88.81	398,120
1982	75	383	60.4	293,740
1983	7	35	8.5	41,500
1984	-	-	62.602	346,375
1985	-	-	34.743	244,717
1986	-	-	116.48	357,895
1987	-	-	64.372	364,514
1988	-	-	no info.	-
1989	-	-	no info.	-
1990	-	-	no info.	-
1991	-	-	no info.	-
1992	-	-	2.24	3,732
1993	-	-	no info.	-

1.9.3 Stock status

In the mid-1980s, Rodwell (undated, mid-1980s, DFMR file) reported that 'estimates of the maximum sustainable yield from the fishery range up to 500 t/year. On the basis of this estimate, [the] fishery has never reached the stage of full exploitation.'

The PNG barramundi stocks are genetically distinct from northern Australian barramundi stocks (Salini and Shaklee, 1987). For this shallow water, coastal species the Torres Strait constitutes a major geographic barrier (Salini and Shaklee, 1987). The observed tendency of

[6] Questions to which I obtained no answer included (1) where are the skins going? (2) what size fish are the skins coming from? (3) where are they obtained - coastal or inland fishery?

barramundi in Australia is to form identifiable localised populations. In contrast, the significant coastal migrations by barramundi in PNG originating from within the Gulf of Papua and its streams, and the Fly River system, has generated a uniform population occupying the area bounded by approximately the Morehead River in the west and approximately the Lakekamu River in the east (I did not locate documentation on the genetic relationship of the barramundi populations east of this area). Hearsay in Daru is that barramundi originating in rivers west if Sigabaduru belong to the Gulf of Carpentaria/West Irian stock but this view is not supported by Salini's and Shaklee's (1987) work nor Moore's and Reynold's (1982) study which showed that barramundi originating from rivers in the Gulf of Papua migrated as far as the Bian and Kumbe rivers in West Irian.

Monitoring of barramundi stocks in the coastal fishery was initiated in 1970 and information on recruitment of 0+ fish spawned the previous season was obtained (Fisheries Research annual report 1979). Recruitment was expressed as the cpue (number of fish per beach seine haul) and represented the subsequent year class strength.

Table 20 Recruitment of barramundi in the coastal fishery:

year	1971-2	1972-3	1973-4	1974-5	1975-6	1976-7	1977-8	1978-9
cpue	2.2	3.2	8.0	6.3	2.7	1.7	1.3	0.5

Despite the decreasing recruitment, catches of adults in the coastal fishery remained high (207 mt).

Table 21 There are sporadic data on cpue for the barramundi fishery. It is tabled here as kg/100 m net/24 hour set

Fishery Year	Coastal 1972	Coastal 1978	Coastal 1979	Coastal 1982	Inland 1982	Inland 1983
August	-	-	-	-	53.8	21.6
Septemb.	-	15.4	-	-	95.8	53.6
October	9.2	17.1	30.6	25.6	31.8	-
Novemb.	19.5	27.6	36.5	13.3	33.9	-
Decemb.	13.8	11.8	25.4	2.9	-	-

(Sources: 1972, 1978 and 1979 data from R. Moore in DFMR files. 1982 and 1983 data from completed returns by the two freezer vessels operating, but its reliability questionable (in Fisheries Research annual report 1983).)

In 1983 and 1984, collection of cpue data from commercial vessels continued to be a problem due to the diversity of gillnet types employed (Fisheries Research annual report 1983). Villagers used both monofilament and multifilament gillnets with mesh sizes ranging from 10 cm to 20 cm, yet because gear was not registered it was not possible to obtain the exact numbers of nets of each type being used (Fisheries Research Annual Reports 1983; 1984).

The change from multifilament nets to monofilament nets in about 1979 had a significant impact on cpue. In both inland and coastal regions monofilament nets proved to be 2.8 times more effective than multifilament nets (source: Fisheries Research Annual Report 1979).

Table 22 CPUE by net type, 1979

1979	Coastal (kg/100 yds/24 hours)	Inland (kg/100 yds/24 hours)
Multifilament	19.6	78.3
Monofilament	56.3	219.0
Average cpue	32.6	122.3

Up until about 1982-83, there appeared to be a relationship between the number of vessels operating in the Coastal and Inland fisheries and the quantity of barramundi landed. From then however, the relative quantity of the catches decreased overall irrespective of the number of vessels operating. Catches did not respond to the increase in fishing effort (as measured by the availability of and fishing by freezer vessels; e.g. compare 1984 data with data for 1988 and 1989) suggesting that the stocks were fully- to over-exploited by the mid-1980s.

Table 23 A comparison of total landings of barramundi in the Western Province with the number of freezer vessels servicing the fishery

Year	1978-79	1979-80	1980-81	1981-82	1982-83	1984	1985	1986
no. of freezer vessels	4	?	8	6	2	2	none	5
catch (mt, total)	212	243	329	347	219	139	85	91.3

year	1987	1988	1989	1990	1991	1992	1993	1994
no. freezer vessels	3	2	2	1	none	none	1	none
catch (mt, total)	130.4	28.2	29.7	5.3	62.5	45.8	44.1	5.4*

(*to end September)

Five freezer boats operated in 1986 (R. Lari, pers. comm.) but their activities were inconsistent as they moved into rock lobster fishing. The last boat servicing the barramundi fishery moved into rock lobster fishing in 1993.

A DFMR project investigating the selectivity of barramundi gillnets was begun in 1990 and was continuing in Lake Murray in 1992 (Fisheries Research annual report 1985-1991)

The influence on effort of freezer vessels in the Daru-based fishery (through their presence supporting the fishery) is minor compared to *the effort increase through netting. This increase has been pervasive and unchecked** since the advent of monofilament nets (see above) as demonstrated by observations such as:

- Opnai and Tenakanai (1987:53), referring to the use of small mesh gillnets in coastal waters, stated that ‘The subsistence fishery is increasing in magnitude and may warrant some form of conservation measures particularly concerning the use of small mesh gillnets...’
- Haines and Stevens (1983:389) observed that 96 ply or monofilament barramundi nets as well as smaller mesh nets are used in most villages of the Purari area. ‘The nets are not fully utilised however, because people have no need for the quantity of fish they can catch, and they are frequently unskilled in net repair.’
- In a 1989 survey, the largest number of [barramundi] nets was at Tirere village on the north-eastern arm of the Fly River delta. This - observed Mobiha and Murri, 1993 - is because of the ease with which the nets can be obtained; i.e. they are converted drifnets washed ashore from earlier Taiwanese shark fishing operations in the western Gulf of Papua.
- Mobiha and Murri (1993) also reported that in 26 villages operating in the coastal fishery, the 182 fishers there owned 228 barramundi nets; and in 13 villages in the inland fishery 84 fishers owned 136 nets. Fishing is constant (in the inland fishery into the Fly River delta) as the fishers often leave their nets in the water.

- Claims by villagers and sportsfishers that in Galley Reach (Central Province), where the use of nets is commonplace, stocks of large barramundi have declined significantly.
- *Economic problems* evident in the fishery in the mid-1980s (Rodwell, undated, DFMR file) may all or in part still be affecting the fishery. Rodwell urged an economic study of the fishery by pointing out that:
- 'The major problems affecting the industry were the low prices paid to the freezer boat operators and the villagers for their catch. Boat operators argued that they could get more for their catch marketing directly through Port Moresby rather than landing at Daru. In turn higher prices could be paid to the village fishers, thus maintaining their interest in the fishery.'
- The switch away from the export market in 1983 may not have been compensated by supplying domestic markets.
- The current level of exploitation [mid-1980s] was inefficient in terms of not providing maximum economic benefits to the local population - for example, increasing local participation in the fishery.

(*: in 1994-95 the fishery was using as many multifilament nets as monofilament nets, mainly because the monofilament nets are more easily damaged and were not being repaired: Mobiha, pers. comm.).

<u>In summary</u>, the status of the barramundi stock and fishery is demonstrated by:

1. undersized fish are coming into the Daru markets;
2. the coastal fishery catches have declined;
3. the inland fishery catches are stable, but collection problems of getting it to Daru are evident;
4. there are reports of locally abundant, large barramundi in inland waters such as the Bensbach River, the Aramia and Bamu rivers, tributaries of the Fly River and certain Gulf rivers;
5. the estuarine fishery has declined, maybe because of inadequate marketing outlets;
6. information on effort in the fishery is difficult to obtain but indications are that there is too much;
7. there is insufficient barramundi being marketed to meet local (domestic and mining company) demand. Excluding the export market (which has ceased) 'barramundi' sold in PNG is either imported Nile Perch (*Lates niloticus*) from Africa or imported barramundi from Australia. Imported fish from New Zealand (e.g. hake, *Rexea solandri* completes PNG demand for 'white' fish); and
8. the barramundi stocks in PNG are over-exploited.

1.9.4 Management

Current legislation/policy regarding exploitation: Although the Kiwai Fishing Law (1974) prohibits the capture for sale of barramundi less than 38 cm total length, the law has never been enforced (Fisheries Research annual report 1982). At meetings in 1982, an agreement was made between national and provincial fisheries officers that supported the nominated size prohibition as well as other measures. As a result, the following regulations were gazetted in 1983:

1. between January and July each year, a minimum size of 38 cm total length applies for barramundi caught between the mouth of the Binaturi River and Sui village, Toro Passage;[7]
2. barramundi less than 50.8 cm total length cannot be sold or shipped at any time within the Western Province;[8]
3. between January and July each year, only standard sized gillnets of mesh size 6.35–12.7 cm inclusive may be used between the mouth of the Binaturi River and Sui village between low water mark and high water mark.
4. the sale in Daru of juvenile barramundi (10-50 cm fork length, or 0+ to 3+ years) between January and July is prohibited.

However, during 1983 these laws were only partially enforced because of staff shortages. In fact, all of these laws are irregularly enforced only, or not at all. A few prosecutions were made in the period shortly after gazettal (A. Mobiha, pers. comm.).

Recommended legislation/policy regarding exploitation: In summary, the barramundi fishery in western Papua consists of a combination of subsistence fishing with small-mesh and large-mesh gillnets and commercial fishing with larger mesh (barramundi) gillnets fishing concurrently. On the coast the spawning run of barramundi is targeted each year between about September and January, but in the period from January to July the juvenile 0+ to 3+ barramundi are also targeted when they gather in inshore coastal waters before migrating into freshwaters. Barramundi are also fished all year in inland waters, where the cpue is higher. Freezer boats and land-based freezers receive barramundi from local fishers and fillet and freeze it. The freezer boats pay the villagers for the product and in turn they are paid when they land the fillets at Daru.

<u>Problems apparent in the fishery</u> are:

- the high numbers of juvenile barramundi being caught beyond the needs of the subsistence fishery;
- a marked decline in the catch of adult barramundi in the coastal fishery;
- insufficient freezer vessels servicing the fishery and/or irregularity in their fishing pattern. For example, they often do not service the more distant areas of the fishery. Where freezer vessels do not service the fishery, product is either eaten, or is waste during the time it takes to transport it to Daru, or, the villagers do not collect fish from their nets;
- inadequate policing of regulations;
- the high level of effort in the fishery.

<u>Recommended management measures:</u>

1. <u>Fisheries awareness (=education)</u> is the most important - to explain to fishers why the barramundi are disappearing. Explanations should include information on size at first maturity, sex change-over, and the biological and economic value of large fish *cf* small fish.
2. Awareness by villagers of the causes of the problems in the fishery could be utilised in managing the fishery. Management measures proposed by the national government can be discussed in the villages and augmented by village proposals. With acceptance of the need

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[7] I was also informed by the DFMR Licencing and Inspection Branch that the legal minimum size for barramundi is 45 cm fork length... but I did not record this from any other source. I have not received information on the status of this report.

[8] I have no information about whether this statement is correct or not.

for management by villagers, the use of village courts to impose fines and regulate should be encouraged.

3. Investigate, by means of surveys, the level of local useage of gillnets for subsistence fishing and for commercial fishing. The relative importance of nets to villagers for supplying food vs money needs to be established before steps to prohibit or restrict the use of gillnets are brought in. Encouraging the use of alternative fishing methods (e.g. fyke nets, seine nets) for subsistence harvesting coupled with restrictions in the length of time a net may be set could be very effective restrictions.

4. A preferred measure is a moratorium on fishing with mesh (gill) nets in the coastal fishery for at least two years. Restricting the use of barramundi nets alone will not stop the catching of juveniles and males with small-mesh nets, and the inverse will catch the few mature females supplying recruits to the fishery. However, problems attendant on the introduction of this management measure include:

   - enforcement;

   - whether fishers should be compensated; and

   - the effect of the subsistence fishery.

5. An alternative would be a *rotational moratorium over several years* - i.e. sections of the coast not fished.

6. The need for a concurrent *moratorium on gillnet use in inland waters* should be assessed.

7. At the end of the moratorium, bring in licences (or are they already in?) and quotas per village community (Western Province only). Stipulate the net mesh sizes and limit net lengths used in rivers so that the nets cannot be hung right across a river. Confiscate all nets (and catches made by them) that do not meet the requirement (see also point 5).

8. At the same time as licences and quotas are issued, implement a seasonal closure to protect spawners and the juveniles before they move into the rivers. This should be from about December through to April (Western Province only).

9. A preferred management measure would be a net buyback scheme; however I recognise that this could be very difficult to implement.

10. Complete the study of mesh selectivity (although time could be saved by utilising information from the Northern Territory and Queensland barramundi fisheries).

11. Ban the sale of juvenile barramundi in Daru market throughout the year instead of the current January to July period. A total ban would obviate logistical difficulties of bringing in and releasing a ban tied to the peak abundance periods of August-September and March-May (refer Mobiha, 1993).

12. Enforce the regulations on the minimum legal size for barramundi. Presently the regulated size is 38 cm, but this probably should be increased. In Queensland, Australia, it is 58 cm fork length. Queensland is also regulating for a maximum legal size of 120 cm to protect the large spawners (M. Potter, pers. comm.). DFMR should consult with Australian authorities with regard to size limits.

13. Strict enforcement of regulations pertaining to barramundi is essential if the fishery and stock are to recover. Enforcement should include laying prosecutions and following them through. A form of 'on-the-spot' fines could be brought in to obviate court delays.

14. It is not necessary to bring such a ban in in the Gulf Province.

15. Encourage fishing of inland waters of the Western Province and the Gulf Province, for example by licensing *freezer vessels to fish there only* during the moratorium and closed seasons (available fisheries statistics show that the cpue is better in the inland). This measure is attendant on the better development of the Baimuru and Kikori stations.

16. Implement an economic review of the fishery with regard to pricing, returns to fishers, best and appropriate landing places, etc.

17. Improve the efficiency of freezer vessels and land-based freezer bases; i.e. make it more attractive for them to operate. In this way, inland barramundi stocks can be better utilised and caught fish is not being wasted through inefficient or absent collecting.

18. Maintain *regular monitoring* of the fishery - primarily catches, recruitment and cpue (preparatory to a stock assessment).

19. Do not discourage recreational tag-and-release fisheries for barramundi. Information from this activity could be used to support research on barramundi stocks.

Future management measures could include:

- banning the import of barramundi to augment local supplies on the domestic market as a means of encouraging the development of the fishery. This presently is inappropriate in this fishery.
- restocking. This is expensive and entails the establishment of rearing facilities in PNG. Attempts at restocking with barramundi fingerlings from Australia should be prohibited as the Australian and PNG barramundi are different genetic stocks. The Boroko Recreational Sportsfishing Club is interested in restocking barramundi in the Galley Reach.
- farming of barramundi. This is carried out commercially in Australia and several Asian countries. Source information is available in Copland and Grey (1987), and there have been many developments in techniques since.

1.9.5 References

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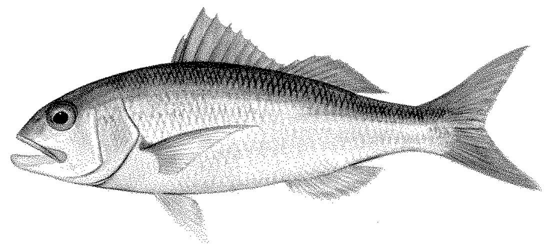
1.10 DEEP-SLOPE DEMERSAL FISHES

1.10.1 The Resource



Etelis carbunculus

Species present: Deep-slope demersal fishes are those inhabiting the depth range c.90 m to more than 300 m. More than sixty species of bony (teleost) fish belonging mainly in the families Lutjanidae (jobfish, sea perch - *Aphareus, Etelis*, *Lipocheilus, Lutjanus, Macolor, Paracaesio, Pinjalo, Pristipomoides*), Serranidae (groupers), Lethrinidae (emperors - *Gymnocranius, Lethrinus, Wattsia*), Carangidae (trevallies), Gempylidae (snake mackerel, oil fish) and Sphyraenidae (sea pike) have been harvested by deep-slope fishing in PNG waters. Oil fish (*Ruvettus* species) and sharks are also common.

The lutjanids and serranids dominate landings in the Western Pacific - including PNG - both in terms of quantity (70-90 per cent of total catch) and value (Moffitt, 1993). Overall, catches by weight of deep-slope fishes in PNG comprise about 65 per cent snappers (Lutjanidae) (Dalzell and Preston, 1992).

The species comprising more than 1 per cent by weight of the catch in any of twelve surveys conducted in PNG are listed below (* refer Dalzell and Preston, 1992; Richards, 1987; Sundberg and Campbell, 1982; Fisheries Research annual reports for 1982, 1983 and 1984. The full complement of species from some of these surveys can be obtained in some of these references).

LUTJANIDAE

Aphareus furcatus: 1.4% (West New Britain)

A. rutilans: 1.8-11.8% (Kavieng); 3.7% (Manus); 11.8% (Rabaul); 4.7% (Wewak)

Aprion virescens: 1-1.3% (Kavieng); 1.1% (Manus)

Etelis carbunculus(**): 7.5% (West New Britain); 8.1-26.4% (Kavieng); 9.5% (Kimbe); 22.2% (Manus); 3% (Rabaul); 6.1-8.1% (Wewak); 47.2% (Manus- Milne Bay-Port Moresby)

E. coruscans: 2.2% (Kavieng); 1.1% (Rabaul); 5.8% (Manus-Milne Bay-Port Moresby)

E. radiosus: 2-3.2% (Kavieng); 2.2% (Manus-Milne Bay-Port Moresby)

Lipocheilus carnolabrum: 1.3% (Manus-Milne Bay-Port Moresby)

Lutjanus argentimaculatus: 3.2% (Kavieng); 1.5% (Kimbe); 5% (Manus); 4.7% (Oro Bay); 1.5% (Wewak); 2.3% (Manus-Milne Bay-Port Moresby)

L. bohar: 2.2% (West New Britain); 3.6-6% (Kavieng); 7.9% (Kimbe); 23.8% (Manus); 1.3% (Oro Bay); 2.9% (Wewak); 1.1% (Manus-Milne Bay-Port Moresby)

L. gibbus: 1.5% (Kimbe); 1.7% (Rabaul)

L. malabaricus: 4.1% (West New Britain); 1-1.7% (Kavieng); 29.3% (Oro Bay); 1.7% (Rabaul); 1.3-2% (Wewak); 1.3% (Manus-Milne Bay-Port Moresby)

L. sebae: 1.2% (Kavieng)

L. timoriensis: 1.8% (Kavieng)

Macolor niger: 1.2% (Wewak)

Paracaesio kusakarii: 2.5% (Kavieng); 10.1% (Rabaul)

Pristipomoides auricilla: 14.9% (West New Britain)

P. filamentosus: 25.9% (West New Britain); 3.6% (Kavieng); 11.2% (Oro Bay); 5.9% (Rabaul); 1.3-2.4% (Wewak); 1.1% (Manus-Milne Bay-Port Moresby)

P. flavipinnis: 2.4% (West New Britain); 1.9% (Kavieng); 1.4% (Kimbe); 2.1% (Manus); 1.7% (Rabaul)

P. multidens: 13.5% (West New Britain); 17.4-26.2% (Kavieng); 14.1% (Kimbe); 6.5% (Manus); 26.5% (Oro Bay); 25.5% (Rabaul); 23.4-35.8% (Wewak); 8.2% (Manus-Milne Bay-Port Moresby)

P. zonatus: 1.1% (Kavieng); 1.2% (Kimbe); 2.9% (Manus); 1% (Manus-Milne Bay- Port Moresby)

(**: Lokani *et al.,*. (1990), cited in Moffitt (1993) found support in length frequency distributions for there being two species of '*Etelis carbunculus*').

SERRANIDAE

Epinephelus areolatus: 2.3% (Oro Bay)

E. chlorostigma: 3.5% (Kavieng)

E. compressus: 4.6% (Wewak); 12.1% (Manus-Milne Bay-Port Moresby)

E. magniscuttis: 2.3% (Wewak); 5.5% (Manus-Milne Bay-Port Moresby)

E. malabaricus: 1.2% (Kavieng)

E. miliaris: 1% (Oro Bay); 1% (Rabaul)

E. morrhua: 3.9% (Kavieng); 1.4% (Kimbe); 2.4% (Manus); 1.1% (Rabaul); 1.2% (Wewak); 1.6% (Manus-Milne Bay-Port Moresby)

E. retouti: 5.5% (Kimbe)

E. septemfasciatus: 6.7% (Kavieng); 9.2% (Wewak)

LETHRINIDAE

Lethrinus chrysostomus: 1.3% (Oro Bay)

L. kallopterus: 2% (Manus)

L. miniatus: 4.7-6.3% (Kavieng); 1.5% (Manus)

Wattsia mossambica: 1.7-5.1% (Kavieng); 2.7% (Kimbe); 3.8% (Wewak)

CARANGIDAE

Caranx ignobilis: 1.8% (Kavieng)

C. lugubris: 1.8-2.5% (Kavieng)

Caranx species: 6.2% (Wewak)

Seriola dumerilii: 1.1% (Wewak)

S. rivoliana: 3.1% (Kavieng); 4.1% (Kimbe); 4.6% (Manus); 2.1% (Oro Bay); 4.7% (Wewak)

SCOMBRIDAE

Gymnosarda unicolor: 1-1.6% (Kavieng); 4.9% (Kimbe); 2.1% (Wewak)

SPHYRAENIDAE species: 1.2% (Kavieng); 3% (Manus); 1.9% (Wewak)

Sharks (Lamniformes) species: 9.8-33.2% (Wewak); 20.7% (West New Britain); 11.8% (Kavieng); 35.5% (Kimbe); 3.8% (Manus); 13.6% (Oro Bay); 20.6% (Rabaul)

Different species predominate (or 'replace' each other) in catches taken at different locations. For example, the distribution of serranid species between areas (above), and that *Pristipomoides auricilla* was harvested only in West New Britain (above). In Ataliklikhun Bay (East New Britain) the catch composition of deep-slope fishes in 200 m reported by the Overseas Fishery Cooperation Foundation (1985) was 48.6 per cent Lutjanidae, 39.1 per cent *Gymnocranius* species and 6.8 per cent Serranidae (*cf* the above). Whereas *Etelis carbunculus* comprised 47.2 per cent of the combined catch weight from surveys in Manus, Milne Bay and Port Moresby (depth range 80-280 m) (Fisheries Research annual report 1982), it only comprised 15.3 per cent of the catch weight off Kavieng (where *Pristipomoides multidens* formed the major catch component) (depth range 80-350 m).

Distribution: Probably all of the species harvested in this fishery in PNG are widely distributed in Indo-Pacific tropical waters.

Biology and Ecology: As adults, these deep-slope fishes occur over rocky and uneven sea floors and reef areas on the continental slope. *Pristipomoides* favours a soft coral habitat (J. Lloyd, pers. comm.). Deep-slope fishes swim in the water column above the seafloor and appear to associate with pinnacles and steep slopes ('drop-offs') at depths between 90 m and more than 500 m. The fish are either solitary or aggregate in small groups. Suites of species exhibit particular depth preferences. Carangids, lethrinids and many serranids inhabit shallower (<120 m) water, *Pristipomoides* and some serranids inhabit water c.120-240 m deep and *Etelis* and a few serranids inhabit water deeper than that (Sundberg and Campbell, 1982; Richards and Tatamasi, 1984; Moffitt, 1993).

Deep-slope fish are opportunistic carnivores. They feed on fishes, deepwater shrimps, crabs, squid, gastropod molluscs, pelagic tunicates and salps and zooplankton (Allen, 1985). Richards (1987) found that *Pristipomoides multidens* caught in 120-260 m off Kavieng consumed mainly fish (in 74 per cent of spew samples), crustaceans (31 per cent of samples) and cephalopods (21 per cent), while *Etelis carbunculus* from 240-280 m off Kavieng had consumed fish (in 82 per cent of spew samples) and crustaceans (65 per cent of samples). Caridean shrimps were the most abundant crustaceans consumed by both species, *P. multidens* consuming mainly *Heterocarpus ensifer*, and *E. carbunculus* consuming mainly *Eugonatonatus crassus*.

Deepwater snappers are serial or multiple spawners (Grimes, 1987, and others, in Moffitt, 1993; Kailola *et al.,* 1993). Populations of *P. multidens* off Kavieng exhibit peaks in spawning activity in February-March and August-September (Richards, 1987), although spawning takes place throughout the year in the western Pacific generally (Grimes, 1987, in Kailola *et al.,* 1993). Serranids are protogynous hermaphrodites (i.e. they function first as females and then as males) and spawning often takes place in large spawning aggregations, at certain periods of the year (Shapiro, 1987, in Kailola *et al.,* 1993). Many lethrinids are also protogynous hermaphrodites (Young and Martin, 1982, Williams and Russ, in press, in Kailola *et al.,* 1993), spawning all year with peaks in the latter half of the year.

Deepwater lutjanids and serranids tend to live a long time and grow slowly, and recruitment is low. Moffitt (1993) discussed some of the difficulties in estimating growth parameters in deepwater fish. Manooch (1987, in Moffitt, 1993) estimated an average K value of 0. 203 for lutjanids and 0.218 for serranids. Richards (1987) estimated K at 0.1875 for *P. multidens* off Kavieng. Deepwater fish attain large sizes - e.g. 40-120 cm TL in lutjanids (Allen, 1985).

1.10.2 The Fishery

Utilisation: Deep-slope fishes are not traditionally fished by Papua New Guineans. However, with the adoption of deepwater fishing in some areas of PNG, local demand for large snappers and groupers has increased. Whereas deep-slope fishes are infrequently sold in local markets in major towns in PNG, there is a steady demand for them by hotels and restaurants and they can be purchased from small stores. Small artisanal fisheries exist at

Kupiano (Central Province), Lae and Wewak; and M. Chapau (pers. comm.) suggested that fishers of deep-slope resources also operate still in Manus, East New Britain and West New Britain provinces.

Deep-slope fishes - especially snappers, lethrinids and serranids - are important as food fish in other Western Pacific countries. They have good quality flesh and are never affected by ciguatera.

Deepwater fishing was trialled in West New Britain in 1979 as part of a South Pacific Commission development project (Fusimalohi and Crossland, 1980). This survey led to an awareness of the resource in PNG, including pilot projects on gears and craft performed in the East Sepik Province in 1983-85 (Chapau, 1986) and surveys carried out at Wewak, Milne Bay, Manus, Huon Gulf, the Central Province and Kavieng/New Hanover from the late 1970s to the mid 1980s.

Fish are caught with bottom longlines or droplines, occasionally (e.g. in the Huon Gulf) by vertical longlines. In fishing trials off Wewak in 60-250 m, Sundberg and Campbell (1982) used PVC pipes with 14 hooks and swivel, horizontal float line, weighted vertical mainline and floats on top. They employed curved hooks, baited mainly with mackerel tuna (*Euthynnus affinis*). The Samoan wooden handreel was found to be a suitable fishing gear for harvesting deep-slope fishes and it is used in Wewak and Rabaul (at least). Fishers in Wewak use 300-400 m, 68-136 kg breaking strain monofilament line with swivel and wire trace terminating in three tuna circle hooks and sinker. Richards and Tatamasi (1984) trialled different types of bottom-set longline fishing gear off Kavieng. Droplining proved effective when fishing the outer reef zone and modified (traces set in PVC poles) bottom-set longlining was the most effective fishing method. [See also gear descriptions in Fisheries Research annual report 1982.) Bottom trapping - as used in the tropical Australian deep-slope fishery - was trialled along the Outer Barrier off Central Province a few years ago (M. Brownjohn, pers. comm.) but was not effective.

Chapau (1986) noted that catch rates of fishers operating off Wewak improved as they became experienced in droplining and use of handreels. Deep-slope fishes came to dominate fish landings at local markets (in the East Sepik Province). Fishers engaged in the fishery also adopted new vessel designs and different outboard motor sizes to improve their time at sea and financial return from the sale of fish.

The preferred bait for droplining is squid, followed by oily fish such as skipjack (*Katsuwonus pelamis*), malambur (*Selar*) (Overseas Fishery Cooperation Foundation, 1985) and mackerel tuna (Sundberg and Campbell, 1982).

Sharks are a problem for deepwater droplining in some areas - e.g. off Wewak and Kavieng - as they attack hooked fish and damage gear, and reduce bottom fishing time. Use of a powered line hauler is effective in reducing hauling time where sharks are a problem (Richards and Tatamasi, 1984). Off Kavieng, sharks are less common in water deeper than 250 m.

Diel variation in catch rates is exhibited with fishing generally ‘better’ at dusk or evening and dawn (e.g. off Wewak - Sundberg and Campbell, 1982). Richards and Sundberg (1984) found that mean catch rates varied significantly with depth zone and time of day (although the average fish weight increased only slightly). Catch rates were overall higher between 1200-1500 hours than between 2100-0900 hours, and between 1500-1800 hours than between midnight and 0600 hours. At 260-290 m, when *Etelis* were the target species, highest catch rates were achieved between 0800 hours and 1200 hours; and at 140-170 m, when *Pristipomoides* were the target species, highest catch rates were achieved between 1200 hours and 2000 hours.

Although there is no seasonality in the catch rates, better than average catch rates occur at Kavieng in the seven-day period after the full moon, and lower than average catch rates occur during the first few days after the lunar month (Fisheries Research annual report 1983).

The number of fish (species abundance) decreases with depth (Richards and Sundberg, 1984; Dalzell and Preston, 1992). In general, average individual fish weight varies with depth, and tends to increase with depth. An analysis of deep-slope fisheries in the South Pacific by Dalzell and Preston (1992) showed that, whereas average fish weight in the 0-50 m depth range is 2 kg, in the 500-550 m depth range it increased to 7 kg.

Table 24 Results of surveys in three PNG provinces in 1982 revealed (source: Fisheries Research annual report 1982)

Depth (m)	Av. wt (kg)	Depth (m)	Av. wt (kg)
80-100	1.6	180-200	6.5
100-120	2.2	200-220	4.3
120-140	2.7	220-240	4.9
140-160	1.3	240-260	5.8
160-180	2.3	260-280	4.8

Deep-slope fishes are also caught as a bycatch of deepwater shark fishing operations (profile 1.21). Deepwater sharks caught as bycatch of the deep-slope fishery are not utilised.

Production and Marketing: There is little information on catch quantities of deep-slope fishes in PNG. If catches are recorded, they are grouped with all other fish in a single category.

Table 25 Landings at the Wewak (Wama) fish plant during several years in the 1980s were (source: Chapau and Dalzell, 1991)

Year	1983	1984	1985	1986	1987
landings (mt)	12	14.3	20	10	5

Pristipomoides species form a major part (6.3 per cent) of the total artisanal landings in the Huon Gulf during the year (Hermes, 1992).

For 220 hours of fishing around Kavieng in 1982, 600 fish were caught with a total weight of 2,215 kg (Fisheries Research annual report 1982). *Pristipomoides multidens* was the dominant species in the catch, comprising 25.8 per cent by weight. Again at Kavieng, 1,601 fish weighing 6,158 kg were caught in a 14-month period (665 fishing hours in total) in water 80-290 m deep (Richards and Sundberg, 1984).

Off Kupiano (Central Province), 2,647 kg of fish were caught from 1,155 line hours (overnight fishing) in a 3.5-month period late in 1983 (Fisheries Research annual report 1983), and 1,838 kg (average 141 kg/trip) were caught in 13 fishing trips in February-April 1984 (Fisheries Research annual report 1984). In the Port Moresby area in 1982, 287 kg of fish were landed from 72 line hours of fishing (Fisheries Research annual report 1983).

The quantity of deep-slope fish bycatch from the deepwater shark fishing operation is occasionally recorded. In 1993, 256 fish weighing 762 kg were recorded in the logsheets from the fishery (analysed by C. Hair, DFMR Kavieng, 11/94), and in 1994, 184 fish weighing 701 kg were recorded. In both years, higher numbers of fish were caught in the Papuan region of the deepwater shark fishery's operation. Fish were recorded on 139 occasions (i.e. in 29 per cent of all shots).

All the most common deep-slope species caught have been accepted as good quality fish by local markets. Larger hotels and restaurants accept large *Etelis*, and the general public take readily to smaller fish. Recent improvements in transportation and icing (ice-boxes) have improved marketability from areas of capture to main centres (e.g. Huon Gulf to Lae, Kupiano to Port Moresby).

1.10.3 Stock status

Based on information from surveys undertaken between 1982 and 1984 at Manus, East Sepik, Milne Bay and Central provinces (Richards and Sundberg, 1982; Sundberg and Campbell, 1982; Sundberg and Richards, 1984), Richards and Tatamasi (1984) stated that there is a significant resource of deep bottom fishes on the outer reef slopes of the mainland and outer islands of PNG in depths between 80 m and 400 m.

Table 26 Average survey catch rates in weight per line hour for the depth range c.80-300 m are given below. These resources would had been unexploited prior to being fished. The relative experience of the fishers would also have affected catch rates.

Locality, date and source	kg/line hour
Port Moresby, 1981 (Fish. Res. ann rep 82)	3.99
Milne Bay, 1981 (Fish. Res. ann rep 82)	2.5
Manus Island, 1981 (Fish. Res. ann rep 82)	4.55
Wewak, 1981? (Sundberg and Campbell, 82)	4.2
Kavieng, 1982 (Malcolmson and Richards, 82)	3.4
Kavieng, 1982-83 (Richards and Sundberg, 84)	3.1
Port Moresby, 1982 (Fish. Res. ann rep 83)	4.0
Kupiano, 1983 (Fish. Res. ann rep 83	2.3
Kupiano, 1984 (Fish. Res. ann rep 84)	3.43

Alternative measures of effort were reported in other surveys, such as:

- Chapau (undated) recorded a catch rate of 3.7 kg/hour when fishing between 60 m and 300 m in the West Sepik Province (between Matapua and Sissano Lagoon).

- the Overseas Fishery Cooperation Foundation (1985) recorded a cpue of 7 kg/hour and an average catch rate of 8 fish (av. 17.6 kg) per 100 hooks when droplining in Atalilikhun Bay (East New Britain Province).

Chapau (1986) found that in Wewak the cpue increased as fishers gained in experience. In 1983, average catch was 34.5 kg/canoe day; in 1984 it was 41.4 kg/canoe day; and in 1985 it was 48.5 kg/canoe day

The average catch rate in Kavieng was 0.2kg/hook/hour (Richards and Sundberg, 1984), although it improved when sharks were less common and when sets were made after the morning.

Dalzell and Preston (1992) reported that catch rates from South Pacific Commission surveys (employing experienced fishers) averaged 5.5 kg/line hour. However, based on surveys such as the two-year Wewak one (3.7 kg/line hour) and 13-month Kavieng one (3.1 kg/line hour) (see table above), they estimated that the cpue at maximum sustainable yield (msy) may be expected to <u>decline</u> to 1.6-1.9 kg/line hour - i.e. to approximately 50 per cent of the cpue on virgin stock (Gulland, 1983, in Dalzell and Preston, 1992).

Biomass estimates of deep-slope fishes are based on the length of the 200 m isobath in nautical miles. Using catch data from the area of the Schouten Islands (East Sepik Province), Lokani *et al.* (1990) estimated that the national yearly msy from deep reef demersal fish stocks might range over 170-270 mt/year. However, they acknowledged that this low yield estimate may be an artefact of the area and not representive of the actual stock size in PNG. In a note to file (DFMR) dated 2/92, P. Lokani estimated that the annual yield of the deepwater fish resource of the Calvados Chain, Milne Bay Province was between 118 mt and 433 mt (assuming that the 200 m isobath extended over an estimated 619 nautical miles). He observed that if pinnacles were present in the island chain, the yield would be higher. P.

Lokani reported that pinnacle yield in New Ireland was 3 mt per nautical mile, and that in the Schouten Islands off Wewak the yield per nautical mile of 200 m isobath was 191.3 kg. When these results are extrapolated to PNG as a whole, biomass estimates vary within ranges of 140-418 mt/year to 2,300-6,900 mt/year.

In general, there appears to be a greater concentration of fish stocks around seamounts than around island shelves (Lokani *et al.,* 1990). The limited surface area of seamounts tends to concentrate the biomass, while over the extensive habitat areas of continental shelves the given biomass is diffuse, generating lower catch rates.

In other locations in the South Pacific, the value of 0.7 mt/nautical mile is applied for estimates of the biomass of deep-slope fishes. Applying this to PNG gives a range of msy values of 511 mt/year to 1,534 mt/year. Independently, A.D. Lewis (quoted in Dalzell and Preston, 1992) estimated a msy of 1,750 mt/year for PNG.

Intensive fishing at a given location of previously unexploited deep-slope fishes may lead to a rapid decline in cpue, and possibly change the species composition of the fished community (Dalzell and Preston, 1992).

1.10.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Properly developed, deep-slope fishing would be a suitable artisanal fishery in PNG (Richards and Tatamasi, 1984). The cost of capital outlay and replacement costs for broken gear could be prohibitive, however. Post-harvesting requirements of careful cleaning and good icing could be developed with support from fisheries extension services. Markets are, or could be, available. Further, there is little effort required in terms of manpower when deepwater hand reels are used. It has been shown that catch rates improve with an increase in fishers' experience and familiarity with fishing grounds, and their use of more seaworthy vessels (e.g. Chapau, 1986).

- Development of the resource. PNG has the largest resource of deep-slope species in the Western Pacific (Dalzell and Preston, 1992). However, where attempts have been made to increase fish production from the resource, enthusiasm for continued fishing usually has not been sustained. Perhaps Kupiano and Lae are exceptions because of the relatively easy access to Port Moresby and Lae markets?

  Chapau and Dalzell (1991) outlined the reasons for the decline in the deep-slope fishery in Wewak, all of them centred on a lack of support services. Services previously offered included subsidised fishing gear, landing and icing facilities available all hours, technical advice and services, transport assistance, financial advice and management. If a viable fishing industry based on deep-slope fish is to be established where there is no tradition of deep-sea fishing - as in PNG, it seems that a range of services to the fishers would have to be developed to sustain their industry and encourage others to take part.

  One provider of services to deep-slope fishers is hotels. As stated earlier, hotels and restaurants are ready buyers of deep-slope fish. To ensure regular supply, hoteliers could be encouraged to support a group of fishers operating in easy-transport distance from their hotel. Support could include the provision of serviced outboard motors, and ice. The added incentive for hoteliers and restaurateurs is that deep-slope fishes are not ciguateric - i.e. they could serve large fish to their guests without fear of causing illness. This is a benefit that cannot be enjoyed from purchasing and serving shallow-water reef fish and Spanish mackerel, for example.

- Dalzell and Preston (1992) pointed out that unchecked expansion of fishing effort may lead to severe declines of deep reef fish stocks, particularly around isolated islands, pinnacles and sea mounts. Deep-slope fish species populations have limited habitat preferences and low recruitment, and these result in their being highly susceptible to overfishing (Moffitt, 1993; Haight *et al.,* 1993). Dalzell and Preston (1992) estimated that in PNG catch rates of between 2.5 kg/line hour and 3 kg/line hour would probably be experienced in a fishery in equilibrium, and 40-50 per cent of the catch would comprise eteline snappers (*Etelis, Pristipomoides*). Close assessments of the resource and regulation of the fishery are important in ensuring long-term viability of the fishery.

Stock assessment of deepwater fish stocks is difficult because of the multispecies nature of the fishery and management measures are not always effective (Haight *et al.,* 1993).

Because the use of a linear measure to estimate biomass (mt/nautical mile) may not be appropriate to PNG (Dalzell and Preston, 1992) the projected cpue at msy may be inaccurate. Accordingly, biomass estimates should be made using the 200 m isobar as an index of fishable habitat. In the short term, these should be based on the information in earlier surveys (I do **not** recommend undertaking new surveys). Operating deep-slope fisheries in PNG needs to be monitored by recording cpue and yield over time. Hences, again, better recording of landings is required.

A mechanism should also be in place to provide adequate protection to the resource if declines in stock are observed. Keeping the fleet size small through licensing, and encouraging rotation among known fishing grounds, are two means whereby the resource can be sustained and catch rates maximised (Latu and Tulua, 1991, in Dalzell and Preston, 1992).

Development of a deep-slope fishery in areas where shallow reef fish stocks are already harvested would act as a conservation measure for the latter. An example of this would be in the Huon Gulf where some shallow reefs are showing signs of being over-exploited (e.g. decreased size of target species at landing place), but where the price offered for fish from both habitats is the same. A price incentive coupled with support services (such as availability of hand reels) and rotation between fishing grounds could result in a very effective and sustainable fishing operation in the area. The Fishery Sector Review (1989) cited East New Britain as another area where deep-slope stocks are untouched while inshore reef areas are either limited or heavily fished.

- Possible difficulties in marketing large deep-slope fishes in PNG have been recognised (Fisheries Research annual reports 1983; 1984). The marketing problems associated with other fish products in PNG apply equally to deep-slope fish. They include irregular transport, high freight costs (large fish are heavy too!), inadequate ice supplies and poor fish quality practices on the part of the fishers. Improvements in handling and use of ice-boxes has ensured good markets for fishers from Kupiano and the Huon Gulf.[1]

  It seems likely that transport difficulties will restrict domestic marketing of deep-slope fish to large coastal centres. Two additional avenues could be explored (only) however. These are:

  1. a domestic market for high quality white fish fillets and cutlets, servicing the Highlands; and
  2. exporting to Australia. Markets for deep-slope fish have established there in recent years, following the development of the 'Timor Box' and North West Shelf trap and dropline fisheries in Australia. Regular and direct air services connect PNG to major Australian cities. The fish would have to be airfreighted and of high quality to compete, however.

[1] I have no information whether this is also the case for Wewak.

Dalzell and Preston (1992) observed that the growth of pelagic longlining in the South Pacific has attracted fishers away from deep-slope resources. They concluded that large-scale commercial expansion of deep-slope fisheries in the South Pacific appears unlikely, given the constraints on supplying quality fish for overseas markets (including marketing arrangements) and the potential production from, and sustainability of, the resource. Although this warning should be heeded, it should not restrict thoughtful exploitation of PNG's almost untapped deep-slope fish resources.

1.10.5 References

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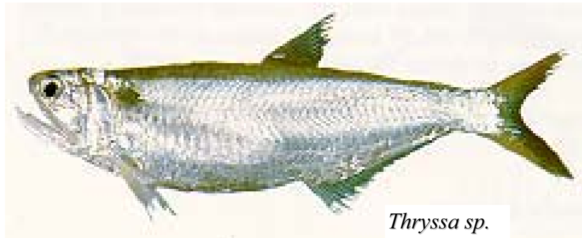
1.11 TRAWL BY-CATCH SPECIES

1.11.1 The Resource


Thryssa sp.

Species present: Numerous species comprise the bycatch resource. As the name implies, they are all species other than the target species. Trawling operations in PNG are directed solely at prawns (Penaeidae): hence, the bycatch resource comprises all other taxa.

Jewfish (Sciaenidae), anchovies such as *Thryssa* species (Engraulididae), ponyfish (Leiognathidae), hairtails (Trichiuridae), grunters (Therapontidae), catfish (Ariidae), tongue soles (Cynoglossidae), bullseyes (Priacanthidae), goatfish (Mullidae), pufferfish (Tetraodontidae), threadfin salmon (Polynemidae), lizardfish (Synodontidae), butterfly bream (Nemipteridae), small sea perch (Lutjanidae), trevallies and other carangids (Carangidae) and herrings (Clupeidae) are usually dominant fish families in the bycatch. Crustacean bycatch includes slipper lobsters or bugs (*Thenus* species, Scyllaridae). Molluscan bycatch includes tropical or saucer scallops (*Amusium* species, Pectinidae) and squid.

The composition of the bycatch varies with season, time of day/night, area trawled, number of trawls, target species and depth of the trawl. For example, Watson's (1984) samples of trash fish taken from the eastern Gulf of Papua between June and September 1982 (the dry, or south-east season) were dominated by weight and numbers by jewfish, anchovies, ponyfish and hairtails. The most numerous families in samples of trash fish Kailola and Wilson (1978) and Watson (1984) obtained in the prawn trawl fishery were fork-tailed catfish, trevallies and scad, anchovies, Bombay ducks, ponyfish, goatfish, javelinfish, threadfin scats, herrings, hairtails, jewfish and grunters. In areas such as off river mouths, fish with adaptations for turbid waters and muddy substrates predominate - for example, threadfin salmon, anchovies, Bombay ducks, jewfish; and where the water is clearer or shallower, fish such as ponyfish, trevally, goatfish and grunter predominate.

Distribution: Species comprising the prawn trawl bycatch are tropical and subtropical taxa, favouring turbid to almost clear waters with salinity ranging from 29.8 ppt (Rapson, 1955, in Kailola and Wilson, 1978) to 35 ppt. They inhabit moderately shallow (less than approximately 70 m depth) water over a mud or sand substrate. Many of the species groups comprising the trawl bycatch in PNG also comprise the bycatch of trawling operations in northern Australia (e.g. Gulf of Carpentaria) and South East Asia (e.g, Gulf of Thailand, Java Sea).

Kailola and Wilson (1978) compared the species composition of trawl fish in the Gulf of Papua by western (west of Orokolo Bay) and eastern sections (to Cape Suckling). As prawn trawling is performed almost exclusively in the eastern section, only their results from that area are considered here.

There is a distinct difference in the dominance of trash fish by depth zone.

Table 27 Kailola's and Wilson's analysis of species dominance showing the top 12 fish groups by percentage biomass for the main prawn trawl grounds of Orokolo Bay and Freshwater Bay.

Family	Common name	10-19 m depth	20-39 m depth	40+ m depth	Total
Ariidae	catfish	8.3	4.5	3.4	5.7
Carangidae	trevally, scad, darts	1.6	0.1	1.1	0.9
Clupeidae & Engraulididae	herrings and anchovies	10.3	14.7	11.5	13.1
Haemulidae	javelinfish	6.6	0.1	-	2.2
Harpadontidae	Bombay ducks	13.3	7.3	1.2	7.9
Leiognathidae	ponyfish	0.7	20.0	17.7	13.9
Mullidae	goatfish	10.8	13.9	14.3	13.6
Priacanthidae	bullseyes	0.6	-	8.3	2.5
Rhinoprenidae	threadfin scats	3.7	2.8	0.5	2.6
Sciaenidae	jewfish	35.1	23.2	11.9	25.2
Therapontidae	grunters	1.9	10.7	25.8	7.7
Trichiuridae	hairtails	3.0	1.2	3.8	2.5

The most common groups of fish in prawn trawls by percentage occurrence (Watson, 1984) are anchovies 65 per cent, ponyfish 54 per cent, hairtails 35 per cent, jewfish 76 per cent, grunters 20 per cent, herrings 20 per cent, goatfish 7 per cent and Bombay ducks 17 per cent.

Biology and Ecology: Trawl bycatch species display a wide range of life histories and ecological preferences. Their spawning times and fecundity, maximum size, schooling behaviour, habitiat preferences, growth rates and diet vary enormously between taxa.

1.11.2 The Fishery

Utilisation: A prawn trawl fishery has operated in the Gulf of Papua since the late 1960s. Retrieval of edible bycatch from the fishery has taken place as opportunity arose and whenever it was economical to do so. The edible bycatch is sorted by value - species such as bugs, squid and scallops first, then larger fish, then other fish. The last category is packed in plastic bags by weight and frozen and inedible or less palatable fish may be included by mistake. The larger fish, comprising fish such as tonguesoles, sea perch, small mackerel (*Scomberomorus* species) and cobia (*Rachycentron* species) are sold individually.

In the 1980s, Yule Aperana Pty Ltd in Konedobu (Port Moresby) retailed 2 kg and 5 kg packs of frozen bycatch fish for perhaps K2/kg. (Yule Aperana is owned by New Guinea Marine Products Pty Ltd).

In 1994, Delta Seafoods retails bycatch fish in Port Moresby for K1.80/kg. The fish are frozen in 10 kg packs and brought in once a week from the company's fleet of four prawn trawlers. There is a large demand for trash fish in Port Moresby, and Delta Seafoods very often runs out of fish.

During the prawn trawl season, trawling is almost continuous. Certain areas - such as Orokolo Bay and Freshwater Bay - are the most heavily fished. The yield of trash fish and bycatch is therefore not evenly distributed throughout the fishery (Watson, 1984).

I did not have opportunity to visit other companies, such as Gulf Prawn Fisheries, New Guinea Marine and Provex.

Production and Marketing: Most trash fish are not marketed because they are too small, or they do not appeal to the existing market (Watson, 1984). Contrary to South East Asia, coastal Papua New Guineans do not have a traditional of consuming many of the bycatch species - either fresh, smoked or dried.

Bugs, squid and scallops are retained, and larger bycatch fish species are usually retained. These include threadfin salmon, jewfish, some ponyfish, trevallies and other carangids, bullseyes, sea perch and tonguesoles. In 1982, the non-prawn weight in each haul in the trawl fishery comprised mainly jewfish (18.5 per cent), anchovies (12.6 per cent), ponyfish (8.7 per cent), hairtails (6.5 per cent) and Bombay ducks (5.7 per cent) (Watson, 1984).

In a six-month study of bycatch composition and quantity in the Gulf of Papua prawn trawl fishery, the average estimated fish-to-prawn ratio was 8.8:1 (Watson, 1984). For Orokolo Bay however, it was 14.8:1 (because of larger catches of threadfin salmon, mainly *Polydactylus nigripinnis*). Hence, the fish-to-prawn ratio varies with area and depth.

In another study in the Gulf of Papua (mid August to early November), Mobiha (1984) calculated that the ratio of fish-to-prawns ranged from 8.9:1 to 11:1. 96 per cent of the fish was rejected.

Whitcombe (1978) attempted to appraise the utility of the bycatch from prawn trawling. He conservatively estimated that trash fish production from 12 vessels operating in the Gulf of Papua is 6,000 mt, giving a 6:1 ratio of fish-to-prawns. Of this amount, Whitcombe estimated that only K0.20/kg could be obtained for unselected trash, bulk packed, frozen whole and landed in Port Moresby. This return would - he said - be acceptable but hardly lucrative (note: in 1978 prawn prices were K5,000/mt and the proposed trash fish revenue of K200/mt - a ratio of 1:25 - would hardly be a reason for the operators to change to trash fish utilisation). Whitcombe also pointed out that the supply of trash fish delivered to Port Moresby would be uncertain and liable to fluctuation; i.e. during peak prawning times little trash would be retained.

Problems in recovery of trash fish include lack of required freezer space on board, additional handling (time), loss of efficiency in prawn sorting and processing, variable processing facilities and relative low value of the fish (Kailola and Wilson, 1978; Whitcombe, 1978). Whitcombe floated several ideas to utilise trash fish from the prawn trawl fishery, including: each vessel delivering 1 mt of trash fish at the end of each voyage if space were available; specially built trash vessels servicing the fishery to tranship bycatch (unsuitable because of weather conditions in the dry season, poor monetary return, cost of boat and its refrigeration, and time for handling); and utilising a low-cost vessel operating from shore to secure trash fish to feed farmed crocodiles. In lieu of a thorough biological and economic study, Whitcombe concluded that the dumping trash fish was the only economic way to handle it. The apparent waste of the majority of trash fish from prawn trawl operations usually initiates ideas for the commercial exploitation of the trash. Often these schemes involve converting the trash to fish meal. The variable physical size, length and weight stretch logistics in handling and this more than the supply and chemical composition of the bycatch is the greatest problem in its utilisation.

Haines and Stevens (1983) reported the results of a trial conducted by the Baimuru Fish Plant in 1980 which supports the bycatch retailing initiatives of companies and partly negates the observations of Kailola and Wilson and Watson.

Table 28 The total catch from three days of prawn trawling by one vessel landed at the plant at the end of October 1980:

Product **	Weight (kg)	% net landed wt	value/kg (K)	gross value (K)
prawn	47.5	1.64	3.50	166.25
squid	11.9	0.41	2.00	23.80
small selected fish	483.0	16.7	0.35 ea	610.05
large selected fish	184.0	6.36	0.55 ea	294.25
unselected fish, 500g bag	945.5	32.68	0.70	661.85
unselected fish, 1 kg bag	335.0	11.58	0.70	234.50
crab	34.0	1.18	0.50	17.00
eel	66.0	2.28	1.50	99.00
sole	16.0	0.55	2.00	32.00
animal feed	550.0	19.01	0.10	55.00
discarded	220.0	7.61	-	-
net landed wt	2,892.9	100.0	-	-
unaccounted	272.1	-	-	-
gross landed wt	3165.0	-	-	-

(**: prawn = head on, green, mixed; squid = includes cuttlefish; crab = *Portunus* species; eel = hairtail; sole = Soleidae; animal feed = very small and damaged fish; discarded = very spiny fish, catfish, seasnakes; unaccounted = original packaging, ice, seeds, debris)

Analysis of the Baimuru Fish Plant samples showed that the small fish had a protein content of 15 per cent, an amount adequate for livestock feed, and Haines and Stevens (1983) suggested that the product could be ground and kiln dried cheaply from burning timber off-cuts from the Baimuru sawmill.

1.11.3 Stock status

Trash fish differ in their perishability and marketability. Whereas some require handling and processing, others are only suitable for fish meal or animal feeds. Hence, if there is a desire to utilise trash fish, studies must be performed to find out its avaerage composition and the relative amounts of each group in the target fishery (Watson, 1984).

The amount of bycatch from the prawn fishery in the Gulf of Papua was estimated at 9,000 mt in 1978 (DFMR files, in Haines and Stevens,1983).

Early in 1983, R. Kuk (pers. comm., in Watson, 1984) estimated that the weight of the Gulf of Papua trash fish from prawn trawling landed and sold in Port Moresby was 250 mt/yr, of which 86 per cent was edible.

Based on the estimated average ratio of 8.8 kg of fish to 1 kg of prawns, the estimated harvest of trash fish in the second six months of 1982 in the Gulf of Papua was 209 kg/hr (Watson, 1984). If that harvest were extrapolated for all trawl hours for 1982 the estimated total harvest was 11,000-17,200 mt or 1.2-1.9 mt /sq km of trawled grounds. The higher cpue's by family belonged to jewfish (23 per cent of the estimated total fish catch of 209 kg/trawl hour) followed by anchovies and ponyfish, each forming 16 per cent of the total. The anchovy catch for example, would be 1,760-2,752 mt/year. However, Dalzell (1983) estimated that the annual catch of anchovies in the Gulf of Papua lay between 250 mt and 700 mt; and in 1993, he estimated that it comprised 1,420 mt (based on an annual bycatch from the gulf prawn fishery of 14,000 mt - see below).

During his 1982 study in the Gulf of Papua, Watson observed that the prawn trawlers operating in the prawn trawl fishery worked their gear each day an average of 20 hours with an estimated daily catch of 4.2 mt. An estimated 68,190 hours of trawling was performed in the gulf in 1982, therefore yielding a total estimated harvest of 14,250 mt of trash fish. Areas like Orokolo Bay had higher trash fish catches. Orokolo Bay and Freshwater Bay are the most heavily fished in the prawn season - thus the amount of trash fish collected may not be same throughout the gulf. For Freshwater Bay and Orokolo Bay alone, Watson (1984) estimated that the 1982 trash fish harvest was 4,140 mt.

In summary, the above studies give estimates of bycatch over the range 9,000 mt to 17,200 mt/yr.

Several studies (by e.g. Sainsbury, 1987, and Harris and Poiner, 1991, both in Blaber *et al.,* 1994) have reported on the changes in faunal composition of an area as a result of continuous trawling activity. Some of this change has been attributed to trawls removing benthic structures such as sponges; others are attributed to the discarded trash fish attracting or producing larger populations of scavenging fauna (Hill and Wassenberg, 1990). In their study of the Gulf of Carpentaria, Blaber, Brewer and Harris (1994) found that fish biomass was twice as high in the prawn trawling grounds as it was elsewhere in the gulf. Harris and Poiner (1991, in Blaber *et al.,* 1994) found that fishing effort and discarding in prawn grounds caused changes in the species composition over a long period, and also changed the diel behaviour of some species -such as javelinfish, goatfish and lizardfish - after intensive trawling. In PNG, those observations are supported by Watson's (1984) comment that areas like Orokolo Bay and Freshwater Bay - the most heavily fished in the prawn season - have the highest trash fish catches.

Although the data are few, already there appear to be differences in species composition in the area. This can be seen by comparing the dominant fish groups recorded in two studies.

Table 29 Dominant fish groups in the most intensively prawn-trawled areas, by per cent weight

Fish group	Kailola and Wilson, 1978	Watson, 1984
Jewfish	ONE	ONE
Ponyfish	TWO	THREE
Goatfish	THREE	-
Anchovy	FOUR	TWO
Bombay ducks	FIVE	FIVE
Hairtails	-	FOUR

1.11.4 Management

Current legislation/Policy regarding exploitation: There is no current legislation.

Recommended legislation/Policy regarding exploitation: The longterm effects on the faunal community of continuous trawling are not known. However, regular monitoring (e.g. every five years) of the bycatch composition of the Gulf of Papua prawn trawl fishery should be conducted.

1. The amount of by-catch, its composition (in broad categories) and the manner of its disposal (e.g. whether and how marketed) should be recorded on prawn fishery logbooks. This measure will provide a better estimate of the resource than is now available. It is necessary information for development - e.g. point 3.
2. It could be worthwhile to undertake an economic appraisal of processing trash fish from prawn trawling, as Haines and Stevens (1983) initiated. Along these lines, input from the prawning companies operating in the Gulf of Papua should be sought. It could be worthwhile to utilise the Baimuru Fish Plant (if it still operational?) as a staging house for the fish bycatch.
3. The possibility of undertaking exploratory fish trawling should be considered. Deeper, trawlable areas do exist in PNG (e.g. in western Papua: *Kulasi* cruises of 1987) not unlike areas in northern and north-western Australia which yield reasonable quantities of quality

table fish such as rock cod (Serranidae), sea perch (e.g. *Lutjanus malabaricus* and other lutjanids), emperors (Lethrinidae) and butterflybream (Nemipteridae). Markets for these fish exist in Australia.

1.11.5 References

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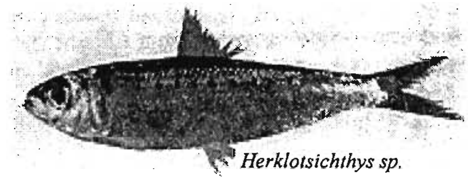
1.12 SMALL PELAGICS (BAITFISH)

1.12.1 The Resource


Herklotsichthys sp.

Species present: Anchovies (Engraulididae: *Encrasicholina* species, *Stolephorus* species, *Setipinna* species), sardines (Clupeidae: *Sardinella* species, *Amblygaster* species), sprats (Clupeidae: *Spratelloides* species), herrings (Clupeidae: *Herklotsichthys* species), roundherrings (Clupeidae: *Dussumieria* species); silversides (Atherinidae: *Atherinosoma* species, *Hypoatherina* species, *Stenatherina* species) are all small pelagic baitfishes. Dalzell (1993) included fusiliers (e.g. *Pterocaesio* species), flying-fish (e.g. *Hirundichthys* species), garfish (e.g. *Hemiramphus* species), scads (e.g. *Selar* species), mackerel (e.g. *Rastrelliger* species), cardinal fish (e.g. *Rhabdamia* species) and large anchovies (e.g. *Thryssa* species) and shads (e.g. *Pellona* species) in this category as well. Some of these groups have been discussed in other profiles. Kailola (1987) recorded 23 relevant clupeid species, 13 engraulid species and 10 atherinid species from PNG waters; and of these, 14 clupeids, eight engraulid and seven atherinids comprise principal baitfishes in PNG (Lewis *et al.,* 1983, in Dalzell and Lewis, 1989).

The dominant species in most South Pacific bait fisheries are/were anchovies and sprats, with clupeids being less important. A survey for small pelagic tuna baitfish in the South Pacific region between 1977 and 1980 showed that *E. devisi, E. heterolobus, Spratelloides delicatulus, Herklotsichthys quadrimaculatus* and *Atherinosoma lacunosa* were widespread and abundant, and that *Hypoatherina ovalaua, Amblygaster sirm, Spratelloides gracilis* and *E. punctifer*, were common (Dalzell and Lewis, 1989). In PNG waters, sprats overall comprise 18.1 per cent of tuna baitfish, herrings and sardines comprise 5.4 per cent and anchovies comprise 62.6 per cent (Dalzell and Lewis, 1989). *E. heterolobus, E. devisi* and *S. gracilis* formed the basis of the tuna baitfishery in northern PNG waters. The two anchovies were dominant in Cape Lambert hauls and the sprat was dominant in the Ysabel Passage hauls (Dalzell, 1990). Catch composition fluctuates widely between successive 10-day periods (Wankowski, 1980). In Cheshunt Bay, southern PNG, the main species are *E. heterolobus, E. devisi* and *E. punctifer* (Cooper and Wankowski, 1980).

The taxonomy and identification of baitfish is not simple as the species are morphologically similar, many similar species co-exist, and have a similar ecology.

Distribution: Small pelagics live in the surface layers of the water column, usually above the continental shelf. Many are associated with coralline areas and are found in bays, inlets and coastal lagoons where there is some freshwater influence. Dalzell (1984a) has shown however that one species, *Encrasicholina punctifer*, is stenohaline and prefers fully oceanic waters.

Apart from their localised distribution, the numbers of small pelagic fish species decrease from west to east - a pattern followed by several other Indo-Pacific taxa (e.g. Siganidae, Acanthuridae, Pomacentridae, many reef-associated taxa). Species diversity is also greater around high islands as opposed to atolls, and stolephorid anchovies are absent from atolls and high islands lacking embayments and lagoons (Dalzell, 1993).

Biology and Ecology: The majority of baitfish species are planktivorous, although the larger anchovies will feed on small fishes (Dalzell, 1993). Chapau (1983) recognised trophic partitioning between two species of *Encrasicholina* and the sprat, *Spratelloides gracilis*, in Ysabel Passage, New Ireland Province.

The small baitfish fall into two groupings based on certain biological characteristics (Conand, 1986 and Lewis, 1990, in Dalzell, 1993). Stolephorid anchovies (*E. heterolobus, E. devisi, E. punctifer*), sprats (*S. gracilis, S. delicatulus, S. lewisi*) and silversides

(*Hypoatherina ovalau*) have a short (<1 year) life cycle and generally attain 7-10 cm maximum length. They are mature by age 3-4 months, are very fecund, and have an extended spawning period. On the other hand, herrings and sardines (*Herklotsichthys* species, *Amblygaster* species, *Sardinella* species), larger anchovies (*Thryssa* species, *Stolephorus* species) and sharp nosed sprats (*Dussumieria* species) live for at least one year (sometimes two) and grow to 10-24 cm in length. They mature later (towards the end of their first year), are moderately fecund and have a restricted, seasonal spawning period.

Summaries of growth, mortality, maturity parameters and spawning seasons for small pelagic fishes are provided by Dalzell (1993). Dalzell (1990) provided tables of age, growth and mortality parameters and exploitation rates for stocks of baitfish from three areas in PNG. Sprats and stolephorid anchovies have protracted or year-round spawning in tropical waters, although Dalzell (1987) found that two taxa - *E. heterolobus* and *E. devisi* in northern PNG waters - exhibited spawning peaks in October-November and May-June corresponding to increases in zooplankton production (Chapau, 1983). Both these phenomena correspond in turn to the change-overs between the prevailing wind directions of the southeast monsoon to the northwest monsoon (October-November) and the converse (May-June).

First maturity in *E. heterolobus* is reached at 50 mm fork length and in *E. devisi* at 41 mm (Dalzell, 1987). Eggs of most species are pelagic; however, *Spratelloides* eggs are laid on the substrate (Dalzell, 1993). Full recruitment to the baitfishery in Ysabel Passage occurs at 26 mm fork length for *S. gracilis* and 36 mm and 38 mm for *E. heterolobus* and *E. devisi* (Wankowski, 1980). Dalzell (1984a) found that there was better recruitment of *E. heterolobus* and *E. devisi* (but not *S. gracilis*) following periods of rainfall, and he pointed to studies which suggested that production of tropical clupeoids is strongly influenced by environmental effects such as wind and rain. For both these species of *Encrasicholina* the optimum rainfall for maximum catch per unit of effort is about 3,000 mm per year and when it is heavier, catch rates decline. However, this drop in catches could be attributed to the effect of increased turbidity in the water on the attractive power of the lights (Dalzell and Lewis, 1989).

Supplemental information on baitfish biology can be found in Dalzell and Wankowski (1980) and Dalzell (1984b).

1.12.2 The Fishery

Utilisation: Prior to the commencement of the pole-and-line tuna fishery in PNG in the 1970s, anchovy and sprat resources were largely unexploited (Dalzell and Lewis, 1989) except for their minimal use in subsistence fisheries. Talai (*Herklotsichthys quadrimaculatus*) are consumed in New Britain, for example. Herrings are caught in the North Solomons Province by hand-held scoop nets (Hulo, 1985, in Dalzell, 1993). J. Wankowski (DFMR file note, dated 8/80) remarked that although small inshore clupeoids are rarely exploited, islanders seasonally catch 'whitebait' runs; and small clupeoids occasionally occur in markets (e.g. Koki market, Port Moresby) as packets of lightly smoke-cured fish.

Commercially, baitfish are captured by the use of "bouke-ami" or stick-held lift nets operated off a tuna vessel. The fish are aggregated at night with the aid of submersible lamps which are gradually dimmed to compact the fish. The net is hauled from below and the fish are concentrated in one area of the net. The fish are later brailed into buckets and loaded into bait wells on the tuna vessel. Baiting was always performed at night.

The live-bait fishery developed in tandem with the domestic pole-and-line tuna fishery during 1971. The fishery contined into 1981 when it was suspended, and recommenced in 1984 (Dalzell and Wright, 1986). The baitfishery extended over eleven sites in PNG, yet 60 per cent of the total catch was made in two locations - Ysabel Passage in New Hanover, and

Cape Lambert in East New Britain (Dalzell, 1984b). Baitfishing during 1984 and 1985 in PNG waters was much reduced due to their being a smaller pole-and-line fleet (nine vessels operating in 1985 *cf* an average of 45 vessels/year between 1971 and 1984 (Dalzell and Wright, 1986). The baitfishery (and pole-and-line tuna fishery) closed altogether in 1985.

There were 14 (Wankowski, 1980) to 23 (Dalzell, 1990) baitfish grounds in PNG. Between 1970 and 1980 the New Hanover/New Ireland and north coast of New Britain grounds each averaged c. 40 per cent of the total PNG baitfish catch. The north coast of New Britain was of greatest importance prior to 1975 and after then, the New Hanover/New Ireland grounds accounted for about 60 per cent of total bait catch and effort (Wankowski, 1980). Fishing effort was lower in the northern grounds between December and March each year, although this decrease was not compensated for by fishing on southern grounds. The southern baiting grounds were only used to any extent in since 1976 (Wanskowski, 1980). There were three baitfishing areas in southern PNG, of which the Cheshunt Bay area (Marshall Lagoon, Central Province) was the most important (Cooper and Wankowski, 1980).

The seasonal abundance of baitfish in PNG waters coupled with random environmental effects such as wind and rainfall, and the existence of only two suitably large baiting areas limited the pole-and-line tuna fishery in PNG when there was low baitfish abundance at those two areas (Dalzell and Lewis, 1989).

Production and Marketing: The harvest from the baitfish fishery came in two forms - quantity of fish, and baitfish royalties.

<u>Quantity of fish</u>

Between 1970 and 1981 annual catches of baitfish ranged from 75 mt to 1,900 mt at the peak of the tuna pole-and-line fishery (Fishery Sector review, 1989; Dalzell, 1990) and a mean of 1,125 mt/yr.

Table 30 Summary of annual bait catch (1000's of buckets) by PNG baiting ground between 1970 and 1979 (from Wankowski, 1980). One bucket-load is statistically equal to 2.4 kg of wet fish.

Year			Baiting	ground			Total
	Seeadler Harbour (Manus)	New Ireland	Sek Harbour (Madang)	N. coast of New Britain	S. coast of New Britain	Cheshunt Bay (Central Province)	
1970	0.05	30	-	-	-	-	30
1971	20	94	72	34	0.06	-	224
1972	1.3	139	58	151	0.5	-	330
1973	18	127	12	297	2	-	456
1974	2	199	16	292	9	-	518
1975	-	182	4.2	178	15	-	379
1976	33	173	-	157	29	-	392
1977	80	351	-	253	66	-	750
1978	27	506	-	208	9	11	762
1979	49	333	-	136	26	25	566

The total catch of baitfish from 1971 to 1981 was 13,451 mt with a mean annual catch of 1,222.8 mt (Dalzell and Wright, 1986). In 1978, the average baitfish catch was 64 buckets/boat/day; and in 1979 it had increased to 94 buckets/boat/day (Cooper and Wankowski, 1980). The higher bait catches in 1979 were accompanied by higher tuna catches (1 unit weight of baitfish : 20 units weight of caught tuna in 1978 *cf* 1 unit weight of baitfish : 22.5 units weight of caught tuna in 1979). The bait was also used more efficiently (Cooper and Wankowski, 1980).

Royalty

Baitfish are a non-traditional resource generated by the reef and the waters in which they occur are not exploited by traditional fishing techniques (Turner, 1990). However, a combination of the incursion of fishing fleets into inlets and bays, their visible active harvesting of fish which were used to catch other fish commercially, and a belief (not proven: e.g. Blaber and Copland, 1990) that exploitation of baitfish has a negative effect on stocks of reef fish probably led to the villagers considering themselves owners of the baitfish resources and having an expectation of compensation for their harvest (Turner, 1990). Accordingly, the baitfish 'royalty' was instituted in 1975. It was agreed it would be 5 per cent of the fob value of the tuna caught by the fleet. Under the scheme, payments were made directly to village people on the basis of the amount of baitfish caught in their traditional fishing areas by the fleet (see: Doulman and Wright, 1983). In 1981, K950,000 was paid out to villagers in the New Hanover area (Ysabel Passage) of the New Ireland Province and up to January 1980, K405,621 had been paid into the baitfish trust account in the Bainings area (Cape Lambert) of the East New Britain Province (Turner, 1990). Villagers in the areas of the less important baitfisheries on the south coast of west New Britain (Gasmata), Manus Island and Madang (Sek) areas received much less in royalties. Baitfish royalty payments ceased with the closure of the domestic pole-and-line tuna fishery in late 1981.

1.12.3 Stock status

Analyses of catch versus fishing effort for bait fisheries in Ysabel passage and Cape Lambert for the general period 1970-81 and 1985 showed that there was no decrease in catch with increasing effort - i.e. a linear relationship existed (Dalzell, 1990; 1993). This relationship was an artefact of the fishery, because when catches dropped off in one area the fleet would relocate to a more productive area. In addition, the component species of the total bait catch fluctuated (e.g. the catch rates of stolephorid anchovies in northern PNG was inversely correlated with fishing effort). In the Ysabel Passage fishery, species other than the three major ones (*E. heterolobus, E. devisi, S. gracilis*) comprised 5 per cent of the catch in the early years (1972-73) of the fishery, but by 1981 they comprised 30 per cent of the catch (Dalzell and Lewis, 1989).

The MSY of exploited stocks of *E. heterolobus* and *E. devisi* (combined) from the Ysabel Passage and Cape Lambert was calculated to be 0.61 mt/km^2/yr (Dalzell, 1983) or 0.65 mt/km^2/year (Dalzell, 1984b), and actual combined yields (during the 1970s) ranged from 0.25 mt/km^2/year to 1.6 mt/km^2/year (Dalzell, 1984b). This equates to 204 mt/year at Ysabel Passage and 208 mt/year at Cape Lambert (Dalzell and Wright, 1986). Estimates of mean standing stock of small pelagics - primarily anchovies and sprats - for the Ysabel Passage and Cape Lambert baiting grounds (Dalzell, 1984b; 1986) were 0.59 mt/km^2 and 0.29 mt/km^2 respectively, with an overall weighted mean of 0.43 mt/km^2 (Dalzell, 1984b). The predicted yield for *E. heterolobus* was 0.44 mt/km^2/year. In 1990, Dalzell proposed that the MSY for bait catches in PNG ranges between 1 mt/km^2/yr and 10 mt/km^2/yr, or a density of one boat/30-40 km^2 of bait ground.

The potential sustainable yield of stolephorid anchovies (alone) from PNG probably falls in the range of 5,000-10,000 mt/year to 40,000 mt/year (Dalzell, 1986). Finally, by applying a formula of primary productivity and continental shelf area, Dalzell (1993) estimated that there is a potential yield of about 130,000 mt of (all) small pelagics in PNG waters.

Wright and Richards (1985) recorded that in 1981, pole-and-line tuna removed 128 mt of baitfish from the shallow waters of the Tigak Islands. This production amounted to 6.16 kg/ha/year.

Although based on little data, present levels of exploitation of all small pelagic species in the western Pacific appear sustainable in the long term (Dalzell, 1993). However, although small pelagic fish populations may demonstrate large natural fluctuations, major changes in species composition and abundance may be induced by fishing pressure (Dalzell, 1990).

How does this analysis rank with Gulland's (1983, in Dalzell, 1993) that species having a short life span and high natural mortality should be fished 'relatively hard' so as to catch them before they die of natural causes, and thus maximise yield?

1.12.4 Management

Current legislation/Policy regarding exploitation: There appears to be none - in the absence of a baitfish fishery.

Recommended legislation/Policy regarding exploitation: There is no baitfishery in PNG now. The baitfishery depends on the pole-and-line tuna fishery maintaining operations, and there are economic restraints on resumption of the domestic pole and line tuna fishery (Fishery Sector review, 1989). This fishery would be less economic now than it was when it closed in 1981, and the reduced fleet size during its short re-opening in 1984-86 highlights the strength of the economic restrictions.

Exploitation of tunas by purse-seine fleets has made pole-and-line tuna fishing redundant in many areas of the South Pacific, although it persists in some countries where it is served by canneries (e.g. in Fiji and Solomon Islands) (Dalzell and Lewis, 1989).

- Small-scale artisanal pole-and-line tuna operations could develop in PNG with the forthcoming establishment of the ZZZ Cannery at Madang.
- Catches could be landed and processed there in conjunction with those from the purse-seine fleet.
- Small-scale artisanal pole-and-line fisheries in PNG would also offer local employment opportunities (Dalzell and Wright, 1989).

If that tuna fishery were to resume, there are stocks of baitfish to support it. However, *access to baitfish would be a precondition to any successful pole-and-line operation*.

The scenario then, is:

1. establishment of shore-based facilities;
2. an economic and sociological appraisal of the utility of initiating a domestic (small-scale) pole-and-line fishery;
3. identification of capital and expertise to initially support the fishery;
4. negotiations with customary rights owners over access and royalties;
5. development of legislation to cover customary access rights (and royalties)(see below); and
6. management of the resource, such as a limitation of effort and the movement of vessels away from fishing grounds that show severe declines in production.

Currently, PNG has a large fish resource which is unexploited. *What if a pole-and-line fishery doesn't develop? Can PNG leave the resource unused?* Look at the paradox: so many fisheries in PNG are operating (often unsuccessfully) in the absence of scientific information and sound assessment of the resource, and here is one which has been thoroughly researched ("... a long term commitment by the Papua New Guinea Government to understanding the biology of exploited baitfish populations": Dalzell, 1990:111) but lacks a fishery. Dalzell and Lewis (1989) wondered whether non-tuna-orientated fisheries could be developed for small baitfish in PNG given the country's small population and lack of markets (and I would add: lack of appropriate expertise in post-harvesting technology). *Could local industries* *producing 'ikan kering' (dried small fish) and brined baitfish; and what about fish pastes; not to mention canned anchovies and herrings*? Some of these products could be exported.

The key is access to the resources.

A *comment on baitfish royalties* is in order. The question of royalty payments for baitfish in particular and marine produce in general has at least four aspects, according to Otto (1989). These are biological, economic, legal and sociological. From a *biological* point of view, conservation of the resource is important, and that involves monitoring the baitfishery, assessing the biological effects (if any) of the fishery and using traditional marine ownership. From an *economic* point of view, bait royalties serve the purpose of ensuring access to the baitfish resource - essential for the pole-and-line fishery - and also providing income to villagers. The *legal* basis for payment and distribution of royalties requires legislation be prepared and included in the Fisheries Act. Although PNG laws do acknowledge existing traditional rights of ownership of waters, no traditional rights existed to regulate the baitfish fishery as baitfish are not a traditional resource. *Sociologically*, baitfish royalty payments expose the lack of traditional ownership over those resources and draw attention to the need for information on traditional fishing techniques and ownership rights and the identification of ownership groups.

Otto (1989) recommended a structure for baitfish royalties which included their distribution by provincial governments who would appoint 'baitfish liaison officers'. The administrative cost of distribution would be met through the levy of a provincial tax on the royalty, and the national government would act as an advisor (only). An opposite view to the role of the national government was provided by Walter, Sam and Vonole (1986) (in Otto, 1989: "A sociological investigation of major baitfish areas in Papua New Guinea: summary report" by the Institute of Applied Social and Economic Research, Port Moresby).

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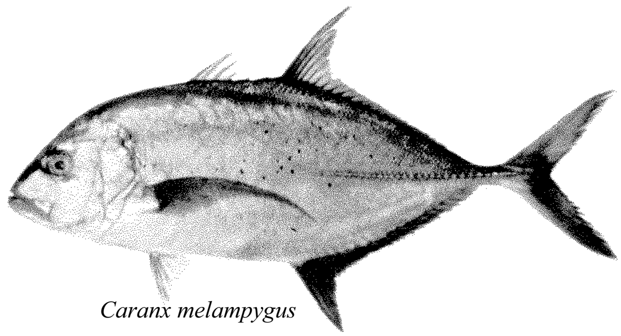
1.13 NEARSHORE PELAGICS - wahoo, dolphinfish, dogtooth tuna, rainbow runner, double-lined mackerel, trevally and barracuda

1.13.1 The Resource



Caranx melampygus

Species present: Wahoo, *Acanthocybium solandri*, dolphin fish (*Coryphaena* species), dogtooth tuna, *Gymnosarda unicolor*, rainbow runner, *Elegatis bipinnulatus*, double-lined mackerel, *Grammatorcynus bilineatus**, trevally, *Caranx* species and *Carangoides* species, and barracuda or seapike, *Sphyraena* species. *S. barracuda* is the dominant seapike in pelagic landings. (**G. bicarinatus* also occurs in southern PNG.)

Although sub-adults of skipjack tuna, *Katsuwonus pelamis,* yellowfin tuna, *Thunnus albacares,* Spanish mackerel, *Scomberomorus commerson,* frigate mackerel, *Auxis thazard,* mackerel tuna, *Euthynnus affinis* and longtail tuna, *Thunnus tonggol,* are also nearshore pelagics, mostly they are discussed separately (profiles 1.13, 1.14, 1.15).

Distribution: All of the species in this category have wide Indo-Pacific distributions. Some species of *Caranx* and *Carangoides* however (e.g. *C. papuensis*) may have a more restricted distribution. Wahoo has a circumtropical distribution (Collette and Nauen, 1983). They inhabit coastal waters around reefs as well as open sea, deeper waters (Lewis *et al.*, 1974; Collette and Nauen, 1983). Rainbow runner inhabit inshore and offshore pelagic waters and are particularly abundant near reefs. Double-lined mackerel are distributed from the Red Sea to Fiji (Collette and Nauen, 1983). Dolphinfish are circumtropical, large ones often caught near coral reefs (Overseas Fishery Cooperation Foundation, 1985). Trevallies are common on the edges of reefs, particularly along steep outer reef dropoffs. Lewis *et al.* (1974) trolled dogtooth tuna along reef edges.

These large pelagics are common in the islands region (A. Wright, pers. comm.) and also on the south-east to central coast of PNG (S. Frusher, pers. comm.).

Biology and Ecology: Dolphinfish, barracuda and rainbow runner tend to form small to medium-sized schools (Richards, 1993). Wahoo are epipelagic fish, frequently solitary or forming loose aggregations rather than compact schools (Collette and Nauen, 1983). In Ataliklikhun Bay, East New Britain, rainbow runner have been observed to form schools at the change of tide in straits between the islands (Overseas Fishery Cooperation Foundation, 1985). Double-lined mackerel and dogtooth tuna are epipelagic in shallow reef waters. Double-lined mackerel form large schools (Collette and Nauen, 1983), but dogtooth tuna are generally solitary, or in small schools of six or fewer fish. Trevally frequently occur in large schools that roam for considerable distances. Some trevally species (e.g. *C. tille, C. lugubris*) inhabit deep water. Trevally and barracuda tend to maintain long periods of reef residence (Lewis *et al*., 1983). Barracuda are fast-swimming fish, frequently occurring in small to large schools, often on the edge of outer reef dropoffs. However, *S. barracuda*, the largest species of barracuda, is often encountered alone (Randall *et al*., 1990, in Richards, 1994).

Most of these nearshore pelagic fishes appear to aggregate for spawning which occurs during the late October-February period, with a peak in December-January (Lewis *et al*., 1983).

Wahoo spawn over an extended period, and fish in different stages of maturity are often caught concurrently (Collette and Nauen, 1983). In Cook Islands, larger fish are more common from May through to September and smaller fish are more frequently taken from October to December (Anon, in press, in Richards, 1993). Wahoo have a high fecundity - 6 million eggs per spawning estimated for one 131 cm long fish (Collette and Nauen, 1983). Trevallies are pelagic spawners that release large numbers of tiny, buoyant eggs. *Caranx ignobilis* is reported to spawn in pairs within aggregations, around the new and full moon (Johannes, 1981, in Richards, 1994). Trevally larvae may lead a pelagic existence for extended periods. The juveniles of *C. ignobilis* and *C. sexfasciatus* are often found in brackish estuaries or in fresh water (Randall *et al*., 1990, in Richards, 1994). Dolphinfish on Cook Islands undergo migrations believed to be associated with spawning (Richards, 1993). In PNG, spawning in dolphinfish takes place throughout the year (Lewis *et al.*, 1974; Chapau, 1991) but there appear to be peaks in spawning activity in March, July-September and at the end of the year. Females are mature between 50 cm and 55 cm (Chapau, 1991). It is possible that dolphinfish are protogynous, as Lewis *et al.* (1974) and Williams and Newell (1957, in Lewis *et al.*, 1974) found that a high female:low male ratio in 1-2 year old reversed in larger (older) fish. Rainbow runners are reported to spawn year-round (Yesaki, 1979, in Wright, 1993). Lewis *et al.* (1974) recorded female *S. barracuda* with stage 3 ovaries in April and May in the New Guinea islands.

Juveniles of some of these species can be caught in dip-net hauls for baitfish (e.g. double-lined mackerel, barracuda).

Lewis *et al.* (1983) reported on the biology of double-lined mackerel, dogtooth tuna and several trevally species.

Wahoo attain 210 cm length and a weight of 83 kg (Collette and Nauen, 1983); double-lined mackerel attain 60 cm and 3.5 kg; while dogtooth tuna grow to 150 cm length and 80 kg. Rainbow runner reach 120 cm in length (FAO, in Hermes, 1992). Trevallies attain various sizes, and Richards (1994) reported that *C. ignobilis* grows to 170 cm and 35 kg. Dolphinfish are known to exhibit very rapid growth, reaching 75-80 cm in their first year (Chapau, 1991). *S. barracuda* achieve lengths of more than 1 m.

All of these species are predators, mostly of fish and invertebrates such as squid (Richards, 1993). *S. barracuda* is active during the day, and is among the top predators of coral reef areas (FAO, in Hermes, 1992). Dolphinfish appear to be opportunistic feeders, eating mainly goatfish (Mullidae), carangids, anchovies (Engraulididae), triggerfish (Balistidae) and squid (Lewis *et al.*, 1974; Chapau, 1991). Rainbow runner feed mostly on crustaceans (Lewis *et al.*, 1974). Large barracuda and large *Caranx* species are often implicated in ciguatera poisoning cases (Richards, 1993; Hermes, 1992).

Most(all?) of these species (dolphinfish and rainbow runner particularly) often associate with floating objects (Lewis *et al.,* 1974; Chapau, 1991). Around Fish Aggregation Devices (FADs) in Ataliklikhun Bay, catches of dolphin fish and rainbow runner were high than for other species (126/131 day set) (Overseas Fishery Cooperation Foundation, 1985).

Rainbow runner (39-76 cm length, at least: Lewis *et al.*, 1974) form surface schools averaging 10 mt (West and Wilson, 1992) in PNG waters. In a survey of tuna and baitfish resources in New Britain and New Ireland waters in 1972 by Lewis *et al.* (1974) pure schools of rainbow runner comprised 3.8 per cent of all sighted schools, and also were components of mixed schools with yellowfin tuna, mackerel tuna and frigate mackerel in various combinations, and skipjack tuna (West and Wilson, 1992). Rainbow runner schools only occur within 12 nautical miles of the coast (West and Wilson, 1992). Dolphinfish were found in mixed schools of skipjack and yellowfin tuna and frigate mackerel, and schools of mackerel tuna, frigate mackerel and Spanish mackerel.

Up to August 1994, 597 nearshore pelagic fishes have been tagged by gamefishers in PNG waters. Of these, barracuda comprised 36 per cent and rainbow runner comprised 43 per cent. No recoveries have been made to date.

Table 31 PNG Game Fishing Association national records as at 30.6.93 for pelagic species were:

Species	Weight (kg)	Locality
barracuda	32.5	Port Moresby
dolphinfish	19.2	Bougainville
rainbow runner	8.0	Bougainville
dogtooth tuna	62.6	Madang
turrum trevally	34.0	Port Moresby
wahoo	42.8	Port Moresby

1.13.2 The Fishery

Utilisation: These nearshore pelagic species are mainly fished to supply artisanal and subsistence fisheries. They are also fished for recreation by gamefishing and sportsfishing clubs.

Most subsistence and artisanal catches are made by trolling and by handlining (mainly trevallies). On the west coast of Manus Island, trolling is performed traditionally from a small, non-motorised monohull canoe (a 'mon') pulling one troll line (Chapau and Lokani, 1986). Rainbow runner, wahoo, dolphinfish and *S. barracuda* are incidental catches in tuna purse-seine and pole-and-line fishing (Wankowski, 1980), forming less than 1 per cent of the catch. In PNG island reefs, trevallies are often caught illegally by bombing (dynamiting) (Wright and Richards, 1983). In East New Britain, vertically hung large woven cane baskets anchored in deep water are used to catch rainbow runner, shark mackerel and other pelagics (as well as malambur - profile 1.15) (Dalzell, 1993).

Lewis *et al.* (1974) trolled most dolphinfish they caught (size range 58-91 cm length) around floating objects and the remainder were poled. They trolled *S. barracuda* (and *S. qenie*) in the size range 54-101 cm both many km from land and reefs as well as close inshore. Double-lined mackerel are seldom caught at the surface but can be trolled 'well below' the surface (Lewis *et al.*, 1974).

When trolling, malambur (*Selar* species) and mackerel scad (*Decapterus* species) are often used for bait. Lures of feathers or native plants may be used, occasionally also bought ones. Trolling rig in Port Moresby may or may not lack trace wires and swivels, and lures are made of plastic bags (Lock, 1986; Dalzell, 1993). In Cook Islands, wire leaders are used when there is a greater chance of catching wahoo, double-lined mackerel or barracuda (Anon, in press, in Richards, 1993). Daugo Island fishers average trolling rates of 6.9 kg/hour (NB: pre-FAD) (Lock, 1986). The fishery is mainly seasonal - from November to March (Lock, 1986) although the islanders are very proficient at trolling in rough weather (in the South-East Monsoon season) (P.Gamini, pers. comm.).

Two FADs were deployed off the East Sepik Province in 1984, nine FADs were deployed in East New Britain in 1983-84, and a FAD was deployed off Daugo Islands near Port Moresby in 1992 (Frusher, 1986; Beverly and Cusack, 1993). Dolphinfish, rainbow runner, wahoo, barracuda and other pelagics are frequently caught around these FADs. Fish are usually trolled near the FADs, but also handlined.

Excluding tunas, the most commonly caught fish around the Daugo Island FAD are rainbow runner, wahoo, Spanish mackerel, dolphinfish and dogtooth tuna (Beverly and Cusack, 1993). Daugo Island FAD fishing is very popular with artisanal fishers and recreational fishers. In January 1993, 10 boats a day were fishing it - usually from daybreak to early afternoon (Dalzell, 1993).

Around the FADs off Wewak, greater catches are made between October and March (Frusher, 1986). Dolphinfish are seasonally abundant from November until April, while rainbow runner are there between September and May (Frusher, 1986). Trapping and jigging were trialled off the Wewak FADs with varying success, catches including rainbow runner, dolphinfish, *C. tille* and *S. barracuda.* Whereas trolling around the FADs was moderately successful for catches of most pelagics, the reef-associated double-lined mackerel was absent. The relative abundance of nearshore pelagics in troll catches at both FADs and in catches by artisanal fishers away from the FADs and by fisheries staff at the FADs is shown below. (source: Frusher, 1986).

Table 32 Relative abundance of nearshore pelagics in troll catches (source: Frusher, 1986)

Species	occurrence at 160 m FAD	occurrence at 390 m FAD	% presence in non-FAD catch	% presence in FAD catch
rainbow runner	rare	moderate	3.1	1.4
wahoo	rare	absent	-	-
S. barracuda	-	rare	-	-
C. tille	moderate	moderate	-	-
dolphinfish	rare	moderate	0.4	2.2
double-lined mackerel	-	-	0.8	0

Surface trolling with lures off the West Sepik Province yielded 22 pelagic species during a survey in the early 1980s (Chapau, undated). Trevally and mackerel tuna schools run close inshore and are targeted by local fishers.

Around Wewak (East Sepik Province) trolling, light fishing at night and a traditional form of pole-and-line fishing is used when fishing for pelagics (Frusher, 1987). The pole-and-line method is used in the offshore islands and along the coast to the west of Wewak. Baitfish (little priest, *Thrissina baelama*) caught the previous night with dipnets are used as chum. The fishing poles are of sago palm midrib frond; and chicken feathers or a baitfish are used on its end. Light fishing for pelagics is carried out around Kairiru and Schouten Islands. Lamps are used to catch *Megalaspis cordyla*, *Decapterus* species, *Rastrelliger* species and *Selar* species (malambur -see profile 1.15), which are then used as bait to catch Spanish mackerel, barracuda, rainbow runner and carangids. Fishing is usually carried out from dusk (1900 hours) to midnight, and 2-3 hours before dawn (Frusher, 1987).

Madang fishers generally use hook and line in the early mornings to target pelagic fishes (H. Bingeli, pers. comm.).

Wahoo, double-lined mackerel and dogtooth tuna are very occasionally caught with hook-and-line in the Huon Gulf (Hermes, 1992). Trevallies are important in the area, and are caught with handlines and sometimes by spearing and trolling. Barracuda are caught by trolling.

Trolling is occasionally conducted by Tigak Island (New Ireland Province) fishers. They use one or two lines. Garfish (Hemiramphidae) is the usual bait for targeting *C. ignobilis*, sphyraenids and Spanish mackerel, while rainbow runner, *C. melampygus, C. sexfasciatus*, frigate mackerel and mackerel tuna are commonly taken on white feather jigs or white or pink plastic squids (Wright and Richards, 1985).

Trolling is not a common fishing method for Tigak Island residents because of the cost of fuel and also because their canoes do not provide a stable fishing platform in unsheltered waters (Wright and Richards, 1985). This situation may be true for many other coastal areas of PNG (Frusher (1986) pointed out that fuel costs deter coastal Sepik fishers from troll fishing because of time spent searching for fish schools). However, people undertaking inter-island voyages do troll - for example, Manus Islanders en route to Kavieng (Wright and Richards, 1983).

Production and Marketing: In a survey of West Sepik Province resources conducted in 1986, *Caranx tille, C. papuensis* and *S. commerson* dominated troll catches. *C. papuensis* made up 7.11 per cent of the trolled catch (Chapau, undated).

Using a traditional pole-and-line fishing technique in the Wewak area (East Sepik Province), catches of more than 50 pelagic species have been made during a morning's fishing (usually between 0630 hours and 1100 hours) (Frusher, 1987).

In a 12-month survey off Wewak, Frusher (1987) recorded variable cpue (kg/hr/day) for pelagics - from more than 8 kg/hr/day (March 1983) and 8 kg/hr/day (December 1983) to less than 1 kg/hr/day in May 1983 and October 1983. Chapman (1982) recorded catch rates of 7.3 kg/hr during his 9-day survey in Wewak.

In his Wewak survey, Frusher (1987) caught a lot of trolled fish in March, June and November 1983 and March 1984 - although little of this was of nearshore pelagics. Spanish mackerel was the second most important component of the trolled catch after tuna. The cpue (kg/hr) was highest in August-April. Decreases in total catches were related to rough seas and strong winds in the North West Monsoon season (December-February). Catch sizes from around the two FADs deployed off Wewak varied, only one of them (in 390 m) consistently providing troll catches averaging 12 kg/hour/vessel (Frusher, 1986; Beverly and Cusack, 1993).

Nearshore pelagic fishes make up the bulk of landings at the Madang fish depot (H. Bingeli, pers. comm.). Dolphinfish and rainbow runner predominate but trevally, *S. barracuda* (individual fish more than 1 m long are not uncommon) and Spanish mackerel are also landed. In 1992, most pelagic fish were landed between April and November (>500 kg/month) with a peak of 2,000 kg in June.

Table 33 Pelagic fish landings (MOMASE Category 1) at Madang in 1992 and 1993 were (source: Madang PFO)

Year	percent of tot. landings (wt)	quantity (kg)
1992	75.3	10,686
1993	51.7	7,597

In the Huon Gulf fishery (Morobe Province) for the period October-December 1991, landings of trevally (mainly *C. sexfasciatus*) comprised 9.2 per cent of total artisanal landings, and barracuda (mainly *S. barracuda*) comprised 1.7 per cent. By group, barracuda comprised 10 per cent of pelagic landings. Hermes (1992) estimated that these percentages would hold true for yearly landings as well. Trevally are also caught with gillnets and seines.

The trevallies *C. sexfasciatus* and *C. melampygus* comprised 10.3 per cent of the total catches brought into the Kavieng (New Ireland Province) fish depot in 13 months from November 1980, while other carangids comprised between 2 per cent and 3.9 per cent of landings. Trevally and rainbow runner were also caught by netting. Trolled fishes comprised 5.9 per cent of the artisanal landings.

Table 34	Composition of trolled catches made by artisanal fishers and DFMR staff in the Tigak Islands differed, as follows (source: Wright and Richards, 1983; 1985; Fisheries Research annual report 1982):

Species	Artisanal catch (% weight)	DFMR catch (% weight)
S. commerson	71.8	39.1
E. affinis	12.8	13.2
C. ignobilis	2.9	2.2
E. bipinnulatus	2.9	11.4
C. sexfasciatus	2.4	8.3
G. unicolor	-	5.2
A. solandri	-	0.1-5.0
G. bilineatus	-	0.1-5.0
C. melampygus	0.1-2.5	0.1-5.0
A. thazard	0.1-2.5	-
S. barracuda	0.1-2.5	0.1-5.0

The improved catch rates by DFMR staff may be because of gear, or experience. During 1,056 hours of trolling, 8,149 kg of fish were landed at a catch rate of 4 kg/line-hour (Wright and Richards, 1985).

From fisheries statistics provided to DFMR Kavieng, an estimate of the nearshore pelagic artisanal catch for Manus Province for the period 1990-93 can be made (excluding 'tuna', 'billfish' and 'Spanish mackerel' but including 'mackerel'. The 'Carangidae' category at least will overlap other fisheries).

Table 35	Estimate of the nearshore pelagic artisanal catch for Manus Province, 1990-93. Figures in kg.

Year	barracuda	carangids	mackerel	pelagics	rain. runner
1990	534	498	843	252	-
1991	149	645	249	605	-
1992	403	749	577	206	-
1993	235	472	89	30	213

In a troll survey of the west coast of Manus Island conducted in July 1986, rainbow runner 37-57 cm long comprised 23 per cent (23.2 kg) of the catch at a catch rate of 1.9 kg/line-hour (Chapau and Lokani, 1986). [The remainder of the troll catch comprised mackerel tuna (72.3 per cent) and frigate mackerel (4.6 per cent).]

The strategy and source used for presenting Manus Province artisanal catches (above) was employed for the East New Britain Province nearshore pelagic artisanal catches.

Table 36	East New Britain Province nearshore pelagic artisanal catches, estimates. Figures in kg.

Year	barracuda	carangids	mackerel	pelagics
1990	175	1,087	371	740
1991	137	792	210	637
1992	74	648	202	740
1993	38	128	33	85

An average troll catch rate of 2.7 kg/vessel/day was recorded for the aggregate of nine FADs in Ataliklikhun Bay, East New Britain (Overseas Fishery Cooperation Foundation, 1985). There is no more recent information on catch rates for these FADs.

Around Tufi (Northern Province) wahoo are caught seasonally with Spanish mackerel. It is sold for comparable prices at local markets (Chapman, 1982).

In 1985, artisanal landings of trolled fish in Port Moresby (National Capital District) were estimated at 46,053 kg. Lock (1986) provided an inadequate breakdown of this catch, although he did record that carangids comprised 15 per cent and sphyraenids 1.6 per cent. Dogtooth tuna formed a high proportion of gillnet landings (Lock, 1986).

There is little information on price except for that in Manus and East New Britain.

Table 37 Price ranges for three general categories can be obtained from the DFMR Kavieng database for Manus and East New Britain landing depots for 1990-93

Species group	Manus price range/kg	E.N B. price range/kg
barracuda	K0.91-1.20	K1.18-1.45
carangids	K0.94-1.18	K1.74-2
pelagics	K0.96-1.20	K1.05-1.30

In Port Moresby, the average price for fish trolled around the Daugo Island FAD was K1.53/kg in January 1993 (Dalzell, 1993). These fish probably fetch higher prices from pelagics caught by other means at Koki market (P. Gamini, pers. comm.).

1.13.3 Stock status

No studies have been conducted on the status in PNG waters of any of these pelagic fishes. At present fishing levels, it is unlikely that any of these stocks are over-exploited.

In the Tigak Islands - and probably elsewhere in PNG - there is a sizeable nearshore pelagic resource, consisting mainly of small tunas and bouble-lined mackerel. According to Wright and Richards (1983) this resources offers the best potential for increasing fisheries production in this area.

Chapman (1982) and Frusher (1987) noted that catch rates mainly improved when greater familiarity of the fishing grounds was acquired, skills in trolling improved and the fishing gear and vessels used was more suitable to the quest.

Table 38 Comparison of recorded cpue (in kg/hr/craft) of larger pelagics* from the Western Pacific. (Source: Frusher, 1987. (*= Spanish mackerel, wahoo, large carangids and sphyraenids)

Area	Av. CPUE	CPUE range	Source	Remarks
NW Australia	20.5	0-62.5	Donohue *et al* 1982	converted cpue
N Australia	7.25	3.9-15.6	Church 1981	converted cpue
Fiji	23.1	6.1-29.8	Lewis *et al* '83	all pelagics
Fiji	3.8	0-5.4	Lewis *et al* '83	only Spanish mackerel
Tufi	28.4	9.5-76.5	Chapman 1982	
Wewak	7.3	0-11.9	Chapman 1982	
Wewak	2.9	0-8.3	Frusher study	

(Notes: Donohue *et al.* and Church references are in Frusher, 1987).

1.13.4 Management

Current legislation/Policy regarding exploitation: The PNG Government supports the development of a national FAD program, with particular emphasis on the use of FADs in fisheries adjacent to large urban populations. The objective behind this polocy is to relieve fishing pressure on inshore resources.

Recommended legislation/Policy regarding exploitation: In many coastal areas small tunas and other pelagic fishes can be caught in great abundance. However - as M. Chapau pointed out - operating costs together with limited market have ensured that this large resource remains underexploited. Even so, Chapau says, it is the largest resource available to artisanal coastal fishers in PNG.

As discussed under other profiles (1.16, 1.17) the traditional ownership of waters and their resources has hindered the development of fisheries in PNG. However, there may not be such a 'need' to transgress boundaries when fishing inshore pelagics to supply artisanal and subsistence markets - i.e. it's not the scarcity of fish (Wright and Richards, 1985; Frusher, 1987), but the cost and safety of fishing them. With improvements in vessels design and gear and also improved market prices, higher landings of these species can be expected - with or without FADs.

- Improved *monitoring* of catches would be an advantage. This would involve recording the catch by component parts, and would require some measure of taxonomic ability.
- *Improved fishing vessels* for trolling are needed. Without them, the nearshore pelagic resource cannot be fully utilised. The DFMR did conduct work in vessel improvements in the early 1980s through to the early 1990s.
- The need for *training in trolling skills* to increase catch rates was highlighted in several studies. Along with this, is instruction in the most appropriate rigs. I think studies should be conducted (or cribbed from elsewhere) of the *most appropriate rigs* for different species - at different age classes and seasons, for example. Could the PNG game fishing association and local sportsfishing clubs be the first ports of call?
- The program of *deploying FADs* in strategic locations in coastal locations in PNG *should be maintained*. As well as their deployment detracting attention on heavily exploited inshore fish stocks, they can boost the harvest of nearshore pelagic fishes. These structures increase catch rates and quantities of these species as well as offering an alternative fishery.
- The deployment of FADs in PNG waters has been welcomed by some but opposed by others. The FAD to the west of Port Moresby has been sabotaged, and others off Madang and East New Britain have been set adrift (pers. comm's). The issues seem to stem from traditional fishing rights - i.e. in whose area they are sited - and village 'politics' about who has rights to access the FADs. There may also be discontent between village fishers and recreational ('game') fishers over FAD access.

  FADs are expensive to install. They also fish for years if permitted. FADs provide a total community service, they take pressure off adjacent fully-exploited areas (e.g. the Port Moresby artisanal fishery) and they save fuel due to the shorter searching time for fish. Frusher (1986) demonstrated that the use of FADs can greatly reduce the cost of fishing and increase catch rates to as much as 20 kg/line hour. During a FAD trial in the East Sepik Province, an estimated 30 mt of fresh tuna was caught from one FAD which lasted for 18 months (Frusher, 1986). I support a strong 'awareness' campaign aimed at establishing regular dialogue between the users, and I suggest this be undertaken by the DFMR and provincial fisheries officers *as a matter of urgency*. It may be that the user groups will decide that quotas or restricted access periods are needed. If the course of action is decided by the user groups (and not by the government), then the groups will be more likely to support it. However, the DFMR must facilitate the dialogue. Richards (1993) found problems in FAD access in Cook Islands and he suggested that their utilisation may need to be regulated to minimise gear conflicts.

- *Market acceptance* of pelagic fishes? From scant information, carangids seem to fetch higher prices. *A series of short market surveys* conducted in disparate centres in PNG would be illuminating (and don't restrict it to nearshore pelagics). The surveys should include questions on price ranges, preferred species, eating preferences, why's, etc. I have no information on whether such surveys have ever been conducted.

Summary of recommendations

1. Better monitoring of catches
2. Improved vessel design - extension work?
3. Improved gear
4. Training in fishing skills
5. Deployment of FADs
6. Dialogue to be encouraged between FAD user groups
7. Taste, species, price preference surveys to be conducted in markets
8. Provision of cheaper fuel in distant coastal provinces.

A small mention is again made here about *fuel costs* (see also profile 1.1, reef fishes). Price of fuel is a deterrent to pelagic fishing. Although fishing a FAD will reduce fuel costs for villagers lucky enough to have a FAD in their vicinity, market prices do not compensate for fuel costs. There is an inverse relationship between fuel costs and distance. In Port Moresby (where pelagics receive K1.53/kg on average) fuel costs would be lower than they would be in East New Britain (average pelagics price = K1.44/kg) and Manus (average pelagics price = K1.04/kg).

1.13.5 References

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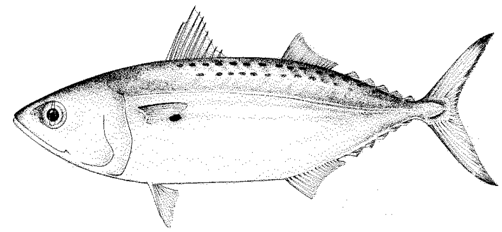
1.14 SMALL PELAGICS

1.14.1 The Resource



Rastrelliger kanagurta

Species present: Chub mackerel - *Rastrelliger* species (three species, *R. faughni, R. brachysoma, R. kanagurta*); big-eye scad or 'malambur' - *Selar crumenophthalmus* and *S. boops*; mackerel scad - *Decapterus* species (*D. macarellus, D. macrosoma, D. russelli*); and finny scad or hardtail scad - *Megalaspis cordyla*. *Rastrelliger* is in the family Scombridae, the other species belong to the family Carangidae.

Distribution: *Rastrelliger* are distributed throughout the Indo-Pacific as far east as Samoa and Fiji. *Megalaspis* occurs throughout the Indo-Pacific as well. *Selar* are tropical species, *S. crumenophthalmus* having a circumglobal tropical distribution (Dalzell and Penaflor, 1989). All species are present throughout PNG waters.

Biology and Ecology: *Rastrelliger* are schooling, epipelagic fish found in coastal tropical waters of more than 17°C. Whereas the other species prefer a fully marine habitat, *R. brachysoma* tolerates reduced salinities in estuarine habitats. *Rastrelliger* are batch spawners. *R. brachysoma* and *R. kanagurta* reach about 35 cm fork length, while *R. faughni* reaches 20 cm fork length. Both species can attain about 500 g (Lewis, 1985). The three species are differentiated trophically by the size and form of plankton they consume (Collette and Nauen, 1983). Chub mackerel grow rapidly and they spawn in their second year. Spawning takes place during summer months (Lewis, 1985). *R. kanagurta* in New Caledonia has been estimated to attain 23.7 L_∞, maximum age of one year (*cf* above), a growth rate (K) of 3.0 and a mortality (M) of 3.7 (Conand, 1988, in Dalzell, 1993).

Megalaspis is a schooling species inhabiting shallow coastal waters, usually near the surface, and are intolerant of turbid water. It feeds on fish and small crustaceans.

Decapterus are schooling, epipelagic fish, generally inhabiting clear, marine inshore waters, including coral reefs and lagoons and open ocean. They feed on plankton. *D. russelli* in New Caledonia has been estimated to attain 24.9 cm L_∞, maximum age of 3 years, a growth rate (K) of 1.3 and mortality (M) of 2.1 (Conand, 1988, in Dalzell, 1993).

Selar form large surface or midwater schools, and their abundance is highly seasonal. They are found from inshore and estuarine waters to reef lagoons and the open sea. Abundant schools are sighted at changes of the tide in straits between islands in Ataliklikun Bay, East New Britain (Overseas Fisheries Cooperation Foundation, 1985). Malambur probably feed on macroplankton, small fishes, copepods, gastropod molluscs and small free-swimming crustacea (Dalzell, 1993). A series of studies on the growth, reproduction, feeding habits, mortality and recruitment have been carried out for *Selar* - mainly *S. crumenophthalmus* - in Indonesia, the Philippines, the Marianas and Hawaii (reported in Dalzell and Penaflor, 1989). Malambur grow rapidly in the first year of life, and studies in the Philippines, Indonesia, Marianas Islands and Hawaii give a L_∞ in the range 26.5-36.5 (Dalzell and Penaflor, 1989). A maximum age of 2.5 years has been estimated for Mariana Islands Selar stocks (Ralston and Williams, 1988, in Dalzell and Penaflor, 1989). In northern Australian waters *Selar* attain maturity in their first year (J. Gunn, pers. comm.) and probably do not live beyond 4 years. Spawning times are allied to the monsoon seasons.

Fish grouped as small pelagics are characterised by having restricted spawning seasons (Dalzell, 1993) and low batch fecundities (400-600 oocytes/g of fish). Their short (2-5 year) life span, rapid growth when young and high mortality rates suggests that they can be fished heavily at small sizes (Gulland, 1983, in Dalzell, 1993).

1.14.2 The Fishery

Utilisation: In the Indo-Pacific, small pelagics are traditionally and commercially fished with a variety of gears including encircling nets, stick-held dipnets, lift bagnets, beach seines, purse seines, trawls, ring nets, lamparas, drive-in nets, gillnets, handlines, cast nets, hoop nets and fish corrals (Corpuz and Dalzell, 1988, in Dalzell and Penaflor, 1989). *Selar* are often fished at night, and around Fish Aggregating Devices (FADs). They are valued as a food fish and as bait for hook-and-line fisheries (Richards, 1993). Their high oil content and compact flesh enhance their bait utility in activities such as trolling for larger inshore pelagics, longlining for tuna, burlying and in strips for handline fisheries.

The leaf sweep, or variations on it, are a traditional method of catching schooling, inshore fish such as malambur and chub mackerel in the New Guinea islands. Wright (1983) described its method of operation. In the North Solomons Province malambur are caught by hand-held scoop nets (Hulo, 1985, in Dalzell, 1993).

Malambur are the main small pelagic fish caught in the Gazelle Peninsula area, East New Britain Province. They are caught with gillnets, handlines and traditional Tolai basket traps. The traps are hung vertically under a Fish Aggregating Device (FAD), itself festooned with vines and fronds. The traps generally are checked every day and emptied every 2-3 days although the weather, season and presence of larger pelagics influences this (Dalzell, 1993). The fish are sold by the fishermen to women for traditional shell money ('mis') and in turn, they sell the fish at roadside markets. In 1992 between 50 and 85 fish traps were deployed around the Gazelle Peninsula (three villages) but in 1993 only 19 traps were deployed. The rope used to anchor the trap is made from rattan cane interwoven with a forest vine on which the fish are said to feed and are hence attracted to the trap (Dalzell, 1993). Fishing is seasonal; on the east coast it is best during the dry season - March to December (but generally better from October onwards), but on the north coast it is best around Easter time. The fish caught in the traps are estimated to be 6-7 months old (Dalzell, 1993) and were immature.

Villagers near Vunapope, East New Britain, catch malambur by hook and line and gillnets from around the wharf there. A very large school of malambur lives around the wharf. Despite being completely absent from the wharf area in some years, the malambur school at the Vunapope wharf has supported a substantial local fishery for at least 15 years. The size range of fish caught at the wharf is small and Dalzell (1993) estimated that the fish are 7-8 months old and immature.

On the west coast of Manus Island, *Rastrelliger* is commonly caught by set gillnets. They are often the most abundant fish caught by this method (e.g. 25.7 per cent of catch, fish comprising 19-30 mm fork length: Chapau and Lokani, 1986).

Light fishing for pelagics is carried out around Kairiru and Schouten islands off Wewak. Fishers use lamps to catch *Megalaspis*, *Decapterus*, *Rastrelliger* and *Selar*. Besides using them as subsistence food, the fish are utilised as bait on troll and handline gear to catch Spanish mackerel, rainbow runner and other larger pelagic fishes (Frusher, 1987).

Women mainly from the Kranket area near Madang catch schools of malambur from canoes by handline (H. Bingeli, pers. comm.). Malambur and *Rastrelliger* are also caught by dynamiting around Madang and in other parts of PNG, such as in the Tigak Islands (Wright and Richards, 1983).

In the Huon Gulf, larger (>40 cm fork length) *Megalaspis* are caught by trolling and smaller ones are caught with seine nets. In the same area, *Rastrelliger* either are caught well offshore over deeper water or in shallow water. Offshore, the *Rastrelliger* are caught at night using a light and fished for with 'mini longlines' - a mainline about 3 m long bearing about 10 branchlines of thin filament, each bearing a small hook. The bait used is chopped malambur (*Selar*). *Rastrelliger* are also caught with cast nets in shallow water by some Morobe fishers. The fish occur seasonally (Hermes, 1992): there are many landings in May and June, then late

July into August, and also October-December. Fishers say that the fish come with the currents. *R. faughni* of about 20 cm fork length is the most abundant small pelagic fish in landings at the end of the year (Hermes, 1992) and is the only small-sized pelagic fish targeted by fishers in that period. *R. kanagurta* makes up a small part of *Rastrelliger* landings.

Production and Marketing: Malambur exhibit seasonal peaks in abundance, as exemplified by catch rates in the Philippines. Annual recruitment forms the bulk of the fisheries catch. The variability in recruitment plus some form of migratory behaviour are reflected in the seasonal peaks (Dalzell and Penaflor, 1989). Catches of *Selar* in the Philippines account for 6 per cent of small pelagic landings there (Dalzell and Penaflor, 1989).

Catch data collected in the Kavieng Fisheries Laboratory from beach seining for malambur in Kavieng Harbour during 1983 and 1984 is presented below. Most of the catch was of *S. crumenophthalmus,* and the fish ranged in size from 10.5 cm to 21.5 cm fork length.

Table 39 Catches of malambur from Kavieng Harbour, 1983-84.

Date	Hauls	Time (mins)	No of men	Total catch (kg)	CPUE (kg/man-hr)
8/12/83	1	40	5	10.00	3.0
24/1/84	1	35	3	38.2	21.83
8/2/84	1	11	4	44.6	60.82
24/2/84	1	25	3	10.4	8.32
16/3/84	1	15	3	25.2	33.6
29/3/84	1	25	4	8.4	5.04
1/6/84	2	40	3	1.95	0.98

Malambur, chub mackerel, mackerel scad and hard-tail scad are commonly seen in coastal markets in PNG. They are sold fresh or smoked.

Estimates of one year's landings at Voco Point (Lae) made early in 1992 showed that 1.13 per cent of the total landings consisted of *Megalaspis* and 6.62 per cent of the total landings were of *Rastrelliger*. The catch rate for *Rastrelliger* using the mini longline method is about 50 fish per hour. *Rastrelliger* fetches K2/kg at the Voco Point landing place.

Juvenile *Rastrelliger kanagurta* are often caught amongst tuna bait hauls in the New Guinea islands. The malambur on the Gazelle Peninsula are sold in local markets for K0.20-0.80 each. Malambur sell for K0.30 each in the Madang market.

Dalzell (1993) estimated catches of malambur in the Gazelle Peninsula from both the trap and gillnet fisheries. Each trap contains about 25 kg of malambur when it is hauled and emptied. At Vunamame village the fishers retrieve an average of 90 kg of fish from six traps; at Barowan(?; Blue Lagoon) village fishers retrieve 200-300 fish (about 12.5 kg/day) daily from nine traps; and at Karabai village, they retrieve about 100 fish (5 kg) daily from four traps. At Easter time, the Karabai catch increases to 200-300 fish/trap/day. Dalzell estimated a malambur annual production of 13.7 mt/year from Vunamame, 3.7 mt/yr from Barowan and 1.5 mt/yr from Karabai.

In the gillnet fishery from the Vunapope wharf, there is an average of 12 nets in operation. These are hauled seven times a day, seven days a week and each haul catches about 70 fish. The daily catch of 5,880 fish thus becomes about 2,150,000 fish a year, weighing about 86 mt (Dalzell, 1993). Dalzell calculated that the nominal production of malambur on the Gazelle Peninsula may therefore be at least 100 mt/yr.

After comparing catches on the Gazelle Peninsula with those from the Hawaiian Islands, Dalzell (1993) estimated a potential yield of between 128 mt/yr and 288 mt/yr just from that region of PNG. These estimations assume however, that there is little seasonal variability in the stock. In Fiji, the fishery for *Rastrelliger* is seasonal (Lewis, 1985), most of the catch being landed between May and September.

1.14.3 Stock status

There is no information on the stock size of any of the small pelagics in PNG waters. However, despite fluctuations in availability it is likely that stocks of small pelagics in PNG waters are under-exploited.

1.14.4 Management

There is potential for small pelagics to be used as bait for longlining in PNG. Currently, longliners use imported frozen squid from New Zealand and Japan, and saury (*Cololabis saira*) from Japan. With the projected huge increase in longlining activity in PNG waters, there is tremendous scope for the supply of their bait being met from local sources. This eventuality would also benefit the local fishers. Dalzell's estimates from the Gazelle Peninsula fisheries lend support to that idea.

However, utilisation of the malambur and other small pelagic resources to supply bait for longlining could produce conflicts of resource ownership, use of the resource for bait and food, and the acceptability of using an important food fish for bait (Dalzell, 1993). The resources occur almost exclusively within customary fishing rights areas. Such conflicts already have arisen in the tuna baitfish and larger pelagic fisheries, for example. Efficient commercial utilisation of the resource would depend on free movement among areas.

In Cook Islands it is thought that production of mackerel scad (*Decapterus*) could be achieved through the introduction of a Hawaiian lift-hoop net, and the establishment and maintenance of mackerel scad aggregation sites (Anon, in press, in Richards, 1993). Depending on the future use of small pelagics in PNG, this is one method that could be trialled at strategic centres.

Deployment of FADs as a means of increasing the abundance of small pelagics in an area has been utilised by the Tolais with their fish traps. More FADs could be deployed in appropriate areas. However, although the FAD off Daugo Island, Port Moresby, was effective in attracting high numbers of *Megalaspis* after only two months' operation, FADs deployed along the north-west mainland coast attracted few *Megalaspis, Decapterus* and *Selar* (Frusher, 1986).

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Small pelagics could have a future as <u>bait supply for longliners</u>. Failing that, their more widespread use for domestic consumption could be encouraged - for example, as smoked product to which their texture and oily flesh lends itself.

In view of their potential importance, it is prudent for <u>assessments</u> to be undertaken of small pelagic resources in PNG. <u>Life history information needs to be collected</u> on the species' composition and distribution in PNG waters, the age and size structures of schools, maturity, reproduction, mortality and growth of stocks and predictions made about the behaviour of the stocks to increased fishing pressure. Concerted data collection programs should be undertaken. Apart from the recent preliminary work by Dalzell and the Moma Coastal Fisheries Development Project at Lae, there is no information on these apparently abundant resources in PNG waters. A beginning would be to obtain information on fishing techniques, species seasonality and abundance and use from all coastal regions.

Until stock assessments are completed, it is not possible to recommend a level of exploitation.

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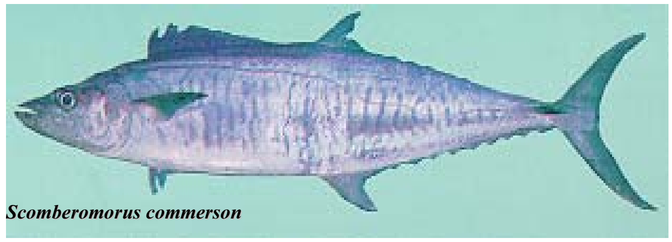
1.15 SPANISH MACKEREL

1.15.1 The Resource



Scomberomorus commerson

Species present: Spanish mackerel, *Scomberomorus commerson*, is the main species harvested. From Kerema (Gulf Province) to Central Province, spotted mackerel *S. munroi* would also be harvested in small quantities, as would school mackerel *S. queenslandicus* in Western Province and Central Province.

Distribution: Spanish mackerel are widespread in tropical and subtropical Indo-Pacific waters from Africa to Fiji. They appear to be present throughout PNG continental shelf waters, from shallow coastal waters to outer reef areas and further offshore.

Biology and Ecology: Spanish mackerel are commonly associated with the current lines and tidal rips of rocky shoals and reefs (McPherson, 1981) yet are often found in waters of low salinity and high turbidity, such as estuaries. Water temperature is the main factor controlling Spanish mackerel distribution (Williams, 1994). Spanish mackerel form large, sparse schools (Lewis, 1981). Some Spanish mackerel undertake long seasonal migrations while others remain as permanent residents in certain reef areas. In PNG waters, seasonal migrations of mackerel have been recorded - for example, at Tufi in the Northern Province; and Spanish mackerel are known to migrate along the Queensland coast to Bramble Cay and western Papua, and there appears to be seasonal movement of the mackerel away from the Cay (M. Brownjohn, pers. comm.) from about November (Williams, 1994). Spanish mackerel landings at Voco Point (Lae) and at Madang are seasonal, also suggesting a seasonal movement of stocks into the respective areas. Yet resident populations exist in most areas - e.g. Western Province, off Port Moresby, Milne Bay, Huon Gulf, the Bogia area-Rai coast, Wewak area, Kimbe area in West New Britain, the south-eastern Gazelle Peninsula in East New Britain and around Kavieng, New Ireland. In East New Britain (Ataliklikun Bay) Spanish mackerel are most abundant in the four months of April-May and September-October. This corresponds with the cessation of the North West season and the South East trade winds (Overseas Fishery Cooperation Foundation, 1985).

Spawning is related to water temperature and takes place off reef slopes and edges. The spawning period varies with locality, but in northern PNG waters it extends from July to December (Lewis *et al.,* 1974) and at least January/February around Port Moresby (Lewis *et al.,* 1974) and the north New Guinea coast (Frusher, 1987). It is most commonly from October to February (Lewis, 1979). Each female spawns several times over the season (Lewis *et al.,* 1974, McPherson, in press, in Kailola *et al.,* 1993). Spanish mackerel move into the Tufi area - a known spawning ground - in early September where spawning takes place from September to December. On the northern New Guinea coast, Hansa Bay is believed to be the spawning ground for Spanish mackerel stocks from Wewak and Madang areas (S. Frusher, pers. comm.; H. Bingeli, pers. comm.; Lewis, 1979). Spawning probably takes place there between March and April as that is when mature fish disappear from the Wewak area (Frusher, 1987). In western Papua, Bramble Cay (in the Torres Strait Protected Zone) is another known spawning ground where the Spanish mackerel gather in spring and early summer. Spawning continues from August to about March (Williams, 1994). Other spawning grounds in PNG are - according to Lewis (1979) - Orangerie Bay in eastern Papua, Arawe in West New Britain, also Kavieng (Wright and Richards, 1985). There is no information on whether other spawning grounds exist in PNG waters. Nevertheless, catch and survey information from these and several other areas of PNG confirm that some spawning takes place locally, probably by resident populations - for example, resident fish in the Wewak area probably spawn throughout the year, with a peak season from September-October to January-February (Frusher, 1987). Tongyai (1970, in Frusher, 1987) showed that Spanish mackerel prefer to spawn in waters of lower salinities (<30 ppt) and high turbidity.

Minimum size at maturity is about 65-70 cm fork length (Lewis *et al.,* 1974; Frusher, 1987); and the maximum size recorded is 240 cm fork length and 70 kg (McPherson, in press, in Kailola *et al.,* 1993). The largest fish are females, males rarely exceeding 17 kg (McPherson, in press, in Kailola *et al.,* 1993). Lewis *et al.,* (1974) and Frusher (1987) found that females dominate the larger size classes; males above 90 cm fork length and 110 cm for length being infrequently caught (Madang to New Ireland, and Wewak areas, respectively). Above 100 cm fork length, females tend to weigh more than males for a given size range (Frusher, 1987), and both sexes showed a significant difference in their condition factor with size. Spanish mackerel usually mature at the end of their second year in PNG, Australia and Fiji (Lewis *et al.,* 1983; in Frusher, 1987; McPherson, in press, in Kailola *et al.,* 1993). However, Frusher (1987) considered that Spanish mackerel in the Wewak area mature at 2-3 years of age.

In growth studies of Spanish mackerel around Wewak, Frusher (1987) calculated a growth coefficient (K) of 0.39, a L_∞ of 132 cm, and instantaneous mortality rate (Z) of 1.08. Frusher considered that the Wewak population's residency in tropical waters accounted for its higher K value (rapid growth).

Spanish mackerel larvae are pelagic and juveniles inhabit shallow, turbid coastal waters. Spanish mackerel feed during night and day on surface schools of small fish and squid. The fish include garfish and longtoms, sardines and anchovies. The diet of juvenile Spanish mackerel in inshore waters includes prawns and ponyfish.

1.15.2 The Fishery

Utilisation: Spanish mackerel are mainly caught by trolling, handlining at night or around Fish Aggregation Devices (FADs) and gillnetting (inshore and shallow waters). Trolling is perhaps the most successful, and is generally performed from outboard-motored canoes and dinghies in the early morning or late afternoon. In northern New Ireland, a 'Wubuna' tuber (family Nymphae) was traditionally used as a lure tied to a hook when trolling for Spanish mackerel was carried out. In some parts of PNG lures are traditionally made from swamp lily stems (Lewis, 1979). When handlining, some coastal fishers use flying fish bait and a pressure lantern (at night) from their canoe to catch Spanish mackerel. Spanish mackerel can also be caught in drifting gillnets, and this practice has been successful in the Gulf of Papua.

In the North Solomons Province, Spanish mackerel are targeted at the periods of new moon and last moon. Landings at these periods in 1984 averaged 34 kg/day in the first 5 and last 5 moon days compared with average landings of 14 kg/day for the remainder of the moon phase (Ito and Selemet, 1985). Fishers from Pukpuk Island near Kieta (North Solomons Province) use suspended kerosene pressure lanterns to attract baitfish around their canoes. They then mid-water jig for Spanish mackerel feeding on the baitfish.

Pelagic schools are located by their activity on the surface: presence of birds or fish jumping. West and Wilson (1981) pointed out that aerial surveys provided a good picture of availability (but not of abundance). Many variables affect catches and catch rates of Spanish mackerel. They include seasons, time of day, areas, water transparency, tide, lunar cycle, bait, lure type, vessel speed and the fishers' skills. Potential trolling areas are along the reef edges and drop-offs where the seabed is seen on one side and blue water on the other. In PNG waters Spanish mackerel often move in association with mackerel tuna (West and Wilson, 1992).

October-December is said to be the best fishing season around Bramble Cay (DFMR files). A large commercial fishery has been known to exist in the Bramble Cay region for many years. In 1950 an average of more than 1,300 kgs of Spanish mackerel was taken each day in five half-day fishing trips by trolling using two dories (Lewis, 1979). In 1977, a Queensland boat, the 'Trader Horn' with six dories in attendance, landed 35,000 lbs of Spanish mackerel from the same area in one voyage. This area is still intensively fished for Spanish mackerel, mainly by Australian fishers (Chapman, 1982).

Dunstan (1961, in Wright and Richards, 1985) reported that Spanish mackerel comprised 46 per cent of the trolled catch he monitored from the south-east Papuan coast.

In PNG, a small well-established fishery exists for Spanish mackerel around Tufi (Chapman, 1982). The major catches are made from mid-October to the end of December, during the spawning period. Wahoo (*Acanthocybium solandri*) is caught with the mackerel and receives similar high prices. Increased catches of Spanish mackerel can also be made during the spawning periods in Tufi, Dampier Strait, West New Britain (Frusher, 1987) and Kavieng (Wright and Richards, 1985). The size range of Spanish mackerel monitored at the Kavieng fish depot during 1981 was 43-107 cm fork length, and Spanish mackerel formed 72 per cent of the trolled catch landed by fishers during that 13 month period (Wright and Richards, 1985).

Around Wewak, a wooden spool with heavy duty nylon line (or a trace) is the dominant trolling equipment. Lures are either shop-bought or of plant material wrapped around a hook. Monofilament line 15-20 m long and 15-30 kg breaking strain, with a lure of chicken feathers around a hook is also used. Fishing is mainly opportunistic - e.g. when travelling - yet some villagers go out to search for and fish schools. Targeted fishing is usually performed from dusk to midnight and a few hours before dawn, and these periods vary in effectiveness over the year. Better catch rates by trolling are usually achieved when reproductively active fish are in the area (Lewis, 1979; Frusher, 1987).

In Wewak, Spanish mackerel is the second most important catch from troll fishing after mackerel tuna. March and November yield highest catches (Frusher, 1987). Spanish mackerel recruit to the troll fishery around Wewak from 2.5-3 years of age. Juvenile schools (fish 50-55 cm fork length) are also caught (Frusher, 1987). For Spanish mackerel, the overall success rate (strikes) of the best lure ('silver spoon') was 60.8 per cent whereas nonsynthetic lures - such as baits of garfish and small seapike - had an 86 per cent success rate (Frusher, 1987). In the Torres Strait fishery, troll lines are usually baited with garfish (Williams, 1994).

Spanish mackerel formed a significant bycatch of the Taiwanese gillnet shark fishery in the western Gulf of Papua during the 1980s. Beginning with five vessels, eventually two vessels fished the area for 12 years. Fishing was usually conducted around 20-30 km offshore from the mouths of the Fly and Bamu rivers or westward adjacent to the Torres Strait Protected Zone. Fishing trips during 1980 through 1982 lasted from 41 days to 125 days. Fishing using drifting gillnets was carried out from more than 20 km from shore, the vessels drifted, fishing, over 8-10 km for a period of 4-5 hours from about 1700 hours. The gillnets were multifilament,12 m deep and in units of 3 km - joined to make 9 km long nets, and fished subsurface at 5-6 m depth. The nets were set at right angles to the shore. Spanish mackerel (probably also spotted mackerel, *S. munroi),* mackerel tuna (*Euthynnus affinis*) and longtail tuna (*Thunnus tonggol*) formed most of the bony fish bycatch. Indeed, anecdotal reports suggest that the Spanish mackerel catch on occasions almost matched the shark catch.

The Taiwanese fished in PNG waters until the end of 1992, after which their licence was not renewed (for further discussion see: profile on Shark). There have been reports of recent (1994) Taiwanese gillnet fishing activity in western Papua and south of West Irian, adjacent to the Torres Strait Protected Zone and bordering the PNG DFZ. In 1992, one of the Taiwanese vessels was wrecked on Turu Cay (inside the Protected Zone boundary, west) and reportedly its hold contained 150 mt of Spanish mackerel - equivalent to the annual Australian catch from the Torres Strait Protected Zone.

Production and Marketing: Spanish mackerel is presented either fresh (whole or in chunks) or smoked in local markets. In hotels and retail outlets it is sold fresh or chilled, either whole, in cutlets or fillets.

Commercial Spanish mackerel catches in PNG come from the Taiwanese gillnet fishery in the Gulf of Papua:

Shark gillnetting in western Papua (Western and Gulf provinces) in 1976-77 yielded catches of Spanish mackerel of 3.4 mt in October 1976, 207 kg in January 1977 and 866 kg in February 1977 (Chapau and Opnai, 1983). DFMR logbook catches from shark gillnetting operations in the western Gulf of Papua in a 12-day period (October 1989) yielded an average of 43 kg/day/vessel; and in a 95-day period between September and December 1990, average catch was 21 kg/day/vessel (higher catches were recorded during September and October when the mackerel are aggregating for spawning).

Records of **artisanal** catches of Spanish mackerel in PNG are few:

In North Solomons Province (1984):

- total of 7 monthly recorded landings at Makaki Point was 357 kg, 220 kg of which was landed on 26 May;

- in the second half of 1984, 12 per cent of the landed fish at North Solomons Marine Corporation consisted of Spanish mackerel.

Table 40 North Solomons Spanish mackerel catches, 1984 (source: Ito and Selemet, 1985):

Period	Jan-June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total 1984
kg	1,368	46	225	327	702	1,187	633	4,488

At Kokopo, East New Britain, minimal quantities (2.6-11.8 kg) were marketed between 1990 and 1993 (source: DFMR database, Kavieng).

Spanish mackerel comprised 71.8 per cent of the fish landed at the Kavieng (New Ireland Province) fish depot in the 13 months from November 1980. The mackerel were caught by Tigak Islanders and some Manus Province people trolling behind their boats while they were 'in transit' to Kavieng. The catch of Spanish mackerel landed by DFMR staff trolling in areas near Kavieng not regularly fished by national fishermen was 39.1 per cent of their total catch (Wright and Richards, 1983).

At Kavieng provincial fisheries extension depot, landings were: 1991 - 68 kg; 1992 - 231 kg; 1993 - 246 kg (source: DFMR database, Kavieng).

At Manus, 42.7 kg (1990) and 56.6 kg (1991) were recorded at the fisheries authority (source: DFMR database, Kavieng).

Results of a 1986 survey of the West Sepik Province marine resources showed that Spanish mackerel comprised 34 per cent of the trolled catch (Chapau, undated). The Spanish mackerel schools ran offshore and were infrequently targeted by local fishers.

The estimated landing of gilled and gutted Spanish mackerel sold to the Wama Fish Depot at Wewak (East Sepik Province) was 200 mt in 1979 (Frusher, 1987).

In the Huon Gulf area (Morobe Province), large individuals formed a substantial part (16 per cent) of the trolling line fishery between October-December 1991 (Hermes *et al.,* 1992).

In Tufi (Northern Province), between 6 mt and 12 mt are caught annually (N. Omeri, pers. comm., in Frusher, 1987), most of the catch being landed during September and October.

Spanish mackerel form a large component of the troll catch landed in Port Moresby's (National Capital District) Koki market and caught by fishers from Daugo Island. Together with mackerel tuna and other small tunas, they accounted for 80.5 per cent of the trolled catch in the market in 1985, and totalled 37, 086 kg (Lock, 1986).

Spanish mackerel could form a bycatch of longline fishing in the New Guinea islands, as it has done in Fiji (Lewis, 1985). There is no information on catches from this activity however.

The largest Spanish mackerel recorded by the PNG Gamefishing Association (as at June 1993) was a 38 kg fish caught off Madang in 1985.

1.15.3 Stock status

Preliminary electrophoretic analyses were performed on blood samples of Spanish mackerel collected from Orangerie Bay-Samarai, Cheshunt Bay (Papua), Kavieng, Bramble Cay, northern Australia and Port Moresby-Finschhafen. The analyses revealed considerable differences between the Kavieng sample and the remainder of PNG plus northern Australia samples (Lewis, 1981). The results indicated that the Kavieng stock was different to the northern Australian-mainland PNG stock which comprise an interbreeding unit. Lewis (1981) said that the deep water channels such as the Vitiaz Strait and St Georges Channel probably form an effective barrier to larval and adult Spanish mackerel in New Ireland.

Later electrophoretic analysis on PNG and Australian Spanish mackerel stocks was carried out by Shaklee, Phelps and Salini (1990). They found that Spanish mackerel displayed considerable genetic heterogeneity in PNG, where three stocks are recognised:

a) one on the south coast (Port Moresby collection),

b) one in the north and east (including Tufi, Wewak and New Britain collections) (this contravened Lewis' observation about the impassability of deepwater areas),

c) one on New Ireland (Kavieng collection).

The stock on the south coast (a) is genetically similar to Spanish mackerel from the Torres Strait region and northern Australia.

Chapman (1982) found a high catch rate from trolling for Spanish mackerel in the Tufi area during the period of the spawning aggregation between August and late November. After this period, the cpue dropped to 3 kg/hr. In Wewak, Chapman (1982) recorded catch rates averaging 7.3 kg/hr/craft and 28.4 kg/hr/craft at Tufi (during the spawning season), while Frusher (1987) recorded catch rates of between 2 kg and 3 kg/hr/craft over the year - with increased catches in the period of October to February corresponding with an increase in gonadal activity preparatory to spawning. Chapman observed that the cpue could be increased with better fishing gear and skills. In Fiji, the average cpue (kg/hr/craft) for Spanish mackerel ranged from 0 kg to 5.4 kg (Lewis *et al.,* 1983, in Frusher, 1987). Mobiha *et al.,* (unpublished) conducted 13.5 hours of troll fishing 30 km east of Bramble Cay (late October) and achieved a catch rate of 3.98 kg/line/hr.

Spanish mackerel resources are 'known to exist from Milne Bay in the south-east past the Siassi Islands off West New Britain to Manus Island and Kavieng in the north' (*Fisheries Research annual report for 1979*). The basis of this statement is not given; yet occasional surveys have shown that catch rates are lower than required to sustain a commercial fishing operation. A survey around payaos in Ataliklikun Bay, East New Britain yielded only 28 Spanish mackerel in 131 days (Overseas Fishery Cooperation Foundation, 1985); from the Huon Gulf, Spanish mackerel landings at Voco Point comprised only 2.8 per cent of the total fish landings in 1992 (Hermes *et al.,* 1992); and a commercial fishery around Wewak, where Spanish mackerel comprised 80 per cent of the trolled catch, was found to be uneconomical (*Fisheries Research annual report for 1984*). However, the survey recognised that vessels travelling from fishing grounds to Wewak could considerably increase the harvest of Spanish mackerel by slightly altering their sea routes, time of travel and their use of more commercially orientated fishing gear (Chapman, 1982).

Lewis (1979) had an opposite opinion. He stated that in an 18 month survey of mainly Milne Bay Province waters, the average daily catch of Spanish mackerel from 'three best areas' was 170 kg; and suggested that catches of Spanish mackerel averaging 1,300 kg/day could be obtained from 'runs' of fish in areas such as Kavieng and Orangerie Bay. I have not seen data to substantiate Lewis' estimates.

In 1979, a tagging program by the Fisheries Division of the PNG Department of Primary Industry in collaboration with the Queensland Department of Primary Industries commenced in Bramble Cay, Anchor Cay and East Cay of the Great Barrier Reef. One hundred and forty eight Spanish mackerel were tagged and released. It was anticipated that the study - which aimed at defining the movement and stock size of Spanish mackerel in the region - would continue to 1983. The program was discontinued - apparently because of logistical problems (DFMR files).

1.15.4 Management

The Spanish mackerel fishery in PNG comprises:

- a species that migrates and remains resident, inhabits coastal waters, has a rapid growth rate, is best taken by trolling and handlining at night or by gillnetting, and forms seasonal spawning aggregations yet can spawn throughout the year;
- at least three separate genetic stocks;
- by trolling and handlining, is only economical in its own right when spawning aggregations are targeted;
- a resource whose biology (especially movement and spawning behaviour) is largely unknown in PNG waters; and
- a resource whose size and sustainability is unknown.

Spanish mackerel are prized as food because of the flavour, firmness and keeping qualities of the flesh, especially if the fish are bled on capture. They fetch a high price at fish landing points and in retail markets. There is potential for the fishery to develop to supply high quality fish to the domestic (and export) markets.

With all planned development of the Spanish mackerel fishery nevertheless, the scope of *ciguatera poisoning* should be investigated; e.g. information should be gathered on from what areas and for what sizes of fish it is influential.

Chapman (1982) found that the gear used by villagers was too light for aimed trolling. There was potential to develop the fisheries for Spanish mackerel using correct trolling gear and training in their use. Chapman achieved catches of more than 100 kg of Spanish mackerel in 2-3 hour periods in both light fishing and trolling in the Wewak area.

Lewis (1979) stated that Spanish mackerel are an important underexploited resource in PNG, and he estimated that the 'present' catch of 200 mt could be increased 'at least ten times' to 2000 mt/year. In the absence of stock assessments, it is hazardous to suggest figures such as that, but there appears no doubt that the Spanish mackerel resource in PNG is underexploited. Comparative catches in neighbouring areas are: 300 t a year landed in Fiji (Lewis, 1985) and 900-1500 mt a year in Australia (Kailola *et al.,* 1993), of which the Torres Strait catch averages about 100 t of fillets every year (Williams, 1994).

Lewis (1979) cited the distance from the fishing grounds to processing facilities as the main problem to the development, and suggested freezer ships servicing village communities and moving around PNG to take advantage of 'runs' as being a solution. Chapman (1982) and Frusher (1987) decided that the main constraint in the development of a pelagic fishery in

PNG is the traditional ownership of fishing rights. I agree with them. Spanish mackerel are highly migratory fish and, to achieve a high enough cpue, a commercial fishing operation would need to follow the fish schools through traditional fishing areas. Only successful and continuing negotiations would ensure the success of the fishery. Such a system would also apply to the idea of freezer ships following the mackerel (see above). As Frusher (1987:88) pointed out, 'commercial fishing for large pelagics is dependant on a large fishable area (often hundreds of kilometres of coastline) in which reef drop offs, points, etc. are fished and, if not successful, the vessel moves onto another locality. In a fishery...where catch rates are low and covering large distances are important, this method of operation presently clashes with traditional concepts.'

Current legislation/Policy regarding exploitation: There is no current legislation pertaining to Spanish mackerel.

Recommended legislation/policy regarding exploitation:

1. Initiate studies on spawning behaviour and movement of fish.
2. Record and monitor catch information throughout the country. These should be aimed at undertaking an assessment of all Spanish mackerel stocks.
3. Complete the analysis of the Taiwanese shark gillnetting operation data, as indications are that it contains a good series of catch information on the Spanish mackerel resource in Papua.
4. A gillnet fishery could be developed in the western Gulf of Papua. Management measures would include restrictions in gillnet length (<1.5 km?) and a minimum mesh size (not less than 75 mm to protect juveniles) (following Lewis, 1985).
5. The use of mother ships and dories could be investigated to support an expanded troll fishery in some areas (if stocks were worthwhile) as is done in the Torres Strait Protected Zone fishery.
6. A minimum legal size somewhat more than the length at first maturity should be imposed.
7. The Tufi fishery could be extended for several weeks either side of its current October-early December period (Chapman, 1982).
8. Presently, the troll and handline fisheries can only enhance other fisheries, such as deepslope and reef fisheries. Investigate the possibility of paying royalties to traditional owners for access to mackerel resources (a precedent has been set in PNG in the tuna pole-and-line baitfish fishery). Mackerel catches could be enhanced with increased deployment of FADs and with the use of better fishing gear and vessels (see also profiles 1.13, 1.16).

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1.16 THE NEARSHORE TUNAS - mackerel tuna, frigate mackerel and longtail tuna.

1.16.1 The Resource


Euthynnus affinis

Species present: The nearshore tuna resource comprises mackerel tuna *Euthynnus affinis,* frigate mackerel *Auxis thazard* and longtail tuna *Thunnus tonggol*.

Distribution: Frigate mackerel and mackerel tuna inhabit warm waters of the tropical Indo-West Pacific (Collette and Nauen, 1983) and frigate mackerel are probably cosmopolitan. The species occur throughout near-shore waters of PNG, especially near reefs. They are most abundant in the north and east of PNG.

Longtail tuna are present in PNG waters only along the south coast from the West Irian border to Milne Bay. Its PNG distribution is peripheral to the species' main distribution (Wilson, 1981a). Elsewhere they inhabit coastal waters from the Red Sea to Japan, western Indonesia and tropical and subtropical Australia (Wilson, 1981a). *T. tonggol* is unique in the genus as it is its only inshore member.

Biology and Ecology: Collette and Nauen (1983) provided life history information on frigate mackerel. These fish are inshore and oceanic, surface tunas living in warm waters. They attain 51 cm fork length but are commonly caught at 25-40 cm. They mature at 29-35 cm fork length (this is so in the Kavieng area: Lewis *et al.,* 1974) and the fecundity has been estimated at 1.37 million eggs in a 44.2 cm fish. Spawning can take place throughout the year, although the population in the Tigak Islands area (New Ireland) appears to exhibit a spawning peak between September and March (Mobiha, 1993). Frigate mackerel consume small fish, crustaceans and squid. Frigate mackerel more often move in mixed schools with skipjack, yellowfin, mackerel tuna, dolphin fish or rainbow runner (Lewis *et al.,* 1974).

Surface schools of adult mackerel tuna are almost always encountered inside the 100 m depth contour, close to shore. They enter bays and harbours where surface salinities range from 30 ppt to 35 ppt and where surface water temperatures average 29°C (Dalzell and Richards, 1985). Mackerel tuna are especially abundant in regions where there are numerous islands and fringing reefs (Lewis *et al.,* 1974). However, based on sightings of mackerel tuna schools at distances of up to 30 miles (c. 50 km) from the 200 m line and 40 miles (c. 65 km) from land it seems likely that the species undertakes some offshore movement (West and Wilson, 1992).

Mackerel tuna more often move as pure schools but otherwise are encountered in mixed schools with frigate mackerel, skipjack, yellowfin tuna (Lewis *et al.,* 1974) as well as *Megalaspis cordyla* (Collette and Nauen, 1983). The estimated tonnage of schools is not above 19.5 mt (West and Wilson, 1992). Aerial surveys showed that mackerel tuna were most common in inshore waters of Manus Island and Bougainville Island.

Mackerel tuna in the Tigak Islands area exhibit a sex ratio of 1.35 males to every female (Dalzell and Richards, 1985). In Dalzell's and Richard's study the imbalance was greater for fish less than 50 cm fork length and fish above 50 cm were all females in Dalzell's and Richard's study. The sex ratio is reported to be closer to unity in mackerel tuna populations studied elsewhere however. The largest male recorded in the Tigak Islands area (mid 1980s) was 49 cm fork length and the largest female was 55 cm long. However, Wilson (1981a) reported mackerel tuna as large as 74.8 cm fork length and 6 kg in PNG waters while Frusher (1987) estimated they attain 78.5 cm in the Wewak vicinity. The largest mackerel tuna recorded by Lewis, Smith and Kearney (1974) in the New Guinea islands was 68 cm. Mackerel tuna can attain 100 cm and 13.6 kg, but commonly reach 60 cm (Collette and Nauen, 1983). Length frequency information from southern PNG (Wilson, 1981b) show that larger fish inhabit Gulf of Papua waters than waters in the Port Moresby area.

Mackerel tuna fecundity was estimated at 200,000 in a fish 46.3 cm fork length (Dalzell and Richards, 1985). Preliminary estimates of K (0.5) and L_∞ were calculated by Dalzell and Richards (1985). Studies reported by Dalzell and Richards (1985) estimated size at age for mackerel tuna of 25-35 cm for the first year, 25-46 cm for the second year, 45-51 cm for the third year and 54-65 cm for the fourth year. Size at first maturity has been recorded as small as 39 cm fork length in Philippine seas (Ronquillo, 1963, in Dalzell and Richards, 1985) although the smallest mature mackerel tuna that Lewis, Smith and Kearney (1974) recorded in PNG waters was 49 cm fork length. Mackerel tuna probably spawn year-round in PNG waters (Wilson, 1981b) although they exhibit peaks in spawning activity such as in spring and summer. In the Tigak Islands area this occurs between August and November (Mobiha, 1993). Along the southern PNG, mackerel tuna spawn between December and March (Wilson, 1981a).

Mackerel tuna feed on small, schooling fish such as 'talai' (*Herklotsichthys quadrimaculatus*) (Dalzell and Richards, 1985). The oceanic anchovy, *Stolephorus punctifer*, dominated the diet of mackerel tuna sampled near the Tigak Islands. Dalzell and Richards (1985) did not detect any seasonal changes in feeding habits or dietary preference in relation to size in their study. This agrees with the results of Frusher's study (1987) of mackerel tuna in the Wewak area and differ to those of Kishinouye (1923, in Frusher, 1987) who said that feeding habits of mackerel tuna vary throughout the year. Collette and Nauen (1983) reported that mackerel tuna feed opportunistically on fish, crustaceans and cephalopods such as squid.

Juvenile mackerel tuna appear to inhabit inshore waters (Dalzell and Richards, 1985) while adult fish may migrate to deeper water as they grow. Juvenile frigate mackerel and mackerel tuna feature in bait hauls (Lewis *et al.,* 1974).

In the Wewak area, tuna schools are equally abundant throughout the year (Frusher, 1987) including between the South-east monsoon and the North-west monsoon periods, but there is some seasonal variation on their abundance at different times of the day. Mackerel tuna are the dominant tuna species in the Wewak region, although they were infrequently encountered near offshore islands - possibly because of the steep drop-offs of the islands. Nearly 70 per cent of tuna school sightings (mackerel tuna and frigate mackerel) in Frusher's study were made in inshore regions.

Longtail tuna display a seasonal pattern of appearance which is both area and size specific (Wilson, 1981a) and they appear to undergo longshore migrations in response to thermal preferences. Longtail tuna sometimes form schools with mackerel tuna or skipjack tuna (West and Wilson, 1992) and are equally common inside and beyond the 12 nautical mile limit. They have been sighted up to 30 km from shore in the Gulf of Papua (West and Wilson, 1992).

Longtail tuna will feed on the trash fish from prawn trawlers. Wilson (1981a) found that they exhibit very little food preference and their feeding behaviour was opportunistic: they consume fish, crustaceans and molluscs with the proportions dependant on fish size and area. In six years of sampling longtail tuna in southern PNG waters, Wilson (1981a) did not observe any ripe or almost mature female longtail tuna. However, gonad indices increased through the year suggesting a late spring/early summer spawning. The smallest fish with maturing gonads were about 60 cm fork length. Longtail tuna appear to move out of PNG waters as maturity approaches and one spawning site is probably the Aru Islands in the northern Arafura Sea (Wilson, 1981a) where spawning probably takes place from late winter-early spring to summer. Fish probably radiate from this area and appear in PNG waters during their second year, where they form a 'residential' group of fish less than 80 cm fork length. Fish first appear in the Gulf of Papua from the end of April and disappear in mid-September (Wilson, 1981a).

For longtail tuna, Wilson (1981a) calculated L_∞'s of 122.91 cm and 131.8 cm (two methods) and growth coefficient (K) of 0.41 and 0.395. At one year of age, longtail tuna were estimated to be about 40 cm fork length, 65-70 cm at two years, between 80 cm and 90 cm at three years and about 100 cm at four years of age when they weigh about 13.5 kg (Wilson, 1981a). The longest fish caught in the Gulf of Papua was 108 cm fork length; probably five years old (Wilson, 1981c).

1.16.2 The Fishery

Utilisation: Many coastal fishermen fish for these species for subsistence use and at artisanal level where good local markets exist. Mackerel tuna is generally the dominant tuna in coastal markets throughout PNG.

Feeding schools of mackerel tuna are located by the presence of birds nearby or from surface splashing as the fish feed. Mackerel tuna are particularly easy to detect as they often form small active surface schools (Wilson, 1981b) and the schools are small (< 5 mt) compared to schools formed by other tunas.

Manus Islanders carry on the tradition for pole-and-line fishing for mackerel tuna (Haines and Chapau, 1991). Bait of mainly *Thrissina baelama* but including some cardinal fish and fusiliers, is obtained close to shore and kept alive in baskets suspended in the water from the canoes as the canoes travel to traditional fishing grounds. Schools of mackerel tuna are chummed and poled, the bamboo poles traditionally having lures of trochus or green snail shell attached to bush fibre rope. Frusher (1987) reported that pole-and-line fishing for inshore tunas was also applied in areas west of Wewak. At Pari village on the Papuan coast, funnel traps were constructed across the known migratory pathways of longtail tuna. Once a school of tuna had passed between the poles a net was dropped across the funnel's mouth (Pulseford, 1975, in Wilson, 1981a). At Gaire village (Central Province) bucketfuls of stolephorid anchovies are used to chum longtail tuna for handlining. The association between the presence of longtail tuna in inshore bays and the nearshore migration of stolephorid anchovies has long been recognised in the Port Moresby area.

Trolling has now become the main method of catching mackerel tuna, frigate mackerel and - to some extent - longtail tuna in artisanal fisheries. Fishing in the early morning for mackerel tuna and frigate mackerel is frequently the most effective (e.g. Frusher, 1987). In the Tigak Islands and off Wewak (at least), fishing is opportunistic - performed by trailing a line behind crafts when voyaging between areas. Active fishing - such as going out to sight and fish schools - is less common. Trolling (in the Wewak area) is either with artificial lures (shop-bought or of plant material or chicken feathers) or with baits such as *Selar, Rastrelliger* and *Decapterus*. Longtail tuna do not form surface aggregations as much as do the other tunas and they do not respond well to poling activities. Longtail tuna are caught in the Port Moresby-Central Province area mainly by trolling and handlining and in the Gulf of Papua by trailing a line with a hook baited with trash fish behind the trawler.

Lewis, Smith and Kearney (1974) found that mackerel tuna are vulnerable to trolling and poling at sizes above 30 cm fork length, and that frigate mackerel are taken at sizes between 29 cm and 49 cm fork length. Trolled or handlined longtail tuna at Koki market (1972-75) ranged between 40 and 90 cm fork length while those caught by prawn trawlers in the Gulf of Papua were between 60 and 102 cm fork length (Wilson, 1981c).

Trolling tends to be a seasonal (November to March) activity in the Central Province (Wilson, 1981a; Lock, 1986) probably dictated by weather conditions outside the barrier reef, although trolling for longtail tuna does take place in inshore waters during the South-east monsoon season.

Longtail tuna can be caught in commercial quantities by gillnet. The Taiwanese operators in northern Australia pre-mid 1980s used 17 cm mesh nets up to 9 km long with a drop of 17 m, set 1-2 m below the surface. They were also caught using drifting gillnets in the Gulf of Papua shark fishery between 1980 and 1992. Mackerel tuna were caught by commercial pole-and-line vessels in PNG prior to the mid 1980s but were frequently discarded because of their low commercial value. They comprised 0.1 per cent of the PNG annual pole-and-line catch (Wankowski, 1980, in Wilson, 1981b).

Tuna and other pelagic fishes can be caught by anchoring Fish Aggregation Devices (FADs) off the coastline and trolling, trapping, handlining, jigging or purse seining around it. Trolling was shown to be the most effective method around FADs off Wewak. Mackerel tuna were the dominant fish in catches, followed by skipjack tuna at a FAD moored in 160 m, and by frigate mackerel and yellowfin tuna at a FAD moored in 390 m. Frigate mackerel dominated the FAD catch in September. For all species, the FAD-caught fish were smaller than fish caught in the artisanal fishery. Interestingly, even though the 160 m anchored FAD was placed in a region where adult mackerel tuna have been caught, only juveniles were caught near the FAD although adults were still being caught in the same region (Frusher, 1986).

Production and Marketing: Inshore tuna species are sold fresh or smoked in coastal markets. The fish generally have higher market values when they are fresh compared to values for smoked products. Mackerel tuna and longtail tuna are important food items in coastal villages in Papua as well as in the artisanal fishery. Between 1972 and 1976 they made up most of the tuna catch at Koki market, Port Moresby: mackerel tuna - 34 per cent; longtail tuna - 22 per cent; Spanish mackerel - 15 per cent; yellowfin tuna - 12 per cent; skipjack tuna - 10 per cent; frigate mackerel - 4 per cent.

Wilson (1981a; 1981b) estimated that fishers caught 280 mt of mackerel tuna annually from PNG coastal waters for both subsistence and artisanal purposes. Judging from recorded relative percentages, the amount of frigate mackerel caught would be considerably smaller. Wilson (1981a) also estimated that the total annual catch of longtail tuna in PNG is between 50 mt and 100 mt.

Lock (1986) estimated that at Koki market in 1985, 58.5 mt of tunas and mackerel (comprising 10.1 per cent of total landed artisanal catch at the market) were offered for sale. Unfortunately the species composition of the tuna and mackerel catch was not stated.

Table 41 Estimated annual artisanal catch of longtail tuna in the Port Moresby area, 1972-76 (source: Wilson, 1981a):

Year	1972 *	1973	1974	1975	1976
tonnes	11	11	6	7.8	8

(*for July-December only)

Table 42 Table Longtail tuna production in the Gulf of Papua (trawling), 1973-76. (source: Wilson, 1981a)

Year	1973	1974	1975	1976
tonnes	c.100	60	48	25

More recent figures are not available. Other landings of artisanal catches are not defined by species - for example, those recorded at the Kokopo (East New Britain) and Manus Island fish markets.

Table 43 Kokopo fish market landings of all mackerel (not Spanish), pelagics and tuna. (source: DFMR database, Kavieng):

Year	1990	1991	1992	1993

kg	6833	3643	2870	499

Table 44 Manus fisheries authority landings of all mackerel (not Spanish), pelagics and tuna. (source: DFMR database, Kavieng)

Year	1990	1991	1992	1993
kg	1654	1268	1544	382

The only other landings information available to me is for New Ireland and North Solomons, yet the recorded catches of mackerel therein are minimal.

Trolling with lures off the West Sepik Province yielded 22 pelagic species of which mackerel tuna comprised 18 per cent of the catch (Chapau, undated).

In their July survey of west Manus Island, Chapau and Lokani (1986) recorded mackerel tuna as the most commonly trolled fish. It accounted for 72.3 per cent of all trolled fish, while frigate mackerel only accounted for 4.6 per cent of trolled fish. The mackerel tuna were between 30 cm and 40 cm fork length.

Although mackerel tuna comprises only a small (<2 per cent) of artisanal catches by New Irelanders, Wright, Chapau, Dalzell and Richards (1983) considered that this small catch was a reflection of the fishing method rather than of the species' abundance. Trolling performed by DFMR staff off Kavieng resulted in a catch of which mackerel tuna comprised 13 per cent by weight (after Spanish mackerel).

In the Huon Gulf, mackerel tuna are the most common pelagic fish landed in the October-December period (31 per cent of the category; fish 40-60 cm long), although their landings are often mixed with frigate mackerel (Hermes, 1992). In 1992 mackerel tuna made up and estimated 5.4 per cent of total landings.

In Wewak, catches of tunas from trolling generally are highest in March, June and November (Frusher, 1987). Mackerel tuna were dominant in March and November, frigate mackerel in June. Except for January and June (1982-84), mackerel tuna catches are dominant - being as high as 85 per cent in the months of October and November. From November 1982 to January 1984 trolled fish brought to the Wama Fish Depot comprised mackerel tuna - 65 per cent; frigate mackerel - 34.5 per cent, and small yellowfins and skipjack tuna making up the remainder.

FADs substantially increase catch rates of pelagic fish. Frusher (1986) ably demonstrated this on the FADs deployed off Wewak, and there is abundant evidence of this phenomen throughout the western Pacific. From July 1984 to July 1985, 8532 fish were caught around the Wewak FADs while only 2,096 fish were caught in the artisanal fishery (Frusher, 1986).

As well as increasing the fish harvest, the FADs gave Wewak consumers and artisanal fishers access to resources to which they previously had not had access: yellowfin tuna and skipjack tuna. Furthermore, catch rates for fishers trolling around FADs improved beyond their non-FAD trolling: levels of 20.85 mackerel tuna/hour and 4.21 frigate mackerel/hour were achieved in Frusher's study at the 390-m anchored FAD, and a mean for both FADs was 10 kg/vessel/hour (Frusher, 1985).

An estimated 15 mt of fresh tuna was caught from the deeper-water FAD over a period of 12 months (1984-85), which was about four times the estimated amount of tuna previously landed per year in Wewak (Frusher, 1985).

Table 45 Comparison of catch composition and species caught in the Wewak between July 1984 and July 1985 (source: Frusher, 1986)

Species	FAD number	FAD %	artisanal (nonFAD) number	artisanal (nonFAD) %
Mackerel tuna	4871	57.1	1503	71.7
Frigate mackerel	1009	11.8	371	17.7
Yellowfin tuna	2122	24.9	0	0
Skipjack tuna	223	2.6	0	0
Dolphin fish	188	2.2	8	0.4
Rainbow runner	119	1.4	65	3.1
Malambur	0	0	112	5.3
Black kingfish	0	0	16	0.8
Double-lined mackerel	0	0	16	0.8

Gamefishing Association record catches of nearshore tunas (as at June 1993) are:

mackerel tuna - 6 kg, off Bougainville; longtail tuna - 9.75 kg, off Port Moresby (no recording for frigate mackerel).

1.16.3 Stock status

There is no information on the size of the mackerel tuna and frigate mackerel stocks in PNG waters (M. Chapau, pers. comm.). Local or regional expressions of the resource size have been made for the Tigak Islands, Huon Gulf and Wewak areas only (see above), and Lock's (1986) information grouped all scombrids. However, a potential yield of several thousand tonnes was recently estimated (Fishery Sector Review, 1989).

Any estimate of stock levels of longtail tuna in PNG would be tentative given the migratory nature of the fish, that PNG is on the periphery of the species' range and that little is known about the species' reproductive biology. However, Wilson (1981a) suggests that the fish in the Gulf of Papua represent a seasonal pocket of the whole population. He estimated that the 1975 biomass of longtail tuna in the gulf was 425 mt, and concluded that a large resource is not present in PNG waters. An annual yield of several hundred tonnes was estimated in the 1989 Sector Review. Generally however, the longtail tuna fishery is characterised by fluctuations in catch probably influenced by environmental features (Wilson, 1981a).

1.16.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: In the absence of limited or no information about the species' biology, abuncance and population dynamics, effective management of the neashore tuna resources cannot be undertaken.

Theoretically - say Dalzell and Richards (1985) - mackerel tuna has the potential to replace some of the imported tinned fish presently being marketed in PNG. It is the most common pelagic fish in coastal markets throughout the year. Their view is shared by others - e.g. J. Wankowski (DFMR files).

Wright and Richards (1983) considered that there is a sizeable nearshore pelagic resource consisting mainly of mackerel tuna and frigate mackerel (plus double-lined mackerel, *Grammatorcynus bicarinatus*) close to the Tigak Islands, and that that resource offered the best potential for increasing fisheries production in the Tigak-Kavieng area. Frusher (1987) drew a similar conclusion about the mackerel tuna frigate mackerel resource in the Wewak area where it comprises 14.8 per cent of the annual catch. The fish, he said, are highly acceptable to the national consumer. A resource appears to exist in the Wewak area, and it could be the basis of a year-round fishery. Mobiha also (in press) suggested that there were sufficient (undifferentiated) scombrid resources in the Madang province to support increased artisanal fishing activity for them.

A number of issues have caused PNG's mackerel tuna resource (particularly) to be under-exploited, although *it could be the largest resource available to artisanal fishers* (M. Chapau, pers. comm.). These issues include:

1. the cost of searching for schools (eg fuel), which has made nearshore tuna fishing largely uneconomic;
2. the limited market (coastal towns and villages), where mackerel tuna and frigate mackerel compete with other accessible (eg reef) fish resources;
3. the inadequate fishing vessels and fishing gear of small-scale fishers (Chapman 1982; Wright and Richards, 1983; Dalzell and Richards, 1985; Frusher, 1987);
4. the lack of adequate shore facilities to handle increased catches of nearshore tunas;
5. the constraint of customary fishing rights when it comes to chasing and fishing moving pelagic stocks (Chapman, 1982; Frusher, 1987).

   Several alternatives can address the above issues.

- The use FADs as a measure to increase the artisanal harvest of nearshore pelagics has been demonstrated in PNG waters (e.g. by Frusher, 1986). The expense of their installation would have to be addressed.
- An intermediate step (from simple search-trolling to targeted trolling around FADs) would be a fishery for pelagics run in conjunction with deep bottom fishing where suitable depths and bottom substrate were available (Frusher, 1987).
- Through the action of a FAD attracting migratory tunas and mackerels to an area, the installation of a FAD can also become a way of overcoming (or alleviating) traditional fishing rights problems when it comes to harvesting such moving resources.
- In non-FAD and FAD areas, improved gear could be introduced along with training on how to use it. The success of such improvements and training were demonstrated by Chapman (1982) and generally (?) by DFMR training schemes in the 1980s and the work of the German Fishing Cooperative in Lae (mid 1980s). J. Wankowski (DFMR files) suggested that small converted pole-and-line vessels could be deployed.
- Improved shore facilities for handling inshore tunas could develop as an offshoot of the new tuna cannery at Madang Province - although the general issue of good shore facilities plus fish harvesting has never been really addressed in PNG. Still, the establishment of the cannery at Madang could in the long term however, facilitate the development of a canning industry for mackerel tuna in PNG.

Smoked mackerel tuna has been trialled already at Wewak (M. Chapau, pers. comm.) and was found to be a very acceptable product, particularly to Highlands people there. Investigation and trials of a suitable smoked tuna product, which could be produced at the village level, is surely within the reach of training schemes in PNG.

Longtail tuna is the least exploited of the commercially valuable *Thunnus* group of tunas (Wilson, 1981a). And in PNG waters, it is not in the same 'quantity league' as mackerel tuna. However, the expected maximum catch levels of 50-100 t obtained in the 1970s (Wilson, 1981a) could be improved upon by gillnetting. This alternative was suggested by Wilson (1981a) in view of the seasonal (South East monsoon) nature of longtail tuna in the Gulf of Papua and its tendency to get caught in gillnets (eg in the earlier Taiwanese fishery off northern Australia and in the Gulf of Papua). The species could support a local gillnet operation in the Gulf of Papua. This gillnet fishery would also target shark and Spanish mackerel (see profiles 1.16, 1.20).

Longtail tuna can be satisfactorily canned (Wilson, 1981c) although there are insufficient quantities in PNG to support the activity. However, its best market possibility in PNG is for the fresh fish 'sashimi' market. Longtail tuna belong in the same genus as yellowfin tuna, bigeye tuna and southern bluefin tuna which are renowned internationally for their quality as sashimi. The current method of capture in the Gulf of Papua - of being handlined or trolled from the prawn trawlers - means that the fish would be in good condition when landed, good freezer space is immediately available, and international markets are very accessible (and already service the fleet).

In the short term, the following should be undertaken:

1. Monitoring and recording of artisanal catches of these tunas (with correct species identifications) should be initiated/continued(?) as a matter of urgency. This activity will reveal sizes, seasonality, reproductive condition, cpue, biomass estimates and growth information, for example. In conjunction with this measure, adequate monitoring of catches made around FADs (eg off Daugo Island, Kavieng) should be performed;
2. Supporting the installation of FADs in suitable areas in PNG;
3. Encouraging enquiry into suitable smoking methods and marketing for mackerel tuna;
4. Supporting the development and availability of better fishing gear and vessels to artisanal fishers;
5. Interest prawn trawler operators in trialling sashimi tuna;
6. Investigate the feasibility of a multi-species gillnet fishery in the Gulf of Papua.

Of all of these, the first item - monitoring and recording - is very much the most important.

A word of warning on the use of FADs with regard to resource sustainability should be made. They have a habit of attracting juvenile pelagics and have been suspected of causing growth overfishing (Floyd and Pauly, 1984, in Frusher, 1986). They could also impinge on the stock structure of targeted populations of nearshore pelagics (Frusher, 1986).

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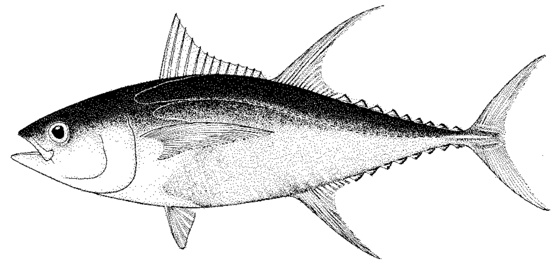
1.17 TUNA

1.17.1 The Resource

Species present: The three main species comprising the tuna resource in PNG waters are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and big-eye tuna (*T. obesus*). Albacore (*T. alalunga*) are caught incidentally.



Thunnus albacares

Distribution: Tuna distributions and habitats are determined by their physiological requirements, in turn dependent especially on levels of dissolved oxygen, water temperature, salinity and forage organisms. Within suitable physical regimes, the availability of forage plays a major role in determining the distribution and aggregations of tunas. Skipjack, yellowfin and bigeye tunas occur throughout tropical and sub-tropical waters of the Pacific Ocean. Skipjack reach their maximum latitudinal distribution in the far western Pacific - to between 40^{o}N and 40^{o}S. They are highly mobile and are capable of long range movements. The overall distribution of yellowfin in the Pacific Ocean is similar to that of skipjack, although unlike them, large (>100 cm fork length) yellowfin are found in both warm surface waters and cooler subsurface waters. Skipjack and juvenile yellowfin tunas often co-occur and fish of similar size often feed together or associate in the same school. Yellowfin can also undertake long-distance movements. In the western Pacific, bigeye also occur between 40^{o}N and 40^{o}S. Whereas juvenile and subadult bigeye occasionally occur in surface waters, adult bigeye occur deeper in the water column than do other tuna species. Adult bigeye occur at depths of at least 250 m during the day and rise closer to the surface at night (Holland *et al.,* 1990, in South Pacific Commission, 1993). Bigeye are capable of undertaking long range movements (at least 4,000 nautical miles recorded: South Pacific Commission, 1993).

The influence of oceanographic conditions on the distribution and hence catches of tunas in PNG waters is reviewed in South Pacific Commission, 1993. A series of aerial surveys conducted of PNG waters during 1972 and 1973 (West and Wilson, 1992) showed that skipjack in pure schools accounted for 50 per cent of all tuna schools sighted, and skipjack + yellowfin associations accounted for an additional 25 per cent. On average, mixed schools of skipjack and yellowfin are considerably larger (21 mt) than pure skipjack (14 mt) and yellowfin (7 mt). The best sightings of tuna were made in the eastern Bismarck Sea and off the north-west coast of PNG. Pure schools are more common outside of the 12 nautical mile zone, while mixed schools are more common inshore.

There is rapid and continual turnover of tunas, particularly skipjack, through the PNG Declared Fishing Zone (DFZ). Tunas tagged in PNG waters move outwards to a wide area of the equatorial western Pacific, from the Philippines to Kiribati, and conversley tunas tagged in a wide area of the western Pacific have been recaptured in PNG waters (Tuna and Billfish Assessment Programme, 1992).

Biology and Ecology: Skipjack spawning occurs in the western Pacific between 35^{o}N and 37^{o}S. It is concentrated at 10^{o}N-10^{o}S, the latitudinal band straddling PNG waters. Spawning occurs year round in the western tropical Pacific (South Pacific Commission, 1993), although seasonal peaks may occur. Concentration of spawning activity may take place in the vicinity of islands. Skipjack are highly fecund, the relative fecundity corresponding to size; estimates range from 100,000 to 2 million eggs per spawning (South Pacific Commission, 1993).

There appear to be three major yellowfin spawning areas in the equatorial Pacific. Yellowfin spawn year-round with a peak in spawning activity usually in the November-April period (South Pacific Commission, 1993).

Bigeye appear to spawn in the western Pacific between 30°N and 20°S; mature bigeye appear to concentrate at 10°N-10°S between April and September (Kikawa, 1962, in South Pacific Commission, 1993). These fish mature at around 100-130 cm fork length.

Density-dependent processes and environmental conditions probably influence larval survival of skipjack, yellowfin and bigeye tunas (South Pacific Commission, 1993).

Tunas eat substantial amounts of food and have rapid growth. They feed on a variety of organisms ranging from zooplankton to larval, juvenile and adult fish, squid and crustaceans.

Growth rates of skipjack are highly variable - e.g. skipjack in the eastern Pacific grow more than twice as fast as skipjack in PNG (Josse *et al.,* 1979 in South Pacific Commission, 1993). Natural mortality in skipjack is also high relative to other tuna species (South Pacific Commission, 1993), is highly variable, and accounts for 80-85 per cent of total mortality. Growth rates of (younger) yellowfin are similar in all areas of the Pacific (South Pacific Commission, 1993). The longline fishery exploits mainly 2- and 3-year-old fish in the western Pacific and mainly 1-year-olds in purse seine sets around logs - also 2- 3-year-old fish in sets on free-swimming schools. Natural mortality rates for smaller yellowfin in the western Pacific have been estimated at 1.07/year, and fishing mortality at 0.2/year (Hampton, 1992). Growth rates for bigeye suggest that these fish are 40-50 cm long at the end of their first year and 100-130 cm long at the end of their third year. Natural mortality rates have been calculated to be much less than fishing mortality rates in older bigeye (South Pacific Commission, 1993).

1.17.2 The Fishery

Utilisation: Despite there being plenty of tuna in PNG waters (next sections), a stable domestic fishery not yet been established. Small quantities of tuna are taken in coastal artisanal fisheries around the country - including around FADs deployed in the East Sepik Province (Frusher, 1986) and Central Province (Beverly and Cusack, 1993) (see also profile 1.15).

The history of the early years of PNG's tuna fishery was given by Doulman and Wright (1983) and there is an overview in Fishery Sector Review (1989).

During the early 1970s a domestic pole-and-line tuna fishing did develop with up to four foreign owned companies (some with PNG based joint-venture partners) fishing with pole-and-line vessels. In that period, Papua New Guinea was the third largest producer of skipjack tuna in the world, with more than 48,000 mt of tuna, mostly skipjack, harvested annually at the peak of activity (Fishery Sector review, 1989). The domestic fishery produced 5 per cent of the total world production of skipjack each year (FAO, 1972-80, in Doulman and Wright, 1983). However, Wankowski's (1980) figures given below, are somewhat different.

Table 46 Catches of tuna from the PNG DFZ for the years 1972-79 (source: Wankowski, 1980)

Year	Total PNG DFZ	% world catch
1972	30,988	1.58
1973	65,217	3.12
1974	105,514	4.68
1975	39,358	1.88
1976	54,238	2.36
1977	*45,910	1.97
1978	63,280	-
1979	**29,972	-

(*: excluding data fom Korean and Taiwanese longliners; **: includes foreign-based vessel catch for August and December 1979 only)

As a result of deteriorating world market conditions for tuna in 1980-81 and increasing operational costs, the last of the foreign owned companies ceased operating at the end of 1981. PNG Government efforts to reactivate the domestic tuna industry in association with Okinawan fishermen in 1984 survived less than two years as depressed market conditions continued.

The pole-and-line fishery operating in PNG in the 1970s was restricted in its area of operation by the location of baiting grounds and the operating range of the vessels (West and Wilson, 1992). West and Wilson found no correlation between the tonnages sighted per hour of aerial surveying of tuna schools in PNG waters and the cpue of the fishery. The pole-and-line fishery was primarily around Kavieng (New Ireland Province) and adjacent to Cape Lambert (East New Britain Province). Other areas of PNG also have good quality baitfish grounds but either the grounds were not available to commercial exploitation for political reasons, or the presence of tuna in those areas was seasonal (Doulman and Wright, 1983).

Almost* the entire PNG catch from the pole-and-line fishery was exported without being landed in the country (Doulman and Wright, 1983). [* A 'katsuobushi' (smoked tuna) plant operated at Kavieng between 1971 and 1978, producing an annual average of 203 mt of product for the Japanese market.]

Table 47 Destination of exports from PNG's domestic pole-and-line fishery, 1979-81 by per cent (source: Doulman and Wright, 1983)

Year	United States	Japan	Other
1979	92.0	8.0	-
1980	96.0	4.0	-
1981	74.0	22.0	4.0
mean	87.3	11.3	1.3

A distant water fishery (operating offshore) is also present in PNG. it is operated by foreign vessels from distant water fishing nations (DWFN) and three fishing methods are employed: purse seining, longlining and pole-and-line.

Purse-seining began in the late 1960s and increased dramatically in the early 1980s. Catches have been close to 200,000 mt annually in recent years (Tuna and Billfish Assessment Programme, 1992). The longline fishery has been operating in PNG waters since the 1960s and catches have fluctuated consistently, peaking at 19,500 mt in 1978 (South Pacific Commission, 1993). Pole-and-line fishing began in 1972 and peaked at more than 45,000 mt in 1974 but catches fell away to almost nothing by 1987 (South Pacific Commission, 1993). Since that time there has been no pole-and-line fishing in PNG waters.

Purse-seining usually takes place on schools of tuna associated with logs, other floating debris or large animals (whales, sharks), although free-swimming schools are also fished. Target species are skipjack and yellowfin. Each vessel in the *longline* fishery sets upwards of 2,000 hooks per day and targets yellowfin, bigeye and billfish (Istiophoridae; profile 1.19). Wright (1980, in Doulman and Wright, 1983) estimated that about 32 per cent of the longline catch is discarded. Most Japanese *pole-and-line* fishing occurred between October and March each year, and most tuna caught was canned. Skipjack averaged 93.8 per cent and yellowfin 6.3 per cent of the pole-and-line catch (Doulman and Wright, 1983).

Table 48 Mean species composition of nominal Japanese longline landed catch from the PNG DFZ for 1972-77, 1979-81 (sources: 1972-77 from Wankowski, 1980; 1979-81 from Doulman and Wright, 1983)

species	av. ann. catch (mt), 1972-77	1979 catch (mt) (last 6 months)	1980 catch (mt)	1981 catch (mt)
northern bluefin	1	-	-	-
yellowfin	4,006	1,375	11,484	13,076
albacore	626?	2	323	1,268
bigeye	1,040	211	1,973	2,050
skipjack	7	-	-	-
spearfish	39	-	-	-
blue marlin	300	41	404	482
striped marlin	6	1	7	10
black marlin	85	14	101	163
sailfish	201	8	85	195
swordfish	-	10	93	123
other*	-	4	87	246

(*includes shark and other less valuable species)

Trends in catch per unit effort in the tuna fishery in PNG are discussed by South Pacific Commission (1993). The purse seine fishery cpue declined at the end of the 1980s but mainly for Korean and Taiwanese log/FAD set skipjack. However, there is no clear trend across fleet, set type and link with oceanographic factors, probably reflecting under-reporting of catch and activity. For longlining in the broad SPC statistical area, bigeye cpue increase slightly while yellowfin cpue decreased - although these changes could simply reflect targeting changes. Catches of yellowfin and skipjack from the SPC statistical area have tended to increase steadily over the past few years.

The PNG national government has licensed the DWFN fishing vessels to operate in its 200-mile DFZ since 1976 (Doulman and Wright, 1983). Following a breakdown in negotiations with the Japanese Tuna Association in 1987, no Japanese vessels have since been licensed. Vessels from the United States of America fish under terms and conditions of a Multilateral Treaty with Forum Fisheries Agency (FFA) member states - ratified in 1988 - while vessels mainly from Korea, Taiwan and Philippines fish under bilateral agreements with PNG.

The PNG Declared Fishing Zone is an important fishing ground for DWFNs, with approximately 130 purse seiners and 20 longliners licensed to fish (1993 figures).

Contrary to the domestic pole-and-line fishery, where nationals were employed and baitfish royalties were paid, PNG benefits from these fisheries only through the payment of access fees (Doulman and Wright, 1983)[1]. Although PNG holds an estimated 20 per cent of the world's tuna stocks (*INFOFISH International* magazine, 4/94) its earnings from marine products are less than US$8 million per year, while foreign fleets harvest an estimated US$400 million a year of tuna from its waters.

[1] I suppose this is still the case? - pending implementation of new provisions?

Table 49 Access arrangements or *ad hoc* licensing arrangements with PNG as indicated by data submitted by PNG and through the USA multi-lateral treaty, to the SPC Regional Tuna Fisheries Database (source: South Pacific Commission, 1993)

Year	Aust.	Indon.	Japan	Korea	Mexico	Philipp.	Taiwan	USA
1978	-	-	-	-	-	-	-	-
1979			LL,PL,PS					
1980			LL,PL,PS					
1981			LL,PS					
1982			LL,PL,PS	PS				
1983			LL,PL,PS	PS			PS	PS
1984			LL,PL,PS	PS	PS	PS	PS	PS
1985			LL,PL,PS	PS		PS	PS	PS
1986		PS	LL,PL,PS	PS			PS	PS
1987		PS	LL,PL,PS	PS		PS	PS	PS
1988	PS	PS		PS		PS	PS	PS
1989	PS	PS		PS		PS	PS	PS
1990	PS	PS		LL,PS		PS	LL,PS	PS
1991	PS			LL,PS		PS	PS	PS
1992	PS			PS		PS	PS	PS

(LL = longline; PS = purse seine; PL = pole-and-line)

The western Pacific purse seine fishery captures yellowfin of 40-50 cm fork length, mainly in association with logs, and larger fish (to 80 cm fork length) in sets around free-swimming schools. Yellowfin larger than 80 cm fork length (mainly 120 cm upwards) in free-swimming schools are caught by the longline fishery (South Pacific Commission, 1993). Bigeye begin recruiting to the longline fishery at age 2 but are not fully recruited until age 5 (Suda and Kume, 1967, in South Pacific Commission, 1993).

FADs increase fishing success and minimise fuel costs for artisanal fishers. Both juvenile and adult skipjack are attracted to floating logs and increasingly to FADs (South Pacific Commission, 1993), and these items play an important role in purse-seine fisheries - e.g. in PNG. Yellowfin are also attracted to flotsam and FADs.

The majority of the bigeye catch in the Pacific comes from the longline fishery. Juvenile bigeye representing up to 30 per cent by number of the catch are caught in purse seine fisheries in sets under logs and near FADs (pooled with yellowfin catch records) (South Pacific Commission, 1993).

Table 50 Composition of target species in catches (mt) by foreign fleets in PNG waters between 1970 and 1991 (source: South Pacific Commission, 1993. This reference should be consulted for its data source).

Year	Skipjack	Yellowfin	Bigeye	Year	Skipjack	Yellowfin	Bigeye
1970	30	2,577	250	1981	22,444	26,130	1,425
1971	359	10,129	1,183	1982	62,544	41,208	1,437
1972	7,847	4,453	1,326	1983	82,756	38,267	1,471
1973	18,501	9,529	1,116	1984	84,537	52,638	1,165
1974	44,975	4,879	1,244	1985	93,955	40,593	1,724
1975	17,215	5,214	905	*1986	52,110	24,871	1,271
1976	14,638	7,438	1,519	*1987	26,342	11,475	150
1977	24,229	16,251	3,028	*1988	45,253	12,543	0
1978	12,969	19,575	2,482	*1989	128,266	57,979	0
1979	1,027	1,718	207	*1990	67,051	22,034	9
1980	9,353	12,158	1,742	*1991	83,615	45,132	27

(*adjusted figures for under- or non-reporting of catches were not available for these years for species composition)

Albacore, a colder water species, is only taken in small quantities by longliners operating in the Solomon Sea. Albacore form an incidental catch to yellowfin and biegeye (Fishery Sector review, 1989).

A Pacific Islands Marine Resources Project (PIMAR) funded by USAID began operation in East New Britain in 1993 with the aim of increasing PNG's tuna exports via a local tuna fishing industry. Within this project, the East New Britain provincial government vessel, the FV *Kuriap*, has conducted longline fishing trials in provincial waters. Fishing has mainly produced large yellowfin tuna (around 50 kg) and some bigeye tuna. Catches were initially marketed at Kokopo, but in early 1994 trial shipments of sashimi-grade tuna were sent to Japan.

In May 1992 an agreement was signed between the PNG Government, the Madang Provincial Government and the Z Fishing Company to build and operate a 200 mt/day (raw fish capacity) tuna cannery at Sek Harbour, Madang Province. The cannery is to be supplied at least by the 12 purse seine vessels owned/operated by the Z Fishing Company and other purse seine vessels and will also buy tuna caught by local fishers. Spin-offs from the cannery will include the conversion of fish scrap to fish meal for domestic feed mill operators and the generation of up to 1,100 jobs for local residents. Much of the finished product will be shipped about twice each month to the target European market.

The cannery will create an ideal opportunity for the development of locally based small boat pole-and-line fishing operations (which may fish inside the 3-mile zone) and eventually for small scale longline operations. The ZZZ Cannery will buy all of the pole-and-line catch (provided it is of suitable quality) in the first instance, as well as establish an ice plant for domestic fishing operations.

Production and Marketing: In the 12 years prior to 1982, marine produce valued at K30-40 million was exported each year from PNG. Of this, the domestic tuna industry contributed 75 per cent. The cessation of the domestic tuna fishery in 1982 impacted greatly on the value of fishery exports which decreased to K8-9 million annually (Wright, 1986). The short-term recommencement of the fishery in 1984-85 added K2-5 million to the value of PNG fishery exports.

Financial benefits to PNG from the tuna fishery are discussed by Doulman and Wright (1983) and Fishery Sector review (1989). Licence fees and other payments from the operations of

DWFNs in PNG waters currently are worth c. K16 million/year, but PNG currently accrues few other benefits.

Table 51 Annual tuna catch and effort statistics for the domestic (PNG-Japan) pole-and-line fisheries in PNG waters, 1970-85, from South Pacific Commission, 1993 (Source: 1970-1981 - PNG Department of Primary Industry, 1984; 1984-85 - PNG DFMR)

Year	Total tuna catch (mt)	Skipjack (%)**	Total days fished	Av. tuna catch per day (mt)
1970	2,430	97	511	4.8
1971	17,003	99	4,060	4.2
1972	13,123	89	4,915	2.7
1973	28,330	96	7,719	3.7
1974	41,780	96	9,408	4.4
1975	17,398	90	6,435	2.7
1976	33,014	74	7,901	4.2
1977	24,411	82	9,736	2.5
1978	48,933	94	9,941	4.9
1979	25,945	89	8,184	3.3
1980	34,098	91	9,483	3.6
1981	*27,705	87	*7,361	3.3
1982	-	-	-	-
1983	-	-	-	-
1984	*2,744	n.a.	*683	4.0
1985	*9,300	n.a.	*n.a.	n.a.

(* SPC (1993) reported that there were variations in the catch data supplied by PNG to the South Pacific Commission and the data on the PNG DFMR records, especially for the years 1981, 1984, 1985. For 1981, the SPC Regional Tuna Fisheries Database records 31,412 mt for 7,861 days' fishing; for 1984 it records 1,478 mt for 436 days' fishing; and for 1985 it records 2,219 mt for 445 days' fishing.; ** remainder comprising mainly yellowfin)

Recent annual catches in the western Pacific have been c. 370,000 mt for yellowfin, one million mt for skipjack, 100,000-150,000 mt for bigeye and less than 10,000 mt for albacore (Hampton, 1993). Total tuna catches in the SPC statistical area (which includes PNG) have exceeded one million mt since 1989. The largest catches were recorded in 1991 (1.4 million mt). In 1993, an estimated 1,259,263 mt of tuna were caught, with skipjack catches showing a slight decrease and yellowfin catches a slight increase (Oceanic Fisheries Programme, 1994).

Artisanal landings of tuna have been recorded for the past four years on the DFMR database, Kavieng. The East New Britain landings records however, include longlined product.

Table 52 Foreign tuna catches (mt) by method in PNG waters between 1970 and 1991 from the SPC Regional Tuna Fisheries Database (sources: primarily South Pacific Commission, 1993, but also Tuna and Billfish Assessment Programme, 1992. These two references should be consulted for their data sources)

Year	Pole-and-line	Purse seine	Longline	Total
1970	-	35	3,884	3,919
1971	-	367	13,420	13,787
1972	8,306	226	6,481	15,013
1973	18,022	1,485	11,398	30,905
1974	45,268	1,178	6,282	52,728
1975	16,335	2,315	5,315	23,965
1976	7,068	10,666	7,062	24,796
1977	17,019	13,507	15,014	45,540
1978	2,346	14,648	19,547	36,541
1979	247	1,157	1,568	2,972
1980	17	11,523	12,424	23,964
1981	-	38,695	12,804	51,499
1982	97	95,203	10,911	106,211
1983	1,797	110,209	11,963	123,969
1984	127	132,091	7,181	139,399
1985	380	126,936	9,779	137,095
1986	155	97,229*	6,350	103,734
1987	2	78,323*	387	78,712
1988	-	78,269*	0	78,269
1989	-	235,018*	0	235,018
1990	-	148,273*	61	148,273
1991	-	182,715*	74	182,715

(* adjusted totals for under- or non-reporting of catches by Korean and Taiwanese fleets)

Table 53 Landings of tuna at the fisheries depot, East New Britain for the period 1990-93 (source: DFMR Kavieng)

Year	1990	1991	1992	1993
quantity (kg)	5,723	2,796	1,929	1,007*
value (K)	5,975	2,479	1,846	259

(* and additional 7,627 kg was longlined)

Table 54 Landings of tuna at the fisheries depot, Manus Province for the period 1990-93 (source: DFMR Kavieng)

Year	1990	1991	1992	1993
quantity (kg)	559	414	761	263
value (K)	282	208	562	285

1.17.3 Stock status

The tuna resource is PNG's largest, with 1993 estimates of sustainable yield as high as 300,000 mt/year (PNG 1993 Policies and Programmes).

Tagging and genetic work both demonstrate the lack of discrete stocks of tunas across the entire western Pacific, with mixing occurring across wide areas (Tuna and Billfish Assessment Programme, 1992).

Generally, stocks of skipjack and yellowfin are still lightly exploited in the western Pacific. Skipjack stocks are capable of sustaining a substantial increase in catches, and yellowfin catches can sustain a moderate increase over present catch rates (Tuna and Billfish Assessment Programme, 1992). A recent assessment of stock status of yellowfin, skipjack, bigeye and albacore tuna for the SPC statistical area has been made by Hampton (1993). In summary:

1. Although yellowfin catches in the western Pacific have doubled in the past decade, further increases in the annual catch to 600,000-800,000 mt could be sustained (Oceanic Fisheries Programme (1993) suggested that 600,000 mt was a suitable catch level).
2. Further increases in western Pacific skipjack catch to around 1.5-2.0 million mt per year on average appear to be biologically sustainable, despite increases in catch and cpue.
3. Bigeye catches of up to 210,000 mt per year probably are sustainable, although the level of exploitation of juvenile bigeye in the surface fishery may require monitoring.
4. Early albacore assessments suggest that increased catches of juvenile albacore could be sustained, although confirmation is required.

The harvest ratio (percentage of total mortality due to fishing) of skipjack in the PNG DFZ is about 9-13 per cent, while for yellowfin it is about 17-20 per cent. South Pacific Commission (1993) stated that these low harvest ratios suggest that large expansions in skipjack harvesting are biologically possible, whole smaller though significant increases in yellowfin catches are also possible. Increases in catches in PNG to up to three times the current level for skipjack and up to twice the current level for yellowfin appear to be possible (South Pacific Commission, 1993). Bigeye stocks are not thought to be over-exploited in PNG waters, especially as now it represented as a bycatch of the purse seine fishery. The stock could support a sizeable longline fishery in the PNG DFZ.

There has been a decline in albacore biomass since the mid 1980s following two poor year classes (1985 and 1990). Continued fishing of albacore at current and increased levels could quicken the decline in biomass (Oceanic Fisheries Programme, 1994). This is especially so for longlining. Oceanic Fisheries Programme (1994) cautioned against further development of albacore targeted longlining in the western Pacific until there is some evidence of stock recovery.

With regard to the structure of the species stocks (South Pacific Commission, 1993):

- for *skipjack,* two categories of hypothesis have been proposed. One category suggests that there is a series of genetically distinct stocks across the Pacific, while the other category suggests there is a clinal series of stocks;
- for *yellowfin*, fish inhabiting the area west of 180^{o} (i.e. including PNG waters) constitute a homogeneous population, and there appear to be three semi-independent western, central and eastern stocks with some mixing between the western and central stocks (and the central and eastern stock) (South Pacific Commission, 1993);
- for *bigeye*, it is assumed that there is a single, trans-Pacific stock.

Generally, no systematic declines in CPUE attributable to fishing activity have been observed for skipjack in the Pacific. Estimates of standing stock vary from 1.8-2.8 million mt (Hampton, 1992) to 2.5-3.7 million mt (Kleiber *et al.,* 1987, in South Pacific Commission, 1993).

It is believed that environmental effects probably have a greater effect on skipjack recruitment than does spawning stock size - for example, sea surface temperatures.

In yellowfin, fishing activity on previous generations have not affected the level of recruitment in populations. Hampton (1992) estimated that recruitment to the surface fisheries in the western tropical Pacific was approximately 190,000 mt/month. Whereas the CPUE of yellowfin from purse seining in the western Pacific has been stable to date, the longline CPUE has fluctuated widely over the years (South Pacific Commission, 1993). Recent analyses of tagging data have indicated a yellowfin stock size (available to the surface fisheries) of 1.8 million mt (South Pacific Commission, 1993).

CPUE of bigeye catches from longlining have been moderately constant since the late 1960s (Miyabe, 1989, in South Pacific Commission, 1993) and the species' population sizes have been constant for the period 1965-85, at least.

It has been recently suggested that albacore in the North and South Pacific constitute separate stocks and that albacore throughout the Pacific be considered as a single stock (Hampton, 1993).

1.17.4 Management

Current legislation/Policy regarding exploitation: PNG's major policy objective is the establishment of a viable domestic industry, comprising fishing fleets, processing and holding facilities such as canneries and cold storage, and onshore support facilities.

To meet this objective, the national government will permit

- national and foreign owned joint venture companies,
- per cent foreign owned operations as long as the companies are registered in PNG and own and operate PNG-registered vessels,
- access for purse seine vessels (in the long term) to territorial seas to facilitate duty free access to the European market for PNG canned tuna under the LOME Convention;

but will not permit

- the charter of foreign vessels by companies other than citizen and national companies,
- access to territorial seas outside of three miles to other than PNG-owned and registered longliners and a restricted number of purse seine vessels off-loading to a PNG cannery. The restriction placed on access to the territorial sea recognises the need to limit competition with coastal fishers.

The need to limit the use of purse seine vessels in the Western Pacific Region has been recognised by FFA member countries. PNG is a signatory to the Palau Arrangement that sets a ceiling on vessel numbers as part of an overall regional management plan. This limitation will create competition for licences in the region, thus increasing access fees and other spin-off benefits in the medium term.

The PNG government also places priority on establishing a domestic longline fishery for sashimi grade tuna, with good access to international air services or feeder routes to Japan.

PNG's longer term policy is to phase out the DWFVs and replace them with a domestic fleet. In the interim DWFVs will continue to operate, but only under formal access agreements with the State. Priority will be given to increasing spin-off benefits under the agreements, viz:

-- all DWFVs will be required to make at least one port call per year for the purposes of transhipment, provisioning and refuelling.

-- access to Archipelagic Waters will be allowed only to fleets that have invested in onshore developments such as construction of wharves, cold storage and/or processing facilities.

To facilitate compliance with access agreements, DWFVs will be required to lodge an annual bond that will be forfeited should the vessel breach its licence conditions.

INFOFISH International 4/94 also reported the imposition of a tightening of regulations to some of those listed above, including:

- foreign fleets to be based in PNG;
- all fish caught in PNG waters to be shipped through PNG ports; - all fuel and provisions required by licenced foreign vessels to be procurred in PNG; and
- licences to be restricted according to the supply of fish and allocated to foreign operators one year at a time. In contrast, PNG operators will be granted licences lasting five years.

Doulman and Wright (1983) pointed out that shore bases for longline caught fish should enhance the profitability of individual operators because, firstly, it would eliminate travel time to and from Japan and, secondly, increase the vessels' fishing time in PNG waters by 30 per cent.

Recommended legislation/Policy regarding exploitation: Some of the management policies which Kuk (1991) suggested *may or may not have been incorporated* into PNG Government policy. These are:

1. a reconsideration of the government's non-discriminatory licensing policy on foreign vessels;
2. provision of incentives for the development of a sustainable, competitive and integrated domestic tuna industry - such as development of infrastructure, exemptions from import duties (also for tuna vessels to be used in the fishery), reduction of export taxes, exemption on all tuna vessels from the fuel import duty of two toea/litre (a further incentive to the vessels basing in PNG) and reduction in the export tariff on round tuna export to be on a par with other PNG food exports such as tea, coffee and copra;
3. the PNG Government taking up equity in a domestic tuna fishery. Precedents have been set in the mining industry in PNG, for example; and
4. the capacities for surveillance and enforcement of regulations in the tuna fishery should be considerably enforced.

Kuk (1991) also suggested that gear selectivity and area and time closures would greatly enhance a future domestic tuna industry.

Regarding an exploitation policy for the tuna fishery, South Pacific Commission (1993) stated that

1. a controlled expansion of catches (by up to 50 per cent of the current catch) phased over several years would not affect the stock. It should be accompanied by improved collection of fisheries statistics; and
2. major under-reporting of catch and effort in the DFZ is being undertaken by Korean and Taiwanese fleets. This under-reporting are severely prejudicing fishery and stock assessments within the zone.

In my view, PNG's inabilities in the development and maintenance of its fisheries statistics base has seriously jeopardised the Government's custodianship role of its national resources and inhibited development in all of its fishing industry. This issue is probably the most important for the Government to address in the sector.

1.17.5 References

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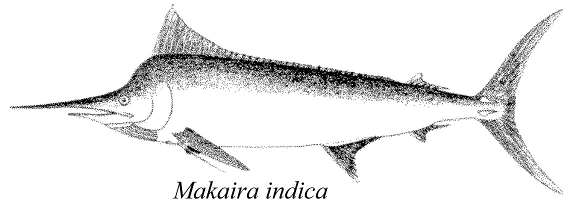
1.18 BILLFISH

1.18.1 The Resource


Makaira indica

Species present: Five species of billfish are present in PNG waters. These are *Makaira mazara* (blue marlin), *M. indica* (black marlin), *Tetrapturus audax* (striped marlin), *Xiphias gladius* (broadbill swordfish) and *Istiophorus platypterus* (sailfish).

Distribution: Black marlin and blue marlin are present in tropical and subtropical waters of the Indian and Pacific (and Atlantic) oceans. Black marlin are more closely associate with land than are blue marlin and striped marlin (Kailola *et al.,* 1993). Young black marlin are seasonally common in continental shelf waters while adults are usually restricted to oceanic waters. Black marlin are highly mobile, and they form major seasonal concentrations in certain areas of their range. The fish can move very long distances, and fish tagged off eastern Australia have been recaptured in the Milne Bay Province and off Bougainville (Williams, 1994). It is probable that the distributions and movements of male and female black marlin differ (Williams, 1994), particularly in the areas influenced by the New Guinea Coastal Undercurrent.

Blue marlin are oceanic fish rarely found in waters shallower than 100 m, or close to land. They concentrate year-round in tropical waters in the Pacific Ocean but part of their population undertakes large seasonal movements away from equatorial waters. The extent of these movements appears to differ between males and females (Williams, 1994).

Striped marlin are oceanic, inhabiting tropical to temperate waters of the Pacific and Indian oceans and are rarely found in shallow coastal waters. They generally inhabit cooler waters than do black marlin and blue marlin and their abundance increases with distance from the continental shelf.

Broadbill swordfish are oceanic fish, present in tropical and temperate waters. As juveniles they are common in tropical and subtropical waters. Broadbill swordfish typically move to surface waters at night and to deep (up to 600 m) waters in the day.

Sailfish are tropical to subtropical fish and, like black marlin, are closely associated with landmasses. Peak concentrations occur in and around PNG waters.

Biology and Ecology: Marlin spend most of their time in the top 100 m or so of the water column, above the thermocline, although the depth of the thermocline varies from one part of the ocean to another. Marlin tend to swim with the current direction.

<u>Black marlin.</u> There is a major concentration of black marlin in the north-west Coral Sea in September-December, where they spawn (Williams, 1994). They disperse after spawning. From April to August, maximum catch rates of black marlin are made in eastern PNG. Black marlin larvae have been found in the north-west Coral Sea. Black marlin females grow in excess of 700 kg (Kailola *et al.,* 1993) whereas males rarely exceed 200 kg. A 450 kg female would be more than 10 years old. Males have a slower growth rate although they mature at much smaller sizes than do females. Information from gamefishing shows that small (<100 kg) black marlin tend to be captured during the South East monsoon season and larger fish during the North West season. There may be major concentrations of immature black marlin (<60 kg) around the islands off south-eastern PNG during the south-east trade season (Williams, 1994).

<u>Blue marlin.</u> Spawning probably takes place year-round in equatorial waters (Kailola *et al.,* 1993). They also spawn in the north-west Coral Sea between December and February. Blue marlin females reach more than 900 kg while males weigh up to 170 kg. Males mature at 30-

40 kg, females generally between 47 kg and 80 kg (Williams, 1994). Growth rates of females are faster than for males after maturity is reached.

Striped marlin are true oceanic fish rarely found in shallow coastal waters. Striped marlin form pre-spawning aggregations off eastern Australia in September-October and spawning aggregations in November-December. There is little difference in growth rate and maximum size between the sexes. Striped marlin grow to 260 kg (Williams, 1994) and mature when 2-3 years old at between 27 kg and 40 kg.

Broadbill swordfish. Spawning takes place in waters warmer than 24°C - year-round in equatorial waters but in spring-summer in higher latitudes. They are reported to spawn in the Gulf of Carpentaria (Zane Grey, in Lewis and Smith, 1977). High concentrations of larvae have been collected south-east of PNG. Female broadbill swordfish grow more rapidly than males after age 2, and attain at least 450 kg (Kailola *et al.,* 1993).

Sailfish. Spawning occurs year-round in equatorial waters, in summer further south. Large fish are generally female. Sailfish may grow to 100 kg (average 25-40 kg) (Williams, 1994). Off eastern Australia, males mature at about 20-25 kg and females at 30-35 kg. Sailfish - more than other billfish - are inclined to form feeding aggregations (consume herring, pilchards, other baitfish, squid and crustaceans). These fish spend considerable time in nearshore coastal waters feeding on baitfish and PNG is regarded as the centre of the most prolific sailfish area in the Pacific (Lewis and Smith, 1977).

1.18.2. The Fishery

Utilisation: Sailfish and juvenile black marlin are caught incidentally by coastal PNG fishers. In the Milne Bay Province, and at Kupiano (Central Province) fishing for billfish is carried out late in the year, from canoes, in a semi-competitive manner.

Billfish are also caught in a commercial fishery and a recreational fishery in PNG.

Marlin form a bycatch of longline fishing operations for tuna in the Solomon and Bismarck seas. Information on catches pre-1970 was obtained by Williams (1994) and also by DFMR during 1991 (data at Kanudi: A. Richards, pers. comm.).

Gamefishing activity in PNG is based in Port Moresby (also accessing Eastern Fields, Gulf Province), Lae and Rabaul, with smaller clubs in Madang and Kavieng(?). Much of the fishing carried out is tag-and-release, and accurate records generally are kept of the fish tagged, or played. Reported good spots for gamefishing are off Bagabag Island near Madang, off Rabaul, and off 'the Hump' near Kokopo. Organised game fishing tours cater for significant numbers of tourists each year.

Production and Marketing: Catch rate information from longlining is summarised in Williams (1994) for Japanese longline activity in the south-western Pacific between 1962 and 1970.

Table 55	Longlined catches of billfish in PNG waters are tabulated below (source: Williams, 1994).

Month	Black marlin	Blue marlin	Striped marlin
January	Coral Sea, N. Sol. Sea, E. New Ireland	heavy in all PNG waters	no info
February	Coral Sea, S. Sol. Sea	ditto	no info
March	N. Solomon Sea	ditto	no info
April	N. Sol. Sea, N. WNBrit, E. New Ireland	Bismarck Sea, N. Sol. Sea, New Irelnd, B'ville	no info
May	N. Sol. Sea, Bismarck Sea, E. New Ireland	almost nil	no info
June	N. of Manus, E of Trobriands, B'ville	N. NG coast, Bismarck Sea, New Ireland	no info
July	Cent. Papua, S. Sol. Sea, SE New Ir + N. Britain	Bismarck Sea, New Irel., cent Sol. Sea, S. NBrit	almost nil
August	N. NG coast, all PNG (few)	Sol. Sea, New Ireland, B'ville, S. N Britain	Bismark Sea, Sol. Sea
September	lot in Coral Sea, Papua coast, N. coast, Sol.Sea, New Ireland, B'ville	Bismarck Sea, W. Sol. Sea	Bismarck Sea, Sol. Sea
October	ditto	few in Bismarck Sea	almost nil
November	ditto	N. NG coast, Bismarck Sea, Cent. Papua	almost nil
December	ditto	heavy in Bismarck Sea + Cent. Papua	Bismarck Sea, Cent. + E. Papua

Black marlin catch rates are low in the north-west Coral Sea in September and January; higher-than-average off south-eastern PNG in January and February; and high around New Britain from August to December. Blue marlin catch rates are high through most of the year in the northern half of PNG and off New Ireland during much of the year, and in the Solomon Sea during the North West season. Striped marlin catch rates in PNG waters are low all year. Broadbill swordfish catch rates decrease towards the equator, and there is a peak in February in PNG. There is no information on sailfish longline catches (although few sailfish are likely to be caught by longliners, which generally set in water deeper than 200 m).

From **gamefishing,** sailfish are the most frequently captured billfish in PNG waters (Lewis and Smith, 1977).

The Madang Gamefishing Club recorded the following catches between July 1988 and November 1992: sailfish - 48 (19-39 kg); black marlin - 6 (23.8-151 kg); blue marlin - 13 (31.5-206 kg).

The Port Moresby Gamefishing Club recorded catches since 1969. Combined catches during those 25 years are tabled below (although effort is not stated).

The largest sailfish landed by the Port Moresby club was 73 kg, largest black marlin was 282 kg, largest blue marlin was152 kg. The national gamefishing records are: sailfish - 79.8 kg (Madang); black marlin - 282 kg (Port Moresby); blue marlin - 253.5 kg (Lae).

Gamefishing clubs engage in tag-and-release activities. To June 1994, four black marlin, eight blue marlin and 72 sailfish had been tagged in PNG waters with NSW Fisheries gamefish tags.

Williams (1994) summarised the information on gamefish captures by gamefishing clubs in PNG.

Table 56 Port Moresby Gamefishing Club records, 1969-94

Month	Sailfish	Black marlin	Blue marlin
January	4	8	1
February	5	3	6
March	8	4	0
April	2	3	4
May	13	5	3
June	17	6	2
July	6	1	1
August	10	5	0
September	14	4	2
October	15	7	1
November	28	9	3
December	12	4	1

1.18.3 Stock status

The possibility of at least three stocks of black marlin has been suggested: south-west Pacific, eastern Pacific and Indian Ocean. However, it is possible that the eastern Pacific and south-west Pacific are one stock, and that interchange also occurs between the Indian and Pacific ocean stocks via the Banda Sea and the north coast of PNG. Juveniles occasionally move through the Torres Strait as well (Williams, 1994). Blue marlin comprise a single stock in each ocean. There is evidence for and against single stocks in the North and South Pacific oceans (Kailola *et al.,* 1993). Evidence supports either the existence of distinct stocks in the North Pacific Ocean and the South Pacific Ocean, or an interchange between these areas. Sailfish probably form many isolated and semi-isolated stocks throughout their range. There are two hypotheses regarding the species' stock structure: there is one stock distributed through the Pacific Ocean but with local areas of high abundance; or there are three stocks based in the north-western, south-western and eastern Pacific.

1.18.4 Management

Current legislation/Policy regarding exploitation: Game fishing tour operations are restricted to PNG citizens under the Investment Promotion Authority Regulations (1993 Fisheries Sector Policies and Programmes). The DFMR has recommended a licensing system for game fish operators in order to regulate the industry's growth and monitor its development. A levy of K100/boat/year has been recommended (1994 draft fisheries regulations).

Recommended legislation/Policy regarding exploitation: Gamefishing activity should be encouraged, because of its tourism potential. Visitors come to PNG specifically to gamefish. The DFMR should be mindful not to single out gamefishing from others as a fishery for 'heavy' regulation. *Gamefishing is the easiest of PNG's fisheries to manage*. Hence, the DFMR should be wary of taking management effort away from other fisheries to apply to gamefishing. In this fishery, the best management will come from collaboration and cooperation. The DFMR should maintain regular liaison with the gamefishing (and sportsfishing) fraternity in PNG as their members are keen fishers and dedicated conservationists. Information can/should be two-way.

Conversely, the catch of billfish from longlining activity should continue to be carefully monitored.

1.18.5 References

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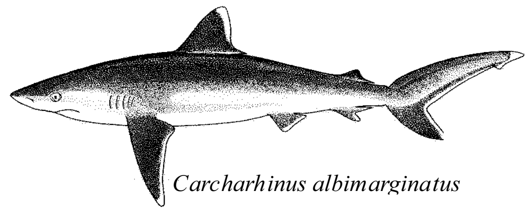
1.19 CARCHARHINID SHARKS (whaler, hammerhead) and PRISTID SHARKS (sawfishes)

1.19.1 The Resource



Carcharhinus albimarginatus

Species present: Carcharhinid and pristid sharks are abundant in PNG waters. Kailola (1987) recorded at least 29 species from PNG, and other species probably occur there (see Last and Stevens (1994).

Carcharhinid and pristid shark stocks supporting subsistence, artisanal and bycatch (commercial) fisheries in PNG waters are those associated with turbid waters on the continental shelf, and oceanic species. Shallow water reef sharks are generally not targeted by commercial operators (* but see profile 1.1, live fish - shark fin) and they are a bycatch of fishing for deep-slope fishes (profile 1.10).

The continental shark fauna in PNG includes common blacktip sharks, *Carcharhinus limbatus,* Australian blacktip sharks, *C. tilstoni,* whitecheek sharks, *C. dussumieri*, pigeye sharks, *C. amboinensis* and spot-tail sharks, *C. sorrah.* Very similar to blacktip sharks, nervous sharks, *C. cautus*, are probably included in commercial catches. Speartooth sharks, *Glyphis* species, inhabit inshore and fresh waters of the Gulf of Papua. Bull sharks, *C. leucas*, also feature in inshore-estuarine areas. Grey reef sharks, *C. amblyrhynchos,* and silvertip sharks, *C. albimarginatus,* inhabit deeper waters off coral reefs, as do tiger sharks, *Galeocerda cuvier* and hammerhead sharks, *Sphyrna* species. Oceanic sharks probably include silky sharks, *C. falciformis,* oceanic whitetip sharks, *C. longimanus,* and mako sharks, *Isurus oxyrinchus*. Blue sharks, *Prionace glauca,* are probably also abundant in PNG oceanic waters. Sawfish include *Anoxypristis cuspidata, Pristis microdon* (reported as *P. pristis* in Kailola, 1987) and *P. zijsron*. Pristid sharks inhabit inshore waters and freshwaters (*P. microdon*).

Distribution: Sharks occupy a variety of demersal, midwater to pelagic habitats over continental and insular shelves and are commonly found close inshore. Although the majority of shark species are truly marine, a number of them readily enter lower salinity estuaries, bays and lagoons and sometimes rivers and lakes. Almost all whalers and sawsharks present in PNG waters are also distributed in Australian waters, and in western Pacific waters.

Biology and Ecology: Nichols (1993) provided a brief overview of the biology of sharks. In general, sharks are difficult to age, have a slow growth rate (except when very young), and females tend to reach greater maximum lengths than males. The majority of commercially important shark species in the western Pacific region are ovoviviparous or viviparous, have a long gestation period and low fecundity. Shark species usually display sex and size segregation and females of some species may move inshore to give birth in selected nursery areas.

The characteristics of low fecundity, long gestation, slow growth, and often very localised movements result in many shark populations being very prone to recruitment over-fishing (Nichols, 1983).

A unique feature of the group is that their skeleton is largely composed of cartilage. They exhibit a top predator life style. Sharks produce few offspring at a time and have a long gestation period. Information on the reproduction of northern Australian sharks (and relevant to PNG) is given in Stevens and Lyle (1989) and Lyle and McLoughlin (1991). A trend is exhibited in sharks for larger individuals to produce more offspring. Sharks generally grow slowly, live for a long time, and take from 3-4 to 20 years to reach maturity (though more rapidly in tropical waters) (Davenport and Stevens, 1988; Nicholls, 1993). The diet of carcharhinid sharks consists largely of fish, yet includes cephalopods and crustaceans (Last and Stevens, 1994). Sawsharks consume approximately equal numbers of prawns and fish (Haines, 1979).

The maximum sizes of the common sharks in PNG waters are (according to Last and Stevens, 1994): *C. albimarginatus*, 275 cm total length; *C. amblyrhynchos*, 255 cm; *C. amboinensis,* 280 cm; *C. cautus,* 150 cm; *C. dussumieri*, 90 cm; C. *falciformis*, 330 cm; *C. leucas*, about 340 cm; *C. limbatus*, 250 cm; *C. longimanus*, 300 cm; *C. sorrah,* 160 cm; *C. tilstoni,* 200 cm; *Galeocerda cuvier*, about 600 cm; *Glyphis* species, 300 cm; *Isurus oxyrinchus*, 394 cm; *Prionace glauca*, 383 cm; *Sphyrna* species,186-600 cm; *Anoxypristis cuspidata,* at least 350 cm; *Pristis microdon*, 200-700 cm; *P. zijsron*, at least 500 cm.

1.19.2 The Fishery

Utilisation: Sharks are taken in subsistence and artisanal fisheries in PNG (although many cultures in PNG have strict taboos on the consumption of shark flesh). Sharks are currently taken commercially as a bycatch. Some shark species - such as whitecheek sharks, *C. dussumieri* - feature in the bycatch of trawl fisheries (of the prawn fishery in the Gulf of Papua). Other sharks are a bycatch of the tuna fisheries(?), of the longline fishery for deepwater sharks (profile 1.21), and of the 'live fish trade' (profile 1.1). Sharks are a common bycatch of commercial tuna fishing vessels in the western Pacific (Nichols, 1983) where usually only the fins are retained, although carcasses may be retained in the longline fishery. Sharks are also caught as bycatch around fish aggregation devices (FADs).

Sharks are utilised for their meat, fins, liver oil (profile 1.20) and skin. They are increasingly used as a source of bio-active agents. Sharkfin extract sells for high prices as a health agent and 'anti-aging' medicine. The Taiwanese value spot-tail sharks for their meat, and to a lesser extent, for their fins.

Sharks are also utilised by gamefishers. The Game Fishing Association of PNG includes five shark categories in its club records (blue, hammerhead, mako, tiger and whaler). Their 1993 all-tackle records are: blue- 42 kg, off Bougainville; hammerhead - 128 kg, off Rabaul; mako - 171 kg, off Port Moresby; tiger - 368 kg, in Langemark Bay; whaler - 183 kg, off Rabaul. Up until the end of 1993, 98 sharks had been tagged in PNG waters.

A noted **subsistence** fishery for sharks is that in the area of Kontu village on the west coast of southern New Ireland Province, where sharks are caught using a specialised rattle and noose (Wright, 1983). Other areas where 'shark calling' is still practised are the Gulf of Papua (Western Province), the Trobriand Islands (Milne Bay Province) and Tanga Island (north of New Ireland). In the Trobriand Islands and the Gulf of Papua, sharks are attracted to baited hooks; in all areas they are snared with loops. Traditionally in coastal areas of PNG, small quantities of shark were caught by coastal fishers for home consumption or for trading for other foodstuffs.

Information on the **artisanal** fishery in the Gulf of Papua is provided in DFMR files - e.g. reports on the Baimuru Fish Plant landings for 1979-81, and in Opnai (1984) for 1982 and 1983. Haines (1979) presented catch rates for shark in the deltas and rivers of the Gulf of Papua with commercial fishing gear. River catches with gillnet: 2-100 per cent composition of catch in night sets, 6-91 per cent composition of catch in day sets. Delta catches with barramundi net: 8-85 per cent composition of catch in night sets, 79 per cent composition of catch in day sets. Delta catches with monofilament gillnet: 2-82 per cent composition of catch in night sets, only 1 per cent composition of catch in day sets. Catch rates varied with time of year.

The basis for a **commercial** fishery was laid in 1976 when a permit was granted for a Taiwanese fishing vessel to undertake exploratory fishing for shark resources in the Gulf of Papua. The survey was conducted in Western Province, from September that year into January 1977.

Fishing was usually conducted around 30 km offshore from the mouths of the Fly and Bamu rivers, in 7-26 m water depth, and the nightly sets were 7-8 hours in duration. The gillnet used was 3,440 m, 14 m deep and 15.2 cm stretched mesh. Caught sharks were gutted, finned, headed and blast frozen.

Table 57 Catch composition of the survey in Western Papua, 1976-77 (source: Chapau and Opnai, 1983)

Species name	Common name	% of catch
Pristis microdon	saw shark	30.1
Sphyrna lewini	hammerhead	18.7
*Carcharhinus sorrah**	blacktip whaler	15.7
*Carcharhinus dussumieri**	Gray whaler	11.9
*Carcharhinus amblyrhynchos**	Tufi whaler	13.6

(*: originally listed as *C. spallanzani, C. menisorrah* and *C. tufiensis* respectively. Probable appropriate names after Compagno (1984), Kailola (1987) and Last and Stevens (1994).)

The whaler sharks accounted for 60.7 per cent of total catch by number. Small quantities of tiger shark (*Galeocerda cuvier*) were also present in the catch. No information is available on the size range of the sharks caught. In Taiwanese markets sharks are graded as small (2.5-15 kg), medium (16-30 kg) and large (>30 kg); and of these, medium-sized sharks gain the better prices.

Bony fish comprised a 10.1 per cent bycatch in the fishery. The fish catch comprised mainly Spanish mackerel (*Scomberomorus commerson*) (profile 1.16), mackerel tuna (*Euthynnus affinis*), longtail tuna (*Thunnus tonggol*) (profile 1.17), cobia (*Rachycentron canadus*), threadfin salmon (profile 1.3), dart (*Trachinotus* species) and queenfish (*Chorinemus* species). The cpue for different depths in the1976-77 survey are given in Table 58.

Table 58 CPUE of shark and fish for different depths off western Papua, 1976-77, in kg/hr:

depth	6-10m	11-15m	16-20m	21-25m	26-30m
C. sorrah	25.2	86.7	57	116.2	58.1
C. amblyrhynchos	17	137.2	87.1	10.8	89.1
C. dussumieri	46.1	37	35.9	3.2	28.8
S. lewini	58.8	61.4	5.5	41.4	25.6
G. cuvier	9.3	7.9	0	0	3.1
Pristis species	94.2	113.7	0	0	8

The cpue was highest for sharks in the most northerly areas - i.e. nearer the coast. Here the water was shallow enough for the nets to touch the seabed - hence accounting for the higher numbers of sawfishes. Carcharhinids were fairly evenly distributed throughout the five north to south fishing areas of the fishery. The highest cpue was in water 11-15 m; and the most productive soaktime was about 8 hours. Sawfishes and tiger sharks were only caught between 7 m and 15 m and again in deeper sets, while the remaining carcharhinid sharks were well-represented to the maximum depth fished of 26 m.

Commercial shark fishing by a Taiwanese fishing company in joint venture with a PNG-registered company commenced in the northern Gulf of Papua in the middle of 1980. Five Taiwanese vessels, using drift nets averaging 9 km in length, operated during 1981 (Richards, 1994b). In 1982 and 1983, only two vessels fished. Fishing trips during 1980 through 1982 lasted from 41 days to 125 days. Either one or two vessels were active in the fishery between 1982 and the end of 1992, and they were licensed to fish with shorter (1.6 km long) gillnets. Information on the fishery after 1983 is confused or not available (see later)as the Taiwanese vessels neither landed catch nor loaded fuel in PNG. They reported in at Port Moresby on arrival and on departure only.

Fishing using drifting gillnets was carried out by the Taiwanese vessels more than 20 km from shore, with the vessels drifting, fishing, over 8-10 km for a period of 4-5 hours from about 1700 hours. The gillnets were multifilament,12 m deep and in units of 3 km - joined to make 9 km long nets, and fished subsurface at 5-6 m depth. The nets were set at right angles to the shore. Sharks were caught in mid-water and catch rates were influenced by water clarity. Better catch rates were achieved on overcast nights than on clear, moonlit nights (Fisheries Research annual report 1982). The Taiwanese vessels were 35.75 m long, of 329 grt, powered by 1100 hp engines and carried a complement of 20.

The Taiwanese fishery in PNG waters ceased with the non-renewal of their licence in 1993. PNG fisheries authorities had received many complaints from prawn trawler captains regarding the navigational hazards caused by driftnet vessels fishing with driftnets 4-5 time longer than the licenced length (1.6 km); and the vessels had also fished in prohibited areas such as the Torres Strait Protected Zone (Richards, 1994b). Stewart (1990) noted a number of recommendations for the fishery, including a moratorium on the issuing of new licences, a cost/benefit analysis, improved management, reporting and surveillance of vessel activities. There have been reports of recent (1994) Taiwanese gillnet fishing activity in western Papua adjacent to the Torres Strait Protected Zone and bordering the PNG DFZ. [also see: Stewart, 1990]

With regard to the fishery for shark fins: The most valuable fin is the lower lobe of the caudal fin; then the dorsal fin, then the pectoral fins. Other fins are not used. The fins are cut with a 'moon cut' off the body, so removing the bulk of the body flesh. The prime species are tiger shark and hammerhead shark, then carcharhinids (e.g. blacktips, reef sharks). Fins should be at least 6 inches (c. 15 cm) long. The fins are graded and accordingly depending on size and type of fin, then colour.

Finally, another commercial fishing operation was a short-lived venture between the Bais Corporation and a Taiwanese company in 1991-92. No catch data were provided to DFMR (A. Richards, pers. comm.).

Production and Marketing: Information on artisanal landings of sharks - all groups - between 1979 and 1983 at the Baimuru Fish Plant is given below. The information is not of total catches, as they include the subsistence catch.

Table 59 Artisanal landings of shark at the Baimuru Fish Plant, 1979-83 (source: 1979-81, DFRM files; 1982-83, Opnai, 1984)

Year	1979	1980	1981	1982	1983
Av. landings (kg)	1,380*	4,056*	5,052*	3,511	12,182

(*: 1979-81 figures here are only for carcharhinid sharks (termed " 'lemon shark' (*Carcharhinus* spp)" in the files. (According to Last and Stevens (1994), 'lemon shark' is *Negaprion acutidens*, a species which inhabits inshore PNG waters). The 1979 to 1981 figures here are calculations of the amount of shark in the monthly average landings (all fish) for those years, said to be 14.11 per cent. The 1982 and 1983 figures are total shark and sawshark landings.)

Table 60 Total shark, whaler ('lemon') and sawshark landings (kg) at the Baimuru Fish Plant for 1984-89 are (source:DFMR files)

year	1984	1985	1986	1987	1988	1989
total shark	1,910	no rec	5,752	6,936	2,929	1,438
whaler shark	1,510	no rec	3,698	4,950	2,390	1,343

s/shark	400	no rec	2054	1986	539	95

Highest landings and cpue are achieved in the wet season (October through June-July).

Historically, product from Baimuru was sold to Goroka Seafoods Marketing, then channelled through DFMR and then Gulf Investments. However, because of an erratic transport system supply of product from Baimuru to the Highlands and Port Moresby (for example) was difficult to maintain. The price obtained in Port Moresby in 1984 was K2/kg (A. Richards, pers. comm.). An example of the amount of shark (all species) comprising the artisanal catch in the Gulf of Papua is shown in the record of purchases by the Baimuru Fish Plant in 1981.

Table 61 Purchases by the Baimuru Fish Plant, 1981 (source: Haines and Stevens, 1983)

Month	kg	Month	kg
February	604	August	853
March	356	September	705
April	195	October	537
May	plant breakdown	November	694
June	plant breakdown	December	373
July	338		

Table 62 Information on shark landings elsewhere in PNG is only available for East New Britain Province (source: DFMR Kavieng database)

Year	1990	1991	1992	1993
Quantity (kg)	218	193	33	1,250

The higher catch in 1993 is from longlining, commenced that year.

In the Western Province Taiwanese shark fishery, the average cpue was 1.01 mt/day in 1981 and 0.8 mt/day in 1982 (Chapau and Opnai, 1983). The relative proportions of species in the catches for both years are given in Table 63.

Table 63 Relative proportions of species in the Western Province shark fishery, 1981-82 (source: Chapau and Opnai, 1983)

Species	% by wt of total catch
Sphyrna lewini	40
Galeocerda cuvier	20
*Carcharhinus sorrah**	14
*Carcharhinus dussumieri**	13
Pristis species	5
Bony fish	8

(*: see explanation above.)

Spanish mackerel (probably also spotted mackerel, *S. munroi),* mackerel tuna and longtail tuna formed most of the bony fish bycatch. Indeed, *anecdotal reports suggest that the Spanish mackerel catch on occasions almost matched the shark catch*.

The 1982 Taiwanese catch in PNG comprised 166 mt of small sharks, 109 mt of medium sharks and 118 mt of large sharks (Fisheries Research annual report 1982).

Export figures for PNG for shark products are tabled below. Figures vary depending on source - e.g. for the Taiwanese fishery, which was apparently the only shark fishery operating in PNG in the early 1980s.

An unpublished report cited by Nichols (1993) in DFMR files entitled 'Taiwanese gillnet fishery in the Gulf of Papua' may provide more information on these catches (I did not know of its existence when I collected source data). In addition, unprocessed information on the Taiwanese fishery in 1990 and 1991 (at least) is at DFMR Kanudi.

Table 64 PNG shark products exported between 1980 and 1993.

Year	Shark meat (mt) source: DFMR files	Shark meat (mt) source: DFMR files via Wright, 1986	Shark meat (mt) source: Chapau & Opnai, 1983	Fins (mt) source: DFMR files	Fins (mt) source: DFMR files via Wright, 1986
1980	na	-	810	-	-
1981	na	471	405	-	-
1982*	107.6	472	-	1	-
1983	80	80	80**	na	-
1984	30	100	100**	na	-
1985	110	110	-	na	-
1986	173	45	-	0.5	0.54
1987	na	-	-	na	-
1988	na	-	-	na	-
1989	na	-	-	na	-
1990	126.2	-	-	na	-
1991	75.5	-	-	1.7	-
1992	19.2	-	-	1.605	-
1993	68	-	-	6.3	-

(*: and additional figure for 1982 is 393 mt, totalled from breakdown figures for shark in the Taiwanese fishery contained in the Fisheries Research annual report 1982. **: information from Chapau and Opnai, 1986).

I am assuming that the 1993 exports of shark products (68 mt meat, 6.3 mt dried fins) came from the tuna longline and prawn trawl fisheries, as well as small-scale sales to Chinese trade stores by villagers, as the Taiwanese fishery ended in 1992. Products may also have come from the miscellaneous dropline fisheries for deepwater snapper and - possibly - from the deepwater shark fishery.

Almost all of the exports go to Asian markets. The value of product ranged from K0.85-0.9/kg in 1986 to K2.40/kg in 1992 (DFMR figures) and dropped again to about K0.47/kg in 1993. Prices for PNG dried shark fin fetched K1.45/kg in Taiwan and K9.58/kg in Hong Kong (Wright, 1986). Prices in 1993 for shark fin in Asian markets ranged from US$11/kg for small (<10 cm) fins to US$79.25/kg for large fins (>40 cm) (source: *Infofish Trade News*).

Frozen shark meat exports from Lae during 1993 were 7,722 kg (Jan.-June) and 8,778 kg (July-Dec.), with a total value of K7,987 (source: Provincial Fisheries Officer, Morobe Province).

Milne Bay Province supplied sharkfins for export: 15.4 kg in 1991, 84 kg in 1992 and 125.9 kg in 1993 (source: Provincial Fisheries Officer, Milne Bay Province).

The DFMR's Women-in-Fisheries group in Lae (Morobe Province) had a training program in 1993 to learn how to better utilise shark meat.

1.19.3 Stock status

A preliminary observation on the status of the Taiwanese gillnet fishery was made by Chapau and Opnai (1986) when they suggested that the drop in cpue in the fishery after May-June 1982 showed that the resource was becoming fully exploited (catches decreased from about 2 mt/day in December 1980 to about 0.8 mt/day in late 1982.) This drop in cpue was based on a total effort of only 1,786 boat days (Chapau and Opnai, 1986).

The recovery rates of fresh to dried shark fins averages about 3 per cent. Although there is no recorded information on either the sizes of finned individual sharks nor on the sizes of fins in wet weight, a recorded export of 6.3 mt of shark fin from PNG in 1993 surely indicates a huge shark biomass. Just these figures convert to 210 mt of wet fin. Just supposing an 'average' shark yields an average of 5 kg of wet fin, the 6.3 mt of shark fin came from 42,000 sharks!

There are various reports about the status of shark stocks in PNG. Sundberg and Campbell (1982) observed that there was potential for a carcharhinid shark fishery off Wewak; and B. Shackles (pers. comm.) noted that high yields are achieved inshore in areas west of Daru.

1.19.4 Management

Current legislation/Policy regarding exploitation: There is no management of the fishery in PNG. Tariffs applying to export are 5 per cent of nominated value. Nichols (1983) says this is K1.50/kg.

Recommended legislation/Policy regarding exploitation: The biological characteristics of shark make stocks particularly sensitive to overfishing and no assessments of shark stocks in PNG have been made. However, determinants other than stock abundance will probably influence the scope and development of shark fisheries in PNG. There is increased international demand for shark products such as fins, oil and meat, especially in Asian markets. Offsetting this is the cost of fuel and the availability of, and access to, suitable fishing grounds.

Expected increases in catches of open ocean sharks in PNG waters will be attendant with increases in tuna longlining operations (witness earlier: the increased East New Britain landings in 1993).

Supply of locally-caught shark meat to the domestic market in PNG could alleviate imports of fish product, although marketing would need to be sensitive to taboos in many PNG cultures. Marketing would have to delete reference to 'shark' - successful in 1984 when shark fillets from the Baimuru Fish Plant were sold in Port Moresby under the name 'lemon fish'. Commercial fishers in Western Province have suggested that a viable fishery exists there for shark. Shark could be harvested from shore or out-to-sea, with 1,500 m gillnets. Larger vessels (20-25 m), with 20-40 mt freezer capacity and brine tanks would be required (B. Shackles, pers. comm.). Haines (1979) and Haines and Stevens (1983) were insistent that the inshore and delta regions of the Gulf of Papua could support a commercial shark fishery.

There is some scope for suggesting that development of an inshore shark fishery in Western Province and Gulf Province could alleviate pressure on barramundi (profile 1.9) stocks or even act as a replacement fishery for Papua New Guinean fishers so engaged. The inshore shark fishery might have to be closed during the seasonal movements of barramundi into coastal waters, but this measure probably would cause huge enforcement problems. Alternatively, different size meshes in gillnets in each fishery could provide a degree of management. Development of a fishery for Spanish mackerel (profile 1.15) in western Papua would interact with a shark fishery as well.

Participants in the shark fishery should be *licenced* and be required to *complete catch logbooks*. conservative allocation of licences should be made in the first instance, and preliminary quotas per licence brought in as soon as possible pending stock assessment estimates of MSY.

Information obtained from the adjacent Northern Territory and Queensland shark fisheries would aid in the management of these fisheries.

The reef fishery for live fish needs to be carefully policed to prohibit the taking of reef sharks for fins. f such harvest is permitted as a bycatch of the fishery, it needs to be carefully monitored and should be treated as a separate fishery. *Licences for live reef fish and aquarium fish harvesting must specifically exclude shark.*

Production of leather from shark skin is another industry based on shark. The leather is in demand on world markets. It is very durable and strong, is resistant to abrasion and has a unique appearance. However, the tanning process is complex and there are caveats on the quality, freshness, source and size of skins sent for tanning.

In summary, development of the southern PNG shark fishery should be encouraged as long as *strict monitoring and enforcement procedures* are in place and implemented. Catches of all shark from PNG waters should be recorded leading to estimates of stock and later of MSY. Because shark stocks are particularly sensitive to over-exploitation, the importance of keeping accurate records of catches cannot be overstressed.

1.19.5 References

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Acknowledgement:

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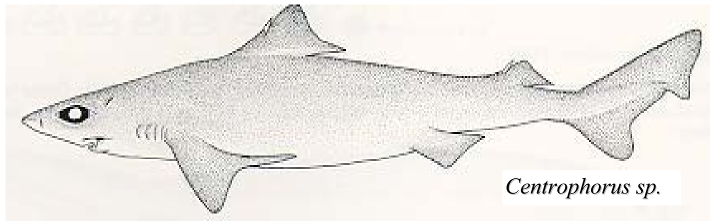
1.20 DEEPWATER SHARKS - SQUALIDAE

1.20.1 The Resource



Centrophorus sp.

Species present: The deepwater shark fauna of PNG is little known. The species of deepwater sharks taken in the PNG fishery are unknown, though it seems likely that a they include a species of gulper sharks, *Centrophorus*, family Squalidae. *C. granulosus* has been recorded from PNG (Last and Stevens, 1994). Other species - such as *C. moluccensis, C. squamosus* - probably also inhabit PNG waters (Compagno, 1984; Kailola, 1987; Last and Stevens, 1994). Last and Stevens recorded 14 genera of squaloid shark from Australasian waters, and of these least nine have tropical representatives. Other taxa which may be caught in the fishery could include the dogfishes *Centroscymnus* species and *Deania* species.

Distribution: Squaloid sharks have a vast geographic and bathymetric range, and they occur in all seas. Most taxa are found on or near the bottom on temperate to tropical continental and insular slopes to at least 3,675 m; members of *Centrophorus* to 6,000 m (Compagno, 1984).

A survey carried out in PNG circa the early 1980s (M. Chapau, pers. comm.) in the Wewak area (East Sepik River) revealed stocks of squaloid sharks to about 450 m. Near Kavieng, New Ireland Province, fishing trials conducted by DFMR staff in the early 1980s with deepsea lines and reels caught deepwater sharks including spiny dogsharks (*Squalus* species) and bull or bramble sharks (*Hexanchus* species). The sharks have little commercial value in Kavieng (Wright *et al.*, 1983). Another survey in deepwater was conducted in Manus Province in 1992.

Biology and Ecology: Gulper sharks (*Centrophorus* species) are larger dogfish occupying the outer continental shelf and slope, usually on or near the bottom 100 m to 2,400 m. *Centroscymnus* species have been recorded from about 200 m to 2,675 m, and *Deania* species from 73 m to 1,785 m. These sharks are ovoviviparous and usually bear 1-12 young. They feed on a variety of prey including squid, crabs, fish and jellyfish. Gulper sharks attain 100-160 cm total length, and dogfish reach about 70-170 cm (Compagno, 1984; Last and Stevens, 1994).

The majority of gulper sharks taken during experimental dropline fishing off Manus Island measured 85-90 cm total length (3-4 kg). The sharks were principally caught between the hours of 1800 and 0630, and none were caught between 1030 and 1730 hours (A. Richards, unpublished data).

1.20.2 The Fishery

Utilisation: Deepwater shark stocks are not utilised in PNG subsistence and artisanal fisheries. However, squaloid sharks are of interest to commercial fisheries because they yield large quantities of high value liver oil, or squalene. They are also processed for fishmeal. Shark liver oil is rich in the vitamins A and D and so is used as a health agent (e.g. in the form of shark liver oil capsules), high quality soaps and cosmetic oils. Shark liver oil is also used in the manufacture of lubricants, bacteriocides and pharmaceuticals. The crude oil is bleached, deodorised and fractionated, so producing several classes of oil products of which squalene is commercially significant (Summers and Wong, 1992). Squalene is often converted through a process known as hydrogenation to form a more stable compound.

The livers of male and juvenile dogfish on average have more squalene than do the livers of female dogfish (Summers and Wong, 1992). Livers of 10 species of squaloid sharks inhabiting New Zealand waters (*Deania, Centroscymnus, Centrophorus, Etmopterus* and

Dalatias species) average 20 per cent body weight. The yield of oil from catches of these species ranges over 74-90 per cent liver weight, with a mean of c. 84 per cent (Summers and Wong, 1992), and the yield of squalene extracted from the oil ranges over 41-73 per cent.

In PNG, a special exploratory fishing licence was granted in 1991 to Fisheries Consulting Services Pty Ltd to investigate stocks of and harvest deepwater sharks. The firm leased two Indonesian owned and crewed vessels and conducted fishing from the West Sepik Province along the northern New Guinea coast to well south in the Morobe Province, and along the southern PNG coast from eastern Central Province to Gulf Province. One fishing day was spent in the West New Britain Province. Over 1992 and 1993 most effort was performed in the East Sepik, Morobe and Central provinces (C. Hair, unpublished data). The original exploratory fishing licence allowed the vessels to fish inside 12 miles. This licence was revoked in 1992 and replaced with a licence forbidding access to waters inside the 3-mile limit. For most of 1994 a single vessel operated, and it is expected that two vessels will be operating the fishery in 1995.

The vessels fish with bottom-set longlines. They reportedly follow the 200-250 m depth contour, but examination of some supplied logsheets[1] show that they also make sets as deep as 900 m. In 1992 and 1993, the mean maximum depth of set was 592 m, and the mean minimum depth of set was 387 m. The mainline averages 12,260 m and is set 4 m off the seabed, with snoods not quite touching the seabed. The average number of hooks per mainline is 3,430 and they are spaced every 3-4 m. The lines are shot in the mornings and allowed to fish for 8-11 hours (C. Hair, unpublished data) before hauling begins (haul and set takes 4-6 hours, total). The trace is wire and circle hooks are used, the mainline is rope and branch lines are about 3 mm thick. Bait used is mainly squid imported from New Zealand, augmented with imported mackerel.

The vessels move regularly along their area of operation, only working one area for 1-2 days. The number of days fished varies within fishing months, a vessel fishing between 3 days and 28 days (average 17 days) per month (C. Hair, unpublished data). There are reports that this shark-fishing operation fishes inside the 3-mile zone - for example, in the Morobe Province and along eastern Papua (Central Province: near Abau and Kupiana). I expect that this is a result of the vessels following selected depth contours.

Shark livers are extracted and either put into aluminium containers or left on metal sheets in the sun. The oil is collected in containers as the livers dry.[2] In overcast weather, a solar drier is used, and the quality of oil gathered from the solar drier is said to be better (? as it takes a longer time to drain). The oil is exported to Japan, apparently via Indonesia (Japan Tariff Association import figures do not record shark liver oil coming from PNG).

Shark trunks are occasionally kept and sold, although storage capacity of the vessel and relative value are determining factors. Shark fins are kept and dried. It is reported that fins are collected from all species caught (including carcharhinid sharks caught as the lines are hauled) and dried. It is also reported that fins from the deepwater sharks fetch higher prices [I do not believe this can be correct: see my question under species 1.20.1. Also, small shark fins fetch only low prices.]

Large snappers (Lutjanidae) and goupers (Serranidae) are a bycatch of the operation and are sold on the domestic market at retail outlets in Port Moresby.

Production and Marketing: The operator reported that they catch 150-200 kg of shark each set and that the sharks weigh between 15 kg and 20 kg each - i.e. 10 sharks/set. However,

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[1] I have not been advised whether these logbooks are supplied voluntarily or not.

[2] I was unable to secure information on how long this operation took. Indeed, the description the operator provided of the processing was not clear.

logbooks show that in 1992 an average of 133 sharks were caught in each set, and in 1993, an average of 98 sharks were caught in each set.

The average weight of deepwater sharks caught in Central and Gulf province waters was 2.6 kg (C. Hair, unpublished data). However, deepwater sharks in East Sepik Province waters of the same species harvested by the PNG operator rarely attain 10 kg (M. Chapau, pers. comm.). Summers and Wong (1992) stated that squaloid sharks (New Zealand waters) range in weight from 2.1 kg to 17.7 kg [a mean of the difference is 7.8 kg].

Recovery rates quoted by the operator are that between 65 per cent and 80 per cent (mean 72.5 per cent) of the liver weight is recovered as oil and that the liver weight is about one quarter of the live weight of shark. This is close to the figure quoted for squaloids by Summers and Wong (1992) (above): 74-90 per cent (average 84 per cent) of live weight recovered as oil, and the liver weight comprising 20 per cent of the body weight.

Taking the conversion figures stated by the operator for PNG squaloid sharks of 72.5 per cent of liver weight = oil weight/shark, and 25 per cent body weight = liver weight/shark, estimates of the numbers of sharks caught in PNG waters for the stated amount of exported shark oil can be calculated.

Extrapolations such as the one below serve only to underline the lack of information in the fishery and the need for impartial observation of the fishing operations and data recording. At the very least, the above table shows that in 1993 there either was serious under-reporting of sharks or, that the DFMR database greatly over-states the amount of oil exported.

Table 65 Calculations of the average weight of sharks caught in PNG waters needed to supply stated export quantities of oil.

av. live shark weight (source)	liver wt/shark	oil wt/shark	no. of sharks for 1991's 46.6 mt oil*	no. of sharks*** for 1992's 57.2 mt oil*	no. of sharks*** for 1993's 141.3 mt oil*
15 kg (operator)	3.75 kg	2.72 kg	17,132	18,824	51,949
10 kg (Chapau)	2.5 kg	1.81 kg	25,746	31,602	78,066
7.8 kg (New Zealand)	1.95 kg	1.41 kg	33,050	40,567	100,213
2.6 kg (logsheets)**	0.65 kg	0.47 kg	99,149	121,702	300,638

(Key: * from DFMR database; ** the logsheets do not state whether this weight refers to whole or processed shark; *** the logsheets recorded 37,551 sharks caught in 1992 and 18,902 caught in 1993).

Note: 1993 records for shark oil exports from Lae are 8.3 mt (Jan-June) and 14.4 mt (July-Dec.) (DFMR database).

According to DFMR the 1991 exported oil was valued at K108,741 (fob) and the 1993 exported oil was valued at K706,735 (fob). There is no Customs duty applicable to shark oil.

Shark oil imported to Japan from Indonesia received 796 Yen/kg in 1989 rising to 1,308 yen/kg in 1991. In 1994 it received 1,279 yen/kg on average (the highest price received for imports from 12 supplying nations in that year).

The PNG operator estimated that 700 kg of fish bycatch are retained and marketed from each trip (relative value of this bycatch and freezer space would influence how much of it were retained). The logsheets do not support that estimation. According to them indeed, for all of

1992, only 762 kg of bony fish were retained and for all of 1993, only 184 kg of bony fish were retained.

1.20.3 Stock status

The PNG operator reported that he has not observed a decline in his cpue. The pattern of the fishery - i.e. constantly moving over a long distance area - would have contributed to a constant stock level. Without information on the resource composition, size and monitoring of the fishing operation, it is impossible to forecast the sustainability of the resource. There is reportedly no difference in catch rates between night and day sets. Daytime sets could yield fewer deepwater sharks (shark attacks when hauling; capture of more bycatch).

C. Hair (unpublished data) found that the inconsistent fishing pattern in PNG waters over 1992 and 1993 made it difficult to interpret trends in the catch. Overall, slightly higher catch rates (calculated as number of sharks/500 hooks) were recorded initially in the northern PNG region, but these dropped off in 1993. The more consistent catch rates in the southern PNG region also dropped off in 1993. Nevertheless, there is a suggestion of seasonal trends in the fishery.

Without knowing how many sharks are being taken, and of what species, it is impossible to detect real trends in this multi-species fishery. Moreover, fishing is taking place over a very wide spatial scale (geographic area) which means that over-exploitation - if it occurs - would be difficult to detect in the short term, even though it may be happening on a local scale (C. Hair, unpublished data).

In New Zealand waters, the catch rate of squaloid sharks is greatest between 600 m and 800 m, and the overall catch rate (all species) is about 200 kg/hr. Summers and Wong (1992) estimated that the annual sustainable yield of deepwater sharks would not exceed 2,250 mt which would yield approximately 450 mt of livers and (by calculation) 378 mt of shark oil.

1.20.4 Management

There is currently no management of the fishery. The operator completes and submits logsheets to the DFMR as part of[3] the licence requirements.

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: The world market for natural skin care products (containing squalene) is growing rapidly and the demand for this substance will increase. PNG's deepwater shark stocks could supply some of this demand, but there is potential for them to be over-exploited unless the existing fishery is contained and developed in a sustainable manner.

<u>Validated information on the deepwater shark fishery in PNG is required urgently. The presence of a trained observer on the operating vessels is a premium requirement.</u> Specimens of shark should be sent for correct identification, accurate weights of caught shark and bycatch fish should be made, sexes of the sharks, and fishing information recorded. Logsheets suited to the fishery should be developed. These are primary steps to permitting an assessment of the stocks leading to recommendations for management.

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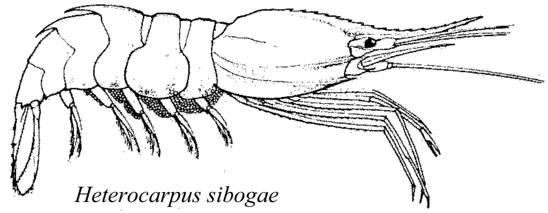
2.1 DEEP WATER SHRIMPS

2.1.1 The Resource



Heterocarpus sibogae

Species present: Shrimps belonging to the division Caridea were found to be present in PNG waters during two short surveys. They are *Heterocarpus sibogae, H. gibbosus* and *H. dorsalis* (off Madang and Port Moresby), *H. laevigatus* (off Port Moresby), *Metanephrops andamanicus, Plesionika longirostris* (both off Madang), *P. bifurca* and *Nematocarcinus undulatipes* (off Port Moresby). Additional species were recorded from spew samples of deepwater snappers (Lutjanidae): *Eugonatonatus crassus* and *H. ensifer* (both off Kavieng: Richards, 1987) and *Nematopalaemon tenuipes* (off Kavieng: King, 1982). The main commercial species in this checklist are the 'nylon shrimps' belong to the genus *Heterocarpus: H. laevigatus* forms the basis of a fishery in Hawaii, and *H. gibbosus* has commercial possibilities in south-west India (Suseelan, 1976, in King, 1988). In addition, scampi (*Metanephrops andamanicus*) has a high commercial value in existing fisheries (e.g. off the North West Shelf of Australia).

Distribution: The *Heterocarpus* species listed above have at least an Indo-Pacific distribution. *N. tenuipes* is also known from the Indo-west Pacific (Holthuis, 1980). According to King (1993) deepwater shrimps have been found in virtually all Pacific Islands where surveys have been attempted, including Fiji, Vanuatu, Samoa, Tonga, Marshall Islands, Hawaii, French Polynesia, Kiribati and Palau.

Biology and Ecology: Caridean prawns differ from penaeid prawns in that the pleuron (covering shell) of the second abdominal segment overlaps the pleura of both the first and third segments, and the third pair of walking legs does not have pincers. Furthermore, carideans carry fertilised eggs externally beneath the abdomen (the 'tail') - which is often proportionally smaller than that of penaeids - while penaeid prawns release their fertilised eggs into the water column (King, 1993).

Deepwater shrimps inhabit the steep outer reef slopes of islands and the continental slopes of large land masses. Their distribution is relative to depth, with each particular species occupying different but overlapping depth ranges. The medium-sized *Heterocarpus* species predominate in catches from depths of more than 400 m. For example, one of the largest species found, *H. laevigatus*, is widely distributed in Pacific islands in depths of more than 500 m. There is some evidence that deepwater caridean shrimps move between different depths on the outer reef slopes. *H. gibbosus* in Fiji appears to move between depths of about 450-550 m seasonally (King, 1993) and in Hawaii, *H. laevigatus* migrates from depths of about 550 m to 700 m during the egg-bearing season (Dailey and Ralston, 1986, in King, 1993). In PNG, *H. sibogae* and *H. gibbosus* were collected from depths of 340 m to 650 m, *H. dorsalis* from 550 m to 650 m and *H. laevigatus* from 650 m (King, 1982; 1988).

Palauan studies showed that *H. laevigatus* tends to be a solitary animal that gradually accumulates around bait sites over a prolonged period (Saunders and Hastie, 1992). It occurs there in the same depth range as the geryonid crab, *Chaceon granulatus*.

Tropical deepwater caridean shrimps have separate sexes. Eggs are carried externally on the pleopods of ovigerous females, and the number of eggs carried may exceed 30,000 on the larger *Heterocarpus* species (King and Butler, 1985, in King, 1993). Female *H. laevigatus* reach sexual maturity between 40 mm and 43 mm carapace length, corresponding to a relative age of 4-4.6 years. The incidence of ovigerous females appears to vary with the time of year. In Fiji, over 50 per cent of female *H. laevigatus* were carrying eggs in the months of April, May, June and July (1979-81). Information from the northern hemisphere for the same species indicates that the spawning season of *H. laevigatus* is the winter season of each hemisphere (King, 1993).

The analysis of length-frequency data has been used to estimate the growth of several species of deepwater shrimps in Fiji, including *H. sibogae*, *H. gibbosus* and *H. laevigatus*. Growth data for *H. laevigatus* in Fiji suggest that the growth coefficient (K) is 0.27 and that the largest size groups in the samples were over 8 years of age, at an L_∞ of 57 mm. Instantaneous natural mortality rates for *H. laevigatus* in Fiji were estimated to be 0.66 yr^{-1} or 48 per cent/year. A combination of slow growth rates with high natural mortality rates suggests that the biomass of shrimps from a given recruitment is maximised at an early age, after which the available biomass rapidly declines. The greatest biomass in an unexploited population of deepwater shrimps is when it's members are about 3 years of age (King, 1993).

2.1.2 The Fishery

Utilisation: There is no fishery for deepwater shrimps in PNG. According to DFMR files, discussions were held with a large Australian fishing company in 1987-88 concerning the possibility of seeking out stocks of commercially acceptable deepwater shrimps (such as *Plesiopenaeus, Aristeomorpha, Haliporoides* and maybe *Metanephrops*) but the surveys were not carried out.

Deepwater shrimps in the Pacific islands countries are caught in baited traps. Although several different types of traps and baits have been used, baits of oily fish such as tuna heads or mackerel, provide the highest catch rates. Most traps are made from steel rod frames, covered with galvanised wire or plastic mesh. Traps with side, rather than top entrances appeared most efficient in Fijian surveys (King, 1993). The traps are usually laid in groups of two or three with the use of an echo sounder to select suitable fishing depths and substrates. The traps are usually left overnight and recovered the next day with the aid of a winch.

Production and Marketing: In a survey of the Hawaiian Islands during 1983 and 1984, a commercial fishing vessel, using traps with a volume of 1.84 m^3 obtained an average catch rate of 12 kg/trap-night (Tagami and Barrows, 1988, in King, 1993) of mainly *H. laevigatus*. Although 159 mt of shrimp were landed in the fishery in 1984, it since declined. Small scale trap fishing has been carried out in Guam and Fiji. Mean catch rates with small traps at optimum depth range from 1 kg/trap/night to 3 kg/trap/night.

Apart from Hawaii, catch rates in tropical Pacific islands so far investigated are not high enough to offset the high cost of fishing them (King, 1993).

Once the shrimp have been harvested, their processing requires special care with adequate chilling, freezing and packaging facilities readily available. Individually quick-frozen deepwater shrimps and fresh (iced) whole shrimps are the most acceptable.

2.1.3 Stock status

There is no information on the status of deepwater shrimp stocks in PNG. A study in the Marianas Islands suggests that *H. laevigatus* is particularly vulnerable to even moderate trapping (Ralston, 1986, in King, 1993).

The brief surveys conducted in PNG indicated the need for further surveys. Areas of suitable habitat were identified by King (1982): off Port Moresby, east of Tufi, Wewak, east of North Cape, Kavieng; also Madang.

2.1.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: King (1982; 1993) provided information on research surveying and methods of stock assessment and yield estimation required to assess the potential for a fishery based on deepwater shrimp resources. In his account he emphasised the importance of collecting financial information related to potential exploitation when conducting shrimp trapping surveys. He advised that the following questions be addressed:

1. are the catch rates from preliminary surveys high enough to justify commercial development?
2. if the catch rates are high enough, at what level of exploitation are the catch rates sustainable?
3. is the market value of the product (price to fishers) likely to be high enough to offset the high costs of fishing in deep water?

For example, based on data collected in Kiribati, King showed that a mean long-term catch rate less than 2 kg/trap may not make the high cost of deepwater trap fishing economically viable.

Added to the cost of required vessels, bait supplies, equipment and so on, the handling and marketing of commercial catches of deepwater shrimps in PNG could present problems because of the large distances and disparate areas (King, 1982). Should future surveys indicate commercial levels of deepwater shrimp stocks in PNG, the stocks could be harvested with other resources. For example, a small-scale fishery combination of deepwater shrimp + deepwater crab (*Chaceon granulatus*)* trapping is developing in Palau (Hastie and Saunders, 1992; King, 1993), and a combination deepwater snapper + deepwater shrimp fishery is also developing in Mauritius (King, 1990). This possibility is more real in PNG (King, 1982). The shrimp traps could be hauled, rebaited and reset before beginning line fishing for snapper. Depending on the target species, the trap fishing time could be longer than one night (a prolonged period required for *H. laevigatus*, for example).

*The deepwater crab, or Japanese red crab has provided yields in excess of 5 kg/trap at optimum depths in Palau (Hastie and Saunders, 1992). This species is highly marketable, already with an established Asian market. The crabs have a high post-trapping survival rate, and can attain a weight of 2 kg. Surveys should reveal whether this crab is present in commercial quantities in PNG waters as well.

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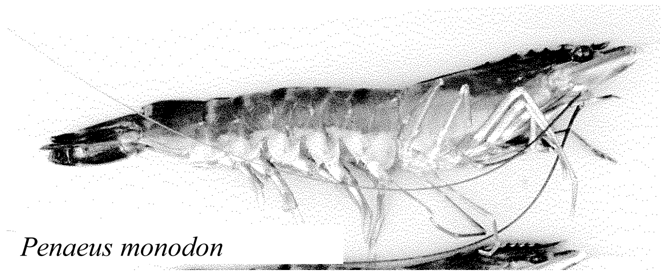
2.2 SHALLOW WATER MARINE PRAWNS

2.2.1 The Resource



Penaeus monodon

Species present: More than 40 species of prawns have been recorded from PNG (Polovina and Opnai, 1988); however, only a few of these are commercially exploited. In the Gulf of Papua prawn fishery, banana prawns (*Penaeus merguiensis, P. indicus*: Wafy, 1991)) form 50 per cent of the catch, endeavour prawns (*Metapenaeus demani* (demon prawn)*, M. ensis* (red endeavour or greayback prawn)*, M. eboracensis* (york prawn)) form 20 per cent, tiger prawns (*Penaeus monodon* (giant tiger or black tiger prawn)*, P. semisulcatus* (grooved tiger or green tiger prawn)*, P. japonicus* (Japanese tiger prawn)) form 10 per cent and coral prawns (mainly *Parapenaeopsis sculptilis*, also *P. cornuta*) form 20 per cent (Frusher, 1984; Opnai, 1988). *Metapenaeus* species, *P. monodon*, *P. merguiensis* and *P. semisulcatus* are also present in Milne Bay (Coates *et al.,* 1984). In the Torres Strait prawn fishery, blue endeavour prawns (*M. endeavouri*) comprise 51-58 per cent of the catch, brown tiger prawns (*P. esculentus*) form 38-46 per cent of the catch and the remaining 10 per cent is largely made up of red spot king prawns (*P. longistylus*) (Staples *et al.,* 1994). *M. dobsoni, M. affinis* and *P. indicus* (Indian banana prawn) occur in the Murik Lakes and waters off the East Sepik Province, Ramu River mouth and Madang, along with other species.

Distribution:

Species	Distribution	Source
Penaeus merguiensis	IWP: Persian Gulf to New Caledonia	Holthuis, 1980
P. monodon	IWP: East Africa to Tonga	Holthuis, 1980
P. semisulcatus	IWP: South Africa to N. Aust.	Kailola *et al.,* 1993
P. japonicus	IWP: East Africa to Fiji	Holthuis, 1980
P. indicus	IWP: East Africa to N. Aust.	Kailola *et al.,* 1993
P. longistylus	IWP: SE Asia to N. Aust.	Kailola *et al.,* 1993
P. esculentus	N. Aust.and Torres Strait	Kailola *et al.,* 1993
Parapenaeopsis cornuta	IWP: India to N. Aust.	Holthuis, 1980
P. sculptilis	IWP: Pakistan to N. Aust.	Holthuis, 1980
Metapenaeus affinis	IWP: Arabian Sea to Hong Kong, N. NG	Holthuis, 1980; Frusher, unpubl.; Wafy, unpubl.
M. demani	N. Aust. and S. PNG	Holthuis, 1980
M. dobsoni	IWP: India to Philippines, N. PNG	Holthuis, 1980; Frusher, unpubl.; Wafy, unpubl.
M. eboracensis	N. Aust. and S. PNG	Holthuis, 1980
M. ensis	N. Aust. and S. PNG	Kailola *et al.,* 1993

(IWP: Indo-west Pacific)

Biology and Ecology: Penaeid prawns, Penaeidea, are commonly referred to as either prawns of shrimps. They are marine prawns and generally inhabit tropical and subtropical waters. Exploited species belong mainly to the genera *Penaeus*, *Metapenaeus* and also *Parapenaeopsis* (coral prawns).

Penaeid prawns generally have an annual life cycle; they are fast-growing and short-lived. Adults spawn in deeper nearshore waters. Unlike other prawn groups, lobsters and crabs, penaeid prawns shed their eggs directly into sea water. The planktonic larvae drift into estuarine areas, deltas, and seagrass beds where they grow to maturity through a succession of moults. The period of time in the nursery areas takes about 3-4 months (to 18-20 mm carapace length (CL) for *P. merguiensis*, to 12-14 mm CL for the metapenaeid prawns). The oceanic stage begins when the prawns emigrate from the nursery areas to inshore waters where, after a period of growth, they move into deeper water to spawn (in 10-20 m for *P. merguiensis, M. demani* and *M. eboracensis*, 35-60 m for *M. ensis* and *P. semisulcatus*) (Frusher, 1982). Most emigrations occur during the wet season (from February to June in the northern Gulf of Papua). The prawns exhibit tidal and diurnal rhythms, with the greatest emigration taking place at night during ebb tides. The size of the emigrating prawns is related to rainfall and salinity.

The importance of coastal deltaic zones as nurseries for the early life history of many species of penaeid prawns has been well documented. In the Gulf of Papua, all of the major species except *P. semisulcatus* use the deltaic zones as nursery regions (Frusher, 1982) and have a `typical' penaeid life cycle. In the Purari and Aird river deltas, juvenile banana prawns are associated with mangroves and areas of high salinties up to 15-20 parts per thousand (ppt) (Frusher 1982; 1984) and juveniles of other species (such as *P. monodon* and *Metapenaeus* species) with mixed vegetation of *Sonneratia* species and *Cyperus* species (Frusher, 1984; Fisheries Research annual report 1985-1991). *M. eboracensis* juveniles show marked seasonal variation and dominate when the abundance of other species is low. They are present in high concentrations during August-September (Frusher, 1982) and in medium salinity. *M. ensis* juveniles are present only in low salinity areas of the Purari River delta and regions further upstream (McPadden, 1980). *M. demani* juveniles are common in less saline areas, dominating where salinity is less than 5 ppt (Frusher, 1982).

In the Torres Strait, the commercial prawn species rely on seagrass beds occurring on many reef tops for nursery and protective areas. Juvenile prawns settle on the reef tops in waves, with January to April being the period of highest settlement (Williams, 1994). Most juvenile prawns emigrate from the beds after about two months, when they are 25-45 mm long. In the Western and Gulf provinces, *P. semisulcatus* postlarvae use coastal seagrass flats as nursery areas (Frusher, 1982) with juvenile prawns being most abundant between September and May (4-22 mm CL) (Fisheries Research annual report 1983).

Chapau (1991) found that concentrations of juvenile and adult prawns in the Murik Lakes (East Sepik Province) varied with depth and salinity - a like situation to that observed in the Gulf of Papua. Chapau found that banana prawns (*P. merguiensis, P. indicus*) inhabited waters of more than 10 ppt salinity while endeavour prawns (*M. dobsoni, M. affinis, M. ensis, M. demani*) inhabited water of 1-7 ppt. The mouth of the Sepik River is suited to endeavour prawns (fresh at mouth). In the Murik Lakes where the salinity is 1 ppt the ratio of prawn species is 15.8 per cent banana prawns and 73.7 ppt endeavour prawns, whereas where salinity is 10-20 ppt, the ratio is 88.2 per cent banana prawns and 11.8 per cent endeavour prawns.

In the Gulf of Papua *M. ensis* occurs in all areas and depths but it is the dominant penaeid species in waters deeper than 30-40 m (Tenakanai, 1980; Branford, 1982; Kolkolo, 1983). *M. demani* and *M. eboracensis* occur mainly in water shallower than 30 m and particularly around Orokolo Bay. Trawls in water shallower than 20 m are dominated by *P. merguiensis* and *P. monodon* inhabits all depths, while *P. semiculcatus* inhabits only waters deeper than 30 m in the western grounds of the fishery (Gwyther, 1980). In Milne Bay, banana prawns similarly dominate in shallower water (5-10 m) and tiger prawns are more common in deeper water (15-25 m) (Coates *et al.,* 1984).

Mature females of all metapenaeid prawn species are present in the Gulf of Papua throughout the year, suggesting both continuous spawning and recruitment (Tanakanai 1980; Gwyther, 1980). The major recruitment is at the beginning of the main wet season for most prawn species. When there is more fresh water around however (in the wet season, April-October in the gulf), there is less available nursery habitat. Annual recruitment of *M. ensis* occurs in two pulses, one much larger than the other (Wafy, 1990). The major recruitment takes place between March and May and the minor one takes place between November and January (Gwyther, 1980; Tenakanai, 1980). Recruitment of banana prawns (*P. merguiensis*) in the northern Gulf of Papua also occurs throughout the year but there are seasonal peaks from March to April and August to November, following the monsoons (Fisheries Research annual report 1985-1991). Time series analysis and monthly progression of banana prawns and catch per unit effort by size studies performed by Polovina and Opnai (1988) suggested that banana prawns recruit to the fishery in February at a mean CL of 25 mm. An inverse relationship between the minimum monthly rainfall in the last quarter of a and prawn catches in the subsequent year was demonstrated for the time series analysis. For example, years with low rainfall around November will result in good catches of banana prawns in the next calendar year and years with more-than-average rainfall around November will result in poor catches. Staples and Rothlisberg (1990) noted that the pattern of two cohorts of banana prawns a year is common in the Indo-West Pacific and that the influence of rainfall resulting in differential survival of juveniles caused one of the cohorts to contribute more to the offshore fishery than the other.

The major metapenaeid in the Gulf of Papua prawn fishery is *M. ensis* (Tenakanai 1980). Male *M. ensis* in the Gulf of Papua are estimated to have growth parameters of CL_∞ = 40.8 mm, BL_∞= 122 mm and K of 2.5/year (Wafy, 1990). Their life duration is slightly more than one year. Mortality (Z=M+F+emigration) is highest for the length range 25-31 mm (CL) - when the prawns are migrating and fishing effort is concentrated on the depth range 20-30 m. Wafy (1990) considered that the high fecundity of *M. ensis* (500,000: Gwyther, 1982) may compensate for the species' high observed mortalities. From tagging data on *P. merguiensis*, Gwyther (1982) calculated a growth parameter of 0.136 and 0.116/week for K, and a CL_∞ of 29.4 mm for males and 35.3 mm for females.

Tagging studies of *P. merguiensis* in the Gulf of Papua in 1979 and 1980 (Frusher, 1985) showed that the distance emigrating prawns moved was similar for both sexes. Of the recaptured prawns (234 out of 8,119 releases) 46 per cent moved in an easterly direction while 40 per cent showed only localised movement (less than 10 km). Frusher (1985) found that *P. merguiensis* undertook large migrations moving up to 80-150 km from a major nursery ground to the main fishing ground. Gwyther (1983) also noted that there appeared to be an adult migration away from the main areas of recruitment of banana prawns - the mangrove areas to the west of the Purari River delta - as the grounds adjacent to Kerema and Cape Blackwood provide the highest comemrcial yield.

Many prawn species favour soft mud substrates, where they feed on particulate matter. Some tiger prawn species however, are found over hard, sandy substrates.

Female *P. semisulcatus* mature at 30 mm CL (Buckworth, 1985 in Kailola *et al.,* 1993). *P. monodon* females grow to 336 mm total length and more than 150 g weight. *P. longistylus* females attain 180 mm total length and mature at 24 mm CL in Torres Strait (Somers *et al.,* 1987, in Kailola *et al.,* 1993). Females of *P. merguiensis* can grow to 240 mm total length and have a fecundity of 100,000-400,000 (Rothlisberg *et al.,* 1985 in Kailola *et al.,* 1993). Males of all prawn species are smaller than females. Banana prawns live 12-18 months.

2.2.2 The Fishery

Utilisation: There are four prawn fisheries in PNG. The Gulf of Papua, Orangerie Bay and Torres Strait fisheries are identified as industrial fisheries, while the Western Province fishery is artisanal.

The Gulf of Papua fishery area is along the coast from the Fly River mouth to Iokea in the east, and extends seaward to the 40 m contour. About 9,603 sq. km of this area are trawlable, although only 1,388 sq km receive more than 50 per cent of the total fishing effort (Vonole, 1989). Fishing effort concentrates in inshore areas between Orokolo Bay and Kerema Bay and Freshwater Bay and the Lakekamu River estuary, an area equal to 13.1 per cent of the defined trawling area for the whole fishery. The areas west of Kerema Bay are the major endeavour prawn grounds (Tenakanai, 1980). Presence of higher stock densities and their more sheltered aspects make these areas more attractive to vessels.

The Gulf of Papua fishery covers the Western Province and the Gulf Province and separate licences are issued for trawling in either province. This fishery is for larger vessels (c. 24-30 m length) because of the prevailing weather conditions, although smaller vessels occasionally fish.

The main season in the Gulf of Papua prawn fishery is from February to August when catches average 96 mt/month, with well over 100 mt/month between April and July (Fisheries Research annual report 1984). From September to January catches average about 10 mt/month lower. The total catch is about 1,200 mt/year with banana prawns (*P. merguiensis*) being the target species (50-60 per cent). *M. ensis* (majority), *M. demani* and *M. eboracensis* comprise another 20 per cent. Tiger prawns comprise 10-15 per cent, and command high prices (Frusher, 1982; Opnai, 1988; Fisheries Sector review, 1989; Wafy, 1990). The remainder of the catch is made up of coral prawns. All of the catch of the larger vessels is processed on board into frozen packs for export, while the catch of smaller vessels is either processed on board or chilled and packed onshore. Banana prawns are mainly caught at Kerema Bay and Freshwater Bay.

The Gulf of Papua fishery has operated commercially since 1967 (Vonole, 1989) and the vessels are usually twin rig, 24-27 m long using 500-600 Hp engines.They have on-board processing and freezing facilities. In 1976, three companies operated with three licences each. In 1978, two old vessels were commissioned by a joint venture company to fish inside the 3-mile limit and in the same year and old trawler returned to Japan and was not replaced. In 1981, four national companies chartered vessels to operate inside the 3-mile zone wile one foreign-owned vessel operated outside the 3-mile zone. This brought the total for that year to 19 vessels. Except for 1981 however, the average number of vessels operating in the Gulf of Papua fishery has been 13-14. During 1986, the number of licensed operators increased to 21, with the introduction of Australian chartered vessels. Vessels used either quad rig or double rig; but increased effort and efficiency did not improve catch rates (averaging 1,100-1,200 mt tails/year). In 1987, there were 23 vessels fishing (including seven using quad rig, and two having higher (1200 hp) engine thrust using very small (2.5 cm mesh) nets). The cpue did not improve in 1987 and actually was declining over 1986-87, with the size of prawns also decreasing.

The Western Province part of the fishery is in two segments. The area from the mouth of the Fly River down to Bramble Cay and west almost to Parama Island, is predominantly a banana prawn fishery with pockets of endeavour and tiger prawns in the southern area; and the area south of Bramble Cay and west to the Warrior Reefs is predominantly a tiger and endeavour prawn fishery with some banana prawns and a few king prawns. A third segment (from west of Boigu Island to the West Irian border and south to Cape York) is not fished. Experimental trawling was carried out there by CSIRO and the DFMR on the *FRV Kulasi* in 1987-88 located tiger prawn resources as well as fin fish.

Prior to 1988, the Western Province had no dedicated prawn trawlers and the area was infrequently fished. In 1989, four tralwers came to the Western Province but departed after two years' of fishing. Between 1991 and 1993 several trawlers came and went; from 1993 some of the Gulf Province trawlers moved to the Western Province because of landowner complaints in the Gulf Province. Problems identified in the fishery in the Western Province include the high cost of fuel (especially as new prawning grounds are being determined), lack of maintenance facilities, wear and tear on gear being used in unproven grounds

<u>Orangerie Bay fishery</u>

The Orangerie Bay prawn resource is known to be seasonal and geographically restricted to an area of 15.5 sq km. It has been fished intermittently by small class vessels (9-16 m length) since 1981. Generally only two licences are issued a year, although in some years three licences have been issued. The catch consists of 83-85 per cent banana prawns, 5-8 per cent tiger prawns (mainly *P. monodon, P. semisulcatus*) and 7 per cent 'mixed' (Fisheries Research annual report 1982). Unlike the evenly distributed prawn stocks in the Gulf of Papua, prawns in Orangerie Bay are found in distinct shoals - as occurs in the Gulf of Carpentaria. The peak season appears to be from April-June and August-November. Despite year-to-year variation, the general pattern is for small prawns (<11 kg tail weight) to comprise 30 per cent by number of catch from September to February and 13 per cent by number from March to August.

In 1984 the fishery suffered from socio-political problems (including direct attacks on one of the vessels) resulting in the fishery closing in August 1984 (Fisheries Research annual report 1984)[1]

The Torres Strait fishery

This fishery was entirely an Australian fishery until 1987 when two PNG vessels entered and by August of that year there were four PNG vessels (Australian boats chartered to PNG companies). The fishery is based on several species not found in the Gulf of Papua. They are tiger prawns (*P. esculentus*), endeavour prawns (*M. endeavouri*) and king prawns (*P. longistylus*).

PNG's total allowable catch (TAC) for the Torres Strait fishery in 1991 was 200 mt with a limit of eight PNG vessels; by 1993 that had changed to seven vessels. The 1993 catch by PNG vessels from the fishery was only 17 mt. PNG licensed two prawn trawlers to operate there and there were no cross-endorsed boats to take the 40 mt for Australia (Australia declined to nominate any boats for cross-endorsement).

Effort in the fishery by PNG vessels has been sporadic. It is possible that the lack of participation by PNG in the fishery may include the differences in technology and fishing techniques when compared with those practised in the Gulf of Papua (Fisheries Research annual report 1985-1991). Those vessels that took part are generally boats from the Gulf of Carpentaria fishery.

Western Province artisanal fishery

In 1982 a survey was performed of the Western Province prawn fishery to see if there was potential for low technology fishing using small boats or canoes (Fisheries Research annual report 1982). Beam trawls, beach seines and light weight otter trawls were employed and fishing was conducted in 1-6 m, from Sui on the mouth of the Fly River to Sigabaduru west of Daru. Almost all areas to within 10 m of the shore were trawlable, depending on the state of the tide. At extreme high tides, trawling to within 5 m of shore is possible but this increases to 200 m at extremes of low tides.

The fishing trials resulted in catch rates of up to 2.17 kg whole prawns/hour (in 1982) to 4 kg/hour in 1983 (Fisheries Research annual report 1983). Catches comprised 70-72 per cent banana prawns, 7-20 per cent *P. monodon* and 10-21 per cent a mixture of endeavour prawns (*Metapenaeus* species) and coral prawns (*Parapenaeopsis sculptilis*). The banana prawns measure 21-35 mm CL and the tiger prawns measure 20-45 mm CL. The abundance of coral prawns and banana prawns showed an inverse relationship (Fisheries Research annual report 1983).

[1] Evans and Opnai (1994) show catch figures for 1984 AND 1985. It is very difficult to evaluate the statements and catch figures provided by Evans and Opnai on the Gulf of Papua fishery and the Orangerie Bay fishery, as they differ substantially to information available elsewhere.

Catches from the fishery are/were[2] sold to Western District Seafoods Ltd at Daru (Fisheries Research annual report 1983). Only areas close to Daru market were exploited (in 1983) although most of the coastline appears suitable. The reason for concentrated effort is the lack of transport. The prawn fishery is very seasonal. Highest catches are made in the early months of each year (peaking in April-May) during the northwest monsoon when fishing conditions are better.

Surveys have been performed in other areas of PNG. Prior to 1970, the *FRV Tagula* conducted extensive surveys for prawn grounds, primarily along the northern and southern coast of mainland PNG.

In 1984, Coates *et al.* conducted a survey in areas within the Milne Bay Province. They found that prawn catches were extremely variable.

Three main surveys for prawn resources were carried out in the East Sepik Province waters (Murik Lakes to Ramu River) between 1965 and 1974 (Campbell, 1981). Surveys were conducted also in the Murik Lakes area in 1981-83 (by Frusher, unpublished) and 1985 (Chapau, 1991).

The *FRV CeeB* spent 33 days fishing in Murik Lakes area. Eight main species of prawns in four commercial grades were identified: banana (*P. merguiensis, P. indicus*), tiger (*P. monodon, P. japonicus* (<1 per cent), *P. semisulcatus* (<1 per cent), small endeavour (*M. dobsoni, M. affinis*) and large endeavours (*M. affinis, M. demani*) (Frusher, unpublished; Fisheries Research annual report 1983). The period June-October corresponded with high banana prawn catches and endeavour prawns dominated during the remainder of the year.

Table 66 Relative abundance of prawns off the Murik Lakes, East Sepik Province.

Main species	Ramu ground	Murik ground	Sissano/Arnold ground
P. merguinensis	***	***	**
P. indicus	**	**	***
P. monodon	**	**	**
M. affinis	*	*	***
M. ensis	*	*	*
M. demani	**	*	*
M. dobsoni	**	*	*

*: minor quantities; ** major quantities; *** dominates

In 1992, Wafy (unpublished) surveyed for possible commercial prawn beds in the areas northwest of the Ramu River mouth and in Astrolabe Bay in the Madang Province. He found that there were generally limited trawlable areas near the Ramu River mouth, and Astrolabe Bay was unsuitable because of deep shelving and 'treacherous bottom conditions'. The trials off the Ramu River yielded good quantities of prawns. The 'Ramu Blue' (*M. affinis*) was the most abundand of the several species caught there and good catches were made of *P. merguiensis, M. demani* and *M. dobsoni*. Other prawn species (black tigers (*P. monodon*), *P indicus* and red endeavours (*M. ensis*) were present but not abundant. The average sizes for banana prawns were 28.4 mm CL (males) and 32.6 mm CL (females) and for *M. affinis* they were 16.2 mm CL (males) and 17.2 mm CL (females).

Surveys conducted elsewhere revealed prawn stocks in other areas, including Sissano Lagoon (West Sepik Province), Huon Gulf (Morobe Province), parts of West New Britain Province and Dyke Auckland-Collingwood bays (Northern Province) (Fisheries Sector review, 1989).

[2] At time of printing, I have no information on whether this arrangement still operates.

Production and marketing: The Gulf of Papua trawl fishery lands about 1,200 mt/year (Opnai, pers. comm.; Wafy, 1990). The Orangerie Bay fishery yields about 40 mt/year. Both these fisheries are being harvested at the level of estimated msy.

A prawn database management system (PDMS) was created for the three industrial prawn fisheries in the mid 1980s, but there have been problems with updating information on it since 1989 because of staff shortages. Since that date, information on the fisheries has been manually extracted from logsheets.

Table 67 Catch (mt tails) and effort information for the Gulf of Papua fishery for the period 1974-93. Effort is expressed in thousands of trawl hours. This data is from Evans and Opnai (1994) and Polovina and Opnai (1988), **but alternative (and often quite different) figures appear in Branford (1982), fisheries resources annual reports for 1984 and 1985-1991, the Fishery Sector review (1989) and Vonole (1989).

Year	Effort (hours trawled)	Catch of *P. merguiensis*	Total catch (all prawns)	no. of trawlers
1974	49	442	733	24
1975	17	258	410	6
1976	48	462	780	12
1977	46	291	562	12
1978	71	531	997	14
1979	78	636	1,221	13
1980	81	668	1,178	13
1981	73	517	1,026	19
1982	69	426	891	11-13
1983	62	638	1,151	12
1984	75	477	1,114	12
1985	78	673	1,334	12
1986	93	571	1,321	17
1987	91	601	1,165	21
1988	76	557	1,100	15
1989	95	-	1,174	15
1990	70	449	873	
1991	46	371	649	16
1992	41	475	860	
1993	47	375	756	

Some of the 1984 increase in prawn trawling effort (34 per cent more than in 1983) would have been due to the closure of the ornate rock lobster fishery to trawling (profile 2.6) (Fisheries Research annual report 1984).

Table 68 Catch and effort information for the Orangerie Bay fishery, 1982-93 (sources: 1982-90 - Fisheries Research annual report 1985-1991; 1991-93 - Evans and Opnai, 1994) (** again, very different figures for earlier years are presented in the 1982, 1983 and 1984 fisheries research annual reports.)

Year	Total effort (trawl hours)	Total catch (mt)	Mean cpue (kg/hr)
1982	151	5.3	35.1
1983	1,039	17.1	16.5
1984	195	10.3	53
1985	1,793	25.8	14.4
1986	no fishing	no fishing	no fishing
1987	214	1.8	8.4
1988	1,298	77.5	60
1989	279	9.4	34
1990	129	1.8	14
1991	1,252	16.2	12.9
1992	825	25.4	31
1993	600	21.5	35.8

Table 69 Catch (kg) and effort information for the Torres Strait prawn fishery for the period 1988-91 1991 (source: Fisheries Research annual report 1985-1991)

Year	1988	1989	1990	1991
no. of vessels	4	4	1*	2
hrs fished	2,664	2,579	656	443
tiger prawns	13,713	21,882	1,716	6,967
endeavour prawns	19,299	11,772	292	5,092
king prawns	1,123	942	24	3,123
other prawn spp	-	-	-	152
Total catch	34,135	34,596	2,032	16,337

(*fished in the Gulf of Papua fishery most of the year)

Table 70 Alternative and extended summary of Torres Strait prawn fishery catches (kg) by species, 1988-93 (source: letter to file, DFMR, 21/12/93)

Year	1988	1989	1990	1991	1992	1993
no. of vessels	3	3	-	1	3	2
black tiger	1,320	33	-	40	-	11,354
grooved tiger	-	-	-	-	-	6,151
endeavour	12,278	8,941	-	2,853	-	12,962
king/other	2,601	2,233	-	261	-	1,071
banana	23,150	2,015	-	-	-	-
tiger	15,833	17,044	-	3,972	-	-
Total catch	55,182	30,266	-	7,126	-	31,538

Table 71 Landings of prawns from the Western Province artisanal prawn fishery at Daru fisheries depot for the period 1986-91 (source: DFMR Daru)

Year	1986	1987	1988	1989	1990	1991
quantity (kg)	9,331	8,920	7,445	0	3,128	9,600

In West New Britain, 174.5 kg prawns were received at the fisheries depot in 1991; only 1 kg in 1992. (Source: DFMR database, Kavieng)

Table 72 PNG prawn exports from 1979, in kg tail weight (Sources: a) DFMR database; b) DFMR-supplied data published in *INFOFISH International* 6/90, 1990); c) PNG prawn exports to Japan (Japan Marine Products Imports Association, in *INFOFISH International* 6/90, 1990). Values in kina (K) are from the DFMR database, a).)

Year	quantity (a)	value (K)	quantity (b)	quantity (c)
1979	993,514	3,812,902	-	-
1980	798,008	3,764,257	-	-
1981	887,099	5,005,034	-	-
1982	322,125	1,666,382	-	-
1983	1,165,450	8,139,647	1,150,000	-
1984	1,100,970	6,457,796	1,114,000	-
1985	1,507,872	9,555,818	1,333,000	1,057,500
1986	1,467,150	8,894,613	1,321,000	916,800
1987	1,096,713	8,783,661	1,165,000	981,600
1988	no info.	no info.	1,197,000	968,232
1989	no info.	no info.	-	954,151
1990	663,825	no info.	-	-
1991	909,500	no info.	-	-
1992	693,715	5,313,552	-	-
1993	707,224	5,882,521	-	-

The prawn fishery generates export sales of between K6 million and K9.6 million each year (Fishery Sector Review, 1989). Most of the product (90 per cent) goes to Japan, United States of America and Europe as frozen 'green headless' prawns (a small amount is exported whole). It generates financial benefits to the national government in the form of taxes, licence fees, export taxes and so on, estimated at K1.2-1.5 million/year (Agrodev Report). Finally, the fishery also provides socio-economic benefit in full-time and seasonal work for nationals, especially on fishing vessels, where more than 80 per cent of the crew are nationals.

2.2.3 Stock status

A prawn stock assessment study performed between 1978 and 1980 on the Gulf of Papua prawn fishery indicated that the resource was being harvested at or near the msy.

In 1985, 86.7 per cent of the msy was harvested. More than half the catch was banana prawns, and the catch (575 mt) was 17 per cent more than the msy for that species (Fisheries Research annual report 1985-1991). In 1986, 85.9 per cent of the msy was taken. In 1987, the total catch represented 75.5 per cent of the estimated msy, with the catch rate of banana prawns declining - 'probably through overfishing (Fisheries Research annual report 1985-1991). In 1987, following complaints from prawn operators, a review was carried out and the government and the companies operating in the Gulf of Papua fishery drew up an interim management plan (IMP) to start in the 1988 season. This review recommended a Management Plan for 1988-89 (Opnai, note to file, c. 1988). After the implementation of an interim management plan, the 1988 banana prawn catch comprised 59 per cent of the total catches. Catches and cpue declined again in 1989, 'possibly due to poor recruitment from adverse environmental factors rather than overfishing.' (Fisheries Research annual report 1985-1991).

Annual trends in the cpue of the fishery between 1977 and 1989 suggest that the fishery was in a steady state of exploitation. Annual catch rates of banana prawns fluctuated around a mean value of 7.4 kg/hour/boat (Wafy, 1991).

Polovina and Opnai (1988) performed an assessment of the Gulf of Papua prawn fishery with commercial catch and effort data for 1974-87. A surplus production model estimated the msy of tails and corresponding effort of 1,538 mt and 198,000 trawling hours for all prawn species combined, 575 mt and 98,000 trawling hours for banana prawns for the entire Gulf of Papua, and 374 mt and 65,000 trawling hours for banana prawns in Kerema Bay. Based on a value-per-recruit model, the 1988 size of prawns at entry to the fishery represented near optimum levels to maximize the value per recruit at the current level of fishing mortality.

Concerning the Orangerie Bay fishery, comment was made in the 1985-1991 annual report that a complete analysis of fishery cannot be made because fishing has been sporadic. Preliminary estimates of the msy range from 35 mt/year to 45 mt/year. Current estimates of the 1982-90 data indicate that the fishery cannot sustain extensive fishing pressure.

Tagging studies in the Torres Strait fishery show that movement of prawns between different areas of the strait is limited and that there is only one stock of each of the major commercial species (Staples *et al.,* 1994). There have been no biomass estimates of the waters west of the Warrior Reef complex nor the PNG waters of the Torres Strait Protected Zone. It is suggested (Staples *et al.,* 1994) that prawns probably migrate from west of the Warrior Reefs into the trawl grounds to the east.

Table 73 CPUE (as kg whole prawns/trawling hour) for prawns trawled between October 1982 and April 1983, in the three main prawn grounds along the East Sepik-Madang provinces identified by Frusher (unpublished) (also: Fisheries Research annual report 1983

Species group	Ramu	Murik	Arnold/ Sissano
banana	2.6	6.5	2.1
tiger	2.3	1.1	1.6
large endeavour	1.8	0.2	10.8
small endeavour	4.0	0.9	4.3
Total all prawns	10.7	8.7	18.7
hours fished	119.4	38.1	117.1

The *FRV Tagula* trawls in the Ramu area yielded an average cpue of 15.5 kg/hour over 12 days; between Cape Gigir and Darapap the average cpue was 7.63 kg/hour ofer 27 days; and in a later survey of the whole area, the average yield over 12 days of fishing was 24.5 kg/day (Campbell, 1981).

Table 74 The cpue's recorded in surveys of coastal waters adjacent to Murik Lakes were summarised by Chapau (1991)[3]

Vessel	Fishing dates	Average cpue(kg/hr)	cpue range (kg/hr)
Tagula	Oct-Dec.65	7.6	0-15.6
Cee-B	10/82-1/83	8.58	5-11
Melissa	Jan-Mar. 85	3	0-7.7

Chapau pointed out that, as these are virgin stocks, constant fishing would reduce the cpue.

In the 1992 Madang Province survey (Wafy, unpublished) banana prawns yielded a catch rate of 5 kg/hour, *M. affinis* yielded 7 kg/hour, *M. demani* yielded 1.7 kg/hour and *M. dobsoni* yielded 1.2 kg/hour. Wafy (unpublished) concluded that the prawn resource is very small and that the area of trawlable ground is small and restricted. He suggested that although the resource could not be economically harvested on a commercial basis, it could be harvested by artisanal fishers using light craft with beam trawls, or by beach seining.

In the Milne Bay Province, catch rates in a survey in 1984 averaged 5.4 kg/hour, with the best cpue obtained being 21.4 kg/hour. Banana prawns (*P. merguiensis*) comprised 61 per cent of catches, on average (Coates *et al.,* 1984).

2.2.4 Management

Current legislation/Policy regarding exploitation: By the end of 1991, the Gulf of Papua fishery was operating under an interim management plan and the Torres Strait fishery was being managed under the Torres Strait Treaty. No formal management policies and plans were in place for the Orangerie Bay and Western Province fisheries (Fisheries Research annual report 1985-1991).

The Gulf of Papua fishery is managed as a limited entry fishery and it is closely monitored. Time series analysis show that the fishery is dependent on a single cohort that settles as post-larvae in mangrove areas around November and migrates to the fishery in about May-July. The estimated msy for the fishery is 1,500 mt/year.

In 1993, the DFMR's policy was to have a detailed prawn management plan on a nation-wide basis, with exemptions for the special requirements of the Torres Strait fishery and the Orangerie Bay fishery. Prawn fisheries would be restricted to Citizen companies only, joint venture operations not being permitted. Vessel numbers would be restricted in each fishery and there would be limits on the number of licences that each company could hold. Vessel charters would be limited also to PNG owned and registered vessels. Vessels would not be permitted within three miles of the coastline, although this restriction would be waived for Torres Strait and Orangerie Bay fisheries. Restrictions would remain on vessel sizes and the types of gear to be used, again with exemptions for the Torres Strait and Orangerie Bay fisheries. On-board processing of product would only be permitted if the relevant grading standards are complied with. In all other cases, grading would be done at an authorised shore facility.

The DFMR recognised (1993 'Policies and Programmes') that opportunities for the development of new ground appear limited, with the possible exception of shelf areas along the coast associated with river systems providing freshwater run-off. The DFMR (in 1993) would permit trial fishing for new areas, but the terms and conditions would be strictly controlled at the direction of the DFMR.

[3] These figures differ substantially from those in the table above. Hence it may be that Chapau converted them to tail weight.

A long-term management plan was implemented for the Gulf of Papua fishery in 1989, following the 1988 interim management plan. This plan is reviewed each year and revised on the basis of available scientific data. An example of a revision was based on the work described by Wafy (1991). Surveys revealed mature size prawns in inshore areas, and that banana prawns constituted more than 60 per cent of the catch between 5 m and 12 m. Growth over-fishing was recognised, and a recommendation was advanced to permanently close waters inside the 3-mile zone all year.

The management plans for the Gulf of Papua fishery aim to promote the recovery of the fishery and increase local participation. In 1988 the prawn fleet was reduced in size and restrictions were placed on gear, vessel size and engine horsepower. The area adjacent to the Fly River estuary and the area west of the Vailala River mouth to Cape Blackwood were closed to trawling in an attempt to protect prawn nursery grounds. The 3-mile zone was also closed to protect and safeguard traditional fishing grounds.

In the early 1980s it was recognised that development of the Orangerie Bay fishery would provide local benefit, but that the small size of the resource and the small area required careful management.

The Torres Strait fishery is managed by Australia and PNG under the Torres Strait Treaty as a limited entry fishery with catch sharing between the parties. Management of the prawn fishery has the following objectives:

a) manage resources for their conservation and maximum utilisation;

b) in a way that avoids damage to other fisheries and the marine environment;

c) implement a seasonal closure between 15 December and 15 April of each year; and

d) implement a permanent closure west of the Warrior Reefs.

Up until 1991 there was minimum joint management of the fishery. After that the area closures came in, aimed at protecting nursery areas and preserving stocks of ornate rock lobsters (profile 2.6) and pearls (profile 2.10) (Fisheries Research annual report, 1985-1991).

Currently PNG is entitled to seven vessels (</= 16 m long) with cross-over endorsed licences permitting them to fish in the Australian area of jurisdiction, and Australia will not nominate any of their boats to fish on the PNG area of jurisdiction. Catch-sharing arrangements are based on a five-year average catch of 1,000 mt for Australian waters and 200 mt for PNG waters, with 25 per cent of these allocations being available to the other country. These arrangements are reviewed every three years, with the next review due in 1995.

Recommended legislation/Policy regarding exploitation: Evans and Opnai (1994) recently supported earlier recommendations (Vonole, 1989; Fishery Sector review, 1989) that the Gulf of Papua fishery be limited to15 licences + two in reserve for traditional resource owners. They also recommended a TAC of 40 mt of banana prawns/year/vessel, with an annual cap on the fishery of 600 mt of banana prawns. An alternative to a 40 mt TAC would be the implementation of a closed season from 1st September to 31st December each year. Trawl fishing should not be permitted within the 3-mile limit in order to a) protect nursery areas, b) not transgress traditional fishing areas and c) conserve inshore fish stocks. Gear restrictions already in place should be maintained (e.g. on headline length, cod-end mesh size, and no more than double rig; engine horsepower and vessel length limits).

Evans and Opnai (1994) also recommended the establishment of a permanent observer program, with observers rotating between the vessels of the three main prawn companies. These authors also suggested the need for further study to determine whether a different msy should apply to the Kerema Bay area and identified the need for further biological studies of the prawn resources in the Gulf of Papua and Orangerie Bay. Only two vessels limited to 10 m in length should be permitted to operate the Orangerie Bay fishery. Gear restrictions and a TAC of 30 mt is recommended.

The possibility of utilising the trash fish from prawn trawling in ventures such as barramundi and grouper (serranid) fish farming, and for bait for yellowfin tuna and mangrove crabs is suggested by Evans and Opnai. In my opinion, barramundi and grouper aquaculture operations are not feasible in PNG presently. Extensive studies would need to be performed to determine the value of trash fish as bait in tuna longlining; and for a high cost operation such as longlining, there is no margin for bait experimentation when other, proven baits are available or could be (squid, profile 2.17; nearshore pelagics, profile 1.15; small pelagics, profile 1.12). Consult also profile 1.10 (trawl bycatch).

There appears little avenue for increased prawn harvest, except for the Torres Strait fishery and localised prawn fisheries. Such localised fisheries could be operated with small vessels and directed at local, artisanal markets. They could use beach seines or small beam trawls. Distance from Port Moresby (ports) is one of the factors identified by the Fishery Sector review (1989) as limiting the development of the present and western Torres Strait prawn grounds. B. Shackles (pers. comm.) suggested that prawners need incentive to survey new grounds because of costs involved. Fuel is a major expense on trawlers - he pointed out - and by the national government lifting the duty on fishing vessel fuel, revenue from the several prawn fisheries in PNG would be greatly assisted.

For the Torres Strait fishery, (Australian) scientists recommend that future catch-sharing arrangements and management of the fishery with PNG should be more closely linked to the current sustainable yield estimates and also take into account the year-to-year variability in recruitment of young prawns (Staples *et al.,* 1994).

DFMR files show that from time to time, interest has been expressed in establishing marine prawn aquaculture operations in PNG. Areas of operation included Ihu in the Gulf Province, the Laloki River in the Central Province, and somewhere in the East New Britain Province. None of the operations have developed.

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Acknowledgements:

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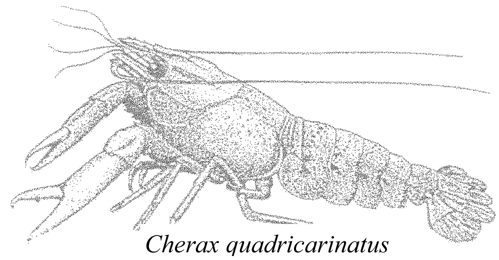
2.3 FRESHWATER YABBIES or CRAYFISH

2.3.1 The Resource



Cherax quadricarinatus

Species present: The resource was identified as *Cherax albertisii* by Professor L.B. Holthuis in about 1976. Probably two other (non-commercial) species of *Cherax* inhabit Western Province fresh waters (Moore, 1979). One of these would be *C. quadricarinatus* (redclaw) (Jones, 1990, in Kailola *et al.,* 1993).

Distribution: In PNG *Cherax albertisii* inhabits the area from the border with West Irian to and including the Bamu/Aramia River system, and extends upriver to Lake Murray (c. 480 km from the coast) and the Ok Ma (Western Province). *C. albertisii* lives in swamp systems associated with rivers (including those on the north and south banks of the Fly River estuary). R. Moore (DFMR files) reported that freshwater crayfish rarely enter the actual river, but early 1980s surveys by DFMR of the Ok Tedi system recorded these yabbies from rivers. *Cherax* is not mentioned in any of Haines' (e.g. 1979, 1983) reports of the gulf rivers further to the east.

Biology and Ecology: *Cherax albertisii* inhabits fresh water and apparently brackish waters. They disperse widely through the floodplains in the wet season and during the dry season tend to congregate in swamps and lake systems. The species' abundance varies seasonally.

Although they are reported to spawn annually during the dry season (FAO, 1982) the yabbies actually mate and spawn continuously (Lili, 1978) while suitable water temperatures prevail and spawning peaks in the dry season. The yabbies are opportunistic scavengers, though they feed mainly on aquatic vegetation (FAO, 1982) and detritus.

Study of *C. albertisii* in 1977 (Lili, 1978) showed that at about 65 mm carapace length the animals weigh 50 g, at about 80 mm carapace length they weigh 100 g and at about 95 mm carapace length they weigh 200 g. Lili recorded a male : female ratio of 1:1.3. The smallest berried female he noted was 34 mm carapace length and the largest was 62 mm. Fecundity ranged from about 300 for a 41 mm carapace female to about 650 for a 54 mm carapace length female.

The life cycle of redclaw (*Cherax quadricarinatus*) in Australia is probably similar to that of *C. albertisii*. Redclaw spawn throughout the year (with less spawning activity during the cooler months of May through to July), females having successive broods. Fecundity varies with the size of the parent, ranging from 300 eggs to 1,000 eggs per brood (Jones, 1990, in Kailola *et al.,* 1993). After mating the 2 mm long, oval eggs are carried beneath the female's tail for 6-10 weeks (depending on water temperature) after which they hatch to produce a small crayfish (about 12 mm long) of adult form - ie, there is no free-living larval stage (Jones, 1994). The hatchlings remain attached to the female for 1-2 weeks and are completely independent after about three weeks. Redclaw grow rapidly with an adequate diet and within three months will weigh 5-15 g, and 50-100 g over the next 6-12 months (Jones, 1994). Both males and females are mature at 6-9 months of age. Redclaw live for 4-5 years, reaching 90 mm carapace length and usually weighing about 300 g.

2.3.2 The Fishery

Utilisation:

Wild fishery

Traditionally, freshwater crayfish are caught by hand or with hoop nets or scoop nets. Fishing takes place during the dry season March-April to about October-early November when the water level drops. Villagers say good catches can be made if the floodplains dry - normally between July and October. Galvanised wire mesh traps were introduced to the fishery over the last 15 years. The best bait is meat, although vegetable material is sometimes effective.

Aquaculture

In 1979 holding ponds were constructed at Wasua village on the north bank of the Fly River and stocked with freshwater crayfish. Problems in maintaining the water level and preventing entry of vermin caused the abandonment of that project (FAO, 1982). Another attempt on the Aramia River met the same fate and stock was lost.

However, freshwater crayfish were successfully reared in 2,000 litre fibreglass tanks at the DFMR station at Kanudi (FAO, 1982). The animals bred freely in the tanks: lowering the water level stimulated the crayfish to breed throughout the year. Growth of juveniles hatched in the tanks was also very rapid. Most individuals matured during their first year.

Hence, aquaculture of *C. albertisii* is possible under controlled conditions.

Production and Marketing:

Pahoturi River area:

The first commercial production of freshwater crayfish was in 1975 when 3.7 mt were collected from the vicinity of Sigabaduru village (65 km west of Daru). The next year, 11.3 mt were taken from Sigabaduru and the neighbouring villages of Gnao and Kodoro. Trapping rates averaged 20-30 crayfish/trap/night, reaching a maximum of 50 crayfish/trap/night. Sigabaduru village was able to produce up to 0.5 mt/day using hoop nets (Moore, 1979).

However, in 1977 only 100 kg were taken from the same area. In 1978 the area yielded 'very few' crayfish (catch rate of one crayfish/10 traps/night) and in 1979 only 2 kg (total) were harvested. There were extended wet seasons in 1977 and 1979.

Aramia River area:

In 1978, catches reached 50 crayfish/trap/night, but in 1979 very small quantities were harvested (FAO, 1982).

Lower Fly River

Around Sui village on the south Fly River estuary, 'semi-commercial' quantities of freshwater crayfish were harvested in 1979, but in villages on the west bank and north bank catches were not commercial (FAO, 1982).

B. Shackles (pers. comm., 1994) reported daily catches of 600 kg from one village but he reported no date or locality.

Occasionally, yabbies are brought to the Daru market for sale.

Table 75 Landings of yabbies at Daru, 1986-91 (source: DFMR database).

Year	1986	1987	1988	1989	1990	1991
quantity (kg)	2,140	79.0	none	none	31.5	none

Catches were made in March, May, June, July, October, November and December. Source of the harvest is not recorded on the database.

2.3.3 Stock status

The DPI annual report for 1975 estimated that villages in the above areas could produce a catch of about 20 mt/yr (FAO, 1982). However, 1977-79 catches indicate that wild stocks in the Pahoturi River system are not commercial as stocks fluctuate widely.

Fluctuations in catch were at first considered to be caused by overfishing (reduction in stocks) in previous years (e.g. 1975, 1976) but Moore (1979) recorded instances of almost complete disappearance of crayfish where no commercial fishing had occurred.

Good yabby grounds are believed to exist in areas around Morehead, Suki, Balimo, Obo and on the mainland east of Daru (Lili, 1978). In the late 1970s plans were made to investigate suitable habitats around the lower Fly River in an attempt to estimate stock abundance and commercial fishery potential. To the best of my knowledge however, these plans were never effected.

2.3.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Although villagers in western Papua are enthusiastic about developing a fishery for yabbies, the history of catches in the province do not support it. A wild harvest is not dependable enough, and requires the input of considerable effort to make it worthwhile - even at the artisanal level (FAO, 1982).

The yabbies are only accessible during the dry season when they are concentrated in smaller areas and can be caught by wading in swamps and billabongs. In the wet season they are dispersed (they respond to flowing water by migrating) and cannot be fished because of high water levels. Lili (1978) cited an average trap rate of one yabby/trap/night when stocks were dispersed during the period of high water (1977). A very extended wet season leaves only a short time for harvesting and it is possible that the extent of their dispersion may be related to the duration of the wet season.

The only way of utilising freshwater crayfish from the Western Province is by aquaculturing them. Whether successful aquaculture of yabbies in PNG is achievable is another question. The FAO (1982) report suggested that farming could be carried out at village levels.

The problem of getting both chilled and live product to market in a timely manner and in good condition is often cited (R. Moore, DFMR files; Lili, 1978; FAO, 1982) as a reason why this resource has been and will be difficult to develop.

Nevertheless, trials in 1979 showed that live crayfish were accepted readily by the market[1]. As recently as 1992 there was Australian interest in farming PNG *Cherax* species (A. Richards, pers. comm.). A market could exist in nearby Pacific countries - such as New Caledonia - to fill a niche market, but high quality and regular supply would have to be addressed. Sweden accepts frozen, cooked yabbies but the demand is seasonal and they have strict specifications regarding the size, species, cooking method and packaging/presentation.

[1] The information source did not state whether it was the domestic or export market.

Redclaw (*C. quadricarinatus*) is successfully farmed in Queensland. Some of the biological characteristics of redclaw may be shared with *C. albertisii* and could be looked for if farming opportunities arise. Redclaw have a broad tolerance to physical extremes, they tolerate a broad range of temperatures, reasonably high salinities and very low oxygen concentrations. They are a good subject for aquaculture because they have a broad diet, are physically robust, breed readily in normal pond conditions, can be managed within an earthen pond system with minimum capital expenditure and technical expertise, have a good flesh recovery rate, are relatively non-aggressive and juveniles are resilient (Jones, 1994). However, they (and other *Cherax*) are prone to crayfish diseases which can cause major mortalities.

Points about marketing freshwater crayfish (yabbies) - adapted from Downing (1994) -are:

1. Two major prerequisites for successful marketing are *consistent quality* and *supply*. Currently, PNG cannot meet either. Quality in the industry is determined by: thickness of shell; degree of vigour; freedom from parasites and discolouration.
2. The import duty (15-18 per cent) applied to Australian yabby imports to the European market would be reduced for PNG product. This is a 'positive'.
3. Most countries (including Europe and Australia) impose stringent disease-free guidelines for the import of live product. PNG probably cannot meet this requirement. A large proportion of the 1976 PNG production had high bacterial count and was unsuitable for export (Lili, 1978).
4. Whereas there is a high demand for crayfish in Asia and Europe the market is met by either local production or products guaranteed as 'clean'.
5. Production of yabbies in Asia has a low cost. PNG is most unlikely to be able to compete - even just on the basis of freight costs.
6. Yabbies compete in the catering industry with marine prawns, scampi and rock lobsters. Production costs of prawns and rock lobsters in PNG must be cheaper than those for *C. albertisii*.
7. The market preference for live yabbies means that transportation would have to be efficient and timely. This cannot be guaranteed in PNG. Lili (1978) reported that there were problems in handling the harvest, resulting in 29 per cent mortality of a consignment only as far as Daru. However, yabbies can survive several days out of water (Lili, 1978) when wrapped in damp, cool *Melaleuca* bark.
8. In PNG, wild-caught freshwater yabbies are available at the same time as freshwater prawns, *Macrobrachium*. The domestic market can only absorb so much.

There have been suggestions that yabby farming or harvesting could be successful if it were undertaken in conjunction with another fishery - for example, freshwater eel harvesting or farming (B. Shackles, pers. comm.) or barramundi fishing (FAO, 1982). If this were contemplated, the above points should be seriously considered.

<u>In summary</u>:

At present PNG cannot proceed with a fishery for *Cherax*. It cannot guarantee quality and consistent supply.

It is however, worthwhile to <u>monitor catches</u> of yabbies and compile information on their <u>biology and ecology</u>. <u>Aquaculture methods could be investigated,</u> using the role model of redclaw yabbies in Queensland.

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A good general reference on the redclaw industry in Australia is *Australian Fisheries* magazine, vol. 49 (11). November 1990.

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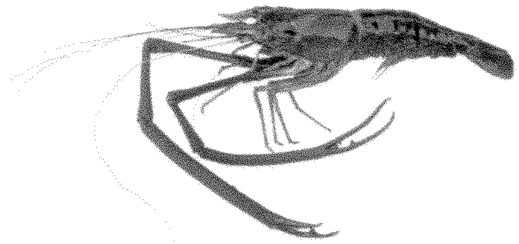
2.4 FRESHWATER PRAWNS - Macrobrachium species

2.4.1 The Resource



Macrobrachium lar

Species present: Eighteen species of caridean prawns of the genus *Macrobrachium* have been recorded from PNG, according to Robertson (1983). In the Sepik River seven species have been recorded: *M. rosenbergii, M. mammillodactylus, M. weberi, M. lar, M. scabriculum, M. mirabele* and *M. papuanum* (Robertson, 1983), of which the first three listed species are the main harvested species. *M. rosenbergii* is probably also the most commonly harvested species in southern rivers.

Distribution: Freshwater prawns have an Indo-Pacific distribution from East Africa to the Marquesas (Holthuis, 1980).

The distribution of *Macrobrachium* throughout PNG is not known (Frusher, 1982). In the Sepik River system *M. rosenbergii* and *M. mammillodactylus* have been recorded throughout the middle and lower river and as far upstream as Green River (a distance of 600 km from the sea) and *M. weberi* occurs mainly in the lower Sepik (Robertson, 1983). The prawns primarily inhabit the main river channels. They are also present in swampy areas more than 100 km from the coast along the Sepik River (Frusher, 1982).

In the Ramu River the 'Ramu prawns' are caught in freshwater from just above tidal influence - at about Bosmun River - to at least Aiome. *Macrobrachium* inhabits all areas of fresh and brackish water in the Western Province (B. Shackles, pers. comm.) and appears to favour areas with a current flow. It is known that *M. rosenbergii* are caught by villagers at least 100 km inland along the Vailala River in the Gulf Province (Frusher, 1982) and are the commonest prawns (with other *Macrobrachium* species?) of the upper estuaries of the Purari-Kikori river systems where they extend into the freshwater above the mangrove zones (Liem and Haines, 1977).

The dominant *Macrobrachium* species in PNG is *M. rosenbergii*. This species has a western subspecies (Indonesia westwards) and an eastern subspecies (Australia, PNG and the Philippines). Hence, biological information on *M. rosenbergii* from Asia - such as life history and breeding times - is not entirely applicable to the eastern subspecies in PNG (Robertson, 1983).

Biology and Ecology: In order to grow, all freshwater prawns have to regularly cast their exoskeleton in a process called moulting. There are four distinct phases in the life cycle of the freshwater prawn: egg, larva, post-larva and adult. The time spent by each species of *Macrobrachium* in the different phases of its life cycle and its growth and maximum size varies, not only specifically but according to environmental conditions - mainly temperature. Many species of *Macrobrachium* have to enter saline water for part of their life.

The life cycle of the western subspecies of *M. rosenbergii* is summarised in New and Singholka (1982) and Tseng (1987). According to Tseng (1987) *M. rosenbergii* has a life span of 7-8 years. Juveniles in the freshwaters of rivers mature after 3-6 months and start to swim downstream towards the river mouth. Before arriving at the spawning ground, the prawns mate at night and the eggs are fertilised externally 24 hours after mating. Fertilised eggs are carried by the female on her swimming appendages and kept there until they hatch. During this time the eggs change colour from orange to greyish (and eyed). The number of eggs varies from several thousand to 50,000 according to the size of the female. There is a downstream movement for hatching, and the eggs of *M. rosenbergii* hatch after 17-23 days in nearshore, low salinity water. After another 30-45 days of drifting they become post-larvae and then juveniles. The juveniles usually remain in brackish water for 1-2 weeks prior to migrating upstream into fresh water (Ling, 1969). At this stage they are 1-2 mm long. After 3-4 months the juvenile prawns grow to about 80 g. As the female matures, its cephalothorax becomes yellowish purple at the time the ovary is mature.

Freshwater prawns are spawned and hatch in the mangroves in the Gulf of Papua. The small prawns move in swarms adjacent to the river banks throughout the year (Frusher, 1982). The prawns grow and mature in fresh water and then (at least, the females: Frusher 1982) migrate back to the river mouths to shed their eggs. Berried females (no males) and juveniles of *M. rosenbergii* are present throughout the year in the Purari River delta (Frusher, 1982). Berried females have been caught in the Aird River delta in salinity as high as 15-18 parts per thousand (Frusher, 1982).

In the Sepik River, *M. rosenbergii* spawns towards the end of the wet season and during most of the dry season (i.e. May-August). Evidence for this comes from the following observations: a) the proportion of gravid females declined from a maximum of 85.7 per cent at the start of the dry (fishing) season to 30 per cent in November 1982 (Robertson 1983) while b) immature females increased in abundance from nil in May to 66.7 per cent in November; c) females with orange eggs (early development) and females with eyed eggs (advanced development) are present throughout the dry season at Angoram (Robertson, 1983); and d) during the mid wet season, most females were immature. In the Ramu River, berried prawns are caught in the dry season also (A. Koyo, pers. comm.).

However, berried female *M. rosenbergii* are found throughout the season at Magendo (near Angoram) and it was suggested (Fisheries Research annual report 1982) that although some of the female population migrates to spawn in the estuaries a considerable number of females release their eggs without migrating downstream. On the basis of river current velocity and distance from the sea, Robertson (1983) concluded that breeding migrations to estuaries was not vital for *M. rosenbergii* whose larvae can survive a few days in freshwater. [This phenomenon also may be because the river water at Magendo becomes more saline as the dry season progresses, so providing suitable conditions there for spawning. Are they migrating at the beginning of the dry season and remaining at the end of the season?] However, Haines and Liem (1977) noted that berried *M. rosenbergii* are found in both estuaries and freshwater sections of rivers in the Purari and Kikori river deltas, and stated that this distribution indicates breeding in both areas. Robertson (1983) suggested that large male *M. rosenbergii* migrate (?downstream) between May and June.

Spawning of *M. mammillodactylus* in the Sepik occurs all year but increases to a peak towards the end of the dry season. The main spawning ground is around Mumeri on the Korasameri River on the middle Sepik. *M. weberi* spawns primarily during the wet season (October-April) with peaks in the middle of the wet season (January-March) (Robertson, 1983).

When 50 per cent of *M. rosenbergii* females in the Sepik River population are mature their average carapace length is 36.7 mm. For males, 50 per cent maturity is achieved at an average carapace length of 60.5 mm. At the 50 per cent level for *M. mammillodactylus*, females range from 13.1mm to 16.1 mm carapace length and males average 18.7-19.8 mm carapace length. In both sexes of this species, locality influences size at maturity (Robertson, 1983).

Fecundity increases with body length, the range being illustrated in the following table (after Robertson, 1983):

Table 76 Increase of fecundity with body length of *Macrobrachium* spp.

Species	*rosenbergii*	*rosenbergii*	*mammillodactylus*	*mammillodactylus*	*weberi*	*weberi*
carapace l (mm)	43.1	73.3	14.4	24.9	15.0	28.3
no. of eggs(F)	17,525	141,587	701	6,111	1,481	27,409

In the Ramu River, female *Macrobrachium* in berry as small as 100 mm total length have been caught (A. Koyo, pers. comm.).

In all *Macrobrachium* species males attain a much larger size than do females, and they can be readily distinguished by their larger claws and slimmer bodies. The largest *Macrobrachium* (from the Ramu River) recorded at the Madang fisheries station was 600 g. The largest individuals of three *Macrobrachium* species collected in the Sepik River in 1982 - all males - are shown in Table 77.

Table 77 Largest individuals of three *Macrobrachium* species collected in the Sepik River in 1982 (after Robertson, 1983).

Species	*rosenbergii*	*mammillodactylus*	*weberi*
weight (g)	905.8	30.7	13.8
carapace length (mm)	118.0	38.3	27.6
total length (mm)	297.9	-	-

Robertson (1983) presented length-weight relationships for five species of *Macrobrachium* found in the Sepik River, but growth rates and size-at-age are unknown. Juvenile prawns migrate upstream from estuarine areas primarily at the end of the wet season and the dry season. A steady level of recruitment of *M. rosenbergii* juveniles to adults occurs in the Sepik throughout the year. Recruitment of *M. mammillodactylus* is higher at different times of the year depending on the location along the river - earlier near the sea, later upstream. For *M. weberi*, Robertson (1983) calculated that the lag between spawning and the return migration upstream of juveniles and subadults is only 3-4 months.

Freshwater prawns are more active at night than during the day. They move along the edges of rivers, seeking food draining from swamps and billabongs.

Macrobrachium are omnivorous bottom scavengers. Haines (1983) recorded detritus, plant material and small invertebrates in the guts of *M. rosenbergii* specimens caught in the Purari River, Gulf Province. In Malaysia (Ling, 1986) *M. rosenbergii* feeds mainly on aquatic worms and insects, insect larvae, small molluscs and crustaceans, parts of fish and other animals, grain, seeds, nuts, fruits, algae and leaves and stems of aquatic plants. According to the Madang fisheries officers, 'very large' Ramu prawns are mainly carnivorous.

2.4.2 The Fishery

Utilisation:

Wild fishery

In the Fly River woven baskets are used to catch *Macrobrachium* species (Maunsell and partners, 1982, in Robertson, 1983).

Both freshwater and marine prawns are important food items to inhabitants of the delta region of the Gulf of Papua (Frusher, 1982). Freshwater prawns (*Macrobrachium*) make up most of the prawn harvest of rivers such as the Purari River - especially from the freshwater and upper estuarine zones of the delta (Haines, 1983). *M. rosenbergii* are more abundant in village markets in the Gulf Province at the end of the dry season and at the beginning of the wet season (January-June) (Frusher, 1982). Hand traps and V-shaped push nets are used by women in shallow water in the delta systems of the Gulf of Papua to catch the prawns.

In the Sepik River the *Macrobrachium* fishery is an important subsistence and artisanal fishery. The fishery is seasonal because it is mainly based on the largest species, *M. rosenbergii*. Low catches of freshwater prawns are made between December and March (wet season) and higher ones between May and November (dry season). *M. rosenbergii* occurs in large numbers around Angoram and its fishing season is during the dry - usually starting in May and peaking in June and July. It is rarely caught outside the dry season. On the other hand, *M. mammillodactylus* and *M. weberi* are more dispersed in the river system and are available all year along the middle and lower Sepik (Robertson, 1983). For *M. mammillodactylus* catch rates are highest between June and September (Fisheries Research Annual Report 1982) - although they vary considerably.

Traditionally, *Macrobrachium* in the Sepik River system are caught by three methods, and always by women. One of these methods is employed at Magendo village (near Angoram) to catch *M. rosenbergii* and is a combination of deep-water hooking and scoop net from a dugout canoe moored near the riverbank. Deep-water hooking is performed at night and each fisher uses only one line. Another method is a combination of shallow-water hooking and scoop net in mudbanks along the river bank, and is performed during the day. Up to 100 lines are set. *M. mammillodactylus* and *M. weberi* are targeted by this method. The third method - basket traps - are used in most parts of the middle Sepik. The unbaited baskets are staked in groups of three or four beside the riverbank, their mouths facing downstream. The baskets are checked and emptied each morning. The species commonly caught in the traps are *M. mammillodactylus, M. weberi* and *M. scabriculum*. *M. rosenbergii* is also caught by spearing with multi-pronged spears at night (Robertson, 1983).

In the Ramu River, freshwater prawns are fished when the water level is low - from June to September. There is no fishing in the wet season because the river level is too high and the current too swift. Women set the long ovate baskets they wove from sago palm fronds along the river banks. The traps are baited with garden scraps, coconut, banana and so on, staked, and set in 1-2 m water depth a short distance off the bank. The traps are put in in the afternoon and are left there for 1-3 days before being hauled. The prawns caught vary in size from very small (about 50 mm total length) to larger (about 125 mm total length and about 150 g). Much larger prawns (eg averaging 350 g) are also caught. The very small ones are used as bait for catching big ones. Big prawns are caught either in the trap or with small hooks and lines baited with meat or small prawns. Line fishing is done also by the women. The prawns from traps and hook are put into a holding pen for buyers from larger villages, Bogia and Madang. The prawns are cannibalistic and tend to eat each other in the traps and the pens, the amount of cannibalism depending on the size range of the prawns in the traps/pens and the time they are kept there.

Modern fishing techniques for freshwater prawns include fishing nets, bought hooks and lines, and traps.

Production and Marketing: The DFMR has no fisheries statistics for *Macrobrachium*. However, the FAO Fishery Statistics Volume 66 (in *Infofish International* 6/90) stated nominal catches of freshwater prawns in PNG for each year from 1984 to 1988 (inclusive) as 5 mt/yr. This figure may be too high.

The Sepik River prawn fishery is a subsistence one although some product (mainly *M. rosenbergii*) is sold at Angoram market and there are irregular sales to Angoram Hotel, hotels in Wewak and private citizens and tourists. The price offered for *M. rosenbergii* in 1979 at Angoram market averaged K2.50/kg or from K0.40 to K0.90 per animal (Robertson, 1983).

Deepwater hooking for *M. rosenbergii* in the Sepik River at Magendo village yielded a catch rate of 5-6 prawns/line-hour in the middle of the season (this amounted to 1-2 kg/line-hour). Total production for the village for 1982 was estimated at 1,525 kg (Robertson, 1983) with an estimated maximum production of 325 kg/month.

In the Ramu River fishery, the catch rate for trapping is about 5-6 prawns/trap/set (although it would be more if the traps were hauled more often: A. Koyo, pers. comm.). The line fishing for larger prawns yields perhaps 4 larger prawns/night.

Fishers are paid K3.50/kg for Ramu prawns at the Madang fisheries landing place, and the prawns are then retailed for K5-6/kg. A trial shipment to Lae (1994) was well received where the prawns sold for more than K8/kg. The sales record for freshwater prawns at the Madang fisheries landing place is 350 kg sold in one day. Freshwater prawns comprised 8.1 per cent of landings for 1993 (up to October) at the fisheries depot.

I have no information on prices and yield from southern rivers except that they can form up to 20 per cent by weight of the traditional subsistence catch in the Purari River delta (Frusher, 1982).

Catch rates of *M. rosenbergii* in the Sepik River are heavily influenced by water turbidity: in the dry season when the fishery exists the water is usually clear, but in the wet season no catches are made in the turbid waters and higher (by 1.5-2 m) river level. Catch rates of *M. mammillodactylus* and *M. weberi* are also affected by rainfall and water turbidity (Robertson, 1983). Catch rates for *M. mammillodactylus* increase up the river with increased water flow after rainfall.

2.4.3 Stock status

There appears to be no information on the status of *Macrobrachium* stocks in PNG.

2.4.4 Management

Current legislation/Policy regarding exploitation: There is none. The fishery remains commercially undeveloped despite efforts to create regular markets by various private enterprises.

Recommended legislation/policy regarding exploitation: The *Macrobrachium* fishery in PNG presently is characterised by:

- seasonality of the main species, *M. rosenbergii,*
- lack of chilling or freezing storage facilities,
- limited access to domestic markets,
- subsistence fishing practices,
- ignorance about the distribution, size and composition of the resource, and the biology (e.g. growth rates) of the main species,
- inadequate quality control and hygiene standards.
- inadequate handling

Restrictions on development of the fishery include all of the above as well as:

- relatively high costs of freight/transport in PNG
- limited access to export markets,
- limited scope for aquaculture given
  a) the difference in biology of the eastern subspecies of *M. rosenbergii* with the western subspecies - which is successfully cultured. If aquaculture were pursued it would mean

that the aquaculture technology developed for the western subspecies could not be transferred and so additional time and costs would be required to develop a technology suitable for the PNG stocks[1];
b) irregular availability of *M. rosenbergii* stock for grow-out ponds;
c) availability of flowing water (at least in the Sepik; and, I suspect, the Fly River system);
d) inexperience of nationals in prawn farming;
e) the aggressive behaviour and cannibalistic tendency of *Macrobrachium* (as opposed to penaeid prawns) would mean that stock would have to be separated by size and sex, turn-around of stock would have to be timely, and sufficient land (for ponds) would have to be available;
f) cost of suitable feed

- high freight costs: these could be offset internally by the relatively high product value but would impede successful export marketing.

Some of the above points are expanded below.

1. The local markets are easily satisfied. Large catches of *M. rosenbergii* at the Angoram market remain unsold if buyers from Wewak do not visit (Robertson, 1983). The same is true for Ramu prawns.
2. The frozen product is brittle. The long arms break off and market appeal is lost. Thawed, frozen *Macrobrachium* have lost much flavour and texture.
3. *Macrobrachium* have a softer body texture than marine prawns and a lighter taste. Chilled freshwater prawns deteriorate more quickly (2-3 days) than do marine (penaeid) prawns, and they acquire the usual problems of uncooked prawn product, such as general spoilage and melanosis ('black spot'). These problems are obviated by proper handling and quality control.
4. If plans to export live or chilled freshwater prawns to Australia and many other countries are made, the prawns would have to meet high quarantine standards and this may not be possible. Robertson (1983) recorded parasitisation of Sepik River *Macrobrachium* species by the isopod *Palaegyge bengalensis*: possible deleterious effects of this (and other?) organisms on the taste, appearance, texture and general hygiene standards of export product are unknown. Generally, the hygiene and quality control problems of handling PNG riverine fresh food products identified as affecting the freshwater eel and yabby (*Cherax* species) markets would apply also to freshwater prawns.
5. The Asian market would not be available - as Asians produce their own *Macrobrachium* and export them. The only possible export markets would be Hawaii, Fiji, possibly other Pacific countries and Latin America and Peru where *Macrobrachium* are known and liked. The flavour and texture of freshwater prawns are different to those of penaeid (marine) prawns which enjoy a wider market. Also, *Macrobrachium* generally realise lower prices internationally than do marine prawns of comparable size (Fishery Sector review, 1989).

Given the above, development of the *Macrobrachium* wild harvest fishery can be done through

1) <u>improved collection and marketing during the season</u>. The higher market value of *Macrobrachium* should offset most of the costs involved with the above. Marketing would be enhanced by *advertising*.

[1]A report completed in 1988 by Canaan International Pty Ltd, entitled "A comprehensive plan for the freshwater prawn hatchery/farming program for the Department of the East Sepik Province Papua New Guinea" was roundly criticised by C.H. Robertson (DFMR files). However, Robertson did recommend that a growout farm facility could be trialed at Angoram or Wewak using wild-caught juveniles. Such trials - he said - would provide information on achievable yields under local conditions, market possibilities, private enterprise possibilities etc at minimal cost. Supervision by a biologist experienced in commercial prawn farming would be necessary - Robertson said - for collection, identification and stocking of juveniles, as well as daily pond management.

- Robertson (1983) suggested the use of a *mobile freezer [chiller*, preferably - see above]. A mobile chiller/collector vessel would be economical if it were also used to collect other perishable product (e.g. fish fillets) AND if it were utilised in the *Macrobrachium* off-season.
- The Madang fisheries officers have successfully *transport*ed chilled Ramu prawns to Lae by road (about four hours' drive) in 15 kg packs - poly-lined cardboard boxes packed with broken ice. Admittedly, other areas where *Macrobrachium* are harvested are not accessible by road to other districts.
- Instead of the villagers waiting for buyers to come to them (which often results in unsold or cannibalised produce), they could be encouraged to take their product *to* the buyers - either alive (see below) or chilled (if suitable packaging material and crushed ice were available). [I am thinking of Wewak, Madang/Bogia, Kerema and Daru here]
- *Macrobrachium* can survive for some time out of water if kept moist and secured in taro leaves. Depending on timing and distance, live prawns could be marketed in provincial centres.
- A domestic marketing outlet common in Asia but infrequently seen in PNG is the *food stall*. With enhanced marketing, could we see *Macrobrachium* offered for sale, on ice, at local markets in centres such as Daru, Port Moresby, Lae, Rabaul and Highlands towns?

2) improved fishing gear - especially traps. Lightweight steel or metal traps could be trialed

3) improved fishing techniques by villagers. For example, checking traps more reqularly would recover more product; using more efficient gear or fishing at better times would yield higher catch rates (cf line fishing all night for 4-5 large prawns is hardly efficient!). Developments in this area would have to be done in recognition of traditional constraints or motivation

One additional possibility on marketing could come from investigating the marketability of the other two harvested species in the Sepik River system which are available all year. According to Robertson (1983) *M. mammillodactylus* forms a significant resource in most parts of the Sepik although *M. weberi* appears to be there in smaller numbers. Presently they are sold in small numbers or traded. With the support of collector vessels, increased harvest of these smaller species could assist keeping the domestic *Macrobrachium* market alive during the wet season. Are there companion species in the southern rivers?

Expansion of the *Macrobrachium* fishery in PNG can be realised only if it is supported by efforts to assess the biomass, the species composition by region, the species' distribution and behaviour and the catchability of target species. All sales and landings should be recorded and gathering of simple information such as sex, maturity stage, weight and length should be kept.

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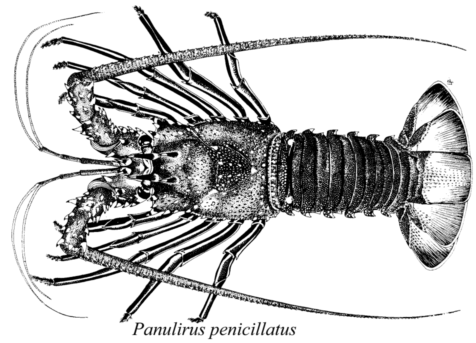
2.5 TROPICAL ROCK LOBSTERS

2.5.1 The Resource



Panulirus penicillatus

Species present: Besides ornate rock lobsters (*Panulirus ornatus*) (see also profile 2.6, ornate rock lobsters) there are five species of tropical rock lobster in PNG waters (Pyne, 1970; Holthuis, 1991). These are the double-spined rock lobster *Panulirus penicillatus*, the painted rock lobster *P. versicolor*, the blue-spot rock lobster *P. longipes femoristigma*, the scalloped rock lobster *P. homarus* and the dentate rock lobster *P. polyphagus*.

Distribution: Geographical distributions, keys to species identification and some biological information about the known marine lobster species are provided in Holthuis (1991). *P. penicillatus* is the most widespread species of spiny lobster, and is found in the Indo-West Pacific and Eastern Pacific regions from Africa to Mexico. It is the most common species in PNG (except for ornate rock lobsters). *P. versicolor* is found in the Indo-West Pacific region from the entire Red Sea and east coast of Africa, southern Japan, Micronesia, Melanesia, northern Australia and Polynesia. *P. longipes femoristigma* is the 'eastern subspecies' of *P. longipes* and inhabits waters of Japan, the Moluccas, Papua New Guinea, eastern Australia, New Caledonia and French Polynesia. *P. homarus* and *P. polyphagus* inhabit tropical Indo-west Pacific waters. Holthuis (1991) recorded *P. homarus* in the western Pacific from southern New Guinea, New Caledonia and French Polynesia. Similarly, he recorded *P. polyphagus* from the Gulf of Papua (and north-western Australia).

Biology and Ecology: *P. penicillatus* typically occurs in clear water, often in the surf zone and surge channels on the windward side of oceanic and barrier reefs. It occupies a depth range of 1-4 m and is found in rocky, coralline substrates and crevices (Prescott, 1988; Pitcher, 1993). It is not gregarious and is nocturnal, hiding in crevices during the day, moving out onto the reef top at night. *P. l. femoristigma* has a similar habitat preference to *P. penicillatus*. It occupies a habitat of clear or slightly turbid water of 1-18 m depth, just on the lagoon side of reef edges amongst dense coral growth and rocky areas. It is nocturnal and not gregarious. This species does not move up onto the reef flat at night, instead foraging on the reef slope. *P. versicolor* has a broad habitat preference, being found from clear water, exposed reef slopes, through prolific coral areas to sheltered lagoons and rather turbid coastal waters. It is nocturnal yet conspicuous and gregarious under coral heads. *P. versicolor* occurs from sub-littoral to 15 m water depth. *P. polyphagus* inhabits muddy substrates and sometimes rocky seafloor. It is often found near river mouths and in turbid water in the depth range of 3 m to 90 m (Holthuis, 1991). I have no information on the habitat preference of *P. homarus*.

Rock lobsters are generally omnivorous scavengers, although they are somewhat selective in their diet towards food items with a higher nutritional and energy value. The range of food items they consume includes molluscs (mainly gastropods), crustaceans, echinoderms (including chitons), seagrass and algae (Phillips *et al.,* 1980, in Pitcher, 1993). Little is known of their foraging patterns except that *P. penicillatus* browses on the algae and small animals on the reef crests and flats, while *P. l. femoristigma* forages below the crest on the reef slope. *P. versicolor* probably covers most of the coral garden habitat in lagoons (Pitcher, 1993).

The sexes are separate in rock lobsters. Male lobsters mate with intermoult females that have developing ovaries. The male deposits a mass of spermatophores on the female's sternal plates. When the female extrudes her eggs she scrapes the spermatophore so releasing the sperm to fertilise the eggs. The female carries the eggs under her tail for about a month before the tiny phyllosoma larvae are released and carried about in the ocean currents. Phyllosoma larvae go through a series of stages before changing into the puerulus stage which eventually settles to the sea floor and moult into pigmented juveniles. The whole process may last a year or more. Settlement of *P. penicillatus* pueruli probably occur throughout the year in much of the tropical Pacific (Pitcher, 1993). Because of the considerable time and extensive dispersal of the larval stages between mating and puerulus settlement, recruitment may occur from spawning adult populations a considerable distance away.

P. penicillatus carry between 8 and 11 broods each year. Breeding in this species and *P. versicolor* is aseasonal and continuous in tropical waters. Information on the other species is lacking. In Solomon Islands *P. penicillatus* are mature at a carapace length of 7.5-7.9 cm (Skewes, 1990; in Pitcher, 1993). Fecundity varies with size and the brood size can be as much as 500,000 in rock lobsters 13 cm carapace length (Prescott, 1988).

The size at which lobsters become mature is a basic biological parameter that is also an important consideration for management. Pitcher (1993) summarised the known information on growth rates, fecundity and sizes at maturity.

Like other crustaceans, rock lobster grow by a process of ecdysis, or successive moulting of smaller to larger shells with males attaining a significantly greater size than females. The most noticeable difference in patterns of growth is between male and female *P. penicillatus* throughout the Pacific. Females initially may grow slightly faster than males, but then slow substantially. In comparison, the males continue to grow relatively quickly. The Pacific average asymptotic carapace length (L_∞) for male *P. penicillatus* is 15.7 cm and for females, 12.2 cm. For *P. l. femoristigma* from Tonga, L_∞ for males is 13.3 cm and for females, 11.8 cm (Pitcher, 1993). According to Holthuis (1991) *P. femoristigma* reaches a maximum body length of 30 cm (carapace 12 cm) and *P. penicillatus, P. versicolor* and *P. polyphagus* each reach about 40 cm maximum body length.

2.5.2 The Fishery

Utilisation: The most common fishing method is by walking on reef flats and catching by hand at night. Diving using a waterproof torch is another method. Using tangle nets also obtains a good cpue. Some studies have shown that moon phase is important for fishing for these lobsters (DFMR file).

The Lavongai Islanders (New Ireland Province) use freshly killed octopus to catch lobsters by scaring them out of their crevices (Wright, 1983).

Traditionally, traps of various kinds were widely used in the Pacific to catch lobsters, but now they are used in only a few fisheries. *P. penicillatus* and *P. l. femoristigma* occasionally enter traps, but *P. versicolor* does not (Prescott, 1988). *P. penicillatus* and *P. longipes* are commonly caught in traps in the Philippines (Juinio and Gomez, 1986)

Fishers prefer to catch *P. penicillatus* and *P. longipes* by hand when they come to the reef top at certain combinations of moon and tide (Adams and Dalzell, 1993). *P. versicolor* is mainly caught by spearing.

The product is sold either as frozen tails or live. Tail weight as a percentage of total weight varies between approximately 40 per cent for females of most sizes to as low as 25 per cent for large males. Lobsters collected locally on a small scale are sold to hotels, shops, municipal markets and wholesalers, though a substantial proportion of the catch is consumed at home or bartered in villages (Pitcher, 1993). Quality standards for the live (export) markets are very demanding (Lewis, 1985).

Production and marketing: The few fisheries statistics available on reef lobster landings in PNG are given below.

<u>New Ireland Province</u>: During 1968 and 1969, an annual harvest of 11 mt of rock lobsters was produced (Wright *et al.,* 1983). In 1979, 12 kg and in 1983, 7 kg of lobster tails went through the Kavieng fish depot, and for the one year period June 1993-July 1994, 8,475.1 kg

of whole lobsters and 46 kg of lobster tails were sold privately in Kavieng (source: DFMR Kavieng database).

Table 78 Reef lobster landings for areas other than the New Ireland Province (source: DFMR Kavieng database)

year	1988	1989	1990	1991	1992	1993
East New Britain (kg, tails)	-	-	16.8	14.0	7.5	1.6
West New Britain (kg, whole)	-	54.0	28.0	119.4	29.5	179.2
Manus (kg, tails)	146.0	90.4	50.8	140.8	46.8	259.7

Live crayfish exports through Rabaul (harvested from Tanga Island, New Ireland Province) were (source: DFMR Rabaul):

1992 - 4,773.8 kg worth K26,496 fob

1993 - 2,500 kg worth K22,875 fob.

Prescott (1988) recorded catches and cpue for reef lobsters in PNG over five nights. All were single night catches, made on dark nights.

Table 79 Catches and cpue of reef lobsters in PNG over five nights (after Prescott, 1988)

kg	10	14	26	15	48
cpue	2.3	3.1	5.8	3.3	8.0

This harvest rate was comparable to that made in the Solomon Islands, Tonga and Eniwetak Atoll.

At the Lae and Madang landing places, 1994 wholesale prices are K4/kg for whole lobster and K6/kg for tails.

In eight Western Pacific nations, the annual catch of mainly *P. penicillatus* fisheries averaged 10.13 mt between 1981 and 1990 (Adams and Dalzell, 1993) (this was in comparison with the *P. ornatus* yield from northern Australia / PNG for the same period of 175-460 mt (average of 309 mt/year).

Small quantities of live tropical rock lobsters are exported from PNG to Hong Kong and other Asian markets as part of the ‘live fish trade’. However, currently the best markets are domestic consumption and to tourists (at hotels). As discussed elsewhere, although development of the live lobster export trade is enticing, there is uncertainty whether stocks can support it.

2.5.3 Stock status

At the Madang fish depot, *P. penicillatus* is the most common rock lobster brought in, but there are small landings of *P. versicolor* and *P. l. femoristigma.* Rock lobsters are only occasionally brought in - despite their fetching the highest prices of all fish - depending on the needs of the fisherman. This ‘motivational factor’ is common in artisanal fishing in PNG and defaults to ensuring sustainable yield of the resource. In other words, it seems that the rock lobster resources (in Madang) are not over-exploited.

Four species of rock lobster are taken from New Ireland reefs (*P. homarus, P. penicillatus. P. versicolor, P. l. femoristigma*), of which *P. versicolor* is the most common (Wright *et al.*, 1983). Wright *et al.* (1983) estimated that about 8 mt of rock lobsters were harvested annually from the Tigak Islands (New Ireland Province), or a yield of 0.39 kg/ha/year.

There are no estimates of stock sizes for these tropical rock lobsters in PNG, although *P. penicillatus* is probably the most abundant species there. Even so, its stock levels - at least in East New Britain - are probably comparable with the estimates of the Eniwetak Atoll stock (see below) (DFMR file note). Stocks of reef lobster are unlikely to withstand heavy fishing pressure.

Given the probable wide dispersal of *P. penicillatus* phyllosoma larvae, and the many unexploited reefs which can potentially provide recruitment to exploited reefs, *P. penicillatus* stocks in the Pacific are prbobably resilient to recruitment overfishing (Pitcher, 1993). Local overfishing thus would probably have little impact on the breeding potential of the regional stock.

Estimates of natural, fishing and total mortality for *Panulirus* species in the Pacific were summarised by Pitcher (1993), who also provided information on abundance of lobster populations. In the Pacific, the absolute abundance of *P. penicillatus* has been estimated in only a few limited areas of reef slope. Figures from the Solomon Islands indicate that abundance was between 111 lobsters/km and 128 lobsters/km of reef slope, or 46-57 animals/ha (Prescott, 1988). Because the area of habitat available for *P. penicillatus* is limited (a 20-25 m wide strip of windward reef slope, the preferred habitat), stocks of this species can only be expected to sustain small fisheries. Similarly, an estimate of stock abundance at Eniwetak Atoll (Marshall Islands) by Ebert and Ford (1986) based on cpue was an average of 126 individuals/km of reef edge (between 35 lobsters/km and 164 lobsters/km of reef edge). These authors estimated the sustainable catch would be about 20 lobsters/km/year.

Adams and Dalzell (1993) pointed out that the sparse densities of lobsters in the Pacific means that a commercial enterprise would have to collect rock lobsters from a very wide area for a sustainable fishery. This would be difficult to do, given all the fishing rights that would have to be negotiated. Besides, rock lobster stocks are already subject to a certain degree of local exploitation. No accessible reefs nor lagoons have virgin rock lobster stocks in PNG. An indication of the size of the standing stock of rock lobsters is that, even with high prices being offered (at Moma fisheries coastal development outlets, Lae and Madang) and at artisanal markets and retail outlets in PNG, catch rates are not high.

2.5.4 Management

Current legislation/Policy regarding exploitation: Customary fishing rights applying to most reefs and lagoons usually restrict the amount of exploitation (Adams and Dalzell, 1993). For example, custom often prohibits the taking of female lobster with soft shell or berried. Provincial fisheries officers encourage fishermen not to harvest berried females nor lobsters less than 12.5 cm carapace length, and are discouraging the use of spears. Speared lobsters are generally of inferior quality.

Recommended legislation/Policy regarding exploitation: Because of the resilience of *P. penicillatus* stocks to recruitment overfishing, Pitcher (1993) was of the opinion that there is little current need to be overly concerned about the reproductive capacity of lobster stocks. Consequently, he said, there is little need to protect berried females or to introduce closed seasons, particularly as females tend to breed throughout the year. The main biological concern of management is therefore to maximise yield from the available stock, by carrying out Yield Per Recruit research and setting appropriate minimum sizes. A minimum carapace length of 7 cm has been discussed, although Pitcher (1993) suggested that a value in the range 7.5-8 cm would produce the highest Yield Per Recruit overall.

In discussing strategies for managing Pacific lobster fisheries, Pitcher (1993) made a case for keeping fishing methods simple to discourage over-capitalisation and its consequences, and taking into account traditional reef-tenure systems for village-based fishermen. He was also in favour of encouraging diving for lobsters in areas where it is currently not practised, since diving provides access to additional productive habitat (the reef slope) and may also improve egg production by shifting effort from female lobsters - which frequent the reef flat - to males. A move away from spearfishing lobsters to taking them by hand would greatly enhance product quality. Both domestic and export markets for live rock lobsters are now available and offer good prices. Exported product should be inspected for quality and operators licenced.

Lewis (1985) made the timely observation that most lobster fisheries have a history of over-exploitation followed by the imposition of management restrictions. In the competitive lobster export fishery in the Philippines has shown a significant decline in cpue at regular intervals (Juinio and Gomez, 1986).

Lewis (1985), Pitcher (1993) and Adams and Dalzell (1993) stressed the concern for quality product, which may be achieved by discouraging spearfishing and encouraging live catching and improved handling. Justification for refusing all overseas applications to exploit the resource was provided in Lewis (1985). They said that rock lobster fisheries would not support 'big business' as the overall stock size in the Western Pacific is so small; not enough to support an export market on its own. Adams and Dalzell (1993) recommended that the harvest be taken only by smallscale operations or as part of a multispecies fishing operation. Passfield (1988, in Richards, 1993) suggested that imposition of a minimum legal size would encourage the taking of large lobsters - a harvest which the resource could sustain. He also suggested that rotational short-term closures of reef sectors may also be a useful management tool in commercial fisheries (so allowing lobster densities to rebuild after harvest).

In summary:

1. Apply legal minimum size restrictions.
2. Discourage spearfishing as a harvest method.
3. Undertake extension work in villagers directed at teaching better handling techniques and preservation of quality in the product.
4. Improve the monitoring and recording of catch information on the fishery.
5. Consider rotational closure of reef sections.

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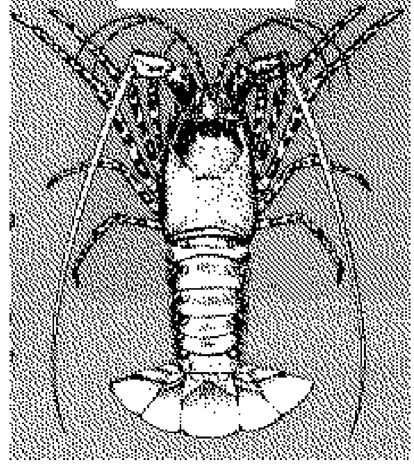
2.6 ORNATE ROCK LOBSTERS

2.6.1 The Resource


Panulirus ornatus

Species present: *Panulirus ornatus*, or ornate rock lobster.

Distribution: *P. ornatus* is widely distributed in the Indian and western Pacific oceans from the Red Sea and east Africa to southern Japan, then Kiribati and Samoa. In PNG their distribution, although they probably occur throughout the country depending on the availability of suitable habitat.

Biology and Ecology: Ornate rock lobsters are found in a range of habitats from exposed oceanic waters as deep as 200 m, sandy lagoons, coral-covered reef flats to shallow (1-8 m) silted rubble areas near river mouths and mangroves (Pitcher, 1993). In Torres Strait, ornate lobsters live in holes and crevices in rocky, weed-covered areas between reefs, on reef tops or under rocks and coral bomboras (Bell *et al.,* 1987, in Kailola *et al.,* 1993).

Ornate rock lobsters move off the reefs of central and northern Torres Strait to breed. At Yule Island, berried lobsters are found between November and April (Moore and MacFarlane, 1984). The ornate lobsters annually emigrate off the reefs in the Torres Strait. Beginning in August, the emigration takes place in waves about every two weeks, until November. Large, mainly male lobsters and juveniles less than two yers old do not emigrate.

Some of the migrating lobsters move north-east across the Gulf of Papua eventually arriving in the vicinity of Yule Island, but the majority of lobsters move east to deep waters off the northern Great Barrier Reef. The ornate rock lobsters move across the gulf in compact aggregations in 14-80 m depth (Moore and MacFarlane, 1984). By the time the rock lobsters reach the Yule Island area they are in very poor condition and large numbers of them die after breeding (Pitcher *et al.,* 1992, in Kailola *et al.,* 1993).

The ovaries develop, pairing takes place and the eggs are deposited during the lobsters' migration. Fertilised eggs attach to the female's pleopods where they remain until they hatch about one month later. The average fecundity ranges from 225,000 eggs (females 70-80 mm carapace length) to 840,000 eggs (females 130-140 mm carapace length) (MacFarlane and Moore, 1986). The larvae are released at the end of the adult migration. The larvae are pelagic and undergo morphological changes as phyllosoma. Their dispersal back to Torres Strait is probably assisted by ocean currents and prevailing winds. After the four-month pelagic phase, the post-larvae (puerulus) settle to the sea floor. Settlement is seasonal - from April-May into October - but most abundant from June to August (Trendall *et al.,* 1988, in Kailola, 1993).

Ornate rock lobsters are fast growing. Females are mature from about 2.5-3 years -of age, at 85-95 mm carapace length (MacFarlane and Moore, 1986). For *P. ornatus* from Torres Strait, L_∞ for males is 16.4 cm and for females, 14.9 cm (Pitcher, 1993).

Recent (1990 onwards) research has shown that a significant proportion of the migrating lobsters move east or south-east from Torres Strait rather than north-east. The deep water off the northern Great Barrier Reef appears to be the main breeding ground for the Torres Strait lobster stock. Some of this research was initiated by J. Prescott who noted (in Prescott and Pitcher, 1991) that

1. there are no deep water breeding aggregations of lobsters in the northern and north-eastern Gulf of Papua;
2. a deepwater breeding population was found outside the Great Barrier Reef in some areas. The densities of lobsters in these areas is far greater than the average density in most of

Torres Strait, but less than that found at Yule Island. It is probably the principle breeding area for the population;

3. the migration across the Gulf of Papua is of lobsters that have moved too far north before moving east, resulting in them looking for deep water to the east but never finding it as they move around the continental shelf. This may account for the wasting of the animals (combined stress of the long migration and breeding) and their high mortality after they have bred.

2.6.2 The Fishery

Utilisation: Ornate rock lobsters are harvested by divers working from outboard-powered dinghies. The lobsters are speared by divers with a short rubber-powered handspear, or collected by hand, in water 1-15 m deep. Recent use of hookah gear has enabled divers to collect lobsters from deeper water. The lobsters recruit to the fishery when they are about one year old. Other rock lobsters, such as *P. versicolor* are harvested as incidental catch to ornate rock lobsters. In PNG the diver catch is high until about September-October when the lobsters move eastwards off the reefs. Monthly catch data (see below) indicates when this takes place. High catch levels into November (e.g. 1987, 1990) suggest either that the migration commenced later in those years or that the PNG divers harvested at the commencement of the migration.

I have no information to advise how much of the landed catch at Daru is caught in the Torres Strait Protected Zone and how much is *bona fide* PNG catch. More information on the distribution of the fishers and the source of their catch would be an advantage.

The catch is brought to processing factories at Daru and Yule Island where the tails are removed and cleaned, weighed and frozen.[1] [Some of the Yule Island catch also goes to Port Moresby: see below]

Ornate rock lobsters usually cannot be caught by using pots or traps.

Production and Marketing: There is a drop in catch rates in the Torres Strait fishery when the mature lobsters move out of the area towards the end of each year to breed. Catch rates prior to 1985 ranged from 2.5 kg/man-day to 5.8 kg/man-day (average 3.3 kg/man-day). Catch rates have risen since then, peaking at 15.13 kg/man-day in 1989 (Fisheries Research annual report 1985-1991).

Table 80 The numbers of lobsters caught at Yule Island from 1978 to 1982 (source: 1983 Fisheries Research annual report)

Year	1978-79	1979-80	1980-81	1981-82	1982-83
total number	955	9,558	1,335	719	1,487

[1] At time of printing, I have no information on whether freezer mother boats operate in the fishery in PNG.

Table 81 PNG production figures in mt tail weight (source: Fisheries Research annual reports for 1983, 1984, 1985-91)

Year	1978	1979	1980	1981	1982	1983	1984	1985	1986
catch Daru	15,400	20,500	35,000	36,000	38,000	32,3012	31,800	c.64,000	c.70,000
catch trawl	70,000*	nil*	197,000 #	100,000	149,000 *	42,000*	10,400	0	0
catch Yule Is	400	4,200	500	300	700	nil	nil	na	na

(* trawl quota in effect) (# 1984 DFMR report stated 221,000 kg). Trawling was banned for the 1985 season onwards.

Table 82 Lobster catch records for 1987-93, Daru only (source: DFMR file dated 19/8/93), tail weight in kg.

Month	1987	1988	1989	1990	1991	1992	1993
Jan	3368.7	3640.7	1827.3	1552.0	1443.0	3158.8	3853.43
Feb	3477.5	3945.1	9804.2	3756.4	1526.1	2300.1	3976.85
Mar	3386.9	6969.0	11313.0	4428.0	8182.4	6511.9	6657.50
Apr	1644.7	7668.9	6327.6	6818.9	9105.1	3321.4	566.98
May	1780.0	6795.1	9010.7	5336.9	7380.1	2776.7	3603.7
June	4519.9	6874.2	5393.8	5524.2	6749.1	5058.0	6095.07
July	3343.1	6245.0	8584.7	6874.9	4511.3	4288.7	6006.83
Aug	4804.0	6956.2	5970.0	7499.7	6557.9	7239.0	540.0
Sept	3829.3	3797.8	4138.1	3640.0	7093.3	6148.1	-
Oct	8327.6	1721.2	3004.3	6068.7	3725.9	3615.1	-
Nov	6015.1	1091.1	3337.6	5976.7	4640.1	3147.5	-
Dec	3243.3	401.2	1552.5	2015.6	2502.4	3031.5	-
Total	47740.1	56105.5	70263.8	59492.0	63416.7	50596.8	31300.4

I do not have (and nor did Philip Polon) catch data for the Yule Island fishery. It was not in the files. The Fisheries Research annual report 1985-1992 pointed out that accurate catch statistics for the Yule Island fishery are difficult to collect because fishers also land their catch at Port Moresby markets.

Table 83 PNG export figures, tail weight, kg (source: DFMR files)

Year	1979	1980	1981	1982	1983	1984	1985	1986
catch (kg)	7184	102696	163749	162956	63969	41525	50273	62,347
value (K)	59526	819051	1355189	1580712	887355	519818	578883	870256

Year	1987	1988	1989	1990	1991	1992	1993
catch (kg)	51818	na	na	42950	57300	34848	52863*
value (K)	763711	na	na	na	na	585718	984274*

(* cf *alternative* figures in the DFMR database for 1993; i.e. 'lobster tails' - 52,863 kg; 'lobster meat' - 3,675 kg; 'lobster' - 200 kg; 'live lobster' - 3,490 kg. I do not know whether and how lobster meat and lobster are different to 'lobster tails'; and I do not know whether the *live* lobster exports consisted solely of *P. ornatus*, or not at all, or whether other rock lobsters were included in the total. In short, clarification is needed!)

Table 84 Comparison of Daru production and exports, 1987-92 (mt tail weight) (source: DFMR Daru)

Year	1987	1988	1989	1990	1991	1992
Daru	47.7	56.1	70.3	59.5	63.4	50.6
Export	51.8	na	na	43	57.3	34.8
Difference*	-4.1	-	-	+16.5	+6.1	+15.8

*NOTE a negative! The difference must be what is sold on the domestic (PNG) market (a check of the 1987 statistics could be worthwhile). However, I did not have time to investigate the domestic market for lobsters.

The ornate rock lobster fishery is valued at between K1.3 million and K2.6 million to the coastal villagers of the Western Province (Fisheries Research annual report 1985-1991).

2.6.3 Stock status

A reliable estimate of the ornate rock lobster population and the percentage of that population that can be caught without affecting recruitment in subsequent years is needed to determine a sustainable level of harvest in the lobster fishery; and catch-per-unit effort is an adjunct to this estimation.

Since 1989 the CSIRO Division of Fisheries (Australia) in collaboration with PNG DFMR, has estimated the numbers of ornate rock lobsters in Torres Strait (Williams, 1994). The 1989 survey estimated that the catch that year was only 10 per cent of the available stock of between 11 million and 17 million (Williams, 1994); the 1990 and 1991 stocks were half of the 1989 level; the 1992 stock level was estimated to be 35 per cent higher than the 1991 level. The 1993 predicted stock level (monitored by catches) did not occur however. Changes in the environment (e.g. changes in the direction of the currents that bring the larvae back to Torres Strait) may contribute to fluctuations in recruitment to the stock in the strait year to year, as well as relocation of diver effort.

The assessments of the ornate rock lobster stock in Torres Strait has shown that it is much underexploited - that even with a four-fold increase in the total catch approximately 74 per cent of the population would migrate and breed each year (Pitcher *et al.,* 1991, in Kailola et al., 1993). Even so, researchers believe that this estimate is conservative.

Recent CSIRO research showed that 93 per cent of ornate rock lobsters that survive fishing in Torres Strait manage to migrate and breed (Williams, 1994). Fishing at Yule Island causes one-third of the lobster mortality in the breeding period of the population that migrates to there. This is a very high figure (Williams, 1994); however, many of the lobsters would have shed one or two broods before capture.

Whereas it is known that most of the ornate rock lobsters arriving in the vicinity of Yule Island die after the migration and breeding (or are harvested), research is continuing into whether the lobsters in the main breeding stock off the northern Great Barrier Reef also die. The results will ensure a greater level of certainty to the annual stock estimates and the recommended level of fishing effort. During rock lobster surveys from a submersible, J. Prescott (pers. comm.) did not discover any exceptionally large lobsters in the deep water breeding areas in the northern Great Barrier Reef areas. He stated (in Fisheries Research annual report 1985-91) that this phenomenon suggests that the majority of the breeding lobsters breed only one season. Physiological stress in the deep water populations may follow a similar pattern to that which we have described from the shallow water [around Yule Island]. Assuming that the majority of lobsters only breed one season, overfishing of a year class may result in low reproductive output for that year. Overfishing on several consecutive year classes could result in a severe decline in reproductive output as there is no resident breeding population to maintain output. In effect:

- the Torres Strait fishery removes individuals that are subadult and have not bred;
- if the adult lobsters breed only in one year (they then die);
- then overfishing of a year class in the diver fishery could result in a decline in catch 2-3 years later.
- nevertheless, because a large proportion of the ornate rock lobster stock is widely distributed in Torres Strait at densities too low for commercial harvesting, it is unlikely that overfishing will take place in the forseeable future (J. Prescott, in Fisheries Research annual report 1985-1991).

2.6.4 Management

A ban on trawling ornate rock lobsters was brought in by the PNG and Australian governments in 1984. Prior to this, trawler operators had been permitted to target the migrating rock lobsters and individual vessel catches of more than 1,000 lobsters per haul were common in the early 1980s (Williams,1994). Because trawling was harvesting berried lobsters, it was having a marked negative effect on replenishment of the common stock. This was evidenced by large declines in the lobster catches by Yule Island fishers and also be declining catches in the Torres Strait reefs. Research in the early 1980s suggested that target trawling the dense aggregations of migrating lobsters had the potential to effectively wipe out the population if it was continued for three consecutive years.

One local effect of the trawling ban was that it ensured the survival of the Yule Island fishery. Of importance to the fishery is the fact that the Yule Islands fishers catch the lobsters after they have released one or two broods of eggs, thus contributing to the stock. By contrast, the trawlers caught lobsters before they had a chance to reproduce.

Current legislation/Policy regarding exploitation: Ornate rock lobsters may not be trawled. Besides prohibiting the target trawling of lobsters the regulations also state that lobsters taken as bycatch to prawn trawling must be returned to the sea, alive if possible (Williams, 1994).

There is a minimum legal size of 100 mm tail length - at least in the Torres Strait.

Recommended legislation/Policy regarding exploitation: In view of the virtual absence of catches in the Yule Island fishery - rather, no information on them - <u>a closer look at the catches of Gulf of Papua prawn trawler operators should be made</u>. I do not know if their catches are ever checked - to see if they are harvesting rock lobsters. Even 'bycatch' is not permitted. Do they record 'lobsters' in their logsheets? Have observers been on board during the September-November breeding migration? Yet maybe a closer monitoring of the Yule Island fishery catches would obviate - or go in tandem with - this?

Stock assessments have shown that the resource is underexploited - at least in the Torres Strait. Therefore, there is <u>considerable scope for an increase in diver effort in the fishery</u> there. <u>DFMR should *monitor the catch-per-unit-effort* annually</u>[2]and continue to collaborate with CSIRO scientists working on the resource. I do no know how much lobster-bearing habitat in Torres Strait is available to PNG fishers.

Catches in the PNG fishery decreased sharply since the trawling ban and from 1985 to 1992 have averaged just over 60 mt/yr (no information is available on the Yule Island fishery). In

[2] Perhaps they already do this?

light of the CSIRO/DFMR stock assessments, there is indeed a case for increasing that catch very substantially.

An economic study should be carried out into the relative costs and benefits of alternative fisheries in the Daru area - western Papua - for example, of ornate rock lobsters, barramundi, mangrove crabd and sedentary resource harvesting. The study should also include processing and marketing aspects, as well as opportunities in the export of live lobsters.

The *P. ornatus* resource is significant for PNG. The yield of this fishery from northern Australia/PNG for the period 1981-90 was 175-460 mt (average of 309 mt/year), more than 10 times the combined average annual catch of tropical rock lobster (mainly *P. penicillatus)* fisheries in eight Western Pacific nations (Adams and Dalzell, 1993). The rock lobster resource is valuable, and it would be well to utilise it fully and effectively.

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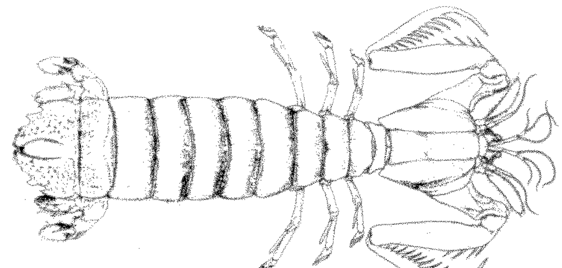
2.7 MANTIS SHRIMP

This presentation was prepared by M. Chapau, A. Richards and P. Kailola.



Lysiosquilla sp.

2.7.1 The Resource

Species present: The banded stomatopod or giant mantis shrimp, *Lysiosquilla maculata*.

Distribution: *L. maculata* is the most common and widely distributed species of the genus *Lysiosquilla* in the Indo-West Pacific region (Angsinco *et al.,*1986). In PNG, the species has been found from the West Sepik Province to Manus Province, Madang Province, Samarai Island and Trobriand Islands in Milne Bay Province and the Gulf of Papua trawl grounds. *L. maculata* commonly inhabits inter-ridal reef flats, sand and seagrass areas and coral rubble. Their burrows can be found in depths ranging from the shoreline to 80 m.

Biology and Ecology: *L. maculata* is known to be the largest species of the Order Stomatopoda. The adult female mantis shrimp is usually distinguished from the male by its distinct tangerine colour at the mid-dorsal abdomen, which indicates developing ovaries. Generally the females are larger than the males. Angsinco *et al*.(1986) found the modal size range of mantis shrimp in the Philippines to be 225-230 mm, at which size males weighed 125-250 g and females 180-330 g.

Most mantis shrimps live in burrows excavated in the bottom sediments or live in coral crevices. *L. maculata* lives in burrows on sand and soft mud banks from the inter-tidal down to the reef breaker zone (Angsinco *et al.,* 1986). The burrow has three sections, is characterised by being either a volcano-like mound of sediments or a funnel-shaped crater, and has a general 'J' shape. The opening is generally proportional to the animal's size - from 3 cm for newly recruited juveniles to 13 cm for adults. In the Philippines study, the diameter of the shrimp burrows ranged from 5 cm to 9.7 cm (Angsinco *et al.,* 1986) and each burrow was usually inhabited by a pair of mantis shrimps, male and female. In the inner burrow wall, the sediment is held together by a sticky substance which is probably excreted by the mantis shrimp.

Mantis shrimp swim in looping motion. Many species of mantis shrimp leave the burrow to feed on small fish, crustaceans and other invertebrates, the prey being caught and killed by an extremely rapid extension and retraction of the movable finger of the second large pair of thoracic appendages. This method of feeding can effectively cut a prawn in two with one slice (Barnes, 1968).

Recruitment of the mantis shrimp *Squilla mantis,* in the Mediterranean Sea tends to occur in shallow waters. Females spawn about 18 months after settlement and may remain in their burrows between spawning and hatching (Piccinetti and Piccinetti Manfrin, 1971, in Abelló and Martín, 1993). Mantis shrimp spawning may take as long as four hours. The agglutinated egg mass which is 2-3 cm in diameter is carried by the smaller chelate appendages and is constantly turned and cleaned. The female does not feed during brooding, which occurs inside the burrow (Barnes, 1968).

Abelló and Martín (1993) stated that few attempts to estimate growth in stomatopods have been performed. Their study of mantis shrimps in the Philippines gave a length:weight range of 50 g at 100-125 mm total length to more than 400 g at 275-300 mm total length. Females were heavier than males. In *S. mantis* from the Mediterranean Sea, growth is fast and similar for both sexes. Life-span from settlement is estimated to be around 18 months, with *S. mantis* exhibiting a high natural mortality (Abelló and Martín, 1993).

2.7.2 The Fishery

Utilisation: Coastal villagers in PNG traditionally have hunted for *L. maculata* using a variety of methods including traps, baited hooks and by hand. However, the most common method is snares (Chapau, 1992). The way the snare is constructed and used varies from coast to coast; in Kavieng it is a string with a loop at the end.

Traditionally, the claws of this species are used for magical purposes in Manus, New Ireland, Karkar (Madang Province) and the Trobriand Islands.

Production and Marketing: Mantis shrimps are used for subsistence and occasionally for sale. An estimate of sales throughout PNG would not exceed 500 kg/year.

There is potential to develop a small fishery based on this resource: the shrimps fetch a high price in local markets, the edible abdomen is large and, in New Ireland and the East Sepik - also in Cook Islands - mantis shrimps are easily sold to local hotels and restaurants. There is also an export market available to Asian centres and Hawaii.

2.7.3 Stock status

There is no information on stock size in PNG. In a study in the Philippines (Angsinco *et al.,* 1986), 57 mantis shrimps were observed from 46 identified burrows in an area of 16 ha, at a density of 3.56 shrimps per ha. In a nearby 10 ha area, the density was 4.2 mantis shrimps per ha. The authors noted however, that their estimates were limited by inefficiency of the traps and number of expert collectors.

In a population of mantis shrimp (*S. mantis*) off the Ebro delta in the north-western Mediterranean Sea, frequency of occurrence of *S. mantis* decreases with depth, the resource being most abundant at depths shallower than 60 m (Abelló and Martín, 1993).

2.7.4 Management

Current legislation/Policy regarding exploitation: There is no legislation regarding mantis shrimps in PNG.

Recommended legislation/Policy regarding exploitation: *Here is a resource that could be developed as a small domestic fishery for coastal villagers*, particularly in the West Sepik, New Ireland, Madang and Milne Bay provinces. Although there is potential for exporting, ensuring quality would be a problem.

<u>Surveys of stock abundance</u> in those provinces should be performed and legislation brought in, such as <u>size limits</u> and a <u>ban on the taking of brooding females</u>. This recommendation follows the example of Aitutaki in the Cook Islands, where the mantis shrimp resource is heavily exploited and locally threatened (Richards, 1993).

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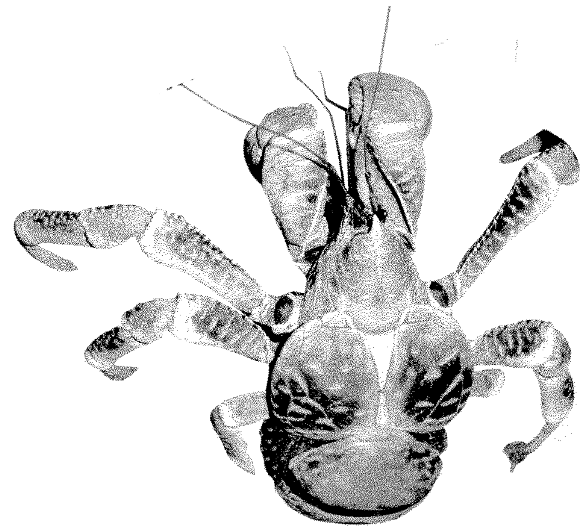
2.8 COCONUT CRAB

2.8.1 The Resource

Species present: The coconut or robber crab (*Birgus latro*).

Distribution: Coconut crabs have a wide tropical Indo-Pacific distribution, from Mauritius in the western Indian Ocean to the Tuamotu Archipelago in the eastern Pacific. They occur only in island habitats. In PNG they inhabit only offshore islands including the Bismarck Archipelago, New Britain, Bougainville and islands in the Milne Bay Province.



Birgus latro

Biology and Ecology: Coconut crabs are terrestrial and hide in holes in the earth and in crevices,under tree roots and in hollow logs, emerging to forage along beaches and over coral rocks. They prefer coastal habitats with dense forest cover.

Coconut crabs generally have a solitary existence. They are omnivorous scavengers and are highly aggressive (Helfman, 1977, in Fletcher, 1993). The species is the largest and least marine-dependent of the land crabs.

Mating generally occurs from May to September, with a peak from July to August (Reese, 1971, in Smith, 1992). The female carries the eggs under her abdomen attached to hairs. After 25-45 days the female moves to the shore and releases the eggs into the sea. Spawning takes place at night, usually about the periods of first and last moon quarters. After hatching, the larvae remain planktonic for around four weeks during which they go through four or five larval stages. After this period the larva metamorphoses into a glaucothoe and settles to the seabed. The glaucothoe seeks out an empty gastropod shell for shelter and after about two weeks moves out of the sea onto the land. It metamorphoses into a coconut crab when it grows to about 5 mm carapace length. The young crab will carry a shell around for about nine months, becoming increasingly terrigenous (Brown and Fielder, 1992). As they grow they move further inland. The crabs moult in burrows they dig out. The time taken to moult is related to the size of the crab: small crabs take a few days; large crabs can take 1.5 months.

Fletcher (1993) found that recruitment success is highly variable with significant recruitment to an area being a sporadic event occurring only every 5-10 years when all conditions are suitable.

Growth is very slow and heavily influenced by environmental factors, which is a key reason why the species cannot be commercially cultured. It takes about ten years for a crab to reach about 1 kg in size (Fletcher *et al.,* 1990) and large crabs may be 30-40 years old (Reese, 1987, in Fletcher, 1993). Large adults may attain a weight of 4 kg (Brown and Fielder, 1992) and the maximum size has been reported as 100 mm thoracic length. Reese (1971, in Smith, 1992) estimated that size at maturity is around 7.6-12.7 cm carapace width for crabs on Eniwetok, at an age of from four to eight years. Fletcher (1988), working in Vanuatu, estimated a 600 g crab to be 12-15 years old. The crabs live for at least 50 years and they have a very slow growth: K 0.06.

2.8.2 The Fishery

Utilisation: Coconut crabs are hunted by local inhabitants wherever they occur, as its flesh is generally regarded as a delicacy. Because they live on the land they are easy to catch. The crabs often are caught with baits of opened coconut, or sought out with stocks while they are in their moulting burrows. The moulting crab's soft body is highly regarded in local diets.

In PNG the crabs are important in the subsistence diet and are not offered for sale in markets.

Production and Marketing: DFMR has export figures for coconut crabs for 1992 and 1993. DFMR did not differentiate 'crabs' in earlier years.[1]

Table 85 1992 export figures for coconut crabs from Rabaul (source: DFMR).

Export date	12/8/92	2/9/92	15/9/92	25/9/92	20/11/92	25/12/92
Quantity* (kg)	20	30	10	10	10	10
Unit rate* (K/kg)	4.50	4.50	4.50	4.50	4.50	4.50

(*these figures total 90 kg and K405. However, DFMR Rabaul figures record that 170 kg with a total value of K765 were exported through Rabaul in 1992. I have no information about which set of figures is correct.)

Table 86 1993 export figures (for all of PNG?) for coconut crabs (source: DFMR database)[2].

1993	January	March	April	May	June	August
quantity (kg)	150	10	20	160	100	3,674.16
value (K)	1,650	45	90	1,845	1,200	67,090.16

1993 exports through Rabaul are recorded by DFMR Rabaul as 40 kg, valued at K180.

The 1992 coconut crabs through Rabaul were probably collected on Tanga Island and Fead Island in the New Ireland Province (Richards, 1993).

2.8.3 Stock status

In 1984 a mail survey of 28 mainly Pacific and South-east Asian countries (Brown and Fielder, 1988) revealed that coconut crabs were considered abundant - in varying degrees - in only six localities: Solomon Islands, Vanuatu, Chuuk (Federated States of Micronesia), Tokelau, Niue and Marshall Islands. The remaining countries indicated that the species was only either locally common or rare.

In PNG, coconut crabs generally are locally abundant and locally common - e.g. in Wuvulu and Aua islands, Manus Island, Mussau Island, Tami Island (Morobe Province) and some of the Milne Bay Province islands. However, they are reported to be rare and decreasing on offshore islands of New Ireland (e.g. Richards, 1993) although in an absence of earlier stock information it is not known whether this phenomenon is through natural fluctuations in the population there or through stock depletion.

Recent genetic research has shown that while the *Birgus* populations in Vanuatu and Solomon Islands probably constitute a single stock, the Indian Ocean and Pacific Ocean populations are

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[1] Because of that situation, I assume that the category 'crabs' in the years prior to 1992 refers only to mangrove crabs (profile 2.9), and that coconut crabs were not exported before 1992. Prior to printing, I have not received alternative advice on this.

[2] These figures need checking, as they appear far too large; e.g. in just the month of August, 3.7 mt were exported!

probably two distinct stocks. In the Pacific there was some indication that coconut crab populations in Niue and the Cook Islands are also separate, independent populations (Fletcher, 1993).

2.8.4 Management

Current legislation/Policy regarding exploitation: There are no restrictions on the capture of coconut crabs. They are considered a nuisance (but not a serious one) to coconut growers.

Recommended legislation/Policy regarding exploitation: Several features of the species' biology urges conservation. These are listed below.

1. Replenishment of heavily exploited populations is slow because of highly variable recruitment success. Recruitment to an area may or may not be affected by adult density (Fletcher,1993) but the presence of large numbers of coconut crabs in an area may affect successful recruitment.
2. Eggs and larvae are not easy to raise/keep alive and maintaining the glaucothoe stage is extremely difficult (Fletcher, 1993). Hence hopes for restocking over-exploited areas are low.
3. Coconut crab growth rates are slow, which suggests that declines in abundance can be expected in areas of high catch rates.
4. The terrestrial habit of coconut crabs makes them easy to catch and transport.

Fletcher (1993) stated that " ..the rational management of this resource should be of vital importance to the governments of all countries with surviving populations of coconut crabs." Wells, Pyle and Collins (1983) stated that " Protection should be afforded to this species in vulnerable areas."

The greatest threat to coconut crabs is the international food market. In conjunction with this is their oddity status and the increased accessibility to their habitat by traders through improved transport systems.

In PNG, protection could be afforded in the form of:

- catch limits (e.g. bag limit),
- the imposition of legal size limits for harvesting, and
- the closure of particularly susceptible areas to harvesting. Unfortunately, this third suggestion is difficult to fulfill in the absence of stock assessments and regional local information on coconut crab biology. Without that information, meaningful quotas cannot be implemented - although
- seasonal quotas could be considered.

To save the time (and cost) of running studies of the coconut crab in PNG, guidelines for the measures suggested could be sought from other Western Pacific countries (where 'coconut crabs' are a bigger business than they appear to be in PNG) as a temporary measure.

- Export statistics on this species should be improved to include the source of the crabs, the prices paid and the period of capture; and fisheries officers should record the quantities and sizes of crabs being exported. And finally -
- As with other protective measures, an education ('public awareness') campaign should be undertaken.

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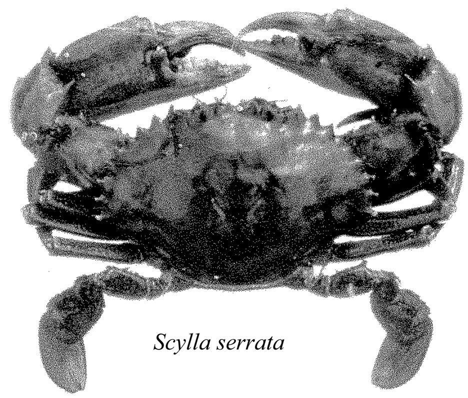
2.9 MANGROVE CRAB

2.9.1 The Resource



Scylla serrata

Species present: There are two, possibly three, species in the PNG fishery. The larger, greenish crab is the *Scylla serrata* form (C. Keenan, pers. comm.) but the correct names for them smaller, brownish species (called *paramamosain* in literature) and the third small, spined species are uncertain. The names *S. olivaceus* and *S. tranquebaricus* are available, but type material has not yet been examined (C. Keenan, pers. comm.).

Brown (1993) recorded the history of classification of the genus *Scylla*, where up to four species have been recognised. The characters used to differentiate the species have been found to vary with age, moult stage and habitat, but some recent authors (e.g. Quinn and Kojis, 1987) recognise one or more of the additional nominal species. Brown (1993) conceded that differences in growth rate and attainment of maturity between populations of *S. serrata* may be indicative of the existence of different species or discrete stocks. Genetic studies aimed at determining the genus' composition have been continued by C. Keenan (Southern Fisheries Centre, QDPI, Queensland) through an ACIAR-funded project. Brown (1993) urged caution in using names other than *Scylla serrata* for mangrove crabs in the western Pacific until the status of the nominal species has been resolved. This caution would encompass attempts to apply different management criteria to morphologically different populations of mangrove crabs. Keenan's study, entitled "Genetic and morphological relationships of mud crabs, genus *Scylla*, from thoughout the Indo-Pacific" is nearing completion.

Mangrove crabs are swimming crabs and their last pair of walking legs have flattened segments.

In the Murik Lakes, East Sepik Province, both forms of mangrove crabs are present (Chapau, 1991): in 1984, small mangrove crabs formed 95.7 per cent of the Murik Lakes harvest and large mangrove crabs formed 4.3 per cent of the harvest. In the Madang Province, mangrove crabs are found in the north of the province towards the Ramu and Sepik rivers where the estuaries are (A. Koyo, pers. comm.), and most of the crabs are the larger form. In the Morobe Province, the small form predominates (A. Tumonde, pers. comm.). In Manus Province, both forms are present (Chapau and Lokani, 1986): in 1986, larger mangrove crabs comprised 34.5 per cent of the Manus west coast harvest and the smaller form comprised 65.5 per cent of the harvest. In western Papua, both forms also occur (R. Moore, in DFMR files; B. Shackles, pers. comm.): the larger form is found around Daru and from Parama Island west to Sigabaduru, and the smaller form from Parama Island to and into the Fly River delta, the Bamu and Gamu rivers and across the Gulf of Papua as far east as Kerema. Large crabs are present around Kupiano (Central Province) (B. Shackles, pers. comm.).

Distribution: A comprehensive description of the Indo-West Pacific distribution of *S. serrata* is given by Dickinson (1977, in Brown, 1993). Brown (1993) stated that any tropical Pacific island large enough to sustain a fluvial delta with associated mangrove forests will support a population of mangrove crabs. These crabs mainly inhabit areas of muddy substrate in mangrove vegetation - habitats typical of sheltered tropical to sub-tropical estuaries, embayments and the lower reaches of rivers and tidal streams (Brown, 1993). *S. serrata* can tolerate a wide range of temperatures and salinities - variably from 2 ppt to 60 ppt, and 10° C to 25° C (Hill, 1979, in Brown, 1993).

Within the Purari River delta, mangrove crabs have a distribution limited to a narrow coastal fringe (Opnai, 1980, in Frusher, 1982) apparently restricted to regions of saltwater penetration. Areas inhabited by mangrove crabs are confined to the coast in the Purari delta yet up to 40 km from the sea in the Kikori-Era deltaic region (Fisheries Research annual report 1979).

Biology and Ecology: Mangrove crabs are usually found in burrows below the low tide mark. The burrows extend obliquely down into the mud at an angle of about 30° to the horizontal and may be up to 2 m long.

Mating takes place when the female's carapace is soft, within a period of about 48 hours following a moult. On New Hanover in the New Ireland Province, the crabs are said to moult with each new moon and breed about two weeks after moulting (Wright, 1983).

Each female will produce between two million and eight million eggs per spawning, depending on her body size. The eggs are attached in a spongy mass beneath her abdominal flap and are incubated there for 2-4 weeks depending on water temperature (Heasman, 1980, in Kailola *et al.,*1993). Berried female crabs move out to sea (or to inshore waters or even river mouths) to hatch their eggs (Hill, 1982, and Mounsey, 1990, in Brown, 1993; Frusher, 1982). Mature and berried female mangrove crabs are trawled throughout the year in the Gulf of Papua, in 7-10 m depth and sometimes as far as 30 km from the coast (Frusher, 1982). In New Ireland, berried female mangrove crabs are present in the mangrove systems. M. Chapau (pers. comm.) suggested that this phenomenon may be influenced by the small amount of freshwater run-off from the island.

Comment [PK1]:

The pelagic crab larvae require salinity of more than 30 parts per thousand and high water temperatures (Hill, 1974, in Kailola *et al.,* 1993). The larvae remain planktonic for two to three weeks during which they undergo a series of changes and are transported by tides and currents back to the estuarine environment. Juveniles (20-80 mm carapace width) remain in seagrass beds or mangrove-lined creeks. Sub-adults (60-130 mm carapace width) and adults (with carapace width greater than 120 mm) migrate at high tide to intertidal habitats such as the mouths of creeks and estuaries and retreat at low tide (Frusher, 1982; Nichols, 1991). Adults generally inhabit deeper tidal waters.

Growth rates and maturity in mangrove crabs vary with water temperature. Brown (1993) reported that in sub-tropical climates, mangrove crabs attain a carapace width of between 8 cm and 10 cm in their first year, and between 13 cm and 16 cm in their second year. In northern Australian waters, mangrove crabs can reach a carapace width of 24 cm, but most fall within the 15-20 cm size group. Crabs can reach 3.25 kg (Kailola *et al.,* 1993).

In the Gulf of Papua, larger and heavier crabs are present in areas where the salinity range is 16-20 parts per thousand whereas smaller and lighter crabs inhabit areas where the salinity range is 0-14 parts per thousand (Fisheries Research annual report 1980 and 1981). In the Murik Lakes, East Sepik Province, areas of lower salinity have a population density of 39 crabs/ha (average weight 218.7 g) while areas of higher salinity support a density of 13 crabs/ha (average weight 331.9 g) (Opnai, 1986).

Sampling of crabs around Uramu and Ini islands (western Gulf of Papua, Gulf Province) showed that the largest crabs were on average 13 cm in carapace width and weighed 660 g. Females of the same carapace width weighed much less. Length/weight relationships: were logW= 0.1+4.45 logL (males) and logW=0.2+3.81 logL (Fisheries Research annual report 1979). The largest size recorded for the small *paramamosain* variety by B. Shackles (pers. comm.) in western Papua is 6 inches (c. 150 mm) carapace width. R. Moore (DFMR files) recorded size ranges of 7-9 cm carapace width for the small form and 9-15 cm for the large form. Crabs above 400 g weight in the Gulf of Papua are all males (Fisheries Research annual report 1979). On the west coast of Manus Island, the average size of mangrove crabs harvested in July 1986 was 404 g and 12.8 cm carapace width (larger form) and 190 g and 11 cm carapace width (smaller form) (Chapau and Lokani, 1986). In the Murik Lakes, mangrove crabs of the large form range in size from 80 mm to 180 mm carapace width and from 214 g to 332 g (mean 260 g) and crabs of the smaller form range in size from 70 mm to 140 mm (mean c.106 mm) (Chapau, 1991: no weights were stated for the smaller form). The mean size of all crabs is 105 mm carapace width and 260.3 g (Opnai, 1986).

Considerable variation also exists in both the size and age at which mangrove crabs reach maturity (Brown, 1993). In the tropics they may mature before 18 months of age, but in higher latitudes they mature at about two years of age. Quinn and Kojis (1987, in Brown, 1993) found mature crabs [in the Labu River estuary?] as small as 9 cm carapace width and the smallest berried 'large' form of *Scylla serrata* recorded by R. Moore off the Fly River delta was 9.6 cm (DFMR files).

Mangrove crabs are opportunistic feeders, subsisting primarily on slow-moving or immobile prey organisms. Their main feeding periods are in the early evening and before dawn. Mangrove crabs consume crustaceans, barnacles and bivalve molluscs, decaying vegetable matter, polychaete worms and dead fish and meat in traps (Kailola *et al.*,, 1993). Feeding is reduced or ceases during the intermoult period, during mating and when the water temperature drops (Brown, 1993).

2.9.2 The Fishery

Utilisation: "Their size, high meat yield, delicate flavour and ease of capture mean that almost everywhere they occur mangrove crabs are highly sought-after as a quality food item." (Brown, 1993:609).

The mangrove crab is the most important crustacean in the diet of the inhabitants of the Purari River delta, and villages on Uramu, Ini and Iviri islands west of Port Romilly have a tradition of trading mud crabs and smoked fish for sago with the Koriki people on the Purari delta (Fisheries Research annual report 1979). The number of crabs consumed in the Kikori and Purari area each year is about 90,000 (Opnai undated, a). The average daily catch is 40 g per head of population (Liem and Haines, 1977). Mangrove crabs are consumed in large quantities by Murik Lakes residents (Opnai, 1986) (except for adherents of the Seventh Day Adventist religion) and the average daily crab consumption of Murik Lakes people was 45.4 g in 1985 (Chapau, 1991). The total daily consumption of mangrove crabs from the four main crab fishing villages in the lake system utilising the resource was estimated at 42.7 kg/day (Opnai, 1986) or 15.6 t/year (5,460-5,460 crabs).

Mangrove crab collecting in PNG is primarily carried out by women. The most effective method of catching mangrove crabs in the Gulf of Papua is the traditional way - hand and hooked stick (Opnai, 1979) and in the Purari River delta they are caught by hand or in finely woven hand traps in shallow water (Haines, 1978-79). In the Murik Lakes (East Sepik Province), the crabs are caught with the aid of a stick. When it is poked into the crab's burrows the crab inside grabs the stick and is hauled out (Chapau, 1991). Fishing is done at low tide when the water is knee deep. Women are the main collectors of mangrove crabs and they fish from canoes. In New Hanover, the women follow the tracks the crabs leave in the mud beneath the mangroves at low tide, and hold the crabs down with a short three-pronged spear while the claws are bound (Wright, 1983). In Manus Province, the women collect crabs either by spearing with a multi-pronged spear or by capturing by hand with the help of a forked stick (Chapau and Lokani, 1986).

Alternative catching methods have been tried. Crab fishing trials were conducted in 1979 in the western Gulf of Papua (Fisheries Research annual report 1979). The results were: baited crab pots of chicken wire gave a cpue of 0.2-1.25 crabs/pot/4 hours (but pots often washed out to sea with retreating tides); 4" (10.2 cm) baited gillnets returned 2-3 crabs/hour (nets often sustained shark damage); 1 cm mesh beach seine yielded 0.4-0.75 crabs/haul. Dillies were not successful. The traditional way of catching crabs - by hand and hooked stick - gave a catch rate of 5.52 crabs/hour at low tide.

The best season for mangrove crab gathering is during the dry in the Siassi Islands, Morobe Province (A. Tumonde, pers. comm.) - as it probably is elsewhere in PNG. In both the Murik Lakes and the Baimuru-Kikori area of the Gulf Province, the best time for crabbing is just after the high tide, and highest production is achieved after high spring tides (Opnai, 1986).

The Uramu, Ini and Iviri island areas are the most commercially exploited in the Gulf of Papua. Whereas the gulf people prefer to eat smaller crabs, they target larger crabs for commercial sales.

The apparently large number of mangrove crabs present in some parts of the Purari River delta resulted in the pilot project for a commercial venture starting in 1977 by the Baimuru Local Government Council. The council purchased live mangrove crabs for live shipment to the Highlands. The Department of Primary Industry took over the business late in 1978 and in March 1979 it was taken over again by the Baimuru Local Government Council and the Gulf Investment Corporation. The main suppliers were fishers from the Uramu Island area who have a tradition of fishing commercially for crabs; and by late 1979 significant catches of crabs from the Maimari and Koriki areas were being purchased (Haines and Stevens, 1983). Live, bound crabs held in *Nypa* baskets were bought from villagers on certain days and flown to the Highlands by a regular plane charter. The villagers produced about 9 mt (c. 22,000 crabs) in the first six months of the project (Haines, 1982) and crab purchases ranged from 400 kg to 800 kg a week. With regular production aligned with plane services and quality control, the project expanded to market crabs in Kerema and Port Moresby as well. However, air services to the Highlands became irregular and in 1979 trials using crab meat rather than whole crab were carried out (Haines and Stevens, 1983) to reduce freight charges. This activity met with varying success: accpetable in Kerema and Port Moresby, unacceptable in the Highlands (Fisheries Research annual report 1979; Fisheries Research annual report 1982). By 1980 the Baimuru Fish Plant was purchasing over 10 t if crabs a year (Opnai, 1986). The Kikori Local Government Council started a similar venture in 1978, purchasing crabs from Uramu Island and Goaribari.

The Gulf of Papua commercial fishery revealed several features about mangrove crab handling:

1. bound crabs in *Nypa* baskets suffered a lower mortality than crabs held in tidal ponds,
2. injured crabs and loosely bound crabs had a higher mortality rate,
3. by purchasing only healthy and well-bound crabs, the mortality rate over 3 days was reduced to only 3.6 per cent,
4. bound crabs covered with wet bags could be held up to10 days, but after five days weight loss and mortality reduced the harvest, and
5. trials conducted at DFMR Kanudi , showed that up to 1,000 crabs could be kept in brackish water for up to 10 days and fed trash fish. Fighting did not take place if the crabs were provided with cover.

Production and Marketing: In the Murik Lakes, East Sepik Province, crab fishing is largely a subsistence fishery although some crabs are sold to local hotels and at the town market. In 1985, the estimated total annual subsistence harvest of mangrove crabs from the Murik Lakes was 20.8 mt for the population over 6 years old. One tonne was sold through the Wama Marine fish plant in 1984 (Chapau, 1991), although the amount of private sales would be significant. The estimated subsistence harvest from Murik Lakes in 1985 was 18.2 t/year (Chapau, 1991). Crabs less than 200 g are not marketed.

Mangrove crabs have only recently been brought to the Madang fisheries depot. The crabs purchased range in size from 12 cm to 15 cm carapace width. The purchase price is K5.00/kg (MOMA Coastal Development Project price).

In the Gulf Province, the estimated annual subsistence catch for the Purari-Kikori deltaic region is about 300 mt (Liem and Haines, 1977). Live mangrove crabs are also a major market item and fetched 10 toea/kg in 1977 in provincial markets. The average weight of the crabs was 290 g.

Table 87 Artisanal/commercial landings of mangrove crabs at the Baimuru Fish Plant, 1978-82, kg live weight and number (1978 only) (sources: 1978 - DFMR file; 1978-82 - Fisheries Research annual reports for 1978, 1979, 1980 and 1981 and 1982; numbers from DFMR file).

month	1978 (DFMR file) - *numbers*	1978 (DFMR file) - kg	1978 (ann. rept) - kg	1979 (ann. rept) - kg	1980 (ann. rept) - kg	1981 (ann. rept) - kg	1982 (ann. rept) - kg
January	-	-	-	155	0	0	0
February	3,217	1,286.8	1,183	844	302	975	0
March	3,776	1,510.4	1,089	668	1,057	1,612	0
April	1,768	851.6	*831	1,176	981	460	0
May	4,875	2,007.2	*2,034	878	1,336	0	0
June	2,841	1,135.6	1,739	752	1,025	0	0
July	830	332	1,830	342	1,401	0	0
August	2,403	961.2	961	1,117	1,554	0	2,000
September	2,482	992.8	993	797	162	550	1,000
October	706	282.4	280	770	935	1,079	0
November	0	0	0	756	903	0	0
December	620	248	248	639	634	0	0
TOTAL	23,518	9,608	11,188	8,894	10,290	4,676	3,000

(*excludes catch for 1 and 2 weeks.)

There is no more information available at DFMR on crab purchases for the Baimuru Fish Plant after 1982.

After 1978, crabs purchased by Kikori and Baimuru fish plants were all >400g in response to consumer preferences in other provinces (in1978 the minimum acceptable weight was 300 g). Individual crabs up to 600 g were recorded at the centres.

Table 88 Kikori Local Government Council crab purchases, monthly, from September 1978 to August 1979, kg live weight (source: Fisheries Research annual report 1979).

month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
kg	1023	655	180	131	0	6	21	6	1676	3495	1190	215

Western Province:

Table 89 Landings of mangrove crabs at Daru from 1986 to 1991, kg whole weight (source: DFMR database):

Year	1986	1987	1988	1989	1990	1991
quantity (kg)	19	559	67	no info	4,989	896

In 1991, the crabs were caught only in the months of February and March, and August and September. (Note the high increase in catch in 1990. I have no information on why.)

Morobe Province:

In the Huon Gulf's fisheries landing site in Lae, few crabs are landed, but some are brought to the town market for sale. Mangrove crabs are marketed from different parts of the province depending on the time of year (season). Those that come are mainly from the areas south of Lae. In a two-week period in December 1993, 7.5 kg only of crabs were offered for sale at the Lae main produce market (Hermes *et al.,* 1994). The price the crabs fetched was high (K1.00-5.00), mainly in response to the high transport costs. High transport costs in the province deter regular marketing of mangrove crabs (A. Tumonde, pers. comm.).

New Ireland:

About 7.6 mt of mangrove crabs are caught in the Tigak Islands are sold in Kavieng each year (Wright *et al.,* 1983).

Table 90 Landings recorded at Kavieng, kg live weight, are (source: DFMR database, Kavieng).

Year	1979	1980	1981	1982	1983
quantity (kg)	97	32	90	0	56

(Average price: K0.60/kg)

Private sales of mangrove crab in Kavieng for one year (July 1993-June 1994) were 1,060.8 kg (source: DFMR database, Kavieng)

West New Britain:

Table 91 Mangrove crabs purchases at the Kimbe fish landing place, kg whole weight (source: provincial fisheries officer).

Year	1989	1990	1991	1992	1993
quantity (kg)	186	13	0	0	0

North Solomons Province:

Mangrove crabs are occasionally sold at retail outlets in Arawa and Kieta, but quantities are not high: for example, only 50 kg were recorded as sold at Arawa (K4.00/kg) in 1984. The crabs (then) were caught on Buka Island (Ito and Selemet, 1985).

Table X PNG crab exports. (Sources: first column - FAO Fishery Statistics, volume 66 (in *INFOFISH International* 6/90); second and third columns - DFMR database)

Year	Quantity (kg)	Quantity (kg)	Value (K)
1979	-	-	-
1980	-	-	-
1981	-	-	-
1982	-	150	-
1983	-	-	300
1984	3,800	221	-
1985	2,600	-	1,105
1986	2,000	-	-
1987	1,700	174	736
1988	0	no info.	no info.
1989	-	no info.	no info.
1990	-	390	-
1991	-	600	-
1992	-	1,020*	8,535*
1993	-	500	6,000

(* figures for *live crabs* (the only ones stated). ** see also and compare with the figures for coconut crabs (profile 2.8). *There appears to be a problem in defining/recording the different crabs***)

A breakdown of the 1993 figures is: 200 kg in April valued at K2,400; 200 kg in May valued at K2,400; and 100 kg in September valued at K1,200. These figures surely must be wrong: i.e. they are always = K12/kg, and they are neat, round, convenient figures.

2.9.3 Stock status

The large *S. serrata* do not appear to be abundant in Western Province, according to B. Shackles (pers. comm.), and the maximum purchases by Daru Trading of 50-60/day is possibly the best the stock can sustain. However, Shackles reported that there are 'huge' stocks of the smaller form of mangrove crabs.

The population density of *S. serrata* in the Purari River delta is about twice that of neighbouring regions: at Maipenairu on the Purari delta there is an estimated 21.4 crabs/ha whereas at Abigai on Uramu Island (Aird River delta) the estimated density is 10.4 crabs/ha. However, the average size is smaller (Frusher, 1982): the average weight/crab is 220 g at Maipenairu (thus an average of 4.7 kg/ha) cf 240 g at Abigai (thus an average of 2.5 kg/ha). It has been suggested (Fisheries Research annual report 1980 and 1981) that reduced crab population density in the Abigae area - where crabs have been exploited traditionally for years - has increased food availability and thus caused an increase in the crabs' average weight.

Liem and Haines (1977) estimated the population density of crabs in the Purari River delta as 2 kg/ha/year. Haines (1978-79) calculated a cpue for two villages adjacent to or in mangrove-mudflat habitats in the Purari delta for a 25-day period early in 1976 of 20.6 crabs/person/year (Barea) and 87.8 crabs/person/year (Morowan). Haines calculated that the average weight of crabs caught/person/day was 400 g, which - based on relevant population census figures at the time - gave an estimated annual total harvest of 146 mt for the Baimuru subdistrict and 300 mt for the Purari-Kikori deltas. All of this would be used in subsistence or small artisanal (trading) purposes.

Wright *et al.* (1983) estimated that the standing stock of mud crabs in the Tigak Islands was 13.5 mt (on the basis of 6,760 ha of mangrove area and using a low rate of 10 crabs/ha based on the Gulf of Papua calculations).

In 1985, the mean mangrove crab density in the Murik Lakes was calculated to be 23 crabs/ha (Chapau, 1991). With crabs having an average weight of 260.3 g, the biomass was therefore 6 kg/ha. For the estimated 18,500 ha of mangrove forest in the lakes system, the biomass was thus estimated to be 108 mt (range 68.4-147.6, 95 per cent confidence limit). The subsistence + artisanal cpue during a 6-week survey there was 4.6 kg/woman/day. Chapau (1991) estimated a MSY of 133.9 mt/yr (115.7 mt of which would be commercial harvest and 18.2 mt would be subsistence harvest). Based on this calculation, 7.4 kg of mangrove crabs/ha/year (or 28.6 crabs/ha/year) could be harvested. However, based on assumed catch rates for the Murik Lakes, Chapau concluded that the total potential yield of lakes system is 71.3 mt/year. Different or complementary figures come from Opnai (1986): The subsistence cpue in 1985 was calculated as 14 crabs/woman/day or 4.6 kg/woman/day based on an average harvested crab weight of 326 g. Opnai estimated that, if the women increased their catching efforts as part of a commercial venture, the annual total production from the four villages could be between 173.2 mt and 226.4 mt (56,000-73,800 crabs). Opnai then estimated that 200 mt/year of mangrove crabs (or 70,000) could be taken out in commercial fishing from the Murik Lakes. Using Chapau's (1991) mean population density of 23 crabs/ha, Opnai (1986) estimated a crab population of between 198,000 and 630,000 in the Murik Lakes.

The PNG mangrove crab stock is largely under-exploited (Brown, 1993). His view is supported by the above sets of information; and Haines (1978-79) considered that the quantity of mangrove crabs harvested by the Purari delta villages was very low in comparison with the quantity available.

Chapau (1991) recommended that there should be only modest attempts to increase commercialisation of the mangrove crab resource in the Murik Lakes because of the importance of the resource to the subsistence diet, the identity of the stock, uncertainty about its biological parameters and the unknown level of commercial harvesting already taking place. His own and Opnai's figures, plus the information from the Gulf Province, do not substantiate such caution.

2.9.4 Management

Current legislation/Policy regarding exploitation: There are no restrictions on the fishery (Brown 1993).

Recommended legislation/Policy regarding exploitation: *S. serrata* is a significant resource in the estuarine mangrove habitats of the Western, Gulf and East Sepik provinces. PNG has the most extensive areas of mangrove habitat and silty riverine deltas in the western Pacific and probably has more than does tropical Australia. The mangrove crab resource in these areas is hardly tapped. <u>There is considerable potential to increase the landings of crabs in Kikori, Baimuru and the Murik Lakes, at least.</u>

The advantages and probability for success of a crabbing operation are:

- It requires minimal investment in plant (freezers are not required because the crabs can be kept alive out of water for periods of 5-7 days under optimum conditions without loss of body condition)
- and equipment (wrapping and shelter of bush materials).
- Quality control (rejection of undersized and damaged crabs) is simple and
- the product commands high prices.

- Because of the effectiveness of traditional capture methods (e.g. in the Gulf Province) people would not have to be taught new skills to catch them. Where strong tides are not an issue - e.g. in the Murik Lakes - traps could be used to augment harvesting by traditional methods. Studies in Australia (in Brown, 1993) showed that short soak times yielded a higher catch, but that crabs did not enter a trap if there was another crab in it (especially if the resident crab were larger).

  Mangrove crabs are best handled - and fetch the best prices - when marketed alive; however

- crab claws are proving to be an acceptable product (according to the Fishery Sector review 1989).
- Mangrove crab fisheries have always shown a high return from investment because of low capital costs.

The Baimuru and Kikori crabbing operation was successful and there is potential to re-instigate it. As Haines (1982) pointed out, the venture was successful [from the *gatherers'* point of view] because it fully utilised traditional skills. Production was also decentralised and divided into many small subunit fisheries exploited by villagers at different rates according to their own needs and resources [an important 'plus' compared with the regular production difficulties facing other fisheries resource developments in PNG]. Because crabs can be kept alive for long periods, distance from point of sale - in this case, Baimuru and Kikori - was no obstacle. [However, it *is* an obstacle if the crabs are to be onforwarded to other domestic centres or overseas, in good condition - especially for the overseas market where the crabs' condition would determine the price received by the consignment on the auction floor.] (see follow-on discussion below)

Wright *et al.* (1983) mentioned the possibility of farming mudcrabs but recognised that the size of the (natural) resource can support (1983) demand; and also that the cost of farming was unlikely to be recompensed at expected (1983) market prices. These points have also been realised in Australia (Kailola *et al.,* 1993). However, *mangrove crabs are susceptible to overexploitation* because of their sedentary habits, accessible habitat and relative ease of capture (Brown, 1993). Mangrove crabs do not move between neighbouring areas separated by unsuitable habitat and there is little exchange between an estuarine system and the same bay (Hyland *et al.,* 1984, in Brown, 1993). This again warns that localised over-exploitation could occur. Opening up a lightly exploited resource to heavier fishing pressure also creates a 'fish-down' effect in cpue (Opnai, 1986): large catches are achieved initially; the reduction in competion for habitat and food encourages a population increase which temporarily masks the effect of fishing; but under consistent fishing pressure the population increase would not be maintained.

Accordingly, issues to be addressed for successful re-development of the mangrove crab commercial fishery in PNG are:

- the size of the resource (estimates have already been made) so that an estimate can be made of how much can be taken out commercially (msy);
- the systematic status of the resource;
- the maintenance of reliable records of landings and catch-and-effort from different areas. No monitoring has been carried out on the mangrove crab resource of the Gulf of Papua since Opnai's work in the early 1980s; and the information on the Murik Lakes resource reported here is the result of less than one-month's survey.
- Catch-and -effort and landings statistics can enable calculation of cpue and provide and index of population density. Depletion experiments could be used to estimate crab population densities and catchability coefficients (Brown, 1993); and
- biological parameters such as recruitment and growth rates.

Management of the fishery is dependent - as always - on reliable catch and effort and locality information.

The *different markets* for mangrove crabs should be examined. In late 1978 the minimum acceptable size for mangrove crabs on the PNG domestic market was increased to 400 g (Fisheries Research annual report 1979). There are commercial and biological repercussions on this:

a) larger crabs, being heavier, incur a higher freight cost;

b) as many adult crabs in the mangrove areas of PNG are below this weight appplication of this weight rule limits the commercial market;

c) as crabs of 400 g and above are mostly male, are there deleterious effects on the population of targeting males? and

d) selective targeting of part of a population prior to analysing the status and nature of the population could be harmful.

People in the Gulf of Papua prefer to eat smaller crabs and target larger crabs for commercial sales only. It appears that Asians also prefer smaller crabs. Mud crabs are cultured in ponds in Taiwan (Chen, 1976, in Wright *et al.,* 1983) and sold when they reach 220 g or 12 cm carapace width at 5-6 months after stocking. Utilisation of the smaller form of mangrove crabs could be effected in two ways therefore:

1. by despatching live crabs to Asia. Prices received should offset freight costs (although competitive selling for live product on the Asian market could depress the price: B. Shackles, pers. comm.). Mid-1994 prices for mangrove crabs in Asia ranged from US$5.00/kg to US$8.00/kg (source: *INFOFISH Trade News* 16 September 1994); and
2. by implementing a domestic (e.g. to restaurants, hotels, and the Highlands) marketing campaign advising that small crabs are as good to eat as are large ones.

One of the beauties of despatching *live* product to Asia is that quarantine restrictions/food quality standards would not have to be met (cf *Macrobrachium,* profile 2.4 and yabbies, profile 2.3).

An example of the 'ready international market' for live mangrove is given by Ferdouse (1990). She stated that the supply of mangrove crabs in countries traditionally supplying Malaysia (Indonesia, Vietnam, India and Bangladesh) is becoming less dur to over-exploitation, and that importers are looking for alternative sources. Prices paid (1990) for crabs on import ranged from US$1.70/kg to US$4.40/kg. Interestingly, Ferdouse reported that large crabs 6-8 kg each *from PNG* and Fiji also are marketed in Malaysia, fetching very high prices.

In view of the need to market the product *live*, deliveries from harvesters to collection points would have to be timely, regulated, and domestic transport dovetailing with international flights would have to be effective. A complementary facility would be to establish holding ponds in the Port Moresby area (see earlier). B. Shackles (pers. comm.) suggested that use of a collecting vessel having a pontoon with suspended cages and moving from village to village could also facilitate timely collection of crabs to meet with domestic plane services or charters. (*See also above.)

Resource management. In other countries a legal minimum size is imposed. In Western Australia, the minimum size is lower in those parts of the State where the smaller form is prevalent (Kailola *et al.,*1993). The legal minimum size imposed in other western Pacific nations ranges from 127 mm to 150 mm carapace width (Brown, 1993). Other measures in place are a closed season during the reproductive period and prohibition on the destruction or damaging of crab burrows. Depending on the results of annual stock assessments of the resource, other input regulations (e.g. bag-limits, closed areas, limited gear use) may be imposed.

From the available information on PNG's mangrove crab resources, imposition of (a) minimum legal size(s) cannot be done. Once it/they can be imposed however, effective regulation would again be an issue. Imposition of other management regulations are dependant on fisheries landings and catch-and-effort information.

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2.10 BLACKLIP and GOLDLIP PEARL OYSTERS

2.10.1 The Resource

Pinctada magaritifera

Species present: The blacklip pearl oyster (*Pinctada margaritifera*) and goldlip pearl oyster (*P. maxima*). The brownlip pearl oyster (*Pteria penguin)* also occurs.

Distribution: The blacklip pearl oyster ranges from Baja California to the eastern Mediterranean Sea (Sims, 1993). It is distributed throughout the tropical Indo-Pacific, reaching its greatest abundance in the lagoons of the Tuamotu Archipelago of French Polynesia and the northern group of Cook Islands. The goldlip pearl oyster ranges from Burma to Solomon Islands.

Biology and Ecology: Blacklip pearl oysters inhabit lagoons, bays and sheltered reef areas to around 40 m depth, but are most abundant just below low-water. Strong byssal threads attach the oyster to rocks or other oysters. Goldlip pearl oysters are most abundant between 10 m and 60 m on the open shelf areas of continents and large islands, although they are occasionally found on reef flats and in deeper water (to at leasy 75 m in the 'Darnley Deeps', Torres Strait (Williams, 1994)). These pearl oyster are attached by strong byssal threads as juveniles only.

Pearl oysters are found only in warm tropical waters. Water quality and current strength influence size, growth rates, shell growth and shell colour, and blacklip pearl oysters do not favour areas of high turbidity (Sims, 1993). Pearl oysters are non-selective filter feeders.

Goldlip and blacklip pearl oysters generally are mature at two years of age. Most are males initially, but sex changes occur such that an even sex ratio is achieved by the fourth or fifth year. Temperature is the main influence on sexual development and spawning patterns. However, spawning is not limited to distinct seasons, and protracted spawnings may occur throughout the year. Blacklip pearl oysters usually exhibit two periods of maximum spawning (Sims, 1993).

The planktonic larval stage in blacklip pearl oysters may extend to four weeks but it is somewhat shorter in goldlip oysters. Larvae settle out onto suitable available substrate but retain some motility before beginning to secrete byssal threads. Age-fecundity patterns, density-dependant effects and larval and juvenile survival rates are not well understood. Larval drift patterns are difficult to predict and wind-driven eddies may cause highly patchy spat-falls in enclosed lagoons. Spat collector records and observations of wild stocks suggest that recruitment fluctuates from year to year (Sims, 1993).

Growth rates vary markedly between individuals and between locations. Rapid initial growth results in shell diameters of between 100-120 mm in blacklip pearly oysters after 2 years, and 100-160 mm for goldlip pearl oysters over the same period. Subsequent growth consists mainly of increasing shell thickness, with the oyster continuing to secrete nacre (the pearl material) throughout its life (Sims, 1993).

Pearl oysters suffer greatest mortalities as larvae and immediately after settlement. Predation in the plankton is high, and many spat are carried by currents away from suitable benthic habitats. Juvenile predation produces skewed or bimodal size-frequencies. Predation by fish, octopi and gastropod molluscs is the main cause of natural mortality in adults. Shell borers include sponges, bivalves and polychaetes. Older oysters are more prone to borer attack, but regular shell cleaning can reduce the problem on farms (Sims, 1993).

2.10.2 The Fishery

Utilisation: The thick, nacreous shell of the pearl oysters has engendered their harvest, and traditionally they were used in the manufacture of fish hooks, tools and ornaments (Sims 1993). In New Ireland, blacklip pearl oysters are traditionally collected from the shallow water of coral reefs and used mainly as sweet potato and yam peelers (Wright *et al.,* 1983).

Pearl oysters are collected by free diving. They have been harvested in PNG for production of mother-of-pearl (jewellery and ornaments) and button manufacture for many years. The target oyster during and before 1975 was the goldlip pearl oyster (the 'kina'), or mother-of-pearl shell. The blacklip pearl oyster was harvested to a much lesser extent. Goldlip pearl oysters are now rarely found within the limits of free diving (Glucksman and Lindholm, 1982).

Historically, pearl oysters were farmed for pearls in two areas in PNG - at Fairfax Harbour near Port Moresby, and at Samarai in the Milne Bay Province. Currently, there is no cultivation of pearl oysters in PNG. The manner of pearl culture is described in several reports (e.g. Sims, 1993; Richards, 1993; Williams, 1994) as well as below.

The Fairfax Harbour pearl farm (source: Dept External Territories, 1970).

In 1965, Pearls Pty Ltd, a joint Australian-Japanese company based at Kuri Bay in Western Australia, established a pearl culture farm in Fairfax Harbour. Four shipments of goldlip pearl oysters were made each year between August and December (25,000 dozen each time) from Western Australia to Fairfax Harbour. They were transported in a special carrier ship having free-flooding holds and forced water circulation. When the ship arrived, oysters were transferred to baskets and suspended in the sea from the rafts for about six months. After three months, they were cleaned and put into clean baskets.

Oyster culturing (seeding) usually started in April and continued into July. The oysters were cleaned, and a small piece of nacre-producing mantle was grafted into the gonad of each oyster. A nucleus was also inserted during the operation. After three months the oysters were taken out of the water and X-rayed to ascertain whether the oyster had retained the nucleus and a pearl was being formed. Oysters which have accepted the nucleus were returned to the water, their shells cleaned every three months, and allowed to grow for two years before X-raying again to see if the pearl was ready to be extracted - usually when the nacre coating the nucleus is about 2 mm thick.

Oysters which had rejected the nucleus insertion were later used for half pearl production. In half pearl operations, the half marble-shaped nucleus was glued to the inside of the shell. Three or four of such nuclei could be placed in the one oyster. The mantle covered the nuclei with nacre and in about nine months, half round pearls were ready for harvesting. The half pearls were drilled off the killed oyster's shell.

Cultured round and half pearls were sent to Japan for processing and from there onto world markets. By July 1974, the Fairfax Harbour pearl farm had suffered a serious decline in production and ceased operation in 1975. High mortality in the oysters - possibly from pollution in the harbour - forced the shutdown (Lock, 1982). For the 10 years of operation, the farm reportedly produced 40,000 pieces[1] each year from gold-lip oysters (Lock, 1982).

The Samarai pearl farm (source: George, 1978)

The site for the pearl farm, at Dagadaga Island, was selected in 1966, and the Australian colonial government granted a lease of land in 1967. 'Lapi shell' (*Pinctada fucata)* and goldlip pearl oysters are abundant in the Milne Bay Province (lapi shell is especially abundant in the Trobriand Islands) and were used in the pearl farm. Goldlip were collected with hookah

[1] There was no information whether this represented half or round pearls, or both.

gear down to 40 m and were used initially in the farming operation. The first half pearls were harvested from them in September 1968. Lapi shells also yielded prolific numbers of small-size pearls of yellowish colour. A continuous supply of pearl oysters was aided through the use of spat collectors and spat culture. Spat collection on plain nylon rope was extremely successful (Lock, 1982).

Dennis George claimed that the Samarai pearl farm was the 'first economic village level development ever introduced' to the area. Nationals were trained in maintaining the farm. By 1972 the farm was operating on a technically sound basis. The Milne Bay pearl farmers' association formed in September 1973 and the pearl farm was officially opened in January 1975.

The farm eventually produced half pearls from goldlip, blacklip and brownlip pearl oysters and lapi shells, and spherical pearls formed in goldlip and blacklip oysters and lapi shell. From August 1973 to September 1975, 67 pearl production operations had been carried out at the pearl farm and 7,230 pearl shells were operated on to produce half pearls. Between March 1973 and December 1974, 9,450 pearl shells were fished from the area. In 1975, 15 farms handling a total of 20 cultivating rafts had been established on four islands (Lock, 1982). By December 1975 however, financial problems started to beset the pearl farm and pearl production ceased about 1976.

Production and Marketing: Glucksman and Lindholm (1982) overviewed the market and production of pearl oysters (and other shell in PNG) to the end of the 1970s. Exports from 1952 to 1976 ranged from 3 mt (1952) to 70 mt (1971). Highest recorded production was in the early 1970s. Dalzell and Wright (1986) reported that between 1950 and 1984, 17,004 mt of pearl shell was exported from PNG with a mean annual shell harvest of 485.8 mt. Available figures since 1976 are given below.

Table X Quantities (kg) and values (K) of blacklip pearl shell exported from PNG.

Year	DFMR (kg)	DFMR (value)	DFMR (kg) (file)	DFMR (value) (file)	DFMR (kg) Wright (1986)	DFMR (value) Wright (1986)	Philipson 1989** (kg)
1979	5,700	K 9,000	-	-	-	-	-
1980	-	-	-	-	8,375	K12,582	8,000
1981	-	-	-	-	4,993	K 8,584	5,000
1982	836	K 1,547	-	-	1,863	K 3,003	1,000
1983	13,327	K35,991	-	-	14,367	K25,501	13,000
1984	6,128	K 7,912	-	-	6,500	K 8,656	6,000
1985	4,017	K 9,351	4,700	K 9,351	4,016	K 9,352	4,000
1986	5,121	K10,175	5,000	K10,176	*1,575	*K 2,678	5,000
1987	16,329	K42,914	19,000	K53,916	-	-	16,000
1988	-	-	22,700	K115,033	-	-	
1989	-	-	28,000	K141,432	-	-	
1990	14,090	-	18,200+	K134,199	-	-	
1991	5,800	-	-	-	-	-	
1992	none	-	-	-	-	-	
1993	?	?	-	-	-	-	

(*: to May 1986; **: originally written in tonnes; +: to June 1990)

Miscellaneous production figures for other provinces are:

East New Britain Province (source: DFMR Kavieng database): *blacklip* shell - 1990, 72 kg.

New Ireland Province (source: DFMR Kavieng): *blacklip* shell - 1989, 750 kg (value K4,170); 1990 (to May), 1,200 kg (value K7,680); *goldlip* shell - 1989, 250 kg (value K1,750)

Table 94 North Solomons Province: *blacklip* shell.

Year	1983	1984	1985	1986	1987	1994 (1st 6 months)
quantity*	1.8 mt	2.7 mt	-	0.7 mt	0.5 mt	132 kg
quantity**	1.068 mt	1.707 mt	-	-	-	-

(sources: * - DFMR database, Kavieng; ** - Ito (1984) and Ito and Selemet (1985)).

Ito and Selemet (1985) reported that 0.78 mt was exported in 1983 (fob K1,773) and 1.395 mt was exported inn 1984 (fob K2,691). Most production was from the Carteret Atoll, Buka Island and the Wakunai area.

Manus Province:

Table 95 *Blacklip* pearl shell production in kg (sources: 1987-90 - Lokani and Chapau, unpublished; 1991-94 - DFMR Kavieng database)

year	1987	1988	1989	1990	1991	1992	1993	1994*
harvest	833	3000	3127	6555	1002	325	78	none
price/kg	K0.85	K1.99	K2.98	K4.33	-	-	-	-

(* 6-month period to June 1994)

Table 96 *Goldlip* pearl shell in kg (sources: 1987-90 - Lokani and Chapau, unpublished; 1991-94 - DFMR Kavieng database)

year	1987	1988	1989	1990	1991	1992	1993	1994*
harvest	39	60	117	666	91	99	10	none
price/kg	K1.00	K1.00	K0.98	K1.57				

(* 6-month period to June 1994)

In 1984, 4.3 mt of pearl shell (mother of pearl) was exported from Alotau (Milne Bay Province) (Ito and Selemet, 1985).

In 1984, 833 kg of mother of pearl was exported out of Lae, Morobe Province (Ito and Selemet, 1985).

In Manus, the mean size of harvested blacklip pearl shell (1991) was 10 cm and 120 g. Thirteen per cent of the blacklip sampled was less than the legal minimum size of 9 cm width (Lokani and Chapau, unpublished). Lokani and Chapau (1992) observed that harvesting effort fluctuates with price offered. Most of the blacklip is harvested from the reef tops.

From 1980 to 1985, Japan took 64 per cent of blacklip shell exports. The remainder went to Korea, Hong Kong, the United Kingdom and Singapore (Wright, 1986). In 1988 Japan imported 15.66 kg of round pearls from PNG, valued at $1,442,000.[2]

There are minor quantities of goldlip pearl shell exported. DFMR records only 4,443 kg in 1990. Wright (1986) recorded 74 kg (worth K118.40) in 1980 and 53 kg (K58.30) in 1984.

Glucksman and Lindholm (1982) suggested that the reasons for decreased shell production in PNG (to that date) included increased collection costs and fewer shell merchants. Wright (1986) observed that shell prices gradually increased (to that date), and that shell production was on the increase - for example, in West New Britain.

[2] How can this be? Pearl farming ceased in Fairfax and Samarai in 1975 and 1976: so these must have been wild harvest. The table (on DFMR file 3-6-1) is on pearl, not pearl shell. No explanation was forthcoming at time of printing.

In 1990, a national government policy was brought into force that only Papua New Guineans were to harvest and trade sedentary resources and only 100 per cent national-owned companies were to buy and sell sedentary products. This policy has reduced significantly the number of licenced buyers and exporters in PNG (e.g. from 14 to one in Lae) and in some areas (e.g. Madang, Morobe and Northern provinces) caused a reduction in the amount of shell being harvested: added freight costs cause lower price/kg being offered to the harvester (R. Hermes, pers. comm.).

There are no export nor production figures for brownlip pearl shell.

2.10.3 Stock status:

In 1988 (letter on DFMR file), blacklip pearl oysters were thought to be locally abundant in PNG, and that some provinces have unexploited resources of goldlip pearl oysters located far from centres of population - for example, in the Steffan and Byron straits in the Tigak Islands, New Ireland (Wright *et al.,* 1983).

The five years of export figures for the North Solomons Province suggests that blacklip pearl oysters may have been over-exploited by the late 1980s, but the onset of the civil unrest on Bougainville c. 1987 has probably enabled the populations of pearl oysters to rebuild. This phenomenon has been demonstrated with trochus and greensnail stocks in the Province (W. Nankin, pers. comm.).

Sedentary resources surveys have been undertaken in four PNG provinces since 1987. In New Ireland Province - on Tigak, Mussau, Emirau, Lihir,Tabar and Djaul islands - blacklip pearl oysters are limited to shallow areas on the reef flats and goldlip pearl oysters to sand and rubble flats in the deeper areas. In Manus Province, blacklip was found in very low densities (Lokani and Chapau, 1992), although the range of villages producing blacklip suggests that the species has a continuous and wide distribution in the Province (Lokani and Chapau, unpublished). Goldlip pearl oyster is more widespread in Manus than earlier thought (Lokani and Chapau, 1992) and is most common in deeper water (eg more than 20 m depth at Kali Bay). Fishermen dive for it in the bay and lagoon areas. In the 1992 survey of the Madang Province, despite the presence of suitable habitat, goldlip pearl oysters were not found while blacklip pearl oysters were very rare (Lokani, unpublished). Production is very small, probably as a result of past exploitation (Lokani, unpublished): 620 kg were reported harvested in the years 1991-92. Pearl oysters were not reported from the DFMR 1991 surveyed area between Gasmata and Kalia in West New Britain (P. Lokani, unpublished data).

2.10.4 Management

Current legislation/Policy regarding exploitation: Legal harvestable sizes for pearl oysters were declared in the Fisheries Act of 11 May 1992. Blacklip pearl oysters must have a minimum size of 9 cm at the base (there is no maximum size) and goldlip pearl oysters must have a minimum basal size of 13 cm and a maximum basal size of 23 cm. Pearl oysters may not be harvested by the use of scuba or hookah gear, nor may ships be used to search for the resources.

Following a survey of the Madang area in 1992, the DFMR recommended an indefinite ban on pearl oyster harvesting in the Madang Province (Lokani, unpublished). However, a small amount of harvesting continues (H. Bingeli and A. Koyo, pers. comm.).

Recommended legislation/Policy regarding exploitation: The relative benefits of suitable management measures for pearl oysters are described by Sims (1993). They include permanent reserves, moratoriums on harvesting in certain areas, closed and rotational seasons, quotas, size limits and gear restrictions. Spat collectors can be used to re-establish over-exploited stocks or enhance existing stocks.

Philipson (1989) and Sims (1993) observed that long-term prospects for high returns for pearl shell production in the South Pacific are good because of the oysters' limited supply. Increased downstream processing - i.e. making button blanks within the region rather than exporting the uncut shell - could also increase export value. Any increase in harvest would have to be accompanied by estimates of stock size and sustainable yield to prevent overfishing.

PNG is in a position to take a proactive approach to maintaining and capitalising on its pearl shell resources. This should encompass the following:

- undertake surveys of resources in areas of either historical or known shell abundance - e.g. the Milne Bay area, Manus and North Solomons provinces; also Western Province (known Warrior Reefs pearl grounds are within Torres Strait PNG waters: Williams, 1994). Background information on pearl stocks in Torres Strait is given in Colgan and Reichelt (1991);
- implement the installation of spat collectors and foster spat culture in areas of suitable habitat and especially where depleted populations of shell occur. This practice would increase the resource in those areas. Techniques for pearl spat collection and culture are now well-established (Sims, 1993). Lock (1982) reported that pearl oysters were being cultured in a few small village farms in the Samarai area. By growing out oysters to large sizes before marketing them, a farmer would receive a higher price for the shell and also ensure that the oysters had spawned at least once before they were harvested and so ensure a reliable source of juvenile oysters. The complicated marine tenure system in place in much of coastal PNG suggests that the best village involvement in a pearl farming operation would be the collection of shell for sale to the farm (Lokani and Chapau, unpublished). Farms would have to be managed properly - including implementing an area limit to the number of pearls farmed, and correct spacing and cleaning of the oysters;
- increase the legal minimum size of harvestable shell to a size past the size of first spawning. The basis for this would come from growth studies. Fiji's minimum shell size for blacklip is 100 mm (A. Richards, pers. comm.). The regulations should be policed at the point of sale;
- leave larger, older shell on the reefs to promote spat-fall;
- invite overseas expressions of interest in establishing a pearl culture facility in joint venture with a PNG group. Experienced PNG pearl divers work in the pearling industry in Torres Strait and are familiar with all facets of the industry. One suitable area could be around Samarai,* the site of the Dennis George pearl farm venture: villagers in this area have experienced pearl farming and otherwise expected land tenure issues may be minimal [*: Lokani and Chapau (unpublished) suggested Manus Province]. Depending on the stock structure of pearl oyster species in PNG, shell for the culture facility could be supplied from other PNG areas. PNG could utilise the increasing world prices for black pearls: high quality black pearls were produced at the Samarai pearl farm. Black pearls attract top prices because of their rarity and colouration, and cultured black pearls and half ('blister') pearls enjoy similar values.

A Cairns-based company, Australian Pearl Farms has recently expressed interest in setting up a commercial pearl farm in PNG. In Torres Strait, pearls have been cultured since about 1893 and currently seven farms are involved in either culturing or collecting shell. Pearls (especially blister pearls) from the Torres Strait are considered very high quality in Japanese markets (Williams, 1994). The commercial value of the pearl culture industry in Australia was estimated at $A131 million in 1993 (McLoughlin *et al.,* 1994).

A precedent has already been established in the Cook Islands where pearl farming commenced in 1973 and cultured round black pearls were first exported in 1989 (Richards, 1993). Whereas the quality (and value) of the Cook Islands pearls has yet to mature, the possible availability to PNG of quality goldlip pearl shell (in Torres Strait) would augment the longterm prospects of culturing both pearl species in PNG. Fassler (1994) reviewed new technologies and the rapid developments in pearl farming in the Pacific and pointed to the potential for new markets.

In constrast to most fishery resources in PNG, pearls do not require refrigeration and other methods of preservation, their transport does not incur high freight costs, and they can be stored easily for any length of time to utilise demand-and-supply peaks in international markets.

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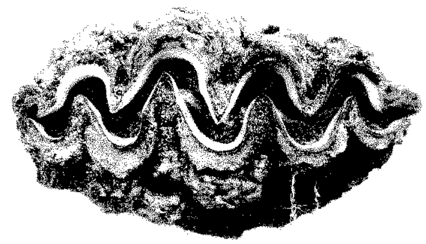
2.11 GIANT CLAMS

2.11.1 The Resource

Species present: Five species of *Tridacna* and *Hippopus hippopus* , the 'horse's hoof', inhabit PNG waters. The *Tridacna* species are *T. crocea* ('boring clam'), *T. derasa* ('smooth giant clam'), *T. gigas* ('giant clam'), *T. maxima* ('great clam') and *T. squamosa* ('fluted clam') (Lucas, 1988). The giant clams belong to the family Tridacnidae.



Tridacna maxima

Distribution: The global range of the giant clams occurring in PNG waters is outlined by Lucas (1988) and Munro (1993).

Species	Distribution
H. hippopus	Burma, SE Asia to northern Aust., Marshall Islands, New Caledonia
T. crocea	southern Japan, SE Asia to northern Aust., New Caledonia, Palau, Solomons
T. derasa	SE Asia to northern Aust., New Caledonia, Palau, Tonga.
T. gigas	Historically from Burma, China, SE Asia, to West. Pacific, northern Aust., New Guinea, New Caledonia, Polynesia. Eliminated from many areas.
T. maxima	East Africa to southern Japan, Asia and Polynesia (Tuamotus Islands)
T. squamosa	East Africa to southern Japan, Asia and Polynesia

Giant clams are coral reef dwellers. *T. derasa* prefers clear offshore or oceanic waters well away from freshwater influence (Munro, 1993), often in sandy areas. *T. maxima* and *T. crocea* usually bore into the reef. *T. maxima* is often found on the reef tops, while *T. crocea* tends to occur intertidally. *T. squamosa* is usually found closer to shore in fairly sheltered lagoon environments, on rubble and in cracks in the reef. *T. gigas* and *H. hippopus* are the most versatile of giant clam species, being found in all habitats - lagoon or fringing reefs, sandy areas and exposed intertidal habitats (*H. hippopus*).

All species are depth limited because of the need of their symbiotic algae to utilise sunlight in photosynthesis.

Biology and Ecology: Giant clams have a symbiotic relationship with dinoflagellate algae (zooxanthellae) living in their mantle cavity. The clams' food intake from filter feeding is supplemented by nutrient molecules gained from the photosynthesis of the zooxanthellae, especially glucose (Lucas, 1988). This relationship means that (a) clams only inhabit water shallower than 40 m (Munro, 1993) or less in turbid conditions and (b) the tissue of their siphon is modified to become large mantle tissue (where the zooxanthellae are located (Lucas, 1988).

All giant clams are protandrous hermaphrodites. In other words, they become sexually mature as males and after two or more years become simultaneous hermaphrodites, where both male and female tissue is contained in the gonads (Lucas, 1988). During spawning of fully mature clams, sperm are released first, followed by eggs some hours later. Breeding may extend throughout the year in the tropics. The gametes are expelled through the excurrent aperture in large 'puffs', the male gametes first followed about 30 minutes later by the female gametes (hence, self-fertilisation is probably avoided). Giant clams respond to the presence of gametes in the water and in natural populations there is often a chain reaction of egg and sperm release along the current line (Lucas, 1988). Giant clams are highly fecund, individual clams producing millions of eggs - up to 240 million in 70-80 cm *T. gigas* (Munro, 1993).

There is little information on the size of giant clams at maturity. *T. gigas* on the Great Barrier Reef reached male maturity at 35-35 cm length (Nash *et al.,* 1988, in Munro, 1993) and produce eggs at about 50 cm length. *T. maxima* appear to mature as males at around 6 cm length, with 50 per cent of individuals fully mature (male and female) at 10-11 cm and 100 per cent fully mature by 14 cm length (Lewis, 1987). *T. squamosa* mature at 5 cm length yet do not produce eggs until 15 cm (Munro, 1993).

The fertilised eggs develop into trochophores and then shelled veligers within a couple of days. Settlement of the planktonic larvae takes place 8-15 days after fertilisation. The pediveliger metamorphoses into a juvenile clam (or 'spat'). The spat creep about the substrate searching for a suitable place to settle. They have usually located a final resting place by the time they have attained several cm in length (Munro, 1993). *T. crocea, T. maxima* (both living in the reef) and *T. squamosa* remain attached to the substrate throughout their lives, but the other species eventually rely on heavy shell thickening near the umbo to give them stability and keep them orientated (Lucas, 1988).

The growth rates of juvenile clams are slow, most species attaining only between 2 cm and 6 cm by the end of the first year (Munro, 1993). Growth in the larger species is more rapid after the first years but still increases only slowly in the smaller species, and environmental factors also influence growth rates. Information on projected shell lengths in successive years is provided by Munro (1993).

Estimates of maximum size are several; probably Lucas' are a 'bench mark' here. Munro's figures are L infinity projections. The lengths given from the two recent PNG studies are questionable (and suggest misidentifications).

Table 97 Estimates of maximum size for several species of giant clam

Species	Lucas (1988)	Munro (1993)	Polon (unpubl.)	Mobiha *et al.* (unpubl.)
H. hippopus	about 40	40	29.5	79.9
T. crocea	about 15	-	89	12
T. derasa	up to 60	-	52	-
T. gigas	over 100	80 / 100	17	-
T. maxima	about 35	30.5	-	-
T. squamosa	about 40	38.5	42	31

(Munro (1993) cited studies by Munro and Gwyther (1981) and Munro and Heslinga (1983).)

Mortality rates of juvenile giant clams is very high (to total) if they settle in unprotected reefal areas. It is assumed to be very low in middle-aged clams, the thick shell and partial embedment conferring considerable protection. Estimated annual survival rates for adult *T. maxima* are 81 per cent in an unexploited population and 75-78 per cent in an exploited population at Aitutaki (Lewis, 1987). Giant clams may live for several decades, the oldest reliably dated clam being a specimen of *T. gigas* calculated to be more than 50 years old (Lucas, 1988).

Studies on recruitment of giant clams are hampered by their cryptic nature and some species only become `findable' at 20-25 cm length (Munro, 1993). Recruitment appears to be erratic and limited. Pearson and Munro (1991) estimated that annual recruitment on Michaelmas Cay on the Great Barrier Reef was only 1.5 per cent for *T. gigas* and 4 per cent for *T. derasa*.

When giant clam populations fall below a certain density they will become non-sustaining (Munro, 1993) as the reproductive chain of events relies on conspecific giant clams in the vicinity. Hence, giant clams are highly vulnerable to local stock depletion which will result in a collapse in the fertilisation rates and consequent reduction in recruitment rates. If a reef is denuded of clams, repopulation will depend entirely on planktonic larvae brought in from other reefs by prevailing currents. If the reef is isolated or the current direction unfavourable, the re-establishment of a stock could take hundreds of years (Munro, 1993).

2.11.2 The Fishery

Utilisation:

Wild fishery

Giant clams are harvested for subsistence purposes in coastal areas of PNG and they form a significant part of the diet in some areas. In Manus, Morobe and Northern provinces surplus clams (*T. gigas, T. squamosa* and *T. derasa*) have traditionally been collected and placed in stone-walled enclosures ('clam gardens') in the sea near the village where they are kept for later consumption (Maclean, 1978; A. Tumonde, pers. comm.). According to Polon (unpublished), only traditional consumers 'are permitted' to exploit the clams within their jurisdiction.

Giant clams are traditionally gathered by villagers along the Papuan coast (Swadling, 1982) and at Pari (Central Province) *H. hippopus, T. crocea, T. maxima* and *T . squamosa* form a significant part of the shellfish diet. Swadling reported that, pre-1980, giant clams were regularly seen at local markets in Port Moresby - *cf* the Morobe Province, where villagers prefer to keep harvested clams for their own consumption (A. Tumonde, pers. comm).

Giant clams (mainly the larger species, *T. gigas* and *T. derasa*, which are easily spotted lying on the sandy bottom) are much sought after by the Taiwanese who target two large muscle blocks in the clam ('adductor muscle'), mainly for human consumption. The Taiwanese cut the meat out of the clam with clam chisels while it is lying on the bottom, and leave the shell there. All of the soft tissues of giant clams are edible except for the kidneys (Lucas, 1988), however. According to Lewis (1985) the meat comprises 15-20 per cent of the clam total weight, of which the mantle comprises 60 per cent and the adductor muscle comprises 15 per cent.

Aquaculture

Spawning of giant clams can be readily induced, producing heavy spatfalls and enabling significant numbers of giant clams to be reared to a marketable size. At ICLARM's Coastal Aquaculture Centre in Solomon Islands, larvae are reared in semi-intensive culture until they are about 14 days old when they are stocked into settlement tanks where they remain for 3-6 months (Munro, 1991). The young clams may remain in nursery tanks for up to a year before transfer to protective ocean enclosures. When they are sufficiently large to escape much predation (at 10-20 cm shell length) they are moved to less protected grow-out plots on the reef. After this, grow-out to marketable size presents few problems.

Further information on giant clam aquaculture is available in Lucas (1988), Copland and Lucas (1988) and no doubt more recent publications and information are available from ICLARM in Honiara.

In PNG, several giant clam species have been cultured successfully in a University of PNG/ACIAR project (Fishery Sector review, 1989) in 1976.

Are clam gardens a form of aquaculture? Johannes (1982) declared that this is not so, as the practice is just one of minding and does not promote the growth and raising of clams. (Interestingly, Johannes also reported that the people of Andra Island, Manus Province, say that the practice actually seems to reduce the growth rates of the coralled clams.)

An interesting adjunct to the popularity of clam meat for human consumption is the possible effect seasonal occurrences ('blooms') of the toxic dinoflagellate *Pyrodinium bahamense* var.

compressum (or 'red tide') can have. This organism causes paralytic shellfish poisoning. Whereas other shellfish (mussels, oysters) purge themselves of the offending organism after several weeks, giant clams hold them for several months in their mantle and siphon (G. Hallegraeff, pers. comm.).

Production and Marketing: The two species of giant clam most heavily targeted are *T. gigas* and *T. derasa*. This is because of their size, they can be picked up (e.g. for clam gardens) and they are easily located.

There is no information on the subsistence consumption of giant clams in PNG, although giant clams have been increasingly targeted over the last 15 years (at least) (Swadling, 1982; Lokani and Chapau, 1992; Lokani, unpublished; Polon, unpublished).

Swadling (1982) observed that in Central Province, whereas in the past all available edible shellfish would be gathered, village people (in 1980) tended to gather only the clams.

Giant clam meat is not usually sold in markets. Swadling (1982) observed that clam was occasionally sold in Port Moresby markets; and there are some recent records on the DFMR database in Kavieng, viz:

Manus: 1987 - 101 kg (K125.50)

Kimbe: 1989 - 332 kg; 1990 - 52.5 kg; 1991 - 392 kg; 1992 - 303 kg.

Also Samarai (Milne Bay): 1981 - 200 kg (source: Fisheries Research annual report 1980 & 1981).

A trial shipment of 80 kg of 'shell meat' (which almost exclusively refers to giant clam muscle) was exported from PNG in 1982 (Wright, 1986), although there appeared to be a 1979 export also (Fisheries Research annual report 1979). Exports continued until early 1988 when the fishery was stopped by the PNG Government. Prices received ranged from K0.88/kg in 1982 to K6.50/kg in 1986. Hong Kong took 44 per cent of shell meat exports. Other countries to which shell meat was sent between 1982 and 1986 include the United States of America, West Germany, Australia and Taiwan (Wright, 1986); generally the highest prices were offered by Hong Kong.

Table 98 PNG declared exports of shell meat (sources: DFMR database and Wright, 1986).

Year	DFMR weight (kg)	DFMR value (K)	Wright (1986) weight (kg)	Wright (1986) value (K)
1979	**2,300	**5,000	-	-
1980	-	-	-	-
1981	-	-	-	-
1982	80	71	80	70.97
1983	9,830	13,294	10,204	13,294
1984	949	3,407	949	3,407
1985	4,202	24,684	2,502	14,482
1986	21,030	157,652	*1,500	*9,750
1987	31,657	336,262	-	-

(*first five months only) (** Fisheries Research annual report 1979)

A clam export fishery began in the Milne Bay Province in 1983 operated by the Milne Bay Fishing Authority with support from the IFAD Project, and ceased in May 1988. All species of clam were harvested, although probably the largest harvest in terms of weight came from the larger species, *T. derasa* and *T. gigas* (Munro, 1989). The areas yielding most clam were the Tagula Island area (31,845 kg) and the Calvados Chain (14,717 kg).

Table 99 Recorded landings of clam muscle at Samarai for the period 1983-88.

Year	1983	1984	1985	1986	1987	1988*
Weight(kg)	5,721	1,211	6,428	34,374	27,795	10,043*

(*to the end of May, 1988)

Two points to bear in mind when considering these statistics are:

a) they are probably not reliable (Munro, 1989). For example, whereas the 1984 harvest was reported as 1,211 kg a written account in correspondence cited landings of 'less than 13 tons'. Hence the recorded total for the period - 85,572 mt - is conservative.

b) not all of the clam meat exported from the Milne Bay Province was recorded in the national statistics. For example, compare the years 1984-86 in the tables above.

After a peak in production in the first quarter of 1987, there was some evidence that the availability of clams in the Milne Bay Province was declining (Munro, 1989).

Munro (1989) calculated that between 71,000 and 74,000 adult *T. gigas* and *T. derasa* were harvested by the fishery during its four years and five months. [Calculations were made on the basis that virgin stock densities would have been comparable to Great Barrier Reef densities, that mainly only *T. gigas* and *T. derasa* were collected, that shell lengths would have averaged 75 cm and 45 cm respectively and that the average muscle weights at those shell lengths are 1,900 g (*T. gigas*) and 270 g (*T. derasa*).]

Increased prices for clam meat (may) continue to stimulate production (Wright, 1986).

Giant clam adductor muscle attracts high prices on South-east Asian markets and has long been the target of illegal fishing in PNG waters, especially by Taiwanese vessels. There is no information on the <u>poached harvest</u> - only empty shells, and there have been no surveys of these. In early 1984, the off-the-boat selling price for frozen adductor muscle in Taiwan was US$20-22/kg (Lewis, 1985). When dried, the muscle could fetch six times that amount. In 1989, the PNG fob export price for adductor muscle was K10-12/kg (Fishery Sector review, 1989). The demand for clam meat remains strong from Hong Kong and Taiwan markets. Dawson (1988) found that the market for frozen adductor muscle was confined to the exclusive restaurant trade (in Taiwan), assessed at 100 mt.

2.11.3 Stock status

There has been widespread overfishing of giant clams in recent times. This reduction has been effected by poachers of clam adductor muscle and by continuing local harvests by expanding human populations. Polon (unpublished) found evidence of widespread overfishing of giant clams by villagers in the West New Britain Province. Polon stated that the reasons for this were increasing population pressure and the availability of modern fishing gear such as dive masks, snorkels and fins, and power boats. Motorised vessels can now access reefs more distant from the village and aided diving enables access to giant clam stocks in deeper water. Lucas (1988) suggested that another factor in the decline is a general deterioration of coral reef environments in some regions. A sympton of the overfishing is that the natural range of *T. gigas* has been greatly reduced, with relict populations only or total absence in many previously inhabited areas (Munro, 1993). Cultivated stocks of *T. gigas* have, however, recently been established in some Western Pacific countries. Conversely, the range of another species, *T. derasa*, has been extended by introductions (Munro, 1993).

Stock densities of *T. gigas* and *T. derasa* have been recorded up to several hundred/ha on unexploited reefs in Queensland (Munro, 1993) and *H. hippopus* densities of 30-90/ha are quite common. Smaller giant clam species reach very high stock densities. *T. maxima* reaches densities as high as 60 clams/m^2 in some parts of Polynesia (Lucas, 1988) and *T. crocea* occurs at densities of more than 200 clams/m^2 in the Great Barrier Reef region.

Estimates of giant clam stocks are difficult to make owing to the cryptic nature of the animals. Although the smaller species can be located at a smaller size because of their colouration, the juveniles of the larger species only become ‘findable’ with increasing size - at about 20 cm length (Munro, 1993). Such should be borne in mind when reading the following.

Based on stock densities on the Great Barrier Reef - where average densities of five *T. gigas* and five *T. derasa* per ha (occasionally several hundred per ha) have been observed (Braley, 1987, in Munro, 1989), plus Frielink’s (1983) estimate of shallow reef areas in PNG, Munro (1989) estimated that the Milne Bay Province carried a virgin standing stock of 6.5 million adult *T. gigas* and 6.5 million *T. derasa*. Using these parameters, an estimate of PNG’s unexploited standing stock of large clams is c.40 million (i.e. 10 large clams/ha, estimated shallow reef area of 3,994,000 ha).

In Milne Bay Province, clam stock densities on Siata Reef (Nuamata Island, D’Entrecasteaux Group) in May-June, 1980 were estimated by Tarnawasky (1980, in Munro, 1989).

Table 100 Clam stock densities on Siata Reef, Numata Island, Milne Bay Province: May - June 1980

Species	Clam density/ha	Mean length (cm)
T. gigas	10.2	34.6
T. derasa	10.2	30.5
T. squamosa	33.3	25.2
T. maxima	197.3	17.4
H. hippopus	89.8	24.0

Munro (1989) also calculated rates of recruitment for the estimated Milne Bay Province stocks of giant clams and concluded that an annual harvest of 47.3 mt of *T. gigas* and 112.8 mt of *T. derasa* (where the legal miminum shell length were 45 cm) was quite sustainable.

A survey of 12 sites in Manus Province revealed that although the six species of giant clam were present, the three larger species were only present on small islands away from the main island. *T. crocea* and *T. maxima* were the most abundant clams in Manus Province (Lokani and Chapau, 1992) because they are not collected for clam gardens (because of their burrowing habit) while the three *Tridacna* species that are collected for clam gardens are now only present in very small numbers. The survey results are tabulated below.

Table 101 Results of giant clam survey in Manus Province (Lokani and Chapau, 1992)

Species	*T. gigas*	*T. squamosa*	*T. derasa*	*T. maxima*	*T. crocea*	*H. hippopus*
presence in total survey(%)	1.25 % of clams recorded	1.74 %	0.25 %	14.7 %	76 %	6 %
clams/ha (range)	0-7.14	0-5.36	0-1.8	0-42.7	0-289.7	0-13.75
clams/ha (mean)	0.77	1.05	0.15	9.64	43.97	4.08

In West New Britain Province a survey (possibly in 1991?) of six sites revealed the following densities (number of clams/100 transect x 4 m width):

Table 102 Results of giant clam survey in the West New Britain Province

Species	*T. gigas*	*T. derasa*	*T. squamosa*	*T. maxima*	*T. crocea*	*H. hippopus*
no. of clams	8	3	43	123	395	12
site presence	4	2	6	6	4	1
clams/ha (mean)	3.6	1.3	19.2	54.9	176.3	5.4
presence in total survey (%)	1.4%	0.5%	7 %	21.1%	67.6%	2.1 %

(Care should be taken when using this information, as it is possible that mis-identifications occurred.)

Polon (unpublished) estimated a standing stock of 35 million giant clams on the 137,000 ha of suitable habitat in West New Britain Province (Frielink, 1983), comprising 78 per cent of the burrowing clams (*T. maxima, T. crocea*) and only 2 per cent of the larger clams (*T. gigas, T. derasa*).

In 1991 a survey of five sites in the Madang Province was conducted by DFMR (Lokani, unpublished). Four species of giant clam were observed - *T. gigas, T. squamosa, T. maxima* and *T. crocea*.

Table 103 Densities per ha at five survey sites in the Madang Province (animals/100 m x 8 m transect).

Locality	Bagabag	Karkar	Bogia	Madang area	Rai coast
T. gigas	3.47	0.8	3.33	0	*4.1
T. squamosa	2.77	3.8	*1.1	5.56	1.93/*1.4
T. maxima	2.08	4.2	2.5/*19.65	1.39	7.5/*2.35
T. crocea	4.17	2.1	0	0	0

(*estimates from towed swim per 10 m wide path)

Empty shells of *H. hippopus* were present on the reef flats at Bagabag. Lokani observed that the environmental conditions in Madang provincial waters probably affected clam abundance there. No attempt was made in the survey to ascertain the rate of subsistence exploitation of the clams.

At six sites in the Western Province, Mobiha *et al.* (unpublished) recorded the numbers of giant clams observed along 200 m x 4 m transects during October-November 1993.

Table 104 Numbers of giant clams along transects; Western Province.

T. squamosa	*T. crocea*	*T. maxima*	*H. hippopus*
6	456	1	20

T. crocea was present on all of the reefs. (Care should be taken when using this information, as it is possible that misidentifications occurred.)

The adoption of the Seventh Day Adventist faith in some coastal areas of PNG has rendered protection for giant clams in Mussau Island (New Ireland Province) and Wuvulu Island (East Sepik Province). The meat of the clams is not eaten; although some Wuvulu islanders harvest meat from their abundant *H. hippopus* and *T. maxima* stocks and sell it either fresh or dried at the Wewak market (Swadling, 1982).

2.11.4 Management

Current legislation/Policy regarding exploitation: The species *T. gigas* and *T. derasa* were listed as threatened species (Appendix II) by the IUCN in 1983. Subsequently all giant clams were included in the Appendix. Munro (1989) analysed the application of CITES with regard to the Milne Bay Province fishery. Being listed by CITES means that trade in the species cannot take place unless it is shown that the product traded came from farmed stocks or that the product was harvested in a controlled manner and its trade would not affect the sustainability of natural populations and came; i.e. the stocks have to be shown to be 'not threatened' by continuing trade. Exported product must be certified as fulfilling those conditions. Member countries who are CITES signatories may not accept uncertified product. Taiwan is not a signatory, and although most other Asian nations are, they only loosely enforce CITES conditions.

The PNG Government has banned the collecting of sedentary organisms by local inhabitants (of which clams are included) *by using ships for searching for and taking*; and by the use of lights at night.

Recommended legislation/Policy regarding exploitation: Giant clam stocks in PNG are under pressure from three sources: 1) increased populations of coastal villages; 2) poaching of clam stocks by non-traditional owners; and 3) poaching from foreign fishing fleets and from foreign commercial fishing companies licenced to harvest different reef resources (e.g. 'live fish' trade).

Who is the main culprit?

The need for *rational exploitation* and *proper management* of giant clam resources is obvious. One problem with clam harvesting is the uneven distribution of fishing effort. Reefs closer to population centres can be denuded of clams while more remote reefs can be in a pristine condition. Because clam spawning relies on close association of mature clams, reduction of stocks below a certain, unknown point results in a collapse in recruitment and hence of stock. Re-establishment of a stock on a denuded reef can take hundreds of years (Munro, 1989).

Giant clams are not a commercial fishery in PNG (*cf* other sedentary resources) and hence the national government's role in managing clam stocks would be one of *conservator* - that is, unless it decides to permit controlled harvest from wild stocks or from farming operations.

There may be grounds for re-opening the fishery for clam meat. Munro's (1989) ballpark estimates of standing stock may not be fanciful. Controlled export of clam meat would go a long way to reducing poaching and it would provide a handsome income for coastal villagers and the nation. If PNG were to follow Fiji's model and insist that all of the edible clam - muscle and meat - has to be exported (Lewis, 1985), markets would have to be found for all of that product. Unfortunately, to be able to trade clam meat, the PNG Government would have to follow the conditions of CITES and provide evidence that stocks were not endangered. It cannot do that. The only surveys in recent years have been of reefs heavily fished by local residents: with one exception, no assessments have been made of unharvested reefs in PNG waters. A commercial fishery would have to target those distant reefs anyway in order to secure enough clam for marketing; and it could not fish inshore reefs where it would run into conflict with traditional ownership expectations.

The PNG Government is in a cleft stick: it can re-open the fishery subject to fully-enforced regulations such as annual quotas and size limits, manage it through annual estimates of sustainable yield based on properly conducted stock assessments, and reap some export income; or, it can continue its ban on clam meat exports and again be faced with having to enforce the ban to prevent poaching by foreign vessels while being aware that a black market trade in PNG clams exists which, because of the ban, precludes PNG from making any money from its own resources. Either way, strict enforcement is needed, as unless harvesting of clam populations is carefully controlled, the ability of the remaining individuals to re-stock an area can be seriously impaired.

How effective is the PNG Government's enforcement of its ban on clam meat exports with regard to foreign vessels? Poaching could increase in PNG waters, driven by declining global stocks of larger clam species, high prices, constant demand and increasing surveillance over poaching activities in other countries. Australia, Solomon Islands and PNG have the last remaining large natural populations of large giant clams (Munro, 1993). Dawson (1988) stated that foreign clam boat owners were starting to avoid Australian waters because of the effective surveillance and enforcement capability, and also to avoid Pacific nations who imposed harsh penalties - e.g. Palau. PNG's vast area of sea and reef is almost unpoliceable and there are no records of clam poachers being intercepted. PNG is in a relatively short steaming distance to Asian markets.

Another direction the PNG Government could follow is the mariculture of clams. Munro (1989) suggested that a small scale hatchery could be developed at DFMR Kavieng and later in the Milne Bay Province once expertise was established. Munro also suggested that the Motupore Island Research Centre and the Christensen Research Institute should be encouraged (with funding) to continue research on giant clam cultivation. These ventures would require the support of the national government with either direct funding or assistance in securing funding.

An offshoot from direct mariculture is the extension of the 'clam gardens' idea - where undersized clams could be accumulated in individually owned gardens until they attain the minimum harvestable size. The village 'farmers' could be supported by trained clam mariculture officers.

However, it takes 8-10 years' growth before the adductor muscle of one of the larger clam species is large enough to be marketable in Asia. Would a village farmer wait that long? And grow-out clams require intensive farming for their first few years. Alternative though limited markets for farmed clams (J. Bell, pers. comm.) are the aquarium trade (for live 'baby clams') and the sashimi market. Both of these would be based on 2-3 year old clams. Furthermore, how effective is the traditional clam garden in resource security? I don't think it is... It simply *makes the resource more available*. Traditionally small clams were not collected (Maclean, 1978); and the collected clams were generally eaten in a year or so.

Actions to protect clam resources for traditional consumption can only emanate from a combination of the traditional owners themselves and the national government.

The most effective management scheme is village awareness (=education). Encourage the village community to protect and manage the resource; to report poachers, and protect the reefs.

Imposition of a legal minimum size , rotational closures of harvest areas and collection without assisted diving (scuba and hookah) are management measures that should be implemented with the assistance of communities. In addition, the establishment of permanent breeding reserves in reef complexes would ensure continuing, self-sustaining recruitment. The government and the communities could also work together to ban the sale of clam in local markets.

In summary,

- consider re-opening a wild harvest fishery
- investigate the possibility of clam mariculture
- send a DFMR officer for training in mariculture techniques
- investigate the ability of PNG to enforce clam conservation measures in its waters (on both foreigners and nationals)
- encourage village participation and support for the conservation of clam resources - by rotational harvesting, size limits, reserve areas and limited collection methods
- undertake proper stock assessments of fished and 'unfished' reefs with a view to making MSY estimates.
- ensure a method of continuous monitoring of clam resources is set in place (if it is not a commercial fishery, the usual monitoring methods by way of fishermens' returns do not apply)

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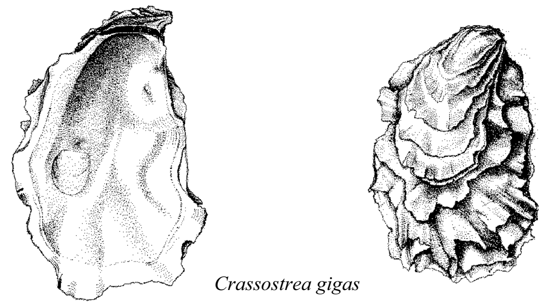
2.12 OYSTERS

2.12.1 The Resource



Crassostrea gigas

Species present: There are several species of rock oysters in PNG that could be considered for farming. These are *Saccostrea echinata*, *S. ?commercialis* and *S. cucculata*. *S. cucculata* occurs as very large, isolated individuals and *S. ?commercialis* and *S. echinata* are clustering species, forming discrete intertidal zones in harbours and bays or - in the case of *S. echinata* - also occurring as large individuals on mangrove roots and stones and known locally as 'mangrove oysters' [it is possible that the two forms of *S. echinata* may be distinct taxa]. Maclean (undated) also recorded other oyster species in PNG but observed that they probably would be unsuitable for farming: *Hyotissa hyotis*, *Dendostrea folium* and '*O. trapezina*' are common in the sublittoral zone but occur as isolated individuals; and a small, intertidal *Saccostrea* species is too small (1.5 cm diameter). [Maclean's original nomenclature has been amended by Shirley Slack-Smith, Curator of Molluscs at the Western Australian Museum. Dr Slack-Smith did not recognise Maclean's '*O. trapezina*'. Furthermore, Dr Slack-Smith advised that the names applied to mangrove oysters in the Morobe Province - *Crassostrea tulipa, C. braziliana* and *C. belcheri* - in a report for CARE Australia prepared by a consultant are erroneous as they refer to non-Indo-West Pacific taxa.]

Distribution: Rock oysters occur around most of the PNG mainland and outer islands where estuarine conditions, mangrove forests or other suitable substrates occur. They also inhabit coastal or estuarine lakes - e.g. in the Morobe Province. *S. ?commercialis* prefers stone surfaces on more exposed areas, the smaller form of *S. echinata* prefers vertical structures in sheltered areas (e.g. wharf areas) and the large form of *S. echinata* favours exposed areas with a fast current, on stones and mangrove roots and lower trunks.

Oyster encrustations can be extensive. For example, oysters in Salus Lagoon in the Morobe Province can form bands at least 1 m wide over mangrove roots.

Biology and Ecology: Oysters are broadcast spawners, releasing male and female gametes into the water where fertilisation occurs. The free swimming larvae are hatched shortly after fertilisation and after one to several weeks of a planktonic existence, they settle as miniature adults on clean substrates in estuarine and coastal waters. Settled oyster larvae are known as 'spat'.

Growth rates vary with local conditions. Most oysters mature at one year of age (probably less in tropical waters) and they are either hermaphrodites (i.e. both male and female sex organs in the one individual) or change sex during life (function first as males and later as females).

Oysters are filter feeders, straining planktonic algae from the water.

2.12.2 The Fishery

Utilisation: In most coastal areas of PNG, oysters are gathered along with other edible shellfish. Gathering of shellfish is almost always performed by women and girls. The oyster meat is eaten (probably cooked or smoked) and the shells are often used to produce lime for mixing with betel nut.

In many tropical Asian countries, *S. cucullata* is commercially exploited and *S. echinata* is exploited in the Philippines (Angell, 1991). *S. cucullata* is harvested from wild populations except in Thailand, where it is cultured intertidally; and *S. echinata* is cultured only.

Production and marketing: There is no information on the consumption of locally grown oysters in PNG.

Oysters from Australia (not the same taxa as PNG oysters) are imported to service hotels and restaurants. According to a report prepared for CARE Australia in 1993, about 100 dozen oysters valued at c. K5.00-6.00/dozen are imported every week; i.e. an annual import valued at about K30,000.

2.12.3 Stock status

There is little information on the status of oyster resources in PNG. Stocks of oysters in coastal lagoons near Lae are said to have declined significantly over recent years because of the demand for lime (for betel nut chewing) by Morobeans and Highlanders (A. Tumonde, pers comm).

2.12.5 Management

Current legislation/Policy regarding cultivation: There is none.

Recommended legislation/Policy regarding cultivation: A proposal is being considered by CARE Australia and the DFMR's Women-in-Fisheries group in Lae to undertake oyster cultivation in estuarine lagoons in the Morobe Province. The rationale of the proposal is that such an industry would provide a cash income (from meat sales ± lime production) and outgoing activity for the women in the villages, provide national assistance by replacing imported oysters, and replenish stocks of oysters in the lagoons. CARE Australia projected (1993) that 1000 oysters per week could be harvested for 10 weeks each year which would give a conservative production from 10 villages of more than 100,000 oysters a year. The project was costed at A$70,570.

This proposal should be considered in light of the following information.

A. Cultivating native oysters.

Most of the information on PNG oysters with regard to their suitability for cultivation comes from studies carried out in and around Port Moresby by J.L. Maclean (a biologist formerly at the PNG Department of Primary Industry) during 1972 and 1973.

Maclean (undated) measured the average sizes of 120 individuals of each of the three farmable species, as shown below (figures are volume in millilitres).

Table 105 Average sizes of three species of oysters in PNG:

Species	whole	shells	meat
small *S. echinata*	9.0	6.2	1.8
large *S. echinata*	43.0	34.4	1.3
S. ?commercialis	9.2	6.5	6.6

The small *S. echinata* is always flat and thin-shelled, indicating rapid growth, while the other two species are well-cupped and with thick shells, indicating slower growth.

Maclean (undated) also assessed the seasonal condition, spawning seasonality and periodicity of spat settlement of the three oyster forms in the Port Moresby area.

The combined results of these settlement, gonad and condition data experiments indicated that the oysters there do not possess a clear reproductive cycle but probably spawn sporadically throughout most of the year. Spawning peaks do occur - evidenced by patchiness of spat settlement in the small form of *S. echinata*, and periods of good condition in *S. ?commercialis* and the large form of *S. echinata* - but they are not seasonal. Although some spawning occurs during the dry season, there is almost no spat settlement then because of the hypersaline conditions (i.e. salinities above 35 parts per thousand) existing during that period (Maclean (undated) recorded salinities of 36-38 parts per thousand during dry season months). It is possible that better conditions exist for spat settlement in PNG other than those existing in the Port Moresby area, which experiences a prolonged dry season - i.e. salinities would not be as high elsewhere.

Because of its size and attainment of good condition, Maclean (undated) found that the large form of *S. echinata* is probably the most promising species for farming. However, it does not settle in discrete zones and Maclean's (undated) attempts to collect spat were unsuccessful. Furthermore, it shows erratic period of good condition (oysters are only marketable during periods of good condition). However, in the Kerema area (Gulf Province) it is in good condition (flesh fat and full) late in July, the only period when it is gathered for consumption by villagers (Kari, 1977).

B. Cultivating an introduced oyster species

Farming the Pacific oyster, *Crassostrea gigas*, in PNG waters has been considered (Maclean, undated). This species was introduced to Fiji in 1971 and showed rapid growth and fattening at some sites - e.g. to 10.5 cm length 12 months after seeding (Maclean, undated). However, the current status of *C. gigas* stocks and farming in Fiji is unknown.

C. gigas would not be a suitable oyster species in PNG for the following reasons:

1. The water temperatures in PNG are too high. Optimal water temperature conditions for *C. gigas* are 23-25°C, although they can tolerate temperatures up to 15-30°C. Water temperatures in Port Moresby range from 24.9° to 30.4°, and would probably be higher in the lower latitidues of most of the country. The warm temperatures also would stimulate production of gametes over a long period, resulting in the exhaustion of mature oysters. Exhausted oysters do not have the good condition required for marketing.
2. The water salinity in the Port Moresby area is too high for *C. gigas* (which prefers salinities of 23-38 parts per thousand) although water salinities in estuarine areas and higher rainfall areas elsewhere in PNG could be suitable.

Because of the above physical conditions, an industry based on *C. gigas* would require imported spat each generation, and even then the oysters may not have the ability to tolerate the stressful conditions existing in PNG. Locating *C. gigas* farms away from the high salinity conditions of Port Moresby would not obviate the high water temperatures and would incur additional problems of distance from markets.

C. Influence of 'red tide'

Above all the problems of oyster growing itself, is the constraint to a possible industry by the seasonal occurrence ('blooms') of the toxic dinoflagellate *Pyrodinium bahamense* var. *compressum* (or 'red tide') in PNG waters. This organism causes paralytic shellfish poisoning (PSP) and deaths from eating oysters affected by *P. bahamense* have been recorded in PNG (Maclean, 1973). *P. bahamense* is the most potent of all dinoflagellates, and is particularly prolific in tropical waters of high temperatures (G. Hallegraeff, pers comm) - i.e. as exist in PNG. The toxicity of the dinoflagellate *P. bahamense* is not destroyed by heat (cooking). Environmental conditions linked to the occurrence of *P. bahamense* blooms in PNG waters were analysed by Maclean (1989) and Seliger (1989).

If commercial cultivation of oysters were to be performed in PNG constant monitoring would have to be conducted for *P. bahamense*. Furthermore, a non-harvesting period of several weeks after the disappearance of a bloom would be required for the oysters to rid themselves of the toxin (G. Hallegraeff, pers. comm.). Although blooms have doubtless occurred since the last thorough documentation of 1973, records from then on have been sketchy (Riroriro and Sims, 1989) and currently there is no regular surveillance for the organism in PNG. Mortalities and illnesses caused by eating toxic shellfish almost certainly occur in PNG but may not be reported to health authorities and/or diagnosed correctly. There are some villages and areas where the link between 'red tides' and food poisoning is well recognised and where shellfish are not consumed fore several months following a bloom (Riroriro and Sims, 1989). Adherence to this tradition probably contributes significantly to reducing fatalities caused by *P. bahamense*. Would the tradition be applied to a new fishery such as shellfish cultivation?

An alternative would be to locate farms in areas away from recorded areas of *P. bahamense* occurrence. Maclean (1989) recorded *Pyrodinium* from mainland sites between Wewak (East Sepik Province) and Yule Island (Central Province), the Trobriand Islands (Milne Bay Province) and northern West New Britain Province. Bivalves collected during *P. bahamense* blooms in two considered areas for oyster cultivation (Port Moresby and lagoons in the Morobe Province) were found to be highly toxic (Maclean, 1975a; 1975b).

D. Hygiene and quality control

Bacterial and viral pollution probably affects all edible molluscs in PNG (at least in areas adjacent to human settlement) and the organisms causing the pollution are destroyed by cooking. However, oysters for commercial harvest are marketed and consumed *raw*: i.e. added to the issues of oyster cultivation and red-tide 'exclusion', would be the issue of quality control and depuration. Of all the issues possibly affecting the oyster industry in Australia (and elsewhere) adequate depuration of oysters is perhaps the most important; and even when following all possible precautions against pollution, it is common for sections of the industry to be closed until environmental and processing facilities are cleared of the pollutant(s).

The problems experienced in PNG in maintaining adequate icing and quality control in other sections of the fishing industry are known and have been cited (e.g. for freshwater eels; *Macrobrachium*). Whereas other fisheries products are consumed after being cooked, oysters are not. Accordingly, the likelihood of an outbreak of food poisoning occurring from consumption of locally grown oysters is very high in PNG. It would cause an immediate cessation to the success of any oyster farming operation.

Angell (1991) and Newkirk (1991) remarked on the slow expansion of the oyster industry in Asia and identified a number of problems associated with it. They are collectively identified as sanitation. Oysters harvested from polluted waters are a public health hazard. Environmental degradation (e.g. deforestation resulting in increased runoff and siltation), sewage disposal, red tide occurrence, stock depletion and lack of quality control are all incorporated. Market limitations, insufficient seed supply, and insufficient suitable culture areas are other problems.

In summary, oyster farming is not recommended for PNG because of:

- the apparent difficulty of cultivating local oyster species,
- the unsuitability of a proven culturable oyster, *C. gigas*, for PNG conditions,
- the prevalence of the toxic dinoflagellate *P. bahamense* in PNG waters, and
- the problems of depuration and quality control in the industry under PNG conditions.

These difficulties are exclusive of the requirements of training, facilities and timely marketing.

2.12.5 References

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2.13 TROCHUS

2.13.1 The Resource

Trochus niloticus

Species present: The turban snail or topshell, *Trochus niloticus*. The closely related, white-based topshell (*T. pyramis*) also is present (at least in Manus: Lokani and Chapau, 1992). The white-based topshell is not utilised commercially.

Distribution: The natural distribution of trochus is on tropical and subtropical reefs from the Andaman Islands in the Indian Ocean to the islands of Fiji and Wallis in the Pacific (Bour, 1990). It has a naturally discontinuous distribution but since the late 1950s, trochus has been successfully introduced into nearly all island groups of Polynesia (Sims, 1988).

Biology and Ecology: Trochus prefer to live on the ocean side of reefs where the wave action is greatest. Although on some islands they are found in the deeper waters beyond the reefs (to 25 m: Asano, 1963, in Nash, 1993; Sims, 1988), trochus are rarely found below 12 m. Trochus are found in greatest numbers on reefs whose outer reef flat is regularly exposed at low tide, and on those with a boulder-strewn windward face (Nash, 1993). The mean size of trochus increases with depth. The larger shells (animals) are generally found in water deeper than 1 m, and the smaller shells on the inter-tidal reef-flats among coral rubble and rocks and on the reef crests which are often exposed at low tide. Nash (1993) noted that high density trochus populations will only occur where both adult and juvenile habitats are present. In Manus Island Province, the density of trochus increases with depth from 2 m to 6 m, then declines in 8 m depth zone; but - as Lokani and Chapau (1992) pointed out - this density difference may be the result of fishing pressure, as shallower depths are more easily fished.

The sexes in trochus are separate but cannot be distinguished by any external features. Trochus in the Andaman Islands, the Great Barrier Reef, New Caledonia and Palau first mature between 5 cm and 9 cm shell diameter when the animals are probably about two years old (Nash, 1993). The fecundity of females increases with age (Bour, 1990). Estimates of fecundity at different shell sizes have been made using several methods, but Nash (1993) counted egg numbers of individual females and the egg numbers ranged from 300,000 to 2 million; and approximately 3 million eggs were released by an 11 cm diameter trochus. Fertilisation occurs externally, the eggs and sperm being released into the surrounding water at night, usually a few days before the new moon (Bour, 1990). It is believed that spawning takes place throughout the year in low latitudes and during the summer months in higher latitudes (Nash, 1993). In the tropics, each female spawns about every 2-4 months (Bour, 1990).

The fertilised eggs become planktonic larvae after 9-10 hours, and settle out as juveniles on the reef flat in the intertidal zone after a few days. Overall, trochus have a short larval life and this suggests poor dispersal potential (Nash, 1993). Trochus show rapid growth during the first 3-4 years of life, the rate being strongly determined by environmental conditions. Growth parameters have been calculated for trochus from several parts of their range, and mean lengths at age 1, 2 and 3 years were estimated at 33 mm, 58 mm and 76 mm respectively (Nash, 1993). Subsequent growth is much slower, 11 cm basal diameter being reached at an age from 5-8 years (Sims, 1988). A size of 15 cm basal diameter is reached after 12-15 years (Lewis, 1985) and the maximum recorded size is 165 mm for an animal collected in the Loyalty Islands (Bour, 1990).

The rate of annual natural mortality of trochus is around 0.08 (Bour, 1990). Trochus are herbivorous and feed on the epibenthic film of microalgae that covers dead coral debris as well as on small invertebrates, foraminifera and bottom sediments. Known predators of trochus include hermit crabs and turtles. A number of plants and invertebrate animals will encrust on, or bore into, the shell.

2.13.2 The Fishery

Utilisation: Trochus is collected for the production of quality buttons and ornaments made from its nacreous inner layer. The powdered scraps resulting from button manufacture are used in lacquers and shampoos. At the Lucky Star factory in Rabaul 12 different sizes of buttons (or button blanks) are made from trochus, depending on the size of the shell. The scraps of shell are also valuable: whereas it would have *cost* Lucky Star approximately K450/mt to dump their scrap at the Rabaul tip in 1993, they exported it instead and *earned* K279,000.

The shell trade is important to coastal villagers. Expensive equipment is not required to collect the shell which is non-perishable, is easily stored and has meat which is eaten. The shells are collected by hand, usually by walking the reef flat at low tide, or by free diving. The meat is either eaten fresh or is preserved for later consumption by either salting or smoking. Trochus is an easy resource to harvest: it has a wide distribution, can be easily collected by diving or hand and receives a high price. No specialised preservation methods are required and the catch can be accumulated sufficiently to cover transport costs. The shell is graded into three categories (small, medium, large) and sometimes a fourth (wormy).

Trochus is not exploited commercially on the PNG side of the Torres Strait Protected Zone (Mobiha *et al.,* unpublished).

Production and Marketing: Following the return in demand for trochus shell in the 1980s, South Pacific stocks have been increasingly exploited. Between 1948 and 1976, the amount of trochus exported from PNG ranged between 201 mt (1966) and 1,030 mt (1951) (Glucksman and Lindholm, 1982). The highest price was K1,099/mt in 1957. Between 1970 and 1976 the export earnings of trochus and green snail averaged approximately twice that of barramundi (West, 1976, in Glucksman and Lindholm, 1982).

Between 1980 and May 1986, trochus was consistently the major annual export item in terms of value (Wright 1986). As Wright (1986) and Lokani and Chapau (1992) pointed out, the volume of trochus exports tends to increase as prices increase. The price offered for trochus in 1980 was K0.95/kg and this rose to K1.80/kg in May 1986. Note that *values* received reflect world production and exchange rates (Yen, USD) probably more than shell quality.

Table 106 Manus Province production (sources: 1987-89 - Lokani and Chapau, 1992; 1990- Lokani and Chapau, unpublished; 1991-94 - DFMR database, Kavieng):

Year	1987	1988	1989	1990	1991	1992	1993	1994
kg	24,195	46,274	68,225	66,364	20,050	35,996	54,656	4,793*

(*: incomplete - ‘to’ date not stated)

The price paid in Manus for trochus increased from K1.72/kg in 1987 to K4.78/kg in 1990. Shells harvested ranged from 4 cm to 14 cm diameter (average 9 cm).

Table 107 Madang Province production (source: 1987 - Fishery Sector review, 1989; 1989-91 - Lokani, unpublished; 1992-1994 - DFMR Madang)

Year	1987	1988	1989	1990	1991	1992*	1993	1994
kg	5,000	na	15,910	13,740	12,980	8,100	16,380	9,810**

(*: for 2nd half of year; **: for 1st half of year.

Additional information on these Madang figures:

1. In 1992-94, the bags of trochus were not weighed and these figures are based on a standard weight of 90 kg per bag.
2. The price/kg of trochus ranged from K6.11 in 1990 to K5.30 in 1992.
3. The 1989 total weight included 12.9 per cent (2,052 kg) from the East Sepik Province and 3.8 per cent (605 kg) from Siassi in the Morobe Province.
4. The 1990 total weight included 15.3 per cent (2,102 kg) from the East Sepik Province and 21.7 per cent (2,982 kg) from Siassi in the Morobe Province.
5. In 1989 and 1990 Long Island contributed the most amount of trochus of Madang Province production.

The main villages supplying trochus (1994) are on Bagabag and Long islands, and north and south coasts from Madang. Sepik (Wewak) shells are also brought in. Lokani (unpublished) reported that some of the harvested trochus from the Rai coast (Madang Province) goes directly to Lae (Morobe Province).

Table 108 Rabaul (East New Britain Province) production/exports (** information *excluding* Lucky Star - see under 'Export' figures heading). The figures below are from: Anisa Commodity, Meeandah, Atolls Resources, Erakone, Cottage,Village and Marine Products, Richard Gault, Bougainvile Shells and Kiki Marine.

Year	1987	1988	1989	1990	1991	1992
weight(kg)	80,241	87,026	66,460	63,015	30,340	44,236.5
value(K)	191,995	276,460	299,588	422,034	215,726	237,304

Table 109 West New Britain Province production (source: 1986-87 - Fishery Sector review, 1989; 1989-93 - DFMR Kimbe)

Year	1986	1987	1988	1989	1990	1991	1992	1993
kg	43,900	29,200	na	1,084	7,634	1,843	880	1,952

Table 110 North Solomons Province production (source: 1983 - Ito, 1984; 1982, 1984 - Ito and Selemet, 1985; 1990 - DFMR database Kavieng)

Year	1982	1983	1984	1990
weight (kg)	82,400	105,800	144,950	5,935
value (K)	85,932	132,110	213,492	17,291

The Wakunai to Pokpok areas on Bougainville produced the most trochus (Ito and Selemet, 1985).

Table 111 New Ireland Province production (source: Tenakanai 1991) (*: to May only)

Year	1988	1989	1990*
weight (kg)	3,685	57,530	21,500
value (K)	9,441	299,364	126,200

Buyers in Rabaul estimate that 75 per cent of their annual shell purchases come from New Ireland. During 1982 the Rabaul buyers bought 200 mt of trochus from New Ireland and provincial agencies in Kavieng bought 45 mt of trochus (Wright *et al.,* 1983).

Two years of Milne Bay Province harvests of trochus are in the 1980 and 1981 DPI annual report: 1980 - 8 mt; 1981 (to June only) - 5.5 mt.

The Fishery Sector review (1989) estimated trochus harvest by province and often figures different to the above were quoted. The review made a point of noting the *wide discrepancies in records* depending on the information source: from inspection services, from the DFMR, and from the provinces.

Table 112 Estimated trochus harvest by province, 1984-1987 (Source: Fishery Sector Review, 1989)

Province	shelf area ('000 ha)	1984 prod.(mt)	1985 prod.(mt)	1986 prod.(mt)	1987 prod.(mt)
Milne Bay	1,287	13	66	153	195
North Solomons	240	134	167	166	83
Manus	230	40	30	35	105
West N.Britain	137	40	27	44	55
New Ireland	139	40	27	20	47
Central	187	-	3	5	7
Northern	517	2	2	2	8
Morobe	77	1	3	3	7
Madang	29	-	2	1	5
East New Britain	68	-	-	-	-
Sepik (E&W)	41	-	-	-	-

About 84 per cent of the total shell harvest exported from PNG between 1950 and 1984 was trochus (Dalzell and Wright, 1986).

Table 113 Five-yearly exports of trochus for the period 1950-84 in PNG:

year	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84
weight (mt)	3,154	2,789	1,406	2,024	2,326	1,323	1,279*

(*: total for 1980-84 is *less* than the total of Wright's (1986) figures for the same period, below)

Table 114 PNG exports since 1980 (source: DFMR database, Wright's 1986 report on the *same* database, Chapau's advice on the *same* database) (*: to end of May; **: to end of June):

Year	DFMR weight (kg)	DFMR value (K)	Wright '86 weight (kg)	Wright '86 value (K)	Chapau '90 weight (kg)	Chapau '90 value (K)
1980	-	-	327,371	309,609	-	-
1981	-	-	187,909	147,747	-	-
1982	134,326	114,711	278,297	248,763	-	-
1983	355,703	347,328	357,191	372,798	-	-
1984	312,172	389,057	310,000	379,027	-	-
1985	437,334	686,732	450,290	693,478	450,700	664,298
1986	535,120	937,293	223,215*	359,638*	535,500	952,292
1987	441,963	927,545	-	-	462,600	986,785
1988	na	na	-	-	437,000	1,322,310
1989	na	na	-	-	275,800	1,217,4554
1990	346,321	na	-	-	227,300**	1,472,952**
1991	164,100	na	-	-	-	-
1992	257,986	1,852,789	-	-	-	-
1993***	220,672	1,672,281	-	-	-	-

***1993 figures include whole trochus, button blanks, trochus scraps and finished buttons.

Table 115 By separate category and fob value, the 1993 export figures for whole trochus, button blanks, trochus scraps and finished buttons were (source: DFMR database)

product	weight (kg)	fob value (K)	K/kg (value)
finished button	946.39	113,523.44	119.95
button blanks	17,559.7	640,148	36.46
whole shell	177,405	889,883.75	5.00
trochus scraps	24,445	28,725.40	1.18

Downstream processing was begun in 1992 by one factory (Lucky Star) in Rabaul. Their export figures (supplied by DFMR Rabaul) are given below. These figures (supplied by DFMR Port Moresby) should be compared with those above.

Table 116 Processed trochus export figures, 1992 (Source: DFMR, Port Moresby

Product	1992	1993	1994
button blanks (kg)	5,983	27,547.50	4,810 (1st 2 months)
finished buttons (kg)	NA	864.29	

The value of the 1993 consignment of finished buttons was K82,958.50 (or K96/kg)

Again, the Fishery Sector Review (1989) provided an alternative/supplemental set of figures of trochus exports (mt), by port-of-departure (source: inspection services and DFMR; first three figures for 1984 from Ito and Selemet, 1985)

Table 117 Trochus exports by port of departure, 1983-1987 (Sources: DFMR, Port Moresby: Ito and Selemet, 1985

Port of export	1983	1984	1985	1986	1987
Alotau	56.5	81.7	40.5	17	-
Kieta	97.8	145	166.7	167.8	83.2
Lae	6	96.4	7.6	35.8	162.6
Port Moresby	1.2	2	28.5	141.6	191.9
Rabaul	153.4	118	82.9	10.1	40.3
Kavieng	-	-	-	15	-
Kimbe	-	-	-	43.9	29.2
Madang	-	-	-	-	5
Wewak	-	-	-	-	3
Total	314.9	270.3	326.2	431.2	515.2
Total (DFMR)	355.7	312.2	437.3	535.1	442

Over the 1980-86 period, Japan bought between 66 per cent and 99 per cent of trochus exports (Wright, 1986) with the balance going to Korea, the United Kingdom, HongKong, Singapore, West Germany, Netherlands, Italy and Spain. Lucky Star sends its products mainly to Japan, Hong Kong and Singapore; and William Nankin's buyer (1994) was from Indonesia.

2.13.3 Stock status

Trochus stocks are prone to overfishing (Nash, 1993) probably because they occupy a well-defined habitat, are easily targeted, appear to have limited larval disperal and fetch an attractive price.

Trochus is heavily exploited in the Manus Province as local populations within reef tenure boundaries are fished out (Lokani and Chapau, 1992). Based on the reported volume of shell landed at Lorengau, these authors estimated that half of the biomass is harvested annually. The cpue also dropped from 30.1 kg/fishing trip in 1987 to 13.1 kg/trip in 1990. Trochus stocks on all of the reefs of Manus have been harvested between 1988/89 and 1992, the last virgin population being harvested in 1989. Densities of trochus in 10 sites surveyed were found to be higher on northern reefs (17.5-157.5/ha, av. 57.8) where the system of traditional reef tenure remains largely in effect, than on reefs on southern part of the island (7-25 trochus/ha, av. 13). By comparison, trochus densities per hectare from survey results at Aitutaki (Cook Islands) ranged from 325 trochus to 723 trochus (Nash *et al.,* 1992).

Lokani and Chapau (1992) calculated that the average length and weight of trochus on Manus was 9.2 cm and 210 g. They estimated that the average stock density was 46.5 trochus/ha and that suitable habitat is about 5 per cent of the total shallow reef area. This gave a biomass of 112.7 mt. From this estimate, Lokani and Chapau decided that the average (50.7 mt) of the 1987-90 trochus harvest was equal to 45 per cent of standing stock. They then assumed that 83.5 per cent (or 94 mt) of the trochus biomass of animals larger than or equal to 6 cm basal diameter "might be removed through intensive fishing." Lokani and Chapau (unpublished) used a surplus yield model to estimate the MSY of trochus for Manus, arriving at a figure of 64.5 mt/yr. These authors also recorded a large increase in fishing effort over the period 1987-1991 and noted that it continued to increase even while cpue decreased. Localised overharvesting of trochus is evident on Manus.

Trochus stocks in West New Britain Province are said to 'be depleted' (Fisheries Research annual report, 1985-1991).

Reef surveys done on the New Ireland Province islands between about 1988 and 1990 gave estimates of trochus densities ranging from 135 trochus/ha on Mussau Island to 34 trochus/ha on Djaul Island (Tenakanai, 1990). Although the density estimates were well below published criteria for harvestable trochus resources (Muller, 1973, and McGowan, 1958, in Tenakanai, 1990), Tenakanai pointed out that they were biased because they had been made during daylight hours. Another observation Tenakanai made about New Ireland trochus stocks was that, although the surveyed areas had been commercially exploited for more than 10 years, harvesting had intensified during the previous three years in response to offers of higher prices.

Trochus stocks on North Solomons Province reefs are said to be recovered (W. Nankin, pers. comm.) through the absence of harvesting over recent years.

Surveys conducted in the Madang Province in 1992 (Lokani, unpublished) provided estimates of trochus stock abundance as follows: Bagabag Island - 3/ha on the barrier reef and 20/ha on the fringing reef; Karkar Island - 17/ha; Bogia coast - 15/ha; Rai coast - 28/ha; Madang area - none. There are good habitats for trochus in the Madang area. The mean basal diameter of trochus around Bagabag Island was 10.3 cm. On Karkar Island mean basal diameter of trochus was 10.4 and on Bogia it was 10.5 cm. Lokani estimated potential yield as 302 kg/year for the Bagabag fringing reef and 79 kg/year for the barrier reef, 555 kg/year for Karkar Island, 1,890 kg/year for the Bogia coast and 1,771 kg/year for the Rai coast.

In the Daru area, Western Province, trochus appears to be restricted to Bristow Island and Potamoza Reef (Mobiha *et al.,* unpublished). In a survey of suitable habitat at Bristow Island trochus were observed to be present at an estimated density of 32.3/ha (numbers observed in a single transect). The total trochus stock of Bristow Island was estimate at 33,250 animals.

There is no (or marginal) information on trochus stocks in East New Britain, West Sepik, East Sepik, Morobe, Northern, Milne Bay and Central provinces.

Trochus production - as with green snail - appears to fluctuate in response to periods of high or low harvest rates. For example where the civil unrest on Bougainville has curtailed harvesting activities stocks have replenished. Glucksman and Lindholm (1982) reported a similar phenomenon in PNG during the second world war. Traditional reef tenure has offered protection to trochus stocks in PNG - for example, in the north of Manus Island (Lokani and Chapau, 1992). However, the traditional tenure system is breaking down in a number of provinces under the influence of potential commercial gain.

2.13.4 Management

Current Legislation/Policy regarding exploitation: Changes to the Continental Shelf (Living Natural Resources) Act (Chapter 210) directed at trochus management were gazetted in 1992. Legal minimum (8 cm basal diameter) and maximum (12 cm basal diameter) came into effect on 11th May 1992, and prohibitions on the taking of trochus by scuba or hookah gear, and at night, and by the use of ships, came into effect on 21st May 1992. The minimum size was based on studies on trochus conducted in several Western Pacific and Indian ocean areas, where the most common size reported for age at first maturity was 6 cm basal diameter. By setting the minimum size at 8 cm it was reasoned that the animals would have had the opportunity to breed 1-2 times (Tenakanai, 1990). The 12 cm maximum size is when the shells begin to show evidence of worm damage. They are of no use commercially in this condition while conversely they are at their most productive level of fecundity.

Recommended legislation/Policy regarding exploitation: As with other natural resources where their commercial value becomes much higher than their traditional use, disputes have arisen in Manus over the commercial use of trochus by owners of reef tenure rights (Lokani and Chapau, 1992). Traditional reef tenure rights have/could provide a measure of protection for stocks.

Poaching of trochus is quite common in PNG. Demand for PNG trochus is more likely to rise than decline. Lucky Star informed me that the quality of PNG trochus shell is high and that the company has orders from European countries which they do not meet.

Apart from management concerns common to trochus in the Western Pacific, I have *three main concerns*:

- that of *not knowing the state of stocks in some areas* (Milne Bay, Central and Northern Provinces are cases in point),
- of not knowing the *growth rates of trochus in different regions* of the country, and
- about the *inadequacy of information* on the resources (harvest figures).

All of these issues are addressed below.

- A primary objective of the fisheries managers is to educate. Through education ('village awareness') the villagers can police/maintain their own resources. Education is also needed to explain what happens with indiscriminate harvesting, as well as the laws on sizes and methods of harvesting.
- Assess the appropriateness of the current minimum and maximum legal sizes. Tenakanai (1990) hinted that the minimum size may have to rise to 9 cm, which is the size suitable for button manufacture in most Pacific countries. Before such a change were made, the relative size of trochus and their maturity status would have to be ascertained for different regions of PNG. A minimum legal size should be set such that all trochus have the opportunity to spawn at least twice before they are legally harvestable. As with green snail, there are indications that trochus from different regions in PNG attain different maximum sizes (e.g. Bougainville and Alotau). Either set different minimum sizes reflecting the differences in maturity-at-size (and such regulations would incur huge problems in policing) or *apply a uniform minimum size limit which reflects the different maturity sizes as best as possible*. Nash (1993) pointed out that at high levels of fishing pressure the size limit necessary to conserve stock is high (e.g. 11-12 cm) as it is the older animals that are more fecund.
- Initiate *closed seasons ?* In Cook Islands, the trochus harvest runs once a year for rarely more than one week (Nash *et al.,* 1992). There the resource is localised (the result of a successful introduction) and well policed. Having a closed season on trochus harvesting would be difficult to introduce in PNG. Furthermore, the usual basis for closed seasons is to protect the stock when it is spawning: although it is suggested that spawning occurs year-round, this hypothesis would have to be investigated and the merits of a closed season considered in light of the investigation. If trochus did spawn at different periods in PNG (unlikely?) policing a closed season would be difficult and I cannot see that poaching would discontinue. Closed seasons appear inappropriate for PNG on a large scale, but on a regional scale they are very appropriate *as traditional owners could effectively impose and police them* in cooperation with DFMR.
- Create reserves and sanctuaries to provide buffer zones for harvested stock. This measure could be undertaken in PNG with policing and support provided by the local community. A knowledge of currents with respect to trochus larval dispersion would be required to select appropriate reefs, and also it may only be effective in close reef complexes. Larvae have a short planktonic phase which means they are unlikely to disperse widely (Nash, 1993). *Recruitment rates* of reefs? Nash (1985, in Tenakanai, 1990) showed that it takes a long time for stocks to recover from overharvesting. Tenakanai suggested that where large parent reefs were situated away from harvested islands, the recruitment and recovery rates would become major problems without regulations. Trochus can be successfully

translocated and introduced (e.g. Cook Islands +others) and hatchery production of trochus is feasible. A depleted stock can be replenished by re-seeding but the new population cannot be fished for quite several years (Nash, 1993). Checks of the genetic composition of the stocks would be advisable before translocation took place.

- Moratoria are a crisis management measure which are effective in the short term - yet again require the support of local communities. Moratoria take the place of civil unrest an natural disasters, and now they also take the place of the traditional ownership systems used to protect reef resources. Mobiha *et al.* (unpublished) advised that trochus stocks at Bristow Island (Western Province) should not be fished; and Lokani (unpublished) recommended that there be a two-year ban on the harvesting of trochus for the whole of Madang Province.
- Fiji is *restricting the export of whole shell*. Would this work in PNG? Being able to export whole shell provides an income for nationals who cannot afford to set up downstream processing, or who - if they sent it to a domestic processor - might receive a lower price for their shell.
- Trochus is a perfect example of where an export quota can be applied. It can be policed most effectively at the point of export. Could ITQs be purchased by buyers? Effort and total catch would be limited if ITQs were implemented (e.g. Lokani and Chapau, unpublished). Licensing fishers would not work with trochus as potentially everyone in the village can harvest it (cf barramundi). Could catch quotas (Total Allowable Catch, TAC) for the provinces be implemented? However, quotas depend on stock assessments (see below). An export quota is being implemented in Fiji. Lewis (1985) said that sustainable harvest rates for most exploited species and especially vulnerable ones are generally 20-25 per cent of the available stock. At Aitutaki (Cook Islands) it is the estimate if the proportion of legal-sized shells (8-11 cm) together with the estimate of the total population size that determines the quota for the coming harvest (Nash *et al.,* 1992). The annual quota (TAC) is set at 30 per cent of the assessed number of 8-11 cm trochus over the whole reef based on pre-harvest and post-harvest surveys. Contra the situation in PNG, the Cook Islands trochus stock is extremely localised.
- Nash (1993) pointed out that TACs assigned to small regions for the harvest of trochus are preferable to a single (global) TAC for a large region or country, and that finer subdivisions (e.g. to villages or family groups) are even more preferable. In PNG however, policing in the absence of a licensing system could be a problem.
- The direction of fisheries research on trochus should be towards *stock management*. Field work (e.g. underwater visual census, UVC) is expensive and only assesses a small amount of the stock. Consider that this 'has been done'. Now move on to the instruction available from looking at catch records: after all, the villagers know where the trochus are and that is what is coming through the buyers. This approach could fill temporarily for provinces where no censuses have been made and where there is little information. Biologists could prepare a temporary harvestable stock estimate by calculating the amount of reef, the proportion of that that is within free diving limits and offers suitable sites for trochus (estimated from completed UVC work) and applying the results of the already completed UVC's to get a 'ballpark' figure of the biomass. Tenakanai (1990) attempted to apply just such a method to estimate the total harvestable reef area for the whole of New Ireland but had outdated charts from which to work. He suggested that a reliable estimate could be obtained by using aerial photographs + a digital chart planimeter. The idea is not without precedent, said Tenakanai: satellite images have been used in New Caledonia to assess trochus stocks and estimate total harvestable areas. Stock assessments: scientists at Aitutaki (Cook Islands) tested three different methods of estimating the abundance of trochus for an approximately equivalent expenditure of survey effort - by transect method, mark-recapture and change-in-ratio (of different shell sizes before and after the harvest). They found that mark-recapture was the most accurate - but only in the fishery there,

where harvest is of short duration and a lot of the harvest can be monitored for marked shell. The mark-recapture assessment is robust and requires less survey effort than do other methods.

- It concerns me that the DFMR rarely - if ever - questions the fob value of trochus (and all other exported fisheries products?) nominated by exporters. Are there not independent sources whereby the DFMR can validate the values?
- Better recording of harvests should be implemented by DFMR and provincial governments. *This is the most important recommendation I have*. Trochus is one of the most valuable fisheries resources PNG harvests and will become more so: how can information on the harvest be available in several versions or not at all? The several versions of provincial harvests and exports currently available (ref. above) have no chance of supporting resource maintenance and stability. For the fisheries manager and the scientist there is no alternative to being able to access a good information base of fisheries production: field surveys are limited and expensive, and stock assessments and population dynamics studies are hollow if they are based on faulty catch information. It is simply groping in the dark and leaves the door open to abuse when attempts are made to construct and implement regulations based on questionable data.

To facilitate the recording and collection of accurate information (and the 'rules' outlined below can apply to all harvested artisanal and commercial fish resources in PNG):

1. Buyers should be registered/licensed (with the payment of a fee amounting to (e.g.) approximately 10 per cent of the last year's recorded fob price on their exports) and regular inspection of their books performed. The fee will support the inspection and data service. Also the bags should be weighed, not just counted. Contents of randomly-selected bags should be measured, and fines imposed if undersized or oversized shell are found therein (which should be confiscated).
2. Receipts - stating quantity, price/kg, date, total price and location - should be given to villagers for shell purchases. Villagers should be aware that they are to be given a receipt.
3. Fisheries officers should inspect quantities for export in a timely manner and also their reports should be submitted to HQ/DFMR in a timely manner.
4. Data submitted to DFMR should be entered within a short space of time after receipt and the date of entry noted. Printouts of the entries should be sent back to the fisheries officers - and perhaps the buyers - for them to confirm the data entries. This step is also a feedback mechanism. Once the data has been confirmed/corrected by the fisheries officers it should be certified as 'true and correct' by the data-entry operator and dated.
5. Senior officers should be aware of the composition of the database and should regularly (e.g. every month) endorse and date the certification of the entries as advised by their data-entry operators and inspectors. Dated back-up files should be made of the database and stored securely.

In summary:

- undertake village awareness work;
- assess the appropriateness of the current legal sizes;
- initiate closed seasons in regional areas with the support of the village systems;
- create reserves and sanctuaries, and investigate the possibilities for restocking depauperate areas;
- place moratoriums on collecting in certain areas;
- investigate the feasibility of restricting the export of whole shell;

- investigate the feasibility of applying ITQs and TACs. To support this, obtain 'ballpark' stock assessments as a matter of urgency;
- obtain independent actual prices for trochus shell being exported rather than believe in the prices nominated by the exporters. Ensure a fair price is paid to villagers; and
- *ensure accurate and timely recording of harvests by the provincial governments and DFMR*.

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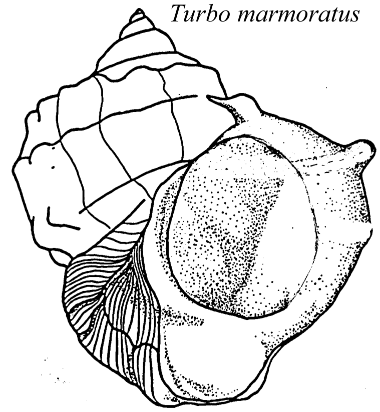
2.14 GREEN SNAIL

2.14.1 The Resource


Turbo marmoratus

Species present: The green snail, *Turbo marmoratus*.

Distribution: Green snail is distributed throughout the Indo-Pacific from east Africa through South East Asia as far east as Fiji. It is rare in Australia south of Torres Strait, and northwards it extends to the Ryukyu Islands in southern Japan. Green snail has been successfully introduced to French Polynesia (Yamaguchi, 1993).

Biology and Ecology: Green snail are gastropods which inhabit coral reef environments influenced by clean oceanic water and bearing abundant live coral growth and algae, and a topography of crevices and elevations (Yamaguchi, 1993). Juveniles inhabit the reef crests in water 1-5 m deep and adults inhabit deeper water, extending down the reef slope to at least 20 m. They are most active at night. Trochus (*Trochus niloticus*) shares this habitat but does not extend into the deeper water. In PNG, green snail is less widely distributed than is trochus.

The sexes in green snail are separate and gametes of both species are released into the water column. Green snail in Vanuatu were estimated to be sexually mature at 15 cm shell diameter (Devambez, 196, in Yamaguchi, 1993) and at 13 cm shell diameter in the Ryukyu Islands. In higher latitudes, green snail appear to breed only in the summer months when water temperatures are higher, but in lower latitudes mature animals probably breed throughout the year (Yamaguchi, 1993). Fecundity has been estimated at up to 7 million eggs in 2 kg female green snail. Spawned eggs are slightly heavier than sea water but are kept suspended by slight current movement and so are likely to be easily dispersed. The eggs hatch into trochophore larvae and the larvae go through veliger and pediveliger steps before settling tothe substrate. In the laboratory, this process is completed after about four days (Yamaguchi, 1993). Small juvenile green snails go through a series of morphological changes until it has achieved an adult-like morphology about six months after fertilisation. Green snails have a shell diameter of 2-3 cm at 12 months of age, and they are mature by 3-4 years of age. The species can grow to 20 cm in shell diameter and 2 kg weight.

Adult green snail graze on epibenthic microalgae and they also ingest macroalgae.

2.14.2 The Fishery

Utilisation: Traditionally, scythe-shaped slivers of green snail shell were used by fishers in the New Guinea Islands region as lures when trolling (S. Philps, pers. comm.). Commercially, the nacreous shell of green snail is highly prized in the mother-of-pearl (MOP) trade for inlay material for lacquerware, furniture and jewellery. A small amount of production goes to the tourist/souvenir trade as well. The animal has been exploited for that purpose for at least a century (Yamaguchi, 1993). In PNG, it has been harvested around Manus Island at least for that long (Lokani and Chapau, 1992).

Green snail is collected by reef walking or free-diving on the reefs. As the animals are nocturnal they are mainly harvested with the aid of torch-lights at night.

Green snail meat is eaten in PNG. The shells are saved and sold to buyers who on-sell them to exporters or the button factory at Rabaul. Green snail is exported as slices (and button blanks[1]?) or as whole shell.

[1] At time of printing, I had not obtained clarification on this matter.

Production and Marketing: Green snail shell has been exported from PNG since the end of the Second World War. The species was heavily exploited between 1952 and 1957, when 1,360 mt are reported to have been exported. From 1970 and 1976 the export earnings of trochus and green snail averaged about twice as much as the barramundi industry (Glucksman and Lindholm, 1982). Green snail has become the most valuable of the MOP shells because of its scarcity. Most of the harvest goes to Japan, Korea and Hong Kong.

The major producers of green snail in PNG have been New Ireland, North Solomons, Madang and Milne Bay provinces. Recorded provincial harvests of green snail are:

Table 118 Manus Province (sources: 1987-90, Lokani and Chapau, 1992; 1991-93, DFMR Kavieng database).

Year	1987	1988	1989	1990	1991	1992	1993
weight (kg)	403	1005	3636	928	671.7	561.5	73.3
fob value (K)	1,012	4,734	53,704	9,493	16,363	10,373	616

Table 119 North Solomons (sources: Ito, 1984; Ito and Selemet, 1985; DFMR Kavieng database)

Year	1982	1983	1984	1994 (1st quarter)
quantity (kg)	7,584	3,780	6,860	357
value (K)	32,231	18,230	36,545	3,997.20

East New Britain (Rabaul) (source: Anisa Commodities/DFMR Rabaul): 1987 - 3,120 kg (K9,630).

In 1982 buyers in Rabaul estimated that 75 per cent of their annual shell purchases came from New Ireland (Wright *et al.,* 1983).

Table 120 New Ireland (sources: 1982 - Wright *et al.,* 1983; 1988-90 - Tenakanai, DFMR file report 7/91)

Year	1982	1988	1989	1990 (1st 4 months)
quantity (kg)	26,000*	1,215	3,250	1,000
value (K)	**	6,745	85,708	24,600

* plus 3-4 mt produced on eastern islands shipped direct to Rabaul.

** 6 mt of the 26 mt was purchased for K1.30/kg.

Tabar, Lihir, Tanga and Anir islands are the main producers of green snail in the New Ireland Province.

Madang: 1989 - 673 kg (K13,595) (source: Lokani, unpublished)

Table 121` Green snail production from PNG coralline areas over 30 years (Source: Dalzell and Wright, 1986)

Years	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79
tonnes	869	569	98	78	175	214

Table 122 PNG exports of green snail - whole shell, kg (Source: DFMR)

Year	Quantity(kg)	value(K)	Year	Quantity(kg)	value(K)
1979	*59,300	*136,000	**1987	15,960	61,892
1980	-	-	1988	*14,800	*40,365
1981	-	-	1989	*12,100	*220,880
1982	21,943	66,013	1990	4,972	-
1983	29,405	112,354	1991	3,400	-
1984	31,982	162,237	1992	1,435	13,708.50
1985	11,745	67,619	1993	3,704.5	99,954.7
**1986	10,087	35,315	1994		

(* from Fisheries Research annual report for 1979; 1988 and 1989 figures from DFMR files.

** alternative figures from DFMR file: 1986 - 13,100 kg for K41,421; 1987 - 16,900 kg for K69,429.)

All of the 1983-87 export figures from DFMR (above) differ from those given in the Fishery Sector review (1989) (below).

Table 123 Fishery Sector review (1989) export figures (in mt whole shell) for the period 1983-87, gathered from 'ITS'(?), stating export ports. *Some of these figures differ from the independently gathered statistics above.* The first three figures for 1984 are from Ito and Selemet, 1985)

Port	1983	1984	1985	1986	1987
Alotau	1.1	2.3	-	-	-
Kieta	3.1	6.86	4.0	16.4	2.5*
Lae	-	9.1	0.4	-	0.5
Port Moresby	0.7	-	-	4.1	2.9
Rabaul	22.5	12.5	5.1	-	-
Total	27.4	18.0	9.5	20.5	5.9

New Ireland (through Rabaul) and North Solomons provinces were the main suppliers of green snail. (* The civil unrest in Bougainville began about this time led to a fall off in production.)

The mean size of green snail shell landed in Manus Island in 1991 was 16.53 cm mouth diameter (range 9-19 cm) and 900 g (Lokani and Chapau, unpublished). It is possible that green snail in the North Solomons Province are slow growing, as individuals of legal size limit (15 cm mouth diameter) already wear scars from worm infestations (W. Nankin, pers. comm.).

2.14.3 Stock status

The demand for green snail shell has increased greatly in recent years and it therefore receives higher prices than does pearl shell and trochus. Based on DFMR figures, the fob price for green snail - just in the last 10 years - rose from K3.80/kg to K27.00/kg (the average price to fishers for green snail in Manus Province rose from K2.51/kg in 1987 to K14.77 in 1989 and dropped to K8.40 in 1993). The harvest has not increased in response to these prices; instead it has *decreased*: from 29.4 mt in 1983 to 3.7 mt in 1993.

In a 1991(?) underwater visual census of Manus and nearby islands (Lokani and Chapau, 1992), only two green snail were found. (*the survey report does not say how big an area was surveyed!) However, Lokani and Chapau noted quantities of harvested shell. These authors recorded that the cpue related to shell value rather than to quantity - increasing when the price rose, decreasing when the price dropped. Nevertheless, Lokani and Chapau (unpublished) attributed the drop in production in 1990 to over-exploitation. They believed that green snail stocks are low in Manus because of years of harvesting. Once moderately widespread in Manus, the species is no longer present in a number of areas.

A three-year survey/monitoring program of green snail stocks in the New Ireland Province by the DFMR Kavieng laboratory (C. Tenakanai, DFMR file report, 7/91) revealed that green snail is present in only a few localities, although fishers reported that in the 1940s and 1950s it could be collected anywhere in the province. By 1991 green snail was absent from the Tigak Islands, south coast of New Ireland, and many localities on the west coast. DFMR counts of green snail were very low at Mussau, Emirau, Lihir and Tabar islands, and none was present in suitable habitat at Djaul Island.

No individuals of green snail were found in a survey of Madang Province in 1992 (Lokani, unpublished) despite the existence of suitable habitat. In four years of fisheries data collection, green snail was only recorded for 1989 (673 kg @ K20.20/kg). Lokani considered this situation represented an 'extreme case of over-exploitation', and considered it possible that green snail was locally extinct.

In conjunction with the above are reports that green snail coming to buyers is smaller in size than in previous years. Glucksman and Lindholm (1982) reported on observations that size had dropped and overfishing (indicated by there being green snail concentrations only below the free-diving limit - i.e. the snaily had been fished out where accessible) had taken place; e.g. in the Schouten Islands and at Manus Island.

Although the species' abundance is more difficult to assess due to the deep habitat preference of adults, it seems unlikely that the PNG stocks will increase significantly nor that new populations of green snail in PNG will be identified. In North Solomons Province, the 6 year period of the civil unrest has decreased fishing pressure on green snail (and trochus) stocks and shell numbers have increased (W. Nankin, pers. comm.).

Local overharvesting of green snail stocks has occurred in Milne Bay Province (Tenakanai, 1990).

2.14.4 Management

Current legislation/Policy regarding exploitation: Changes to the Continental Shelf (Living Natural Resources) Act (Chapter 210) directed at green snail management were gazetted in 1992. Legal minimum (15 cm mouth diameter) and maximum (20 cm mouth diameter) came into effect on 11th May, 1992 and prohibitions on the taking of green snail by scuba or hookah gear, and at night, and by the use of ships, came into effect on 21st May, 1992.

Recommended legislation/Policy regarding exploitation: The green snail (and trochus) trade is an important fishery for coastal villagers as it does not require expensive equipment to harvest, the meat can be eaten and the shell requires no preservative and is easily stored and packed. There is therefore every reason to secure the future of the resource as a revenue earner and food source for both the coastal villagers and the nation.

Experience in several Indo-Pacific areas have suggested that green snail populations cannot sustain intensive fishing over long periods: they are rapidly depleted from actively fished areas and the population takes a long time to recover after fishing has ceased.

From discussions with the Rabaul button factory manager, it is clear that the global demand for green snail will increase rather than decrease. Hence, PNG's existing green snail stocks will be placed under further pressure. Some protection of the resource has been afforded from two sources - its own depth preference precluding it from easy harvest by free-diving, and the PNG Government's regulations on harvesting methods and sizes. With ever increasing prices for green snail however, the incentive exists for rules to be broken (e.g. Lokani and Chapau (unpublished) noted that buyers bought undersized shell; and also that traditional fishing rights over reefs were coming under pressure in Manus) which in turn puts more pressure on fisheries officers to enforce the regulations.

In that scenario, a national-government imposed moratorium would be unsuccessful. And presenting *live* green snail for inspection (so that undersized ones can be returned to the sea) is impractical.

There is hope for green snail 'rehabilitation' however. The species can be translocated successfully - but only of similar genetic stocks, and effective quarantine measures should be in place to prevent the inadvertent translocation of unwanted organisms (Yamaguchi, 1993). Techniques for raising green snail in aquaria have been developed (Yamaguchi, 1993) and techniques for successfully releasing hatchery-raised juveniles to establish on reefs are being trialled in southern Japan.

The early stock assessments of green snail in PNG have not led to an estimate of sustainable harvest levels, yet such research has not been performed anywhere in the species' range. How far do the larvae disperse? Can the remaining deeper water stocks supply recruits to shallow water areas? (possibly - as long as assisted underwater breathing (scuba and hookah) harvesting is prevented.)

Yamaguchi (1993) expressed reservations about the value of the existing size limit of 15 cm shell width applied in the western Pacific. He pointed out that the growth rate of young adults is not known. In lieu of research on the size at maturity of green snail in different areas, imposition of a 15 cm legal minimum shell diameter is arbitrary and of questionable value. Such may be the case in PNG (supported by limited observation). To further support Yamaguchi's and local observations, Stojkovich and Smith (1978, in Wright *et al.,* 1983) noted that in Guam, different size classes of trochus inhabited different reef zones with the largest animals living seaward of the outer reef flat. The apparent influence of environmental factors on green snail (and trochus) growth rates should be borne in mind when adjudicating on size limits of a stock across such a geograpically broad area as PNG.

PNG, Vanuatu and Solomon Islands are the only countries with sizeable natural populations of green snail, a species which has been included by the International Union for the Conservation of Nature in its list of 'commercially threatened invertebrates' (Tenakanai, 1990). This situation further behoves the PNG Government to ensure the well-being of its green snail resources.

<u>Recommendations:</u>

1. Village <u>education</u> ('public awareness) regarding the effects of overharvesting on green snail stocks should be undertaken. This should include the effects of harvesting green snail before they are mature and have spawned, and when they are large and useless because they bear worm grooves or worm holes. There is growing concern by villagers in PNG about the depletion of their green snail resources.

2. Villagers should be encouraged <u>to regulate their own resources</u> and government support should be offered to that end. A *quota* system is one way for this to operate. Another

(temporary) measure would be the imposition of a *provincial ban* on exploitation for a defined period.

3. Imposition of a fallow reef /rotational harvesting system should be investigated. Provincial government cooperation should be sought here. The examples of the increased stock from non-harvesting during the Second World War and the civil unrest in Bougainville apply.
4. Green snail should be harvested by national fishers only (I believe this measure is already in effect).
5. Encourage more downstream processing in PNG (better national return).
6. Is there a way of ensuring that buyers pass on the increased prices to the fishers? (There appears to be a large gulf between what the harvester receives and what the buyer receives when onforwarding.)
7. Monitor/participate in research in other countries regarding a more accurate assessment of minimum size at 50 per cent population maturity. This measure would include surveying the sizes and maturity of stocks from different regions of PNG. If there is found to be significant variation in a size/maturity ratio between different regions of PNG consideration may have to be given to either applying different size limitations in different regions, *or* applying a uniform minimum size limit (the current size limit may have to be adjusted to fit the characteristics of the green snail populations in the most accessible regions).
8. Importance should be given to establishing an appropriate maximum size. Large shells are frequently worm ridden and are rejected by buyers. Large green snails should be protected as they are more fecund than smaller animals and are therefore important to stock replenishment.
9. Restocking of reefs could be performed, but *genetic studies* would first have to be carried out.
10. Effective enforcement of the existing regulations is a MUST. Whereas the restrictions on capture method are sound, there are indications that the size regulations are inappropriate.

2.14.5 References

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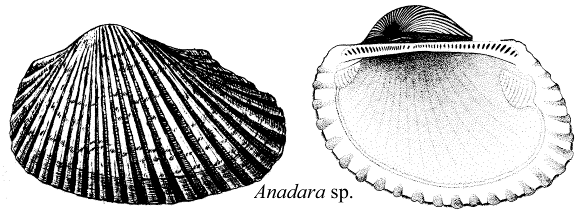
2.15 EDIBLE MOLLUSCS - SHELLFISH

2.15.1 The Resource



Anadara sp.

Species present: Numerous species of shellfish (Mollusca) inhabit PNG waters and many are gathered for human consumption. Some of these species with their preferred habitats, are listed below. (Names have been checked by Shirley Slack-Smith, Curator of Molluscs at the Western Australian Museum, Perth.)

Bivalves

Acrosterigma species. Cockles. Family Cardiidae. Sandy areas; shallow water.

Anadara species, including *A. antiquata* and *A. granosa*. Blood cockles. Family Arcidae. Estuaries, silty areas; also sand on reef platforms.

Anodontia philippiana. Family Lucinidae. Mangrove areas, silt.

Arca species. Burrowing clams. Family Arcidae. Rocky and coral areas.

Asaphis violascens. Pacific asaphis. Family Psammobiidae. Reef platform, sand.

Atactodea striata. Family Mesodesmatidae. Lower coral beach sand, reef platform.

Barnea manilensis. Family Pholadidae. Silty areas, mudflats.

Batissa violacea. Violet mud clam. Family Corbiculidae. Mud, silt; freshwater and brackish water; sago areas.

Chama species, including *C. pacifica*. Jewel box shells. Family Chamidae. Cemented to substrate. Mangrove areas, rock or (dead) coral platforms; lagoon habitats.

Codakia species, including *C. punctata* and *C. tigerinus*. Lucines. Family Lucinidae Mangrove, silty mud.

Donax species. Pipies. Family Donacidae. Sandy areas.

Gafrarium tumidum. Venus clam. Family Veneridae. Mangrove, silty mud; also reef platform, rocks.

Isognomon ephippium. Family Isognomonidae. Mangrove areas, brackish water, river beds; silty mud, dead coral. Attached.

Latona faba. Family Donacidae. Sand and coral reef platform.

Lioconcha species. Venus clam. Family Veneridae. Sandy areas; shallow water.

Lucina corrugata. Lucine clam. Family Lucinidae. Mangrove, silty mud.

Periglypta puerpera.Venus clam. Family Veneridae. Muddy sand on coral reef, or strong mud; also mangroves.

Pinctada fucata. Pygmy pearlshell. Family Pteriidae. Sand, shell and rubble; muddy habitats; often attached to seagrasses or on clumps of dead shells.

Pinna species. Razor clams. Family Pinnidae. Sand.

Pitar pellucidus. Family Veneridae. Sandy areas on coral reef.

Placuna species, including *P. placenta* and *P. sella.* Family Placunidae. Mangrove, silty mud.

Polymesoda (Geloina) coaxans. Mangrove clam or cyrena. Family Corbiculidae. Mangrove swamps, mud, *Nypa* and mangrove swamps; mudflats.

Quidnipagus palatum. Family Tellinidae. Sandy areas on coral reef platforms.

Semele species. Semele clams. Family Semelidae. Sandy areas on reef platforms.

Solen species. Finger-nail clams. Family Solenidae. Silty mud.

Spondylus species, including *S. ducalis*. Thorny oysters. Family Spondylidae. Attached to substrates. Mangrove areas, dead coral, rocks.

Tapes literatus. Family Veneridae. Mangrove, silty mud.

Unio anodontaeformis. Family Unionidae. Freshwater; silty areas.

Vasticardium species. Coconut scraper cockle. Family Cardiidae. Sandy areas on coral reef.

Gastropods

Astraea rhodostoma. Star shell. Family Turbinidae. Sand, silt.

Auriculastra subula. Family Ellobiidae. Mangrove, silty mud.

Bulla species, including *B. ampulla*. Bubble shells. Family Bullidae. Sandy patches, coral reefs.

Cassidula angulifera. Family Ellobiidae. Mangrove, silty mud; *Nypa* palm areas.

Cassis cornuta. Horned helmet. Family Cassidae. Coral sand.

Cerithidea rhizoporarum. Horn shell. Family Potamididae. Mangrove, silty mud; on tree trunks.

Cerithideopsilla cingulata. Family Potamididae. Mangroves, silty mud.

Cerithium nodulosum. Cerith. Family Cerithiidae. Weed covered rocks and reef platforms; also muddy flats and mangrove areas.

Charonia tritonis. Trumpet triton. Family Ranellidae. Sand and rubble areas on reefs.

Chicoreus species, including *C. ramosus* and *C. torrefactus*. Murex. Family Muricidae. Sand and rubble areas on reefs.

Chrysostomus paradoxum. Top shell. Family Trochidae. Reef platforms.

Conus species. Cone shells. Family Conidae. Sand on coral reef platforms.

Cypraea species. Cowries. Family Cypraeidae. Weed covered rocks and reefs.

Cypraecassis rufa. Helmet shell. Family Cassidae. Coral reefs.

Ellobium aurisjudae. Family Ellobiidae. Mangrove areas, moist habitats.

Lambis species, including *L. lambis* and *L. truncatus*. Spider shells. Family Strombidae. Reef platform, sand.

Littorina scabra. Winkle. Family Littorinidae. Sand and silt.

Mitra species. Mitre shells. Family Mitridae. Sand and rubble areas on coral reef platforms.

Nassa species. Jopas shell. Family Thaididae? Sand and rubble areas on coral reef platforms.

Nassarius species, including *N. dorsatus*. Nassa shell; tambu shell. Family Nassariidae. Intertidal sand and mud flats.

Nerita species, including *N. abicilla, N. gagates, N. lineata, N. ornata, N. polita, N. peloronta* and *N. ziczac*. Nerites. Family Neritidae. Mangrove, silty mud. Also reef platform, rocks, sand; tree trunks and *Nypa* fronds in swampy areas.

Ovula ovum. Egg cowrie. Family Ovulidae. Weed covered rocks on coral reefs.

Patella flexuosa. Star limpet. Family Patellidae. Attached; intertidal rocks

Polinices species, including *P. flemingiana, P. melanostrombus* and *P. opaca.* Moon snails. Family Naticidae. Sand and rubble areas on reefs.

Pythia species, including *P. scarabaeus* and *P. undata*. Family Ellobiidae. Mangrove swamps, on rotten leaves and branches; also weed covered rocks.

Rhinoclavis vertagus. Cerith. Family Cerithidae. Weed covered rocks, reef platforms.

Strombus species, including *S. aurisdianae, S. canarium, S. gibberulus gibbosus, S. labiatus, S. lentiginosus, S. luhuanus* and *S. urceus.* Strombs. Family Strombidae. Reef platform sand; also mangrove, silty mud.

Tectus pyramis. Top shell. Family Trochidae. Weed-covered and rocky reef platforms.

Telescopium telescopium. Creeper. Family Potamididae. Mangrove and *Nypa* swamp, mud.

Terebra species. Auger shells. Family Terebridae. Sandy areas, shallow water.

Terebrallia sulcata. Sulcate creeper. Family Potamididae. Mangrove; silty mud.

Thais bufo. Rock shell. Family Thaididae. Mud and rubble flats.

Tonna species. Tun shells. Family Tonnidae. Sand and rubble areas on reefs.

Triton shells. Family Ranellidae. Coral reefs.

Turbo species, including *T. chrysostomus, T. crassus* and *T. setosus*. Turban shells. Family Turbinidae. Reef platforms, sand.

Vasum turbinellus. Pacific vase shell. Family Vasidae. Sand and rubble areas on reefs.

Volema cochlidium. Melongena shell. Family Melongenidae. Mud; mangrove areas.

Volute shells. Family Volutidae. Sand and rubble areas on coral reef platforms.

[Note: generally, turban shells (Trochidae), clams (Tridacnidae), pearl oysters (Pteriidae) and other oysters (Ostreidae) are discussed in other species profiles]

Distribution: Most of these edible molluscs have a wide distribution in the tropical Indo-Pacific region (Dance, 1992; Hinton, 1976). Within PNG waters, they are found wherever their habitat preferences occur.

Biology and Ecology: The bivalve molluscs are mainly filter feeders, straining food from the water column with their gills. (Clams feed by filter feeding and the aid of algal symbionts). Some bivalves are attached to a substrate (e.g. the oysters, Ostreidae (profile 2.12), *Spondylus* and *Chama* species. Other bivalves burrow in the substrate - for example *Asaphis, Anadara* species, *Periglypta* and *Batissa*. *Anadara* in the Murik Lakes are half-buried in the soft mud in depths ranging from about 60 cm to 2 m, depending on tide level (Chapau, 1991).

The gastropods feed by either browsing with their radula on coralline or algal-covered rocks and in weed beds, or by scavenging animal material from the substrate. Predaceous and scavenging molluscs include the Mitridae (mitre shells), Volutidae (volute shells), *Polinices* (moon snails), Tonnidae (tun shells), *Chicoreus* (murex shells) and *Vasum* (vase shells) (Swadling, 1981). Other, normally epifaunal gastropod species also burrow - for example, *Cerithium, Strombus* and *Lambis* species.

Edible 'shells' vary in size from the tiny nerites to the large tun and triton shells. The small shells are mainly collected and their soft parts eaten by children.

Strombus luhuanus occurs in local colonies and the colonies differ in their composition and their depth distribution. Young juveniles bury more frequently than adults (Poiner and Catterell, 1988). The life cycle, growth and population of the stromb, *S. luhuanus,* in the Tubusereia area (Central Province) is described by Poiner and Catterell (1988).

On the whole, little is known about the environmental requirements and tolerances of the edible shells in PNG (Swadling, 1982).

2.15.2 The Fishery

Utilisation: Traditionally, PNG nationals gathered hundreds of different shellfish species for food and other uses (Swadling, 1982) but a much smaller range is gathered today - probably because bought items (e.g. tinned fish) are being used instead. Shellfish are used mainly for subsistence purposes, although they are also traded and sold at coastal markets in PNG. The shellfish are usually sold live, but small amounts may be smoked (Chapau, 1991).

Polymesoda coaxans and *Batissa violacea* are esteemed food sources in the Daru area, Western Province (Mobiha, in press), Purari River delta and Kerema Bay areas of the Gulf Province (Poraituk and Ulijaszek, 1981). In the Gulf Province fisheries, the shellfish are collected intensively from one location until the population is depleted and then the collectors move on to another area. River species such as nerites (*Neritina* species) are also preferred by Purari River delta inhabitants. Some other esteemed coastal species in the Purari River delta (e.g. *Telescopium, Placuna, Anadara* species) are collected intermittently and are often traded with inland people (Poraituk and Ulijaszek, 1981). *Periglypta* and *Anadara* (and the mangrove oyster, *Saccostrea echinata*) are the most important species economically in the Murik Lakes, East Sepik Province (Chapau, 1991). The main species collected at Nukakau Island (West New Britain Province) are the bivalves *Polymesoda coaxans, Anadara antiquata* and *A. granosa* (Swadling, 1981).

Shellfish gathering is almost always the work of women and children, who mainly collect in intertidal areas. However, men and boys now frequently collect shellfish (e.g. in communities where unemployment is high) and they collect subtidally (Poiner and Catterell, 1988).

Shellfish are harvested in a variety of ways: by walking and wading on mudflats using the feet to feel for the animals, by night-time walking over reef platforms and gathering shellfish with the aid of a lantern, by fossicking along intertidal areas turning over rubble with a stick, by free-diving and hand collection, by digging out of mud with a stick, by picking the animals off roots and rocks, by using knives or sharpened sticks, and even by collecting with a shovel (for large colonies of clumped animals) (Chapau, 1991).

Apart from day to day decisions to gather shellfish, people often gather them when fishing is poor and/or the weather is too rough for fishing parties to go out. Certain shellfish are also collected customarily for the needs of aged people, pregnant women and sick children. Some shellfish are gathered only at certain seasons - e.g. cowrie and Thais shells are gathered during November and December in the Kerema area (Kari, 1977) and oysters are gathered only when they are plump. In areas where periodic blooms of the toxic dinoflagellate *Pyrodinium bahamense* var *compressum* are sighted by their phosphorescence, shellfish are not gathered and for a period afterwards (e.g. Trobriand Islands, Milne Bay Province) (Seliger, 1989).

The nutritional value of shellfish is high and comparable with other animal foods (Poraituk and Ulijaszek, 1981). Besides their primary use as food however, the shell of some species have other uses. *Polymesoda coaxans* shells are used for scraping coconuts, sago, opening betelnuts, as eating utensils and peeling vegetables (Kari, 1977). Cowries are used for decoration, razor clams (*Pinna*) are used as vegetable peelers, *Isognomon ephippium* is used for making shell money in West New Britain (Swadling, 1981), tambu shell (*Nassarius*) is traded and top shells (Trochidae) and *Donax* species are used for money in New Ireland (Wright *et al.,* 1983).

In addition to the above uses, many shells are reduced to make lime to chew with betelnut. The bivalves *Polymesoda, Periglypta, Batissa, Anadara, Asaphis* and *Lioconcha* species as well as oysters (Ostreidae: profile 2.12) are frequently made into lime. *Polymesoda* is used extensively in Kerema to supply the Gulf and Central provinces and National Capital District with lime (A. Tumonde, pers comm). Turban shells (*Turbo* species) are also used for lime production, and clams (Tridacnidae) are used occasionally.

An attempt at commercial harvesting of mangrove clams, *Polymesoda coaxans*, was undertaken at the Baimuru Fish Plant in 1979-80 (Haines, 1983). Although supplies were overwhelming, problems with marketing and high transport costs to Port Moresby and the Highlands curtailed the operation. Although the clams are usually sold alive in the shell, marketing problems were alleviated somewhat when the clams were shelled and frozen at Baimuru before transporting.

Production and Marketing: Edible shellfish are always are on sale at coastal local markets throughout PNG. Quantities appear to vary according to season and gathering instensity. Bivalve molluscs are some of the main market species in the Purari River delta (Poraituk and Ulijaszek, 1981). *Polymesoda coaxans* and *Telescopium telescopium* are sold at the Kerema local market (Kari, 1977). *A. antiquata, A. granosa, Polymesoda, Strombus luhuanus* and *Telescopium* are regularly seen at local markets in Port Moresby (Swadling, 1982).

In the Murik Lakes, the average daily consumption of *Periglypta puerpera* and *Batissa violacea* clams in January 1985 was 10.8 g/person (Chapau, 1991) and the annual subsistence production from the lakes was estimated at 4.9 t of clam meat. Mangrove clams are common in the diet of Murik Lakes villagers, particularly those from Karau and Mendam where clam stocks are abundant. Chapau (1991) projected that the annual harvest of mangrove clams in the two Murik Lakes was 95.5 mt and of this, 4.9 mt was harvested for subsistence.

In a two-week period in December 1993, 25.7 kg of fresh and smoked mangrove clams [species?] were offered for sale at the Lae main produce market. 11.6 kg of lime was also offered for sale (Hermes *et al.,* 1994). Most came from the coastal village of Labu Miti, Morobe Province.

During 'peak' (unstated) periods of sales of *Polymesoda* at Daru market, 'large numbers' (unstated) of *Nypa* palm baskets of these bivalves are sold (Mobiha, in press). It is estimated (Mobiha, in press) that each basket contains 150-200 individuals.

Wright *et al.* (1983) estimated that between 2.0 mt and 2.5 mt of edible shells comprising mainly *Anadara granosa, Polymesoda coaxans* and *Batissa violacea* are sold in the Kavieng market annually.

Lime production and value in the Lae (Morobe Province) is as follows (A. Tumonde, pers. comm., 1994): When sufficient shells from consumed shellfish have been gathered, they are washed and dried and packed into hollowed-out rods of bamboo which are stacked up and burnt. After burning, the ash is collected, washed, dried and the ash/lime is pounded. About 10 oysters (large form of *Saccostrea echinata*) of average size yield 50 g of lime. A 50g bag of lime retails in Lae for 30 toea - more if it is sold in the Highlands (the price increases with distance travelled). Thus in Lae, one average-sized oyster is worth about 3 toea. Lime made from shells is generally more acceptable to Highlanders and many mainland coast dweller than lime made from coral. Thus shell lime is of importance in PNG and is becoming increasingly so.

2.15.3 Stock status

In reponse to expressions of concern by villagers on Daru (Western Province) with regard to the sustainability of stocks of *Polymesoda coaxans,* a survey of the stock was conducted by DFMR[1] in suitable habitats. The survey revealed that *Polymesoda* densities ranged from 0.07/sq. m in Muwegido to 0.19/sq.m near the Daru airport (Mobiha, in press). Contrary to expectation, densities were highest near urban areas of population, and there was no significant reduction in average size in those areas (Mobiha, in press). Local depletion in some areas of suitable habitat was thought to be the result of collecting.

[1] I have no information on when the stock survey was conducted.

In a six-day period in January in the Murik Lakes (East Sepik Province), the cpue for *Batissa* and *Periglypta* clams ranged from 1 kg/man-day to 2.8 kg/man day over five villages (Chapau, 1991). However, Chapau believed that the cpue was generally much higher.

There are reports of shellfish depletion in various areas of PNG. Shellfish resources are usually badly depleted near those villages where there has been a large population increase or those near urban areas. For example, gathering pressure has increased substantially on the shellfish beds near Pari village (Central Province) (Swadling, 1982). Shellfish resources are not satisfying local demand in such areas and - Swadling (1982) remarked - shellfish are becoming a delicacy. Another cause for pressure on stocks is the breakdown of traditional ownership. For example, Kari (1977) reported that in the Kerema area where the system of traditional ownership of mudflats has broken down, there are no restrictions on shellfish gathering. However, in coastal villages where the population adheres to the Seventh Day Adventist faith, shellfish stocks are abundant (Swadling, 1982).

Poraituk and Ulijaszek (1981) determined that intensive collecting of *Polymesoda* and *Batissa violacea* in the Purari River delta was decreasing the total population of these molluscs in 1980. In West New Britain, where *Isognomon ephippium* is used for both food and shell money, Swadling (1981) found that populations of the species were depleted.

Indications of overharvesting of shellfish are usually scarcity of the resources and changes in morphology. Swadling (1981) found that increasing harvesting pressure on shellfish stocks in West New Britain caused a decline in shell size and an increase in juvenile characteristics in the populations. She suggested that where shellfish stocks in PNG are under constant and heavy exploitation, the populations are coming to comprise younger individuals with smaller shell size.

Swadling (1982) found that younger age classes (juvenile traits, smaller average shell size) dominated the structure of populations of *Anadara antiquata* and *Strombus luhuanus* the Pari village area (growth overfishing). Poiner and Catterell (1988) found that in an uncollected site near Tubusereia village (Central Province) the *S. luhuanus* density was 23.4 individuals/sq. m, while in the most intensively collected site near Tubusereia the stromb density was 8.4 individuals/sq.m. However, these authors found that the *S. luhuanus* population in the area was very resilient to exploitation - by both traditional and contemporary methods. Whereas traditional gatherers rarely collected buried or subtidal individuals and those less than 30 mm shell length, and contemporary collectors have increased the accessible depth range by free diving, buried and juvenile shells still escape collection as do populations in deeper water. Poiner and Catterell (1988) decided that the size and age-dependent burying and partly subtidal distribution and of *S. luhuanus* and the existence of unexploited stocks provide refugia which buffer the populations from human predation. These traits enable the species to maintain recruitment and growth to maturity at high densities under traditional gathering pressure but shifts to population dominance by juveniles and subadults has resulted from heavy contemporary gathering methods.

Even given the above sets of information, it is unlikely that edible shellfish stocks are depleted nationally. Indeed, they are probably considerably under-exploited in areas (e.g. the Fly, Aramia and Kikori river deltas of the Western and Gulf provinces). Although there are no national statistics on the status of shellfish stocks, it is worth considering the production in some other South Pacific Forum countries: up to the mid 1980s, production of *Batissa violacea* in Fiji averaged about 1,400 mt a year, and *Anadara* production in Tarawa Lagoon in Kiribati approaches 2,000 mt a year (Lewis, 1985).

2.15.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Swadling (1982) pointed out that large projects such as forestry impact on shellfish resources because of their high yield of coastal sediments. In Fiji however, *Batissa* stocks appear to have withstood possible damage to habitat - such as dredging and pollution (Lewis, 1985).

To maintain yields of edible shellfish in areas of population pressure, Swadling (1982) suggested implementation of closed seasons for certain species, and/or the zoning of certain reef strips or sections of known shellfish beds as 'hatcheries'. To achieve these objectives, she stated, education (public awareness) and re-implementation of traditional harvesting rights (in co-operation with DFMR) were required. These measures could be considered, along with quotas, but in the absence of any statistics on shellfish harvesting in PNG, their implementation is a long way off.

The introduction of scuba for shellfish collecting gives collectors access to subtidal and buried components of shellfish resources which otherwise provide recruits to the shallower water populations (Poiner and Catterell, 1988). Collecting with scuba has led to the dramatic decline of stromb species elsewhere (Brownell and Stevely 1981, in Poiner and Catterell, 1988). Collection of shellfish by scuba and hookah gear should be prohibited.

Accurate monitoring (catch weight, quantity, size of shells, number of vendors, time spent collecting) of sales of shellfish at coastal markets by DFMR or provincial fisheries officers over several years and reporting and recording of that information by DFMR is needed to determine the effect of population pressure, loss of traditional tenure rights, unemployment and pollution on PNG edible shellfish resources. Presently there is almost no information on production of edible shellfish in PNG (*q.v.*).

The limited experience of the Baimuru Fish Plant and the example from other nations suggest that edible shellfish stocks are an untapped supply of protein and income for coastal dwellers in PNG. The animals live for a long time out of water as long as they are kept wet: for example, *Batissa violacea* can be kept for up to a week in bags and up to two weeks in regularly changed water with little meat loss (Lewis, 1985). There is indeed scope for encouraging a domestic market for some of PNG's abundant shellfish stocks. Apart from freight costs (and these could be partly obviated: refer the Baimuru experience, above), I see no reason why edible shellfish cannot be transported to Highlands markets, for example. A fishery based in south coast provinces would be a useful adjunct to the proposed development of the mangrove crab fishery (Profile 2.9).

Albeit the above, further development of the edible shellfish fishery should be cognisant of the seasonal and insidious action of the toxic dinoflagellate *Pyrodinium bahamense* var. *compressum* and the associated outbreaks of paralytic shellfish poisoning. Although shellfish are usually cooked before eaten, the dinoflagellate's toxin is not destroyed by heating. Dinoflagellate red tides have spread to new areas in PNG during the past two decades (Seliger, 1989) apparently as a result of increased discharges of industrial and human wastes into major waterways, coupled with deforestation and filling-in of wetlands. These phenomena have increased nutrient concentrations in estuarine and coastal waters, in turn enhancing dinoflagellate reproduction and emigration. Surveillance of red tides and reporting of outbreaks are not presently performed in PNG.

In summary:

- implement closed seasons for certain species and/or zoning;
- undertake village awareness work and encourage the application of traditional harvesting rights;
- prohibit collection aided by scuba and hookah gears;
- undertake accurate monitoring of shellfish sales in all artisanal markets;
- investigate the development of domestic markets for shellfish; and
- re-institute the monitoring of red tide and reporting of outbreaks.

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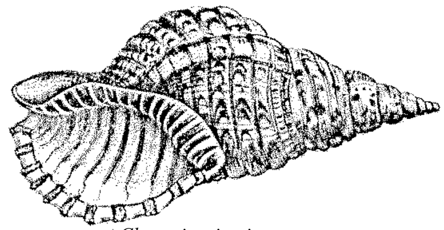
2.16 COLLECTOR SHELLS

2.16.1 The Resource



Charonia tritonis

Species present: There are hundreds of species of shell in PNG waters which are suitable for collection and sale as specimen shells, and many of them are beautiful and decorative. Generally, specimen shells include the class Gastropoda but there is an increasing demand for bivalves (class Pelecypoda as well as tuskshells, class Scaphopoda).

Cowries (family Cypraeidae), cone shells (family Conidae), strombs, conches and spider shells (family Strombidae), egg cowries and spindle shells (family Ovulidae), triton and trumpet shells (family Cymatiidae), murex shells (family Muricidae), olives and ancillas (family Olividae), harps (family Harpidae), mitres (family Mitridae), auger shells (family Terebridae) and volutes (family Volutidae) comprise some of the more popular gastropods.

Bivalves popular in the specimen shell trade include heart cockles (*Cardium* species, Cardiidae), jewel boxes (*Chama* species, Chamidae), lucines (*Codakia* species, Lucinidae), venus clams (*Gafrarium*, *Lioconcha* species, Veneridae), thorny oysters (*Spondylus* species, Spondylidae) and tellins (*Tellina* species, Tellinidae).

Members of the family Dentaliidae comprise the tuskshells and representatives of the family inhabit PNG waters.

Chambered nautilus (family Nautilidae) - free-swimming animals belonging to the class Cephalopoda - are also collected as specimen shells. Two species of *Nautilus* are recorded from PNG waters (Roper *et al.,* 1984): *N. pompilius* or emperor nautilus, and *N. scrobiculatus*.

Land (terrestrial) shells of the family Camaenidae are also popular and attractive shells much sought after by collectors. The Manus Island green tree snail (*Papustyla pulcherrima*) is a well-known shell, and other species in the genus inhabit Bougainville and New Britain islands. Parkinson (1987) noted that there are numerous endemic taxa of land molluscs in PNG and neighbouring countries, many of them having considerable commercial importance.

Distribution: Shells occur in all of the world's seas, but their centre of distribution, and maximum diversity, is generally considered to be the central Indo-Pacific; i.e. the area of Indonesia, New Guinea and the Philippines. A still plentiful but slightly reduced shell fauna inhabits the wider area of about Japan to the north, northern Australia to the south and Fiji to the Pacific (Hinton, 1976).

Biology and Ecology: Shells can be found in every type of marine habitat. Most shells are habitat specific, and there are many examples of specialisation of habitat. Much of the information on habitat and food preferences given below was taken from Dance (1992).

Dolphin shells (*Angara*), ceriths (*Cerithium*), cone shells (*Conus*), triton shells (*Charonia, Cymatium, Gyrineum*), drupes (*Drupa*), spider conches (*Lambis*), mitres (*Mitra*) and vase shells (*Vasum*) mainly inhabit coral reefs and coral rubble areas. Tun shells (*Tonna*) inhabit sandy areas beyond the reefs. Stromb or conch shells (*Strombus*) inhabit shallow water in a range of habitats from mud and gravel to sand and reef. Cowries (*Cypraea*) and latirus shells (*Latirus*) inhabit coral reefs as well as rocky shores.

Starshells (*Astraea*), dwarf tritons (*Colubraria*) are rock dwellers found in deeper water. Nutmeg shells (*Cancellaria*) also live in deep water.

Murex or muricid shells (*Murex*) inhabit coral reefs to intertidal mangrove roots, and some are taken in depths of over 180 m. Nerites (*Nerita*) inhabit rocks and mangroves. Auger shells (*Hastula, Terebra*) live in shallow sandy areas and olives (*Oliva*) and vase shells

(*Vasum*) on inhabit intertidal sandy areas. Flask bubble shells (*Bulla*), turrid shells (*Turris*), volutes (*Voluta*) and bonnet shells (*Phalium*) burrow in or live on sand or muddy sand. Whelks (*Cantharius*) live under rocks and corals, and frog shells (*Bursa*) and mitres (*Mitra*) inhabit sand and coral rubble.

Helmet shells (*Cassis*), harp shells (*Harpa*) and moon shells (*Natica*) are most prolific in shallow water but are also very deep water, sand dwellers. Dove shells (*Columbella*), wentle traps (*Epitonium*) and rock shells (*Thais*) live in intertidal rocky and sandy areas (some wentle traps are associated with sea anemones) and egg cowries (*Ovula*) live in black sponges.

Tuskshells live buried in sandy, offshore substrates (Dance, 1992).

Bivalves inhabit shallow waters, either lying on or burrowing into sand or mud on coral reefs and estuaries. Some species (*Spondylus*, *Chama*) are cemented onto corals and rocks.

Nautilus pompilius usually inhabit waters off steep reef slopes which drop to considerable depths. In PNG they have also been found over substrates of fine silt and sand, also mud (in the Huon Gulf: Saunders and Ward, 1987). Information on depth and temperature preferences and physical shell characteristics of *Nautilus* is provided by Saunders and Ward (1987).

Some shells are herbivorous. They include flask bubble shells (*Bulla*), nutmeg shells (*Cancellaria*), cowries (*Cypraea*) and nerites (*Nerita*) which browse and graze on algae and higher plants.

Many shells are carnivorous scavengers or predators, feeding on sea urchins (helmet shells, *Cassis*; bonnet shells, *Phalium*), small invertebrates (mitres, *Mitra*; nassa shells, *Nassarius*; dove shells, *Columbella*; drupes, *Drupa*; latirus shells, *Latirus*; murex shells, *Murex*; rock shells, *Thais*) or on molluscs and urchins (triton shells, *Charonia* and *Cymatium*; harp shells, *Harpa*; olives, *Oliva*; vase shells, *Vasum*; volutes, *Voluta*).

Auger shells (*Hastula* and *Terebra*) and turrid shells (*Turris*) feed on marine worms.

Moon shells (*Natica*) are cannibalistic, drilling holes in the shells of other molluscs to feed on the animals.

Cone shells (*Conus*) are carnivorous and venomous, and may be divided into three groups, according to their food preference - piscivorous (eat fish), molluscivorous (eat molluscs including other cone shells) and vermivorous (eat small marine worms) (Hinton, 1976).

Bivalves feed by filtering food from the water column. Clams (Tridacnidae) also filter feed and they also gain food from the photosynthesis of zooxanthellae inhabiting them.

Nautilus feeds opportunistically on the seafloor, especially on decapod crustaceans and deepwater echinoids. They also move into shallower water at night and deeper water during the day.

2.16.2 The Fishery

Utilisation: Whereas some shells (*Nautilus, Trochus, Tectus, Pinctada*) are used for inlay in the furniture trade, most are used for individual display, or in jewellery and ornaments and curios. Many shell species of value in the specimen shell trade have traditionally been used as a source of food (see profile 2.15).

Shells are collected by a variety of methods and Parkinson (1987) gave detailed descriptions of most of these:

1. Many species of specimen shells are collected by people walking over areas of sand or coral reef at low tide and turning over rocks and coral slabs and searching under them. This is the most common collection method. Detecting the tracks of molluscs can also be fruitful. The most productive harvesting by these methods is usually performed at night

with the aid of a lantern. It is during this period of the day that the shells are most active, leaving their hideaways in search of food.

2. Shells living in deeper water can be collected by free diving, or by divers trained in the use of scuba or hookah gear. However, this is an expensive form of collection and can only be operated safely when adequate training and support services (e.g. access to compressed air) are available. To be effective therefore, scuba and hookah collection would need to be met with the collection of valuable and/or rare shells.
3. Permanently set-out nets have proved an effective method of shell collecting in the Philippines and could be effectively introduced in PNG. The shells are entangled in the nets as they move about at night; and they must be removed the next day.
4. Leaving baited lengths of strong wire along the seabed is one method of catching certain shells. The lines need to be checked frequently.
5. Specimen shells can be collected from the stomachs of mollusc-eating fish.
6. Trapping. Baited traps are used to catch two types of shells:
7. carnivorous and scavenging gastropod shells such as olives and cones can be caught in traps made of plastic pipe deployed in 60-100 m at night. Bush materials are used in some areas.
8. box-like, wire-mesh covered traps are deployed at night in depths of 100 m and more to catch *Nautilus*. *N. pompilius* has been caught at c.110 m depth off Madang (King, 1988), in Blanche Bay, Rabaul and in the Bismarck Archipelago at 50-100 fathoms (c. 100-200 m), Manus Province (200-330 m), New Hanover, New Ireland Province (145-290 m), Lae, Morobe Province (220-300 m) and Port Moresby (200-300 m). The rarer *N. scrobriculatus* has been recorded or captured from the Admiralty Islands and New Hanover (Saunders and Ward, 1987). Trap yields by Saunders and Davis varied from an average of five *N. pompilius* per overnight set off Lae, an average of seven per overnight set off Port Moresby and an average of eight per overnight set off New Hanover to 20 per three-night set at the Admiralty Islands (maximum of 37 animals in a one-night set).

The preferred shells for sale to dealers and collectors are those that have been caught when they were alive (Parkinson, 1987). Shells can be either boiled in water the extract the meat (not cowries and olives, as their surface will crack) or can be left buried in the sand until the animal rots away. Shells can also be preserved in methylated spirits (Lewis, 1985). Dead shells from the beach or reef are usually worthless, as are damaged shells - those bearing breaks, scars or blemishes.

Once they have been properly cleaned, shells are easily stored and transported. They must be packed carefully in tissue paper and in strong boxes, with fine spines and tips protected. Airmail freight costs can be an added expense for heavy shells such as strombs and tritons.

Production and Marketing: Many abundant species of shell in PNG waters have small values (e.g. less than K1.00) but there are others which are highly valued - either because of their rarity in collections or because of their great beauty. These highly valued shells can form a good revenue source for village collectors, although the lesser valued shells can provide a steady, small income.

Specimen shells are sold in main centres - on footpaths outside main stores, at local markets and at handicraft stores - to expatriate residents and tourists, either singly (e.g. spider shells, strombs, cowries) or in groups (e.g. small shells threaded into necklaces and other jewellery, novelty ornaments of shells). Until recently shells were also exported by collectors living in Rabaul (East New Britain Province) and Manus Island (Manus Province). These collectors sold their shells through the medium of mail order catalogues. I understand that they either purchased their supplies from villagers and/or funded divers to collect certain shells for them.

I could not find any information on the quantity of specimen shells collected and sold in PNG, either locally to tourists or exported. There are so many outlets throughout the country. Lewis (1985) conservatively estimated that the Fiji trade was worth several hundred thousand [Fiji] dollars each year. Compared to Fiji, the volume of tourists in PNG is small; but nevertheless there would be thousands of kinas worth of specimen shells sold locally in the country each year.

Markets for specimen shells exist around the world, especially Europe, the United States of America, Japan and Australasia (Parkinson, 1987). In 1985 more than 300 international shell dealers were listed, and this number does not include the thousands of other vendors who offer shells as part of their stock (Parkinson, 1987).

In 1986 (Parkinson, 1987) prices for shells available in PNG range from (US$) less than $0.50 to $1,000-1,500 for some cone shells (*Conus aurisiacus, C. excelsius, C. pergrandis*), and $475 (*Cypraea guttata*), $1,800 (*C. valentia*) and $3,750 (*Cypraea leucodon*) for cowries. Prices depend on the quality of the shell and its rarity. Even locally common but elsewhere rare low-priced shells can attract relatively high prices if being sought by collectors to complete a set. Giant clam shells (*Tridacna gigas*) fetch high prices - probably facilitated by trade in them being restricted between many countries because of CITES commitments (see profile 2.11).

2.16.3 Stock status

There is no information on the status of specimen shell stocks in PNG. Local areas of depletion may occur (e.g. of certain species, near main towns). However, specimen shell stocks are largely unexploited (except for the green tree snail?) and, in view of the high number of shell taxa recorded from PNG waters and the extensive areas of suitable habitat in the country, are unlikely to be affected by a considerable expansion of the fishery.

2.16.4 Management

Current legislation/Policy regarding exploitation: Permits are required for the commercial export of shell (A. Richards, pers. comm.). Otherwise, there are no government regulations other than a restriction on the export of clam shells (Tridacnidae) and Manus green tree snails (*Papustyla*) through CITES (Convention on International Trade in Endangered Species and Wildlife). These animals are classified in CITES as Appendix 2, meaning that their export must be accompanied by certification from the exporting and importing countries.

Conservation measures have been (or were) introduced in some areas of PNG by local residents. Swadling (1982) reported that Wuvulu Islanders (Manus Province) allow diving but prohibit people taking attractive shells, and that the Department of Commerce at Rabaul (East New Britain Province) was encouraging village people to conserve their shellfish resources. It is probable that traditional conservation measures are in effect in other provinces of PNG.

Recommended legislation/Policy regarding exploitation: Without estimates of stock abundance of shells and knowledge of the life histories of the more popular species, restrictions on harvesting cannot be imposed. There is almost a complete lack of information required to ensure the rational management of shell resources. For example, there are not even records of specimen shell exports from PNG - although the value of these exports must (have) been moderately high.

However, at the *supposed* present rate of exploitation of PNG specimen shells, regulations restricting harvesting are not necessary. Indeed, there is *immense scope for the expansion of the fishery* as it is largely undeveloped in PNG. Specimen shells are a readily marketable commodity for villagers in remote islands who may have few other sources of income. <u>Collection of shells for sale is an excellent village-based fishery for coastal areas</u> and it has provided an income to villagers located near main towns for years. The storage and deterioration problems of fisheries based on fresh product do not exist with specimen shells. Given appropriate management controls, the potential for developing this trade is considerable.

The PNG government could assist the development of this industry as well as monitor it, through the following means:

- Provide the services of an expert on specimen shells and encourage private shell buyers to operate in PNG. These buyers and the government expert also should be familiar with the international trade in and prices given for specimen shells. Familiarity with international shell demands means that fluctuations in demand may be detected in a timely manner, enabling collection patterns to be altered to make use of those changes. Familiarity with prices would enable the accurate recording of shell values so that correct price percentages could be paid to the collectors and the government could be assured of the trade's value. According to the Fishery Sector review (1989), underpricing of shells by exporters has clearly occurred in the past and more timely intelligence would greatly assist resource management. Familiarity with prices and demand will also ensure that overpricing (by the vendors: A. Hinton, pers. comm.) does not occur. The expert could be associated with the DFMR - either with the Research and Surveys section or with the Marketing and Extension section - or with the national government's Investment Promotion Authority.

- The government should encourage nationals to become buyers and exporters of specimen shells (and see below).

- To facilitate accuracy in the fishery, a reasonable library of books should be available. Parkinson (1987) provided a list of 12 basic books for shell projects in the Pacific region. Shell magazines and links with shell dealers in other countries would also encourage familiarity with PNG's specimen shell resources. Ideally, a checklist of the shells available in PNG should be compiled. Hinton (1976) would be a primary source for this; and the data from previous shell surveys done in PNG (mentioned by Parkinson, 1987) should be gathered. One of these surveys was conducted by New Guinea Shells Pty Ltd, which surveyed the Tigak Islands and the east coast of New Ireland in late 1982. The company concluded from the survey that New Ireland has some potential for the development of a small industry supplying specimen and precious shells (Wright *et al.,* 1983; also A. Hinton, pers. comm.).

- The buyers would instruct villagers on the relative value of shells, their habitat preferences, and how to collect and treat them. Buyers would be licensed. If they operate as exporters (which is likely) that activity would also need to be licensed. Exporters/buyers should record sales and purchases and villagers should be given a receipt. This means that export quantities would be recorded by the government, who in any case, provide a permit for exporting.

- Nautilus shells could be collected as a bycatch of the deep-slope fishery (profile 1.4).

- Quality standards would be established from both ends of the fishery: instruction at the point of collection and buying preferences in the international market. The establishment of quality standards will assist in stock conservation (e.g. no damaged shells, habitat maintenance; also importance of leaving fallow/reserve areas)

- It is difficult to record the quantity and quality of domestic shell sales. However, those sold in town markets should be *recorded by the local fisheries officers*.

- Given the capacity for depletion of shells on a local scale, more precise figures on the origin of products are required. These should be accumulated through access to buyer records and information on market sales.

- Mail order and catalogue sales should be encouraged, under the auspices of the buyers/exporters. Lewis (1985) pointed out that this medium enables some of the smaller shells of interest to specialist collectors to be marketed - i.e. lower freight costs mean a greater return to the collectors. The government-associated expert should provide instruction to nationals in producing catalogues, advertising, and establishing mail-order businesses. Export permits would still be required for this activity.

Shell stocks will be maintained if conservation measures are followed. These are:

1. only perfect specimens should be collected (imperfect shells should be left to breed and so ensure the maintenance of the population);
2. searched habitats (e.g. upturned rocks) should be restored and the wider habitat preserved;
3. reef areas should not be gleaned of their shell population: spread the collecting effort out, leave some areas as reserves or place moratoriums on heavily collected areas for certain periods;
4. if netting is used for collecting, the number of nets deployed and the mesh size of the nets should be specified and policed; and
5. the use of dredges for shell collecting should be prohibited because of the dredges' propensity to cause severe habitat damage.

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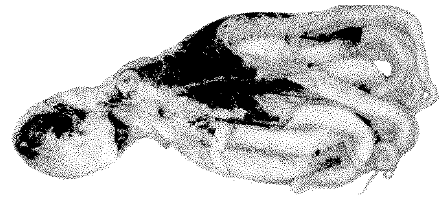
2.17 SQUID, CUTTLEFISH and OCTOPUS

2.17.1 The Resource



Octopus sp.

Species present: Two families of squid are known from PNG waters. The loliginid squids (family Loliginidae) are the main inshore and shelf species in Indo-West Pacific waters, including tropical Australia and countries east to Fiji and the Hawaiian Islands. Species present in PNG include the bigfin reef squid, *Sepioteuthis lessoniana*, the mitre squid, *Loligo chinensis* and the swordtip squid, *L. edulis*. The oceanic squids (Ommastrephidae) in PNG waters are the Hawaiian flying squid, *Nototodarus hawaiiensis* and the purpleback flying squid, *Symplectoteuthis oualaniensis*. Additional species of squid are likely to occur in PNG waters.

The broadclub cuttlefish, *Sepia latimanus* (family Sepiidae) has been recorded from PNG waters and Pharaoh's cuttlefish, *S. pharaonis*, is likely to occur there (Roper *et al.,* 1984).

Octopus species recorded from PNG are *Octopus cyaneus* and *O. macropus*. *O. vulgaris* and *O. aegina* may also be present. A third species, *O. membranaceus*, is known to inhabit PNG waters but because of its small size (30 cm total length) and depth preference, it is unlikely to be harvested by fishers.

Distribution: *Se. lessoniana* is distributed in the Indo-Pacific from the Red Sea and Arabian Sea into the western Pacific (170^{o}E) - including PNG - and northern Australia, then the Hawaiian Islands (Roper *et al.,* 1984). *L. edulis* inhabits the South China Sea, the Philippines and western Pacific waters, as does *L. chinensis*, which also extends into Indonesia (Roper *et al.,* 1984). Whereas *L. edulis* probably occurs around all of mainland PNG and the Coral Sea, *L. chinensis* has only been recorded from southern PNG and the Coral Sea (Roper *et al.,* 1984). Neither *Loligo* species inhabits waters east of the mainland.

N. hawaiiensis is distributed from the South China Sea to the Hawaiian Islands (Wadley and Swainston, 1990) and probably inhabits PNG waters. *Sy. oualaniensis* is a tropical species occurring throughout PNG (and the Indo-West Pacific) waters from East Africa to America).

Sepia latimanus is a wide-ranging cuttlefish species, known from East Africa and the Red Sea to Japan, northern Australia and the western Pacific.

Octopus cyaneus has an East Africa to western Pacific distribution, while *O. macropus* appears to be distributed worldwide in tropical seas.

Biology and Ecology: The sexes in squid and octopus are separate. Males usually possess 1-2 modified arms for mating which is often internal, and the eggs are fertilised as they are laid. Squid and cuttlefish eggs are generally encased in a gelatinous matrix. Clusters of inshore squid eggs are attached to hard substrates, while the egg bundles of oceanic squid drift in the open ocean. Octopuses lay their eggs in crevices and under rocks, and brood them until they hatch. Most squid, cuttlefish and octopus live for less than three years.

Squid and octopus are active predators, feeding on prawns, crabs, fish and other cephalopods. Octopus also consume bivalve molluscs.

Loliginid squids are demersal or semipelagic in habit, living in coastal and continental shelf waters. They often migrate seasonally, and they carry out daily vertical movements through the water column. *L. chinensis* inhabits the depth range 15-170 m (Roper *et al.,* 1984). It forms large aggregations at certain times of the year. Spawning takes place all year, with peaks in the late wet and late dry seasons. Maximum size is 30 cm mantle length. *L. edulis* lives in 15-170 m water depth (Wadley and Swainston, 1990) and migrates inshore to spawn in large aggregations. It attains 40 cm mantle length. *Se. lessoniana* lives in shallower water than do the two *Loligo* species (0-100 m). It attains 36 cm mantle length (and 1.8 kg).

The Hawaiian flying squid (*N. hawaiiensis*) is a bottom-dwelling (demersal) squid inhabiting the continental shalf and slope, and it has been recorded at depths between 100 m and 710 m (Wadley and Swainston, 1990). Its maximum mantle length is 25 cm. The purpleback flying squid (*Sy. oualaniensis*) ranges from the surface to 1,000 m depth and, as does *N. hawaiiensis*, undertakes diurnal vertical movements between the surface at night and deeper layers during the day. This species attains 35 cm mantle length. *Sy. oualaniensis* is a quick and powerful swimmer, capable of propelling itself out of the water and 'gliding' above the surface for a considerable distance (Brown, 1979).

The broadclub cuttlefish, *Sepia latimanus*, is a shallow-water species inhabiting coral reefs. It grows to about 50 cm mantle length.

Most octopuses are benthic animals, usually having cryptic habits, hiding in crevices, empty mollusc shells and seagrass beds during the day and hunting at night. Many species lay large eggs which are brooded by the female during a prolonged incubation period. Octopuses often live in rock holes in reef flats, or in burrows, and these are often identified by the litter of shells and crustacean fragments around their entrance. The harvested octopus species recorded from PNG are shallow water forms inhabiting coral reefs. *O. cyaneus* attains 120 cm total length and *O. macropus* 150 cm. *O. cyaneus* is unusual among octopuses as it hunts during the day (Roper *et al.,* 1984).

2.17.2 The Fishery

Utilisation: Squid are harvested year-round in most coastal provinces in PNG. They are caught with spears, nets and handlines. Most of this harvest would be of bigfin reef squid, *Se. lessoniana*.

Squid and cuttlefish are esteemed by villagers and are generally caught for 'home' consumption. However, fishers often catch these food items for local hotels and restaurants as well.

In Lae (Morobe Province) fishers catch squid and cuttlefish with small baited hooks, using a light at night. The bait they use is either cut-up malambur (*Selar* species; profile 1.13) or squid. At Kokopo (East New Britain) cuttlefish are caught by trolling from a canoe on nights when there is a full moon or when the moon is partly concealed by cloud. A lure is attached to a troll line, and catch rates are usually as high as 4-5 cuttlefish per half hour (Otto from Vunamame village, pers. comm.).

Octopuses are usually caught by first seeking out their burrows or rock crevices. There are several methods by which octopuses are evicted from their holes and caught. Spears and sticks may be used (mainly by women and children) to evict the octopuses from their holes at low tide; or in the Lavongai area on New Hanover (New Ireland Province), an unidentified lavendar type of plant is used to capture them (the octopuses may in turn be used to capture rock lobsters - profile 2.5) (Wright, 1983); or in New Ireland, a sea cucumber (*Holothuria atra*) - which produces a toxin - may be forced into the burrow or crevice so causing the octopus to flee into the open where it can be speared (Wright *et al.,* 1983).

Cephalopods are frequently consumed by skipjack, yellowfin tuna and mackerel tuna. Lewis *et al.* (1974) recorded that their frequency in stomach contents of trolled and polled tunas caught around the Bismarck Archipelago ranged from 17 per cent to 50 per cent. Squid far exceeded other cephalopods in importance as food, with cuttlefish and octopus found among stomach contents on few occasions.

Inshore squid are caught as bycatch of trawling operations for prawns, and they and cuttlefish are also caught by night-light fishing from canoes. Cuttlefish and small squid are a minor but common component of tuna baitfish (profile 1.12) hauls in PNG waters.

Production and Marketing: Octopuses form the basis of a valuable subsistence fishery in parts of the western Pacific. They also feature in artisanal fisheries. In PNG, smoked and fresh octopuses are sold in village markets in Manus Province (C. Hair, pers. comm.). They are also sold at the Kokopo fish market (East New Britain Province) and Bougainville (North Solomons Province), where daily quantities range from 0.5 kg to 7 kg (Ito, 1984). Smoked and fresh octopuses are often on sale at Koki market, Port Moresby.

Squid and cuttlefish rarely are sold in town markets and are sold direct to hotels and restaurants instead. They are classed in Group 5 by the MOMASE project (octopus not classed) and on the occasions when they are brought into the Voco Point landing at Lae (Morobe Province), they fetch good prices: K3.50/kg to K5/kg.

Squid (and probably cuttlefish) are a valuable component of the bycatch from prawn trawling in southern PNG waters. The squid component of the bycatch is retained and sold in Port Moresby. From three day's of prawn trawling in the Gulf Province in 1980, nearly 12 kg of squid was retained (Haines and Stevens, 1983). The value then was K12/kg. I have no more recent information on squid and cuttlefish quantities caught by prawn trawlers, including whether they recorded in the logsheets for the fishery.

2.17.3 Stock status

There is no information on squid, cuttlefish and octopus stocks in PNG waters.

2.17.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Cephalopods support substantial fisheries in the Indo-West Pacific. In Asian countries in 1981, nearly 40,000 mt of cuttlefish and 70,500 mt of inshore squid (Loliginidae) were harvested (Roper *et al.,* 1984). The flesh quality and flavour of *Loligo* and *Sepioteuthis* species is excellent, and the species are targeted or comprise a good bycatch of fisheries in Asia. Oceanic squid are used for bait and human consumption. Octopuses feature in subsistence and artisanal fisheries.

There is potential to increase landings of inshore squid in PNG. Although squid and cuttlefish are already landed as bycatch from the Gulf of Papua prawn trawl fishery, much is discarded at sea (Fishery Sector review, 1989). More of this bycatch could be retained.

Presently, local demand for squid for human consumption is small and it is not likely to increase. The resource amply satisfies it. However, there is potential to utilise local squid as bait for other PNG fisheries. For example, the deepwater shark fishery (profile 1.9) utilises squid imported from New Zealand; and the proposed expansion of the Spanish mackerel (profile 1.14) and mackerel tuna (profile 1.15) fisheries would be enhanced by having locally available squid supples for bait. Another expanding fishery in PNG which could be supplied with locally caught - instead of imported - squid is the tuna longline fishery. In other words, here are four domestic fisheries which could be serviced by local - instead of imported - bait supplies.

The offshore squid resources probably offer little potential for development. *Sy. oualanensis* is only rarely captured by trawl nets (Young, 1975, in Brown, 1979) and a survey in Fiji (Brown, 1979) showed that standard jigging machinery and overhead light attraction were unsuitable for the capture of this species. The flesh quality of *Sy. oualanensis* is not good compared to some other commercial species. The flesh quality of *Nototodarus* is said to be better (Wadley and Swainston, 1990).

As with inshore squid, the demand for octopus as a food appears to be easily satisfied and there is little incentive to increase harvest rates.

There is almost no information on stocks and harvest quantities of cephalopods in PNG. As with other fisheries, catch statistics should be gathered and recordings maintained. In the long run, such information will support stock assessments of cephalopod resources. Catch statistics should be obtained from trawl operators (or collated, if it is already recorded[1], town markets, hotels and restaurants.

Specimens of locally caught cephalopods should be sent for expert identification.

With a view to supplying bait for other fisheries, experimental fishing should be carried out to determine the most appropriate fishing method for harvesting squid in PNG. Trials to assess the effectiveness of PNG squid as bait should also be performed.

A word of caution if/when promoting the use of PNG squid as bait supply and for human consumption, is that access rights to traditionally-fished areas would have to be negotiated. Royalty payments (see baitfish profile, 1.12) may need to be implemented. In addition, commercial exploitation of the squid resources would require knowledge of their distributions and concentrations in PNG. Catch monitoring should support eventual stock assessments.

2.17.5 References

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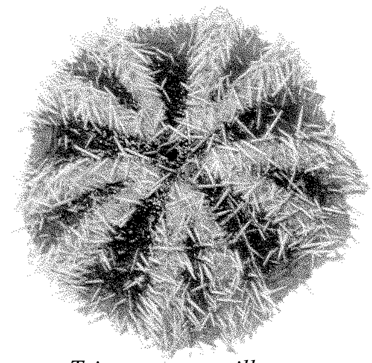
[1] See earlier; I do not know whether this is so.

2.18 SEA URCHINS

2.18.1 The Resource



Tripneustes gratilla

Species present: No taxonomic studies have been conducted on sea urchin resources in PNG. However, it is probable that widely-distributed Indo-Pacific species are present in PNG waters. These include *Tripneustes gratilla, Diadema setosum, Echinothrix calamaris, Heterocentrotus mammillatus, Echinometra mathaei* and *Tocopneustes pilcolus*. Other species from the Pacific used in the sea urchin trade in Japan include species of *Strongylocentrotus, Acanthocidaris crassispina, Pseudocentratus depressus, Temnapleurus loremmaticus, Mespilia globulus, Pseudoboletia maculata* and *Colobocentrotus mertensii*. I have no information on which (if any) of these species of sea urchin are utilised in PNG.

Distribution: The geographic distributions of selected species of sea urchin are listed below, after Guille *et al*., 1986.

Scientific name	Geographic distribution
Tripneustes gratilla	Widely distributed in the Indo-Pacific region
Diadema setosum	Very widely distributed in the Indo-Pacific, including Fiji and Tahiti
Echinothrix calamaris	Widely distributed in the Indo-Pacific, Red Sea, Australia and Japan
Heterocentrotus mammillatus	Widely distributed in the Indian and South Pacific Oceans
Echinometra mathaei	Very widely distributed the South Pacific and Indian Oceans
Tocopneustes pilcolus	Very widely distributed in the Indo-Pacific, Australia and Japan

Biology and Ecology: Sea urchins are in the same group of animals as starfish and sea cucumbers. They have a calcified external shell, known as a 'test', and mobile external spines which may be pointed or blunt and 'pencil'-shaped. The animals are variously coloured, from black to white, with red, green and purple common colours for various species of edible sea urchin. Sea urchins move and feed with a hydraulic system that enables them to move their spines and jaws and stick to the sea floor (McShane, 1992). They often aggregate on reef surfaces, especially in areas where predators (such as rock lobsters) as absent.

Sea urchins feed on seaweed. Because they have no bulky muscles, much of the energy derived from food can go towards reproduction. Up to a quarter of their weight can be gonad, or 'roe'. Sea urchins have separate sexes, but it is difficult to distinguish between male and female gonads. It is the roe that is eaten.

Sea urchins have a seasonal reproductive cycle and that the quality of the roe varies with this cycle. Sea urchins are harvested commercially just before they spawn, as it is in this period when roe yields are greatest. Gonads have a low marketability during the spawning period (when they absorb water) and after spawning (when they are small and flaccid) (Kailola *et al.,* 1993). The quality and quantity of sea urchin roe is also dependent on the amount of available food (McShane, 1992).

McShane (1992) stated that sea urchins are generally considered slow growing and long lived animals. *Echinometra mathaei* are usually found from mid-tide down at 1-8 m, in dense aggregations under thickets of branching corals or on surfaces of rocks (Shokita *et al*., 1991) on the reef flat (Amesbury *et al.,* 1986). Towards low water and on the outer reef face, *E. mathaei* is accompanied by *Heterocentrotus mamillatus*. *Tripneustes gratilla* is commonly found in little exposed areas of the reef in 1-8 m of water (Shokita *et al.,* 1991), among seagrasses or areas of mixed sand and rubble on the reef flat (Amesbury *et al.,* 1986).

Tocopneustes pilcolus is found from 1-15 m deep in lagoonal sheltered moats and rubble flats, whereas *Echinothrix calamaris* is found from 5-40 m in the interior of lagoons (Guille *et al*., 1986). Predators of sea urchins include octopus, rock lobsters and large fish such as emperors and parrotfish.

Despite the high value of many sea urchin fisheries, there is little known about their growth, mortality or recruitment. Because of their wide and patchy distribution on coastal reefs, estimates of biomass are very difficult to make. It is known that recruitment of sea urchins can be highly variable from year to year (Kailola *et al.,* 1993) but the effects of heavy fishing on recruitment are unclear (McShane, 1992).

2.18.2 The Fishery

Utilisation: Sea urchins are eaten at a subsistence level by some coastal communities in PNG. The animals are gathered by walking on the reef flats or diving, and collecting by hand or with spears or knives. The test if broken open and the roe (sometimes called 'sea eggs': Amesbury *et al.,* 1986) is scooped out and eaten. The urchins are harvested only as required, because they do not survive long out of water.

The test and spines of sea urchins are used also for traditional ornamental purposes. The spines of pencil urchins also make curios for the tourist trade.

Sea urchin roe is highly prized as a delicacy by Japanese consumers who eat approximately 50,000 mt (whole weight) of sea urchins each year (McShane, 1992). The demand for sea urchin gonad in Japan is met either by local catch or import: fresh or chilled gonads are flown from the USA, Korea, Canada, Mexico, Hong Kong, China and Australia. Frozen and salted gonads are also imported. In 1991, USA, South Korea and Canada were the main suppliers of fresh and chilled gonad to the Japanese market (Ramachandran and Terushige, 1991), accounting for 29.48 mt (total) having a unit value of US$37.86/kg. Prices for frozen and dried and salted roe are lower. The price received depends on the quality of the roe and the species from which it is obtained. Quality is measured by gonad taste, size, colour and texture and is also dependant on rapid post-harvesting processing and transport (Kailola *et al.,* 1993). The yield of fresh matured gonad from one animal is said to vary between 8 per cent and 12 per cent, depending on the stage of maturity, season, area of fishing and the nutritional state of the animal (Ramachandran and Teruchige, 1991).

Most of the fisheries supplying the Japanese market are also in danger of over-exploitation (McShane, 1992) and there is potential for countries with untapped resources of sea urchins to contribute to this highly specialised seafood market.

Collected sea urchin can be kept alive in sea water. For processing, it is washed and split open with a knife and mallet. The internal organs are scooped out with a spatula and the roe separated out. The roe, of which there are five skeins in each animal, is placed on a wire screen and rinsed in sea water to remove unwanted material. The drained roe is packed in small wooden containers and despatched to market. Roe can also be salted and fermented in three different ways and these receive very high prices.

Production and Marketing: There is no information on the quantity of sea urchin gathered in PNG waters each year. It is not traded nor sold in local markets. There is no export market for sea urchin.

2.18.3 Stock status

There is no information on sea urchin stocks in PNG. However, because they are only subject to subsistence gathering, it is unlikely that they have been affected by harvesting.

2.18.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: For PNG to participate as a supplier of sea urchin roe to the Japanese market, it would have to assess its sea urchin stocks, develop suitable harvest and post-harvest technologies and ensure timely and rapid transport were available. In the present circumstances, I do not believe that these requirements can be met in PNG.

The Japanese market is a fastidious one and stringent processing standards are required to compete on it. In addition, only the roe of some species is suitable for the Japanese market. For example, the roe of the black sea urchin *Centrostephanus rodgersii* - an abundant species in eastern and southern Australia - is unacceptable to the Japanese palate because of the large egg size, colour and the tendency for the skeins of roe to break up. Taste-tests of *T. gratilla* from Tonga also proved it to be inferior (M. King, pers. comm.).

There may be potential in PNG for a small domestic industry to supply freshly collected sea urchin roe to hotels and restaurants. This would be on an individual or village basis.

Legislation may be required if commercial harvesting of sea urchins were commenced in PNG.

2.18.5 References

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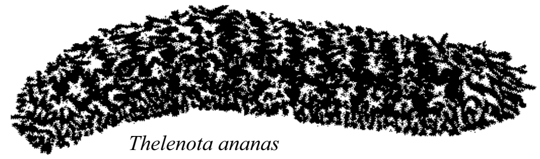
Acknowledgement:

Loisette Marsh - Western Australian Museum, Perth.

2.19 SEA CUCUMBERS

Compiled by P. Kailola with contributions from P. Lokani.



Thelenota ananas

2.19.1 The Resource

Species present: About 1,200 species of holothurians (sea cucumbers) have been described world-wide and about 300 of these inhabit the shallow (<20 m deep) tropical seas of the Indian and Western Pacific oceans (Guille *et al*., 1986 in Preston, 1993). Commercially collected sea cucumbers in PNG number 19-20. There are 26 species in New Ireland waters (Wright *et al.,* 1983).

Table 124 Main commercial species of sea cucumber exploited in PNG.

Common English name	Scientific name	Relative commercial status
sandfish	*Holothuria scabra*	more
white teatfish	*H. fuscogilva*	more
black teatfish	*H. nobilis*	more
elephant trunkfish	*H. fuscopunctata*	more
lollyfish	*H. atra*	less
pinkfish	*H. edulis*	less
snakefish	*H. leucospilota*	less
prickly redfish	*Thelenota ananas*	more
giant bêche-de-mer	*T. anax*	less
greenfish	*Stichopus chloronotus*	less
curryfish	*S. variegatus*	less
deepwater redfish	*Actinopyga echinites*	more
surf redfish	*A. mauritiana*	more
blackfish	*A. miliaris*	more
stonefish	*A. lecanora*	less
chalkfish	*Bohadschia marmorata*	less
leopardfish/tigerfish	*B. argus*	less
flowerfish	*B. graeffei*	less
brown sandfish	*B. vitiensis*	less

Distribution: Most of the commercially important species of sea cucumber inhabiting the western Pacific are also distributed in waters from southern Japan to Australia (Clark and Rowe, 1971, in Preston, 1993). Species diversity decreases in an easterly direction across the Pacific and few of the commercially exploited holothurian species are found as far east as the Hawaiian Islands (Preston, 1993). In PNG, large populations of commercial sea cucumber species were said to be present in the waters of Milne Bay Province (Trobriand Islands), Manus, New Britain and New Ireland provinces and the Western and Central provinces (Fishery commodity report, 1983).

Sea cucumbers generally live on the seabed, inhabiting waters of all depths (Preston, 1993). Commercially harvested species in PNG inhabit shallower water - to about 50 m (see table below). Habitat appears to be the most critical determinant in local species distribution, as it provides food for the animals. Some sea cucumber species occur in more that one habitat or in overlapping habitats, suggesting that factors other than adult habitat preferences (e.g. competition, larval settlement) influence distributions (Preston, 1993; Lokani, unpublished). Substrate type, depth and exposure to water movement were found to be the major limiting factors in sea cucumber species distributions in PNG (Shelley, 1981 in Shelley, 1986). In a New Caledonia study, Conand and Chardy (1985, in Preston, 1993) found that holothurian distribution closely reflects the organisation of the reef system and its component biotopes.

Preferred habitats and depth distributions of some sea cucumber species in PNG waters (after Shelley, 1986, Lokani and Chapau, 1992, Lokani unpublished, Lokani and Kubohojam, in prep.) are given below.

Table 125 Preferred habitats and depth distributions of some sea cucumber species in PNG waters.

Species	Depth dist. (m)	Habitat
H. scabra	1-23; usu. shallow	seagrass beds, muddy bottoms, open sandy areas, lagoon, estuaries
H. fuscogilva	1-54	seagrass beds, white sandy areas, muddy sand, coral rubble, live coral, fringing reef, lagoon
H. nobilis	<1-13	fringing reef, coral, rubble, silty coral, reef flat, sand
T. ananas	1-40	white sand, amongst soft coral and hard coral, white silt-covered sand, reefs, rubble, lagoon
A. echinites	1-6	sand, rocky areas, surf zone, reef flat
S. chloronotus	0-5	fringing reef, lagoon, muddy sand, seagrass beds, rubble
A. mauritiana	1-6	reefs, high energy areas
S. variegatus	0-10	seagrass beds, open sandy areas, fringing reef, lagoon
A. miliaris	1-4	reef flats, living coral, seagrass beds
T. anax	4-9	lagoon
H. atra		reefs, lagoon, rubble, seagrass beds, sand flats
B. argus		fringing reef, lagoon
H. fuscopunctata		lagoon
H. leucospilota		lagoon
B. graeffei		fringing reef

Biology and Ecology: Relatively little is known about the biology of sea cucumbers. They are primarily deposit feeders, feeding on the organic content of sand, mud and surface films as they creep along the seabed with their mouth down. A few non-commercial species are suspension-feeders (Preston, 1993).

Some species reproduce asexually by splitting themselves in half (Lindholm, 1978; Preston, 1993). Hermaphrodite sea cucumbers are rare, the majority of animals having separate sexes and spawning by shedding eggs and sperm into the water. Members of each species spawn simultaneously, the spawning stimulated by a chemical trigger. Spawning takes place at certain times of the year - generally when water temperatures are higher from October-November to January - and lasts for 2-3 months (Lindholm, 1978; Shelley, 1986; Preston, 1993). A study of five commercial species of sea cucumber (*H. scabra, H. nobilis, H. fuscogilva, T. ananas, A. echinites*) in the Tigak Islands, New Ireland Province, showed that these species are reproductively active throughout the year although each has one peak spawning period (a second in September-November by *H. scabra*) (Fisheries Research Annual report 1985-1991). Teatfish generally spawn in the cooler months, with *H. nobilis* spawning mainly in July-August in New Caledonia (Conand, 1989, in Preston, 1993) and *H. fuscogilva* spawning in the winter period in southern PNG (Shelley, 1986). However, in the Tigak Islands *H. fuscogilva* spawns in November-December while *H. nobilis* spawns in April-May and August-September (P. Lokani, pers. comm.).

Smith (1992, in Richards, 1994) reported that a study at the University of Guam Marine Laboratory showed that sea cucumbers take 2-3 years to attain the age of first maturity.

Aquarium studies by Shelley (1981, in Shelley, 1986) suggest that *H. scabra* and *A. echinites* are mature within one year. Shelley (1986) reported the size at maturity for four species: *H. nobilis* - 227 mm, *H. fuscogilva* - 324 mm, *H. scabra* 150 mm and *A. echinites* - 120 mm. Sizes at first maturity of holothurians in New Caledonian waters were calculated by Conand (1989 in Preston, 1993). Fecundity in sea cucumbers appears to be high but is also highly variable (Preston, 1993).

Holothurian larvae are free-swimming before they assume adult appearance and settle. There is little information on the recruitment of sea cucumbers. A laboratory study by Smith (1992, in Richards, 1994) suggests that they have low levels of natural recruitment. In waters of Central Province, Shelley (1981, in Shelley, 1986) noted aggregations of juvenile *H. scabra* of c. 60 mm length on areas of fine sand, and juveniles of *A. echinites* of c. 50 mm length in seagrass beds. Preston (1993) suggested that members of most species recruit to adult populations well before the age at first maturity (and hence become vulnerable to fishing pressure).

Estimates of growth rate are difficult to measure in holothurians as the animals have the capacity to retain different amounts of water. However, Shelley (1981, in Preston, 1993) estimated that aquarium individuals of *H. scabra* grew at a rate of 0.5 cm per month and individuals of *A. echinites* grew at 0.6-0.9 cm per month. Length-weight relationships and calculated growth and mortality parameters are available for some species (Preston, 1993).

2.19.2 The Fishery

Utilisation: In PNG, coastal residents of Manus and Trobriand islands, West New Britain and Central provinces, and some New Irelanders traditionally consumed sea cucumbers (Lindholm, 1978; P. Lokani, pers. comm.) which were eaten grilled (Shelley, 1986). Carteret Islanders (North Solomons Province) are reported to eat sea cucumber gonads (A. Selemet / P. Lokani pers comm.). Lollyfish (*H. atra*) is used as a poison in the Lavongai Islands (New Ireland Province) to catch octopus (Wright, 1983).

The practice of drying sea cucumbers to make bêche-de-mer generally has followed Asian influence and trade routes. Bêche-de-mer are used by Chinese and other Asian communities in soups or as a main course; also as an aphrodisiac (Preston, 1993). They are rehydrated by boiling or soaking until they are soft and can be cut into pieces.

In PNG, knowledge of processing exists where Chinese traders have resided. Russell (1980) and Shelley (1981) (both in Shelley, 1986) described the bêche-de-mer trade in PNG which began before 1900. It was of considerable importance in the early 1900s, especially in the Western Province and Torres Strait. Subsequently and up until about 1986 (Wright, 1986) bêche-de-mer production continued as a minor activity in PNG and only some reefs were fished. P. Lokani (pers. comm.) reported a 1960s proposal to the DFMR to turn PNG's sea cucumber resources into fertiliser - when prices and production were low.

In 1978, Lindholm reported that bêche-de-mer was being produced only from the Louisiade Archipelago, Rabaul, Kavieng and Manus. The fishery in Milne Bay probably operated from about 1976 to at least 1983 (Fishery commodity report, 1983). Bêche-de-mer harvesting and processing were being conducted in Central Province around 1983 as well. In Manus Province, sea cucumbers were harvested sporadically prior to 1991 (Lokani and Chapau, 1992), after which bêche-de-mer production increased markedly. Processing of sea cucumbers was introduced to atolls of the North Solomons Province in late 1981-early 1982 (Ito, 1984).

From the second half of the 1980s the bêche-de-mer fishery grew rapidly in PNG. Fisheries have (re)commenced in the New Guinea Islands provinces and the Western Province and are set to commence in Madang Province.

The bêche-de-mer fishery in the Western Province started (again) in 1989, initially supporting 10 buying companies (R. Lari, DFMR files, 1/93). The smaller buyers ceased operation in 1990 and by 1993 there were only three buyers - all with Asian partnerships. The Daru-based bêche-de-mer fishery attracted fishers rapidly, many of them coming from Kiwai Island. It harvested only *H. scabra* up to 1991. In 1992-1993 other species (*H. atra* and *A. miliaris* mainly) were harvested as well as *H. scabra* because of the lack of large sandfish (Fisheries Research Annual report 1985-1991). This information is demonstrated below (source: Mobiha *et al.,* unpublished.

Table 126 Western Province fishery for bêche-de-mer (figures in kg dry weight):

Species	sandfish A grade	sandfish B grade	sandfish C grade	sandfish mix	lollyfish	black fish	redsurf fish	elephant fish
1992	37,842	56,221	48,112	7,585	2,853	0	84	0
1993	6,211	11,952	17,204	760	70,756	405	135	495
per cent previous year's harvest	16	21	36	10	2,500	40,500	160	49,500

Over time, the fishery moved from the reefs near Daru and mainland villages to the Warrior Reefs complex, and by the close of the fishery, almost all product was coming from those reefs. Eventually, fishers encroached onto Australian sections of the Warrior Reefs. Between 1992 and 1993 more than 300 PNG fishers + equipment were apprehended by Australian authorities for illegally fishing on the Australian side of the Warrior Reefs (P. Lokani, pers. comm.). PNG fishers contested their eviction, stating that the bêche-de-mer constituted a subsistence fishery - but this is not so.

The Western Province bêche-de-mer fishery was closed in March 1993, initially for 12 months. The closure was extended into 1995.

Two additional side effects of the sea cucumber fishery in Western Province are: 1) ornate rock lobster fishers were leaving their industry for sea cucumber harvesting, attracted by the (earlier) higher prices being offered; and 2) the drying and wood-smoking of the bountiful harvest has impacted on mangrove forests leading to local deforestation.

Villagers harvest sea cucumbers by hand or spear when diving, or by wading in shallow water. Fishers target the shallow water individuals before the deeper water ones, which are often larger. In deeper (> 10 m) water the animals are harvested by using a length of rope with a weight on its end bearing a barbed spear which is dropped onto the animal.

Sea cucumbers are readily accessible and do not move away if disturbed. They can remain alive for up to 24 hours after harvesting if they are kept wet (B. Shackles, pers. comm.); however they are generally boiled as soon as the fishers return home. Processing involves boiling 2-3 times, washing, gutting and cleaning, then drying or smoke-drying. They are then stored in mesh bags ready for sale. The processed weight of bêche-de-mer represents an average of 6.5 per cent of their live weight (Preston, 1990) although a ratio of 10:1 is generally adopted (Preston, 1993) and so animals smaller than 0.5 kg are not worth collecting (Lindholm, 1978). The final product can be stored for months in a dry place. If it gets damp, it just needs to be re-dried (Shelley, 1986).

Harvesting and processing of bêche-de-mer in PNG is generally by 'isolated processing', where the fisher harvests and processes his own catch within traditional boundaries, and sells it to a middleman or buyer (Lokani and Kubohojam, in prep.). [Centralised processing, using hired labour, operated at Muwo Island (Milne Bay Province?) and Kavieng (New Ireland Province) in 1987 and 1988.]

Grading is done by size (larger = better), appearance, odour, colour (darker = better), consistency, preparation, dryness (not more than 20-25 per cent moisture by weight) and spoilage (Lindholm, 1978; Kriz, 1994)). Undamaged product (e.g. skin unbroken) receives better prices. Bêche-de-mer are nutritious, having a high protein content (averaging 43 per cent) (Lindholm, 1978; Krishnasamy, 1991).

Production and Marketing: The bêche-de-mer trade is almost confined to Indo-Pacific countries. Total imports to consumer nations have been steadily increasing, rising to 13,161 mt in 1988 with a value of US$42.9 million (Krishnasamy, 1991). The international trade in bêche-de-mer is concentrated in Hong Kong, Singapore and recently, mainland China markets. Historically, markets for bêche-de-mer have been confined to Asia but the expansion of Chinese communities in the West, notably in Canada, the United States of America and Australia has led to the growth of non-traditional markets for bêche-de-mer. This has been further accelerated by international trade and currency regulation, especially in mainland China, which has led to the increasing use of certain types of bêche-de-mer as a barter currency (Preston, 1993). Bêche-de-mer is often re-exported from importing countries.

Singapore and Hong Kong are the main importers of PNG bêche-de-mer, and Taiwan also takes some (Lokani and Kibohojam, in prep.). Whereas in 1984 Singapore imported a negligible amount of bêche-de-mer from PNG, it imported 135 mt in 1989, making PNG its second most important supplier (Krishnasamy, 1991). Hong Kong took 202 my of PNG bêche-de-mer in 1988 and 71.5 mt in 1989 (Preston, 1993). It took 216 mt in 1992-93 at an average price of US$5.50/kg (Kriz, 1994).

Prices for some Pacific bêche-de-mer products in Singapore in 1994 were US$36/kg for grade 1,2 *H. scabra*, US$22-25/kg for lower grade *H. scabra*, US$2-5/kg for *H. atra* and US$27/kg for *H. fuscogilva* (*Infofish* Trade News, September 1994)

Between 1980 and 1983, average bêche-de-mer prices paid by buyers in PNG ranged from K2.34/kg to K3.36/kg; in 1985 they averaged K3.67/kg and K4.64/kg in 1986 (Wright, 1986). In 1994, prices paid to fishers in PNG were said to range from K1/kg to K12/kg (Lokani and Kubohojam (in prep.), but *H. scabra* were fetching from K12.19/kg in North Solomons Province to K18/kg in Manus Province, and *H. fuscogilva* from North Solomons were selling for K30/kg (C grade) to K46/kg (A grade) (DFMR database, Kavieng). The price paid by importers in 1994 ranged from K4/kg to K23/kg (Lokani and Kubohojam, in prep.).

The prices paid to Daru fishers in 1992 ranged from K2.50-6/kg for *H. scabra* to K1/kg for other species (Vonole, 1993). Fishers earned K482,217 that year and the export value (6 companies) was K2,993,924.

Figures below show that the annual production in PNG averaged 6.6 mt between 1960 and 1984. Wright (1986) considered that many villagers capable of producing large quantities of bêche-de-mer leave it unharvested as they are ignorant of how to prepare it for markets. The Carterets Islands (North Solomons Province) situation lends support to Wright's statement where, after the fishery was introduced, the atoll produced 51-55 per cent of the province's production in the next two years (Ito, 1984). As well, Lokani (unpublished) found in 1992 that little harvesting was taking place in the Madang Province, the reasons given by villagers being a) no markets, b) ignorance of the best species to harvest, and c) ignorance of the processing method.

Between 1960 and 1977, PNG exported 102.7 mt of bêche-de-mer, ranging from a low of 1.6 mt in 1960 to a high of 12.85 mt in 1963. The product was exported via Port Moresby, Samarai, Rabaul, Kavieng and Kieta (Fisheries commodity statement, 1983).

Table 127 PNG exports of bêche-de-mer from 1960 to 1978 (kg dry weight). (source: Lindholm 1978)

year	quantity	year	quantity
1960	1,623	1969	12,401
1961	2,400	1970-71	6,527
1962	4,448	1971-72	3,872.
1963	12,845	1972-73	9,869
1964	6,295	1973-74	4,059
1965	4,092	1974-75	1,214
1966	4,413	1975-76	1,665
1967	10,468	1977	5,325 (value K13,297)
1968	11,183	1978 (Jan-Apr)	5,903

Table 128 PNG exports of bêche-de-mer from 1979 to 1993 (kg dry weight). (source:DFMR database and figures, except where stated).

Year	kg exported	value (K)	Year	kg exported	value (K) fob
1979	*1,300	*4,000	1987	121,636	322,536
1980	2,351W	7,445W	1988	see below	see below
1981	11,090W	25,966W	1989	see below	see below
1982	9,000 /22,960W	27,586 /73,409W	1990	214,076	
1983	7,130	23,939	1991	433,800	
1984	4,668	13,472	1992	525,540 /546,000**	4,661,719
1985	16,579 /15,164W	59,022 /55,716W	1993	497,738	3,027,280
1986	119,376	361,336			

(source: *=DFMR annual report for 1979; W= from Wright, 1986; **=DFMR's 1993 Fisheries Sector Policies & Programmes report)

Table 129 *Alternative* and *supplemental* export figures for 1983 to 1990 from A. Lokani, 1990 in Preston, 1993; B: Lokani and Kubohojam, in prep.; and C: M. Chapau based on DFMR export file. Kriz (1994) quoted Lokani's figures. (Values are not included -refer original articles.)

Year	A. Lokani: quantity (mt dry weight)	B. Lokani & Kubohojam (kg dry weight)	C. Chapau: quantity (mt dry weight)
1982	-	8,415	
1983	8	7,630	-
1984	5	4,668	-
1985	19	19,491	19.5
1986	105	105,942	105.2
1987	192	192,055	192
1988	203	202,789	230.3
1989	195	194,896	160.4
1990	172	238,923	77.1 (to June)
1991	-	626,047 (to August)	-

Information I could find on provincial production of bêche-de-mer is given below. Price/kg paid to the supplier have been calculate to give an indication of relative scarcity of preferred species and/or switch in buyer preferences.

Table 130 Purchases of bêche-de-mer in Manus Province (kg dry weight) for 1993 and 1994 were (source: DFMR database, Kavieng):

Year	1993	1994
quantity (kg)	22,375	9,146.5
value (K)	51,820	533,479
av. price/kg (K)	2.32	3.7

New Ireland Province exports of bêche-de-mer (kg dry weight) are given below. This product was largely from the Tigak Islands, yet some was from New Hanover (source: 1988-90 from Tenakanai (1991); 1993, 1994 from DFMR database, Kavieng). The fishery (re)commenced in New Ireland in 1988.

Table 131 Exports of bêche-de-mer (kg dry weight) from New Ireland Province, 1988 - 1994

Year	1988	1989	1990*(1st 5 months)	1993**	1994
quantity (kg)	4,050	15,057	23,825	308	20,354.4
value (K)	32,675	177,985	116,976	788	34,766
av. price/kg (K)	8.07	11.82	4.90	2.56	1.71

(** figures from only one local company)

Table 132 North Solomons Province exports of bêche-de-mer (kg dry weight) were (source: 1982, 1983 from Ito (1984); 1984 from Ito and Selemet (1985); 1994 from DFMR database, Kavieng. D&W= figures from Dalzell and Wright (1986))

Year	1982	1983	1984	1994
quantity (kg)	20,653	6,420	355/1,200 D&W	6,803.3
value (K)	66,404	25,253	662	34,871
av. price/kg (K)	3.22	3.90	1.86/0.55	5.13

The Carteret, Mortlock and Nuguria atolls were the main production areas for bêche-de-mer in 1982 and 1983, producing 97 per cent in 1982 and 87 per cent in 1983. The 1984 produce was from Mortlocks and the Carterets and was not officially exported (Ito and Selemet, 1985). Almost all of the 1982-84 harvest was of *H. nobilis* (Dalzell, 1990).

Table 133 Exports of bêche-de-mer (in dry weight) through Rabaul (East New Britain Province) for 1990-93 were (source: DFMR Rabaul)

Year	1990	1991	1992	1993
quantity (kg)	10,410	1,872*	39,744	95,319
value (K)	59,906	5,820*	252,259	577,467
av. price/kg (K)	5.75	3.11	6.34	6.06

(* incomplete)

In Madang Province, more than 3 mt of bêche-de-mer were harvested between 1990 and 1992 (Madang fisheries officers pers. comm. in Lokani, unpublished). For 1994 (March, April, May, July), 10,130 kg of bêche-de-mer were produced (source: DFMR Madang). These bêche-de-mer were purchased mainly from Bagabag, Karkar, Long Island, Sian Riwo, Bogia and Rai coast and were shipped to Kimbe (West New Britain Province) for export.

Export of bêche-de-mer from Morobe Province for 1993 was 25,175 kg, at K115,105, giving sellers an average return of K4.57/kg (source: DFMR Lae*?).

Central Province purchases of bêche-de-mer for 1984 were 1,900 kg, at K6,100. (source: Ito and Selemet, 1985).

Table 134 Milne Bay Province sales of bêche-de-mer were (sources: Fisheries Research Annual report 1980 & 1981); 1984 from Ito and Selemet, 1985; 1989-93 from DFMR database, Kavieng)

Year	1981	1984	1989	1990	1991	1992	1993
quantity (kg)	c. 8,000	2,070	39,399	58,207	81,717	69,703	5,984
value (K)	-	5,796	-	-	-	-	-

Table 135 Bêche-de-mer purchases (and exports) from the Daru area (Western Province) for 1990, 1991 and 1992 in kg dry weight were (source: DFMR, Daru)

Year	1990	1991	1992	1993
January	1,015	10,490	5,223	15,190
February	1,166	17,927	13,070	13,350
March	1,542	11,796	9,640	20,621
April	2,145	8,287	10,473	*9,840
May	2,484	5,462	18,424	*12,692
June	4,685	14,599	14,616	*6,350
July	6,186	23,411	7,620	*9,214
August	7,510	8,300	10,693	*15,756
September	15,585	16,589	11,115	*4,275
October	19,406	24,214	20,973	0
November	21,804	21,491	31,130	0
December	25,852	21,477	9,720	0
TOTAL	109,380	184,043	162,697	107, 288

(* This material was handled AFTER the ban on trading was announced - although it apparently did not become effective until September 1993: see below. Nil product in the last three months of 1993 is a reflection of the ban.)

(NB: The product listed above is likely to include sea cucumbers poached off the Australian sections of the Warrior Reefs in the Torres Strait Protected Zone - at least in 1992 and 1993.)

2.19.3 Stock status

From information in Lindholm (1978) it appears that surveys of sea cucumbers populations in PNG were performed by McElroy (1971) who reported that commercial stocks existed in the North Solomons Province, Port Moresby, Bubulata, Samarai, the Trobriand and Goodenough islands (Milne Bay Province), Kavieng (east coast near Tsoi Islands) and Madang. Unfortunately, Lindholm did not expand on McElroy's results - nor give a reference citation!

In 1976 a survey of sea cucumber stocks was carried out in the Trobriand and Goodenough islands (Lindholm, 1978). The species composition was found to be: 45 per cent blackfish (*A. miliaris*), 25 per cent prickly brown (? *A. ananas*), 10 per cent tigerfish (*B. argus*), 10 per cent stonefish (*A. lecanora*) and 10 per cent teatfish (*H. ?nobilis*). The density of sea cucumbers in the surveyed area was 300-350 animals/ha. The average length of the animals ranged from 15 cm to 45 cm and the average weight was 1-5.5 kg. The survey participants (Lindholm did not say who they were) estimated that the area could yield a sustainable annual harvest of 50 per cent. [This percentage is commonly applied to new fisheries.]

Table 136 The densities of two commercial sea cucumber species in the 'Papuan Coastal Lagoon' [?=Bootless Bay] pre-1981 (Shelley, 1981, in Preston, 1993)

Species	av. density (animals/ha)	max. density (animals/ha)	Species	av. density (animals/ha)	max. density (animals/ha)
H. scabra	2,900	13,500	*A. echinites*	1,800	12,500

Milne Bay and Central province studies would have been of almost virgin stocks.

A survey of West New Britain sea cucumber stocks was conducted from Gasmata to Kalia during October-November 1991 (Lokani in press, in Preston, 1993; Fisheries Research Annual report 1985-1991). All commercial species of sea cucumber were found and the maximum densities of some(*) are (based on stations where species was present) presented below.

Table 137 Maximum densities of sea cucumber stocks, Gasmata to Kalia: October - November 1991

Species	max. density (animals/ha)	Species	max. density (animals/ha)
H. nobilis	275	*Actinopyga* sp.	38
H. fuscogilva	54	*T. ananas*	79
A. mauritiana	304	*S. chloronotus*	4,258 (at Gasmata)
A. echinites	4,025	*S. variegatus*	456
A. lecanora	25		

(*no information available on the other species)**

The density for commercial species combined, all sites, ranged from 112 animals/ha at Kalia to 1,085 animals/ha at Gasmata (P. Lokani, pers. comm.).

Harvesting of sea cucumbers in the West New Britain Province began in late 1990. Lokani (in press, in Preston, 1993) considered that harvesting has impacted on the distribution and size composition of the sea cucumbers there. Shallow areas have been severely depleted of large sea cucumbers, particularly of valuable species such as *H. scabra*. Lokani also found that the less valuable species had been depleted in number when they occur in high densities (Fisheries Research annual report 1985-1991).

Surveys were conducted of 12 sites in Manus Province in May-June 1991 by Lokani and Chapau (1992). Only species commercially valuable at the time were counted, and of these *S. chloronotus*, *A. mauritiana, A. echinites, H. nobilis* and *H. scabra* comprised 75 per cent of the total. Species composition and density varied greatly between sites, ranging from 4.5 animals/ha to 1,481.3 animals/ha (mean 1,243.4) (Lokani and Chapau, 1992). The average density of all commercial sea cucumber species in Manus Province was calculated to be 214.6/ha and the standing stock at 49,358,000 animals, which when processed, would be 2,256 mt.

Table 138 Summary of the information obtained on the Manus Province survey.

Name	per cent presence in survey	density range (#/ha)	mean density total area (#/ha)	mean density where found (#/ha)	standing stock range (# animals)	standing stock as dry weight (mt)
H. scabra	12.75	0- 130.5	19.13	38.38	220,000-441,312	19.8-39.6
H. fuscogilva	2.34	0- 18	3.5	8.5	241,000-586-500	61.0-149
H. nobilis	13.36	0- 54.38	9.75	11.7	224,250-269,100	20.0-24.2
T. ananas	2.12	0- 5.63	1.63	1.8	112,470-124,200	14.6-16.2
A. echinites	13.85	0-945.88	105.5	180.93	1,698,550-2,912,973	59.5-102
S. chloronotus	20	0- 65.88	16	19.25	736,000-885,500	22.0-26.6
A. mauritiana	17	0- 39.63	9.5	43.23	911,490-994,290	27.3-29.8
S. variegatus	3.7	0- 3.63	8.63	17.19	396,980-760,740	24.2-46.4
A. miliaris	10.3	0-198.8	36.9	49.19	848,700-1,131,370	29.7-39.6
T. anax	4.31	0- 36.3	4.5	24.8	155,250-855,600	20.2-111.2

A survey of sea cucumber resources was performed in the Tigak Islands (New Ireland Province) in 1987 - a year *before* the fishery began (Tenakanai, 1991) and the fishery was monitored during 1988, 1989 and early 1990. Results of the 1987 survey are not available. In 1988, only *H. scabra* was harvested at a catch rate of 205 animals per day (Fisheries Research Annual report 1985-1991). Harvests of *H. scabra* were falling by April 1989, and within six months after it began the fishery shifted away from the Tigak Islands because of overfishing of the larger sized animals (Tenakanai, 1991). Lower value species comprised most of the exports subsequently (see price/kg, above).

Table 139 Change in species composition in the New Ireland bêche-de-mer fishery (from Tanakanai, 1991).

Year	Species	per cent by dry wt
1988	*H. scabra*	100
1989	*H. scabra*	89.1
	T. ananas	7.4
	H. fuscogilva	3.5
1990 (1st 5 months)	*H. scabra*	11.9
	T. ananas	0.9
	H. fuscogilva	0.6
	A. miliaris	2.9
	H. atra	43.6
	H. nobilis	8.9
	S. variegatus	0.6
	A. mauritiana	30.5

A survey of five sites in the Madang Province was performed by DFMR in September-October 1992 (Lokani, unpublished). Numbers of animals/ha are given below.

Table 140 Numbers of animals per hectare: survey of 5 sites in the Madang Province, September - October 1992.

Locality	Bagabag, barrier reef	Bagabag, fringing reef	Karkar lagoon	Karkar, coraline	Bogia	Madang	Rai coast
H. scabra			22.23				
H. fuscogilva		1.3	2.78		7.9		1.1
H. nobilis		50	1.39	5.60	5.5	37.7	0.8
T. ananas	4.7	8.8		2.16	11.7	17.5	3.4
A. echinites	3.1		1.39		15.6		
S. chloronotus		86.3	398.60	150.4	58.6	75	0.3
A. mauritiana	17.2	16.3	4.16	16.38	7.8	207.3	1.7
S. variegatus		1.3	9.44	1.29	1.6	26.7	
A. miliaris	1.5			2.58		12.5	0.8
H. atra	6.3	133.8	175	31.04	39.1	118.8	56.3
H. fuscopunctata			20.84		9.4	40	2.6
T. anax			1.39	0.86	23.5	2.5	1.9
B. graeffei		1.3	1.39	7.33		3.8	
B. argus		10	22.23	13.36	1.6	7.5	2.2
A. lecanora				0.86			
H. leucospilota			2.77		0.8	6.3	
B. vitiensis					0.8	11.7	0.8

The bêche-de-mer fishery in the Madang Province was very small in 1992, so the above densities do not reflect much fishing effort. Lokani (unpublished) found that the availability of suitable habitat strongly influenced the abundance and distribution of the sea cucumber in the province.

Bêche-de-mer yields from the Western Province increased rapidly from its inception and indications that the resource was being over-exploited came from the presence of (very) undersized animals in exports from the province in the latter phase of the fishery. Mobiha *et al.* (unpublished) surveyed six reefs on the PNG side of the PNG/Australia border to the south-west of Daru Island in October-November 1993, two months after a one-year moratorium on the harvesting and exporting of bêche-de-mer from the province actually began. The survey revealed that three of the more valuable species - *H. nobilis, H. fuscogilva, T. ananas* - were only present in deeper water; that some reefs were heavily exploited; on some reefs sea cucumbers were locally abundant.

Table 141 The range in abundance of different species of sea cucumber on the Western Province reefs (in number/200 m^2)

H. scabra	*H. atra*	*B. vitiensis*	*B. graeffei*	*S. variegatus*	*S. chloronotus*
0.4-9.82	0-17.0	0-1.0	0-9.06	0.06-3.08	0-1.21

A. mauritiana	*A. miliaris*	*H. argus*	*H. fuscopuncatata*
0-0.21	0-0.75	0-0.21	0-0.02

In concluding that sea cucumber stocks in the Western Province had been heavily over-exploited, Mobiha *et al.* (unpublished) compared the high species diversity of sea cucumbers on Daru reefs (because the reefs offer favourable habitat - large areas of seagrass + the outflow from large rivers depositing a lot of nutrients on the reef flats) with the very low densities (e.g. of *H. scabra*).

Finally, the trend in production of bêche-de-mer in the major supply areas of the North Solomons Province (three tables, below) illustrates the effect harvesting can have on stocks - and here, in just a two-year period from the fishery's commencement. Overfishing appears to have reduced numbers of the target species (*H. nobilis*) *and* the size of sea cucumbers (information from Ito, 1994, and Dalzell, 1990). Note the dramatic decrease in grade 1 and 2 production of bêche-de-mer in the Carterets.

Table 142 Bêche-de-mer production (kg dry weight) for 1982 and 1983 by grade, where grade 1 >/= 20 cm, grade 2 = 17-20 cm, grade 3 = 15-17 cm. (source: Ito, 1984)

A. At the Carterets.

Period	Grade 1	Grade 2	Grade 3	Mixed	Total	
Jan-June, 82	1,764	1,872	794	145	4,575	Total, 82
July-Dec, 82	68	0	2,558	2,124	4,750	= 9,325
Jan-June, 83	0	0	1,618	0	1,618	Total, 83
July-Dec, 83	33	46	1,057	0	1,136	= 2,754
Total for 2 years	1,865	1,918	6,027	2,269	12,079	drop of 70 %

B. At Nuguria.

Period	Grade 1	Grade 2	Grade 3	Mixed	Total	
Jan-June, 82	63	165	269	0	497	Total, 82
July-Dec, 82	441	353	407	0	1,201	= 1,698
Jan-June, 83	237	90	38	0	365	Total, 83
July-Dec, 83	214	298	24	0	536	= 901
Total for 2 years	955	906	738	0	2,599	drop of 40%

C. At the Mortlocks

Period	Grade 1	Grade 2	Grade 3	Mixed	Total	
Jan-June, 82	14	8	45	2,249	2,316	Total, 82
July-Dec, 82	448	210	112	0	770	= 3,086
Jan-June, 83	227	41	0	0	268	Total, 83
July-Dec, 83	230	107	2	0	339	= 607
Total for 2 years	919	366	159	0	3,693	drop of 80 %

2.19.4 Management

Current legislation/Policy regarding exploitation: Under changes to the Continental Shelf (Living Natural Resources) Act gazetted on 21 May 1992, sea cucumbers may not be harvested with the aid of SCUBA, hookah gear and trawl nets, and they may not be harvested at night with the aid of lights. Changes to the same act gazetted on 28th May 1992 prohibited the taking of certain holothurian species below a stated minimum size, as follows:

Table 143 Size limits for the taking of certain holothurian species in PNG

Species	min. dried size (cm)	Species	min. dried size (cm)
Holothuria scabra	8	*Thelenota ananas*	11
H. nobilis	11	*Actinopyga miliaris*	7
H. fuscogilva	17	*A. echinites*	5
H. fuscopunctata	12		

A moratorium was placed on the harvesting and exporting of all bêche-de-mer species in the Western Province between the period 23/3/93 and 23/3/94, although it appears not to have been implemented until 20/9/93. Subsequently the moratorium was extended until March 1995 (depending on stock assessment results?*).

In 1993 the DFMR decided to impose a nation-wide ban on the harvesting of sandfish (*H. scabra*) (Fisheries Sector Policies and Programmes document). I have no information on whether the ban was implemented and what effect it has, if so.

The bêche-de-mer fishery is designated nationally as an activity restricted to nationals. Measures are being taken to restrict the buying and export of bêche-de-mer by non-citizens, through the licensing of buyers and by thoroughly checking the *bona fides* of companies involved in export.

Recommended legislation/Policy regarding exploitation: This product does not require large capital outlay nor sophisticated technology. It is an ideal industry for village communities. Furthermore, because processed, dried sea cucumbers can be stored for long periods without deterioration the need for immediate transport is eliminated (Lokani and Chapau, 1992).

- However, sea cucumbers are vulnerable to overfishing because they are easily collected and receive a high unit price. Historically the bêche-de-mer fisheries in the western Pacific have operated on 'boom and bust' cycles. These cycles have meant that skills in producing high quality product have to be re-acquired during each boom period (Lokani and Kubohojam, in prep.). New entrants in the fishery in its boom periods do not know how to handle product nor process it properly, hence poor quality results and thus poor prices. In the interest of a) obtaining best prices, b) ensuring a national reputation for quality, and c) not wasting the resource by either its being discarded, or twice as much of it being needed to realise expected returns, the DFMR should have training material and extension staff available to teach processing and appropriate harvesting methods when boom cycles happen. Product value can be increased by better harvesting, processing and grading. To date, South Pacific bêche-de-mer are considered by Asian importers as having inconsistent quality, and this feature is recognised as a major problem to its trade and price realisation in the market (Kriz, 1994). PNG could realise much better prices for its bêche-de-mer exports if the product's quality can be guaranteed. Lokani and Kubohojam's manuscript is a step in the right direction.
- In conjunction with training for the fishery, programs of village awareness should be followed in which villagers are made aware of the problems of overfishing on resource sustainability and encouraged to follow remedial steps. Can traditional fishing rights areas be policed/brought into play again here?
- Implementing closed seasons or areas would relieve fishing pressure off stocks. An appropriate time would be at the end of each year during the spawning period of most species. However, market demand from Asia (for special occasions and festivals: Kriz, 1994) may make closed seasons difficult to enforce when greater profits are to be made. Closures could alternatively be put on reefs for several months on a rotation system. I

wonder about permanent reserve areas: in the absence of much knowledge on larval dispersal and juvenile recruitment, they may be ineffective.

- The best means of policing these closed seasons or areas is through the village community.
- In some western Pacific bêche-de-mer fisheries, management by quotas has been suggested or trialed. Ideally, quotas are based on stock assessments; but even if ball-park estimates were made, it would require fishers or the community to be licensed. I have doubts that implementation of a quota system in PNG bêche-de-mer fisheries would give results commensurate with the costs of policing it. It would be very difficult. The alternative, limited entry, is more likely to work - e.g. restrict the fishery to residents of the area. Traditional fishing rights access could be applied with the support of communities.
- Estimates of total potential yield are needed with some urgency. The Sector Review (1989) suggested that a potential sustainable yield of bêche-de-mer in PNG is 1,000 mt/year. DFMR biologists have information from a number of surveys already and they should be in a position to estimate sustainable yields for some fisheries. Bear in mind though, that it is one thing to nominate a sustainable yield level for a fishery and another to ensure it is met. i.e. maintenance of MSY in a fishery can only be achieved by monitoring the fishery (through surveys and accurate data recording) and enforcing laws relating to it.
- The bêche-de-mer fisheries in PNG should be constantly monitored. It is unfortunate that the fishery in the Western Province was allowed to get to the level it reached, where drastic measures (affecting the well-being of nationals and PNG's international reputation) had to be implemented. I commend the DFMR for taking the unpopular measures that it did. The cyclical nature of bêche-de-mer fisheries is well-documented and timely intelligence on the Western Province fishery would have enabled the DFMR to act strategically earlier.
- There is little information in the western Pacific on the rate of recovery of stocks, although - as with other resources - they do recover in the absence of fishing (e.g. the Carteret Atoll: Ito and Selemet, 1985). Studies should be conducted (or sourced from elsewhere) on stock recovery rates. Planned monitoring of stock recovery in the Western Province should be followed through and information from it should be transferrable to other PNG bêche-de-mer fisheries (so obviating the need for field surveys in all areas). As an aside, Tenakanai (1991) suggested that the exploitation of less valuable species of sea cucumber to satisfy the mainland China market actually relieves fishing pressure on depauperate stocks of traditionally more valuable sea cucumber species. Deeper populations of sea cucumbers do have a measure of protection already - as long as laws on harvesting (e.g. no hookah gear) are strictly enforced - and it is probable that their progeny can restock shallower waters.
- Proper recording of data on bêche-de-mer purchases and exports should be gathered in conjunction with information from stock surveys. Bêche-de-mer appears to be transhipped within PNG more than does any other fisheries commodity - so it will take reliable recording of sales and attention to the company register and areas of operation of exporters to accurately record production. Ideally, records should include harvest date, day period, duration of fishing trip, locality, quantity gathered, processing method, species variety, dry weight of product, price obtained. However, I recognise that not all of this data can be obtained with the resources available.
- As with all sedentary (and other) resources harvested in PNG, the 'official' figures are at variance. *Stability in fisheries and faithful fisheries management strategies MUST come from and can ONLY be generated by a one-only set of accurate fisheries statistics for each unit of the fishery(ies). CORRECT data is VALUABLE.*
- More timely market intelligence would assist resource management as well, according to the Sector Review (1989). Fishers and buyers could be advised of switches in international

demand and in market prices, and harvest to meet those demands (see above). Buyers must be obliged to give receipts to fishers thereby assisting market monitors in ensuring that fishers are receiving a fair price. Receipts will also facilitate a monitoring system (see earlier points).

- Shelley (1986) had already utilised stock surveys, life history and economics. He stated: "In PNG, by combining known densities of holothurians with growth rates and the value of the bêche-de-mer, it was found that harvesting of the shallow water species *H. scabra* and *A. echinites* could result in annual yields of 39 kg/ha/year, valued at approx. $A65/ha/year."
- With regard to the classification of the fishery (including buyers and exporters) to nationals, it could be that nationals may not have sufficient capital to engage in exporting. According to B. Shackles (pers. comm.), quite large amounts of purchasing money must be available as 2-3 shipments of bêche-de-mer have to be sent out before returns come back. Delays in payment are especially likely for new exporters from whom the quality of product is untested in the market place. Accordingly, the PNG Government should consider providing some type of financial assistance to enhance local participation in the buying and exporting part of the fishery.
- While respecting the intentions of the PNG Government in securing the fishery for nationals, I urge that Kriz's (1994) findings on the Asian bêche-de-mer trade are considered; viz: that "*without a Chinese partner or at least a reliable agent, direct distribution by Pacific island exporters appears to be impossible*". There must be some room to manoeuver in meeting the desires for local participation in exporting and the need to ensure that the product is effectively and efficiently marketed. Kriz also found that exporters should also operate through 1-2 importers in the destination countries.
- Further on restriction of the trade to nationals, the suggestion of a local exporter in Kavieng (relayed by C. Hair) is good; i.e. as well as restricting the buying and exporting to citizens, each buyer may only buy from a specified area. For example, if he is based in Kavieng he may only buy from that area; if he is based in Rabaul, likewise. Each buyer may not buy in another area. This policy would certainly assist with monitoring of production (and see earlier point about recording of data).
- Inspectors should be familiar with species identification of both fresh and dried product. Fisheries inspectors should be empowered to inspect catches. As the weight change in processing is roughly known, inspectors armed with a table of weight-size estimates (*previously calculated by DFMR biologists*) would know which product does not meet the minimum size limit. Issuing of on-the-spot monetary fines could be immediate deterants and enable better enforcement of legal minimum size limits. What are the penalties? Buyers receiving undersized bêche-de-mer should be fined and the product confiscated. Fisheries inspectors need to be supported by 'the system', in whatever fishery they operate.
- Studies of holothurian population dynamics within the western Pacific need to be consolidated to obtain information on growth, mortality, recruitment and movement patterns. Such are needed for estimates of yield and stock sizes. Comparative studies of holothurian populations on exploited and unexploited reefs could also be undertaken (Lokani, pers. comm.). However, PNG should avoid setting up expensive aquarium systems for hatchery rearing as a means of stock enhancement for the time being. These techniques are in their infancy elsewhere (Preston, 1993; Kriz, 1994). More immediate gains through less cost would be achieved by following alternative management and resource maintenance measures.

Summary

1. Provide training in product harvesting, processing and grading.
2. Undertake a village awareness program aimed at resource sustainability.
3. Consider the implementation of closed seasons or reef areas.
4. Consider applying limited entry provisions to the fisheries.
5. Endeavour to establish yield estimates for stocks.
6. Monitor active fisheries and recovery rates of depleted stocks.
7. PROPER and timely RECORDING OF DATA.
8. Monitor overseas markets. Ensure vendors are given receipts.
9. Address the need of financial assistance for national exporters and do not close the door to Asian partnerships in these businesses.
10. Each buyer may only purchase bêche-de-mer in a specified area.
11. Empowerment and better training for fisheries inspectors. Ensure support by following through on breaches. Much stricter policing of the fishery's laws.
12. Do not establish hatchery rearing operations aimed at restocking

Good news? There appear to be sufficient stocks of sea cucumber in the Madang Province to support a small fishery (Lokani, unpublished). Although a fishery based on one or few of the more valuable species is not viable, one based on all sea cucumber species should be sustainable at the artisanal level as long as minimum size restrictions are enforced and harvests closely monitored.

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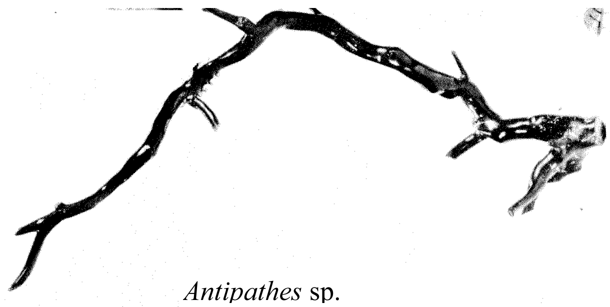
Acknowledgement:

Barry Shackles - Daru.

2.20 BLACK CORAL

2.20.1 The Resource



Antipathes sp.

Species present: *Antipathes* species, probably *A. grandis,* is reported to be the species of black coral harvested in PNG. Whip corals, *Cirripathes spiralis*, is also harvested. Pink corals (*Corallium* species) are occasionally collected, e.g. from Kupiano (Central Province) and Manus Province. Black corals belong in the order Antepatharia, and pink corals belong in the order Gorgonacea (Wells *et al.,* 1994).

Distribution: Black, pink, gold and whip corals are distributed world-wide in tropical waters in the Indo-West Pacific (eg pink corals are collected in Hawaiian waters) and the Caribbean (Grigg, 1984). In PNG, black coral is known from the south coast, from the Western Province to at least Cloudy Bay in the Central Province (Bourne, 1982).

Biology and Ecology: The majority of the 150 recognised species of black coral typically occur at depths of 30-100 m, generally in areas of strong current and hard, clean sea floor; also on reefs (Wells *et al.,* 1994). However, a few species such as whip corals occur from near the surface to water shallower than 20 m. Black corals have a branching form and typically occur at depths of 20-100 m, generally in caves and on the under-surfaces of ledges where there is very little light (Grigg, 1984). Pink corals occur in cooler, mostly deeper waters, in large beds on the sea bottom or attached to rocks (Wells *et al.,* 1994).

Black corals contain no symbiotic algae, hence are negatively phototaxic; i.e. they do not require sunlight. Black corals secrete an axial skeleton which is usually branching in form, although some species are encrusting and others form long, unbranched whip- (or rope-) like colonies. The branching and whip forms may grow singly or in groups (or 'forests'), their branches often attracting fish (Grigg and Ospreko, 1965). Winged oysters (*Pteria penguin*) and pearl shells (*Pinctada* species) often grow on *Antipathes* colonies (Bourne, 1982). A single black coral colony can possess thousands of polyps which form a cortex around the skeleton, making the colony 'slimy' to the touch. Many species are armed with nematocysts (Grigg and Ospreko, 1965).

Growth of the tree-shaped black coral colonies is very slow - 6 cm per year or less - and large 'trees' may be 100 years old. In Hawaii, *Antipathia dichotoma* is reported to grow at least 6.4 cm/year while *A. grandis* is reported to grow at 6.1 cm/year (Grigg, 1984). Experiments with transplanted black coral in PNG revealed a very slow, but unquantified, growth rate (Bourne, 1982). A large black coral bush may be up to 4 m wide in any direction. On average, the stem diameter is usually 20-30 mm but large corals can have a stem diameter of about 80 mm (Bourne, 1982). Considerable mortality occurs when boring organisms undermine and topple the tree base (Lewis 1985).

A whip coral 'rope' may be as long as10 m. Whip corals have different forms (straight, spiral, knotted), the base diameter measuring about 15-25 mm (Bourne, 1982). Whip corals also can be successfully transplanted (Bourne, 1982).

2.20.2 The Fishery

Utilisation: Black, pink and whip corals are used in the production of high value jewellery and ornaments. They are hard substances and take a high polish (Lewis, 1985). Black coral is processed to produce beads, regularly shaped jewellery components, carved jewellery components such as animal figures and unique articles of jewellery such as bracelets and coral sculptures.

Because of the depth at which black coral colonies normally occur, they are usually harvested by hand by divers using SCUBA gear. A small-tooth pruning saw or bolt-cutters may be used to saw through the black coral 'tree' at its base or to remove branches. The harvested black coral is left in fresh or brackish water to cause death and decomposition of the coral. It is then cleaned and trimmed and hung or stacked in a well-ventilated position to 'season' for 3-12 months.

Black coral and whip coral are often washed up on beaches and reef flats and mangrove areas where they are collected - e.g. at Katatai near Daru (Western Province) and at Kupiano and Abau (Central Province). Such pieces are usually either faulty or too small in diameter to be used in jewellery manufacture. Dead and living black coral is occasionally collected accidentally in trawling operations. Dead coral is often encrusted with lime, oysters and seaweeds. The slime on live coral must be cleaned off before the slime dries.

Coral is graded by length and quality (e.g. absence of worm holes, calcareous rings). It is cut with fine fret saws into approximately 40 cm lengths and soaked in a bath of 3 per cent calcium hypochlorite for two hours to lift the scale and calcium encrustaceans. Then it is brushed, rinsed, dried, filed, drilled and sanded and worked into desired shapes, buffed and polished. Processing is a skilled and labour intensive operation, adding considerable value to the raw product (Lewis, 1985; Philipson, 1989; *House of Gemini*, Port Moresby).

Production and Marketing: Bourne (1982) reported that more than 200 kg of dead black coral was collected from foreshores etc. by villagers in the Kupiano area in 1981.

The *House of Gemini* jewellers in Port Moresby (pers. comm., July, 1994) pay between about K40 and K80 per kg for raw black coral, depending on thickness and quality of the branches - i.e. thicker branches without worm holes and fewer calcareous rings fetch higher prices. Thin branches cannot be worked and are used for decoration. The *House of Gemini* estimates that in one year it purchases more than 100 mt of coral. The *House of Gemini* employs about 25 craftsmen of whom on average at least two would be working on black coral pieces at any one time.

There is a ready market for black coral, especially in the tourism trade. It makes very attractive jewellery. PNG prices at the *House of Gemini* for silver-backed items range from K25 (simple earing) to K250 (intricate necklaces) with customised items fetching far higher prices.

2.20.3 Stock status

No assessment has been made of black coral, whip coral and pink coral stocks in PNG waters. I am unaware also of any taxonomic study of the black corals in PNG waters.

In Fiji and Tonga, stocks are believed to be limited and vulnerable toover-exploitation (Lewis, 1985). Hearsay from Port Moreby jewellers is that there is no indication that quantity is in short supply or has decreased.

2.20.4 Management

Because of its vulnerability to over-exploitation, members of the order *Antipatharia* (which includes *Antipathes* and *Cirripathes*) were listed on Appendix II to CITES in June 1981. CITES is the acronym for the Convention on International Trade in Endangered Species of Wildlife. Import to signatory countries to the Convention is only permitted on proof of the coral being obtained prior to the species' listing by CITES, and being accompanied by valid permits - from both exporting country and importing country.

Australia and PNG are signatories to CITES. However, black coral is traded in other countries including Japan, Hong Kong, Korea, Taiwan, Singapore and the Philippines.

Current legislation/Policy regarding exploitation: There is none, other than the obligations borne by PNG as a signatory to CITES. Permits are required for export of black coral.

Recommended legislation/Policy regarding exploitation: Use of black coral that is already dead through natural causes (e.g. broken pieces on seabed, washed up on shores and reefs) does not impinge on the resource; nor does harvest of farmed black coral (grown from transplants). However, proof of these operations is difficult to obtain, especially as there is no monitoring of the supply. Neither vendor nor jeweller are obliged to report information on (e.g.) quantities, source and condition of the traded coral.

Because markets exist in non-CITES signatory nations, there is likelihood of 'black-market' trading of PNG black corals. Black coral fetches high prices. Hence, the DFMR

- should investigate the practicality of monitoring the harvest and trade (even domestic) through implementation of logbooks.
- A DFMR officer should be assigned to keeping a 'watching brief' on the black coral trade in PNG and the world,
- and to securing information on biology, ecology and transplanting techniques,
- and also to securing taxonomic identification of the species inhabiting PNG waters.
- Following Lewis' (1985) suggestions, indiscriminate harvest methods should be prohibited,
- and the export of unprocessed product should be prohibited.

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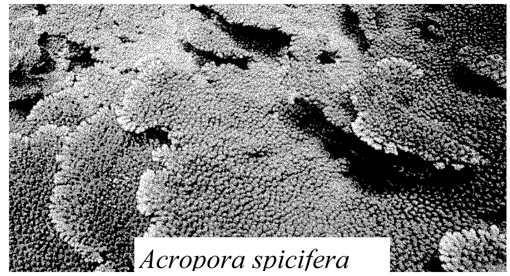
Acknowledgement:

Andy Richards - FFA, Honiara

2.21 ORNAMENTAL CORAL

2.21.1 The Resource


Acropora spicifera

Species present: As with other fisheries resources (e.g. reef fish, specimen shells, aquarium fish) the number and diversity of coral species inhabiting PNG waters is extremely large. PNG is located in the centre of diversity of the Indo-Pacific, and its northern and north-western shores share with Indonesia the highest number of coral species in the Indo-Pacific (J. Verron, pers. comm.). There has been no systematic study of the corals of PNG waters, but about 700 species or reef-associated corals have been described (Wells *et al.,* 1994). Many of these would be described in Verron (1986).

What species are collected for marine curios in PNG is unknown. In the Philippines, over 30 species are collected for curios and in Fiji, 56 species are collected (Wells *et al.,* 1994).

Distribution: Reef building corals are only found in water where sunlight can penetrate, as sunlight is needed to power the zooxanthellae which live inside the coral polyps and which require sunlight to photosynthesise. The 'critical' depth varies with turbidity of the water, but in even the clearest water there is little reef growth below 100 m (Doherty, 1993). Reef building corals prefer water warmer than 19°C.

Given its geographic position and recognised provision of diverse habitats, the species inhabiting PNG waters would probably be widely distributed in the Indo-Pacific.

Biology and Ecology: Corals are made up of colonies of coral polyps which build a shared calcareous skeleton. Different species build different kinds of skeletons. As each generation of coral polyp dies, new polyps grow on top of the skeletons and eventually coral reefs are formed from the millions of polyp skeletons. Living coral polyps are only on the thin outer layer of a coral reef which grows outwards and upwards with each generation. Eventually chemical processes convert the coral skeletons to limestone (and reefs are formed). Corals usually grow very slowly, although there are distinct differences between species. In general, corals that form branching colonies grow more quickly than do those forming massive rounded corals. For example, species having a branching form, such as *Acropora* species, may achieve 10-20 cm growth a year, whereas solid forms like *Montastrea* species and *Platygyra* species may grow only 0.4-2 cm a year (Buddemeier and Kinzie, 1986, in Wells *et al.,* 1994).

The coral polyp collects its food both with the aid of its tentacles trapping tiny food items drifting in the water column, and from plant cells (zooxanthellae) living in the polyp which photosynthesise food. Corals have evolved mechanisms for tapping some of the energy in this food.

Coral polyps produce eggs which are fertilised with sperm and hatch into very small floating larvae. Only a few of the millions of the planktonic polyp larvae reach shallow water and settle onto suitable hard surfaces to grow into new polyps. Eventually many polyps build a shared skeleton which has the characteristic shape of particular kinds of coral. Coral colonies can also reproduce asexually.

Coral colonies occur in a great variety of shapes and sizes. Mushroom corals (*Fungia* species), brain corals (*Goniastrea* species, *Euphyllia* species), staghorn and other branching corals (*Acropora* species, *Seriatopora* species, *Pocillopora* species), organ-pipe corals (*Tubipora* species) and stinging corals (*Millepora* species, *Stylaster* species) are familiar names. The shape of the coral is determined by the species, wave action, currents and exposure of the colony at low tide. The colour of the corals comes from pigments in the tissues of the polyps.

2.21.2 The Fishery

Utilisation: Corals have been sought after by tourists to be used as ornaments and in marine aquaria. They buy coral heads that either have been broken off or chipped off the reefs, then washed and dried in the sunlight, and cleaned and bleached. An estimated 1.2-1.5 million pieces and an additional 500 mt of coral were involved in the ornamental coral trade in 1990 (Wells *et al.,* 1994). The Philippines has been the main exporter of ornamental corals since the 1950s, and concern over the impact of coral collection on its reef systems led to a ban on collection and export in 1977 (Wells and Hanna, 1992). Coral is still being smuggled out of the Philippines at a great rate; for example, most of the 1,456 mt of ornamental coral imported by the U.S.A. in 1988 came from the Philippines. Besides U.S.A., Japan and Europe import considerable amounts of ornamental coral. Indonesia and Fiji are the other main exporters but some other Western Pacific countries export small amounts.

Coral is either exported dead or live (for aquaria). Live corals can be very difficult to keep in captivity - it is thought that 50 per cent of collected corals may die between collecting and reaching retail shops (Wells *et al.,* 1994).

Much of the ornamental coral trade is believed to focus on abundant and widespread species - although little research has been performed on the species involved in the aquarium trade. However, the attraction of certain species can lead to their harvest at levels far greater than what could be considered 'sustainable' (Wells and Hanna, 1992).

Coral are utilised in other ways as well for ornament: a) 'by default', in their provision of habitat for reef fish which are utilised for food and recreation by divers; b) in the form of a reef, the protective breakwaters for the shoreline; c) in a burnt form as lime to accompany betel nut chewing; d) for road and building construction; and e) for medicinal purposes.

Production and Marketing: There is limited sale of dried ornamental coral to tourists and expatriate residents in PNG. No information is available on the amount of coral sold each year.

2.21.3 Stock status

There is no information on the status of ornamental coral resources in PNG.

2.21.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Many conservation groups and scientists have urged that a total ban be placed on the exploitation of corals worldwide (Wells *et al.,* 1994). This request is because of the rapid expansion of the ornamental coral trade in the last 40 years and the perceived long-term effect overharvesting of corals will have on the sustainability of the resource itself, the reef habitat and consequently the communities it supports. The groups and scientists point out that good artificial corals are available (although these would not fulfill the interest of those wishing to maintain live corals in certain situations).

Wells and Hanna (1992) stated that problems associated with coral harvesting are often exacerbated because management of the ornamental coral trade is often overlooked by fisheries departments. The departments do not realise the high economic value of certain species, they have little information on exploitation levels, and are unaware of the problems that may arise from concentrated, uncontrolled harvesting.

The concern for resource sustainability has led to hard corals being listed on Appendix II to CITES (the Convention on International Trade in Endangered Species of Wildlife). PNG is a signatory to CITES and as such is required to follow certain procedures with regard to the export and import of taxa listed by the convention. The two main procedures which affect trade in corals (either bought by tourists visiting PNG or exported product) are that import of the item to a country which is also a signatory to CITES must be accompanied by a permit issued by that country, and it must also be accompanied by a valid CITES export permit issued by the CITES management authority of the country of export - here, PNG.

These provisions can seriously affect development of an export industry in ornamental corals. For example, what tourist would knowingly purchase coral pieces if they knew they would be confiscated when they went back to (e.g.) Australia?; or what tourist would go through the procedure of obtaining first an import permit for their planned purchases before they left their CITES-signatory home base? On the PNG side, the regulations mean that every piece of coral sold in local markets or by vendors outside hotels etc. would have to individually certified by the government.

The export permit required by the exporting country must state (among other things) that the piece was harvested in a careful manner, that its removal will not affect the total reef habitat from whence it came and that the species is not locally nor nationally in danger of being over-exploited.

Albeit this constraint on sale and export, hard corals are abundant in PNG and it seems unlikely that harvesting will ever be at the rate to endanger reefal systems - even those within boating and marketing distance from main centres. The potential for PNG to develop an export trade in ornamental corals is, therefore, considerable. The benefits of ornamental corals (and collector shells - profile 2.16) is their *non-perishable nature* - a factor which considerably eases the problems of collection, storage and marketing. In addition, because there is *an already established international market* (with attendant prices), fewer resources are required to promote the industry to buyers. Furthermore, an export industry for ornamental corals would be a *good industry for villagers* because of the small-scale, intermittent nature of the collection activity.

Safe harvesting however, needs appropriate management measures and in turn these depend on a knowledge of the resource, including information on the rates of regeneration of harvested reefs (Lewis, 1985).

Some of the management measures in place in the coral exporting countries of Fiji, Australia and New Caledonia and some additional ones are listed below. It would be wise for PNG to implement similar measures if it were to proceed to encourage the development of the hard coral industry.

1. An *exploratory survey* of the resource is carried out before people are allowed to harvest it.
2. *Maximum exports* are not allowed to exceed 10,000 pieces of coral and 500 mt a year in Fiji (Wells and Hanna, 1992). In Australia the level is 45 mt and in New Caledonia it is 100 mt (Lewis, 1985).
3. After harvesting, *follow-up surveys* should be made to ensure that the resource has not (superficially?) been damaged by the harvest operation.
4. *Permission from traditional reef owners must be obtained* before harvesting is carried out.
5. *Collectors must be licenced* (this is also required by CITES) and there should be a limit on the number of licence holders. I don't know how this can be implemented in PNG however: it would be impossible to licence the village collector, for example. Perhaps the only workable way would be to licence the vendors (which would include exporters).
6. *Quotas* per individual and per locality(*) should be imposed. (*This would be dependent on stock assessments really, and these have not been performed.)
7. A *prohibition on the use of scuba gear* for collection of corals should be applied.
8. There should be a *restriction on the types of species* to be collected (again, this would depend on knowledge of the resource).

9. *Collection areas should be zoned* - to allow fallow areas for regeneration and maintenance of the reef habitat and its properties. This step would incorporate the concept of marine protected areas.

10. A proportion of the *corals must be processed* before they are exported - e.g. made into curios.

11. *Instruction* should be provided in *how to best harvest* corals. The instruction should be directed at reducing wastage and damage to the remaining coral formation (Wells *et al.,* 1994).

12. *Records must be maintained* of the origin of corals destined for export or domestic sale as one way of monitoring the effect (if any) of coral harvesting on reef habitats.

The Fishery Sector Review (1989) pointed out that a major constraint to development of the ornamental coral industry is the lack of information required to ensure the rational management of these resources. There is no assessment of the diversity and distribution of coral species in PNG, including estimates of sustainable yield.

Finally - if an ornamental coral export industry were developed in PNG - monitoring of world prices for coral would need to be effective so that correct returns are passed on to villagers. A monitoring body should also regulate the flow of exports in response to world demand and prices, ensuring that the best prices are realised for PNG product.

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2.22 COMMERCIAL SPONGES

2.22.1 The Resource


Spongia sp.

Species present: There have been two studies of the taxonomy of sponges in PNG waters. One is by Kelly Borges and Bergquist in 1988 and the other by Gerald Bakus for the Christensen Research Institute near Madang. I do not have copies of these reports.

Probably numerous species inhabit PNG waters, possibly including the woolly sponge, *Spongia officinalis*. This apparently cosmopolitan species has two subspecies (*mollissima* and *adriaticus*) and has been tentatively identified as the species occurring and being farmed in the Federated States of Micronesia in the Pacific (Croft, 1990a). *S. officinalis* is known to inhabit Philippine waters (McCauley *et al.,* 1993).

About 5,000 species of sponge have been described, belonging to four classes. The Calcarea have spicules composed of calcium carbonate; these sponges live in shallow water in most oceans, and rarely exceed 10 cm in height. The Hexactinellida are glass sponges having 6-rayed spicules; average 10-30 cm height and mostly live in water greater than 450 m depth. Most species belong in the Demospongiae whose skeleton also comprises siliceous spicules, bu not six-rayed. The last class is the Sclerospongiae which have a massive limey skeleton. Three orders within the Demospongiae are characterised by a lack of spicules in the skeleton, one of them being the Dictyoceratida. Within this order is the family Spongiidae which contains the common bath sponges. Their skeleton is composed only of spongin fibres only.

Despite there being 5,000 species of sponge, only about 15 of them have any economic importance (Josupeit, 1989). These species are described and figured by Josupeit (1989). Of all marketed sponges, *S. officinalis* and *Hippospongia* species are the most valuable (Josupeit, 1989; Bridgeland, 1992).

Distribution: Some information on the distribution of sponge species in PNG waters may be obtained from the Christensen Research Institute or from Kelly Borges and Bergquist (1988). No other surveys have been reported.

Biology and Ecology: All sponges are sessile - i.e. they are permanently attached to the substrate. Most are marine and they live on hard substrates such as rocks, shells, submerged timbers and coral, also on sand and mud. Sponges vary in size and the type of growth pattern displayed is influenced by the nature and inclination of the substrate, availability of space and the velocity and type of water current. Most of the marketed species inhabit waters between 3 m and 30 m depth.

Sponges are constructed around a system of water canals. The surface of the sponge is perforated with many small openings which open into an interior cavity, the atrium or spongocoel. In turn the atrium opens to the outside through the osculum, a large opening at the top of the tube (Barnes, 1980). A constant stream of water passes through the incurrent pores into the spongocoel and out of the osculum.

The body of the sponge is called the mesohyl and it consists of a gelatinous protein matrix containing the skeleton, dispersed collagen fibrils and sometimes spongin. The sponge skeleton is complex and provides a supporting framework for the living cells of the animal. It is composed of calcareous or siliceous spicules and/or spongin fibres.

Most sponges are built on the leuconoid plan (Barnes, 1980) and have a mass of chambers and water canals. They may attain a considerable size. Many species are vase-shaped and tubular forms in which the excurrent canals empty into a large central chamber, and there may be many osculums.

The water brings in oxygen and food and removes waste. Sperm and eggs are also moved in and out by the water current. Choanocyte cells along the wall of the atrium have flagella which create a current and to some extent, water flow is regulated.

Sponges feed on extremely fine particulate material as well as bacteria, dinoflagellates and other fine plankton (Barnes, 1980). Sponges lack a nervous system. They reproduce asexually by forming buds that are freed by various processes. Sponges can also reproduce sexually. Both hermaphoditic and dioecious sponge species exist although most are hermaphroditic, usually producing eggs and sperm at different times. In the majority of sponges, development of the larval stage takes place within the body of the parent though in some the larva has a brief free-swimming existence.

Some marine sponges live only for one year; others live for many years (Barnes, 1980). Most large tropical sponges are very slow growing (Wilkinson and Cheshire, 1988, in Wilkinson, 1989).

2.22.2 The Fishery

Utilisation: The commercial sponge is the cleaned and dried skeleton of a marine sponge.

Natural sponges have been harvested for centuries in the Mediterranean and Caribbean seas for a variety of uses including cosmetic, bathing, pottery production, printing and lithography, tiling, leather work and, more recently, surgery. It is in this field especially that natural sponges are preferred (over synthetic sponges) because they can be easily sterilised for repeated usage (Bridgeland, 1992). Also in recent years, there has been a shift to using natural bath sponges rather than synthetic bath sponges (Josupeit, 1989) (a manifestation of the 'environment movement').

Experiments in sponge mariculture in the Pacific were undertaken by the Japanese in the 1920s and 1930s but they were abandoned during the second world war. The experiments used four different planting methods including an effective [but unexplained] 'floating bottle method' (Cahn, 1948, in Bridgeland, 1992).

Sponge 'brood stock' are gathered from an area where the density of sponges is high -an area termed a sponge bed. (In deeper water sponges are hard to see as their outer 'skin' is black: Croft, 1990a.) Sponges of 'commercial' size exceed about 35 cm in height (Croft, 1990a), and they are gathered by trained and practised divers aided by scuba gear. The sponges must be kept alive while being transported from where they are collected to the farm site. Sponges are very sensitive to movement, changes in water temperature, and different salinities. Rough treatment during transplanting sponges results in high mortality and/or reduced growth rates (Wilkinson, 1989).

The best practice is for the diver to cut off one half to two thirds of the living sponge (leaving the remaining portion to regenerate). A razor sharp knife is used so that the sponge is not damaged by being torn or squeezed, causing it to die. During transportation to the farm site, the sponges must be kept in (uncontaminated) sea water as much as possible. This is best done by keeping the sponges in a net bag below the boat until ready to travel, and then putting them in a covered 200 litre container on the boat (Bridgeland, 1992). With these steps and a short transport time, mortality can be kept as low as 5-10 per cent (Wilkinson, 1989; Bridgeland, 1992).

At the farm site, seed sponges are cut into small blocks which are either threaded onto loops of string attached to a mainline or threaded directly onto the mainline. Another method is to attach the cut sponge blocks to plastic bases (Wilkinson, 1989). To guard against disease outbreaks, sponge blocks should not be attached too close together (Croft, 1990a). The ends of the mainline are then attached to form a grid with support lines hung between coral formations so that the sponges are suspended 30-60 cm from the sea floor. Croft (1990b) estimated that it would take at least one year to establish a *nursery* farm of 25,000-30,000 cuttings.

The cut sponge blocks are left to regenerate and grow. At harvest, a portion of each sponge block is left to regenerate - and so the process continues.

There are four steps in preparing a sponge block for market (Stevely, 1989, in Bridgeland, 1992). The animal is first killed by removing it from the water for 6-12 hours. Then the sponge is returned to the seawater for 1-2 weeks so that all the organic, non-skeletal tissue can decay. The third step is the removal of the sponge's black outer skin by either slamming the sponge against a hard surface, hammering it, or using a high pressure water jet. The last step is trimming the sponge to a marketable shape. Dry sponges weigh very little.

Production and Marketing: In Pacific waters it takes about two years for farmed sponges to reach the minimum commercial size (Bridgeland, 1992). Thus the farmer can harvest every second year from the one stock. However, if the farmer has planted cuttings for several years he can obtain cuttings on a yearly or even monthly cycle.

<u>Reasons for looking at sponge mariculture</u>

- It offers *sustainable harvests*.
- Diseases in sponges from traditional areas of supply (the Mediterranean - Tunisia; the Caribbean) have led to a *drop in supply just as demand has increased*. This series of events has supported an interest in farming sponges in the Pacific and indicate the fishery could be profitable.
- There is *potential for high monetary return*. The global market is greatly undersupplied and Wilkinson (1989) predicted that current demand and high prices for sponges would continue until at least 2009. Two and a half year old cleaned sponge samples from a pilot farm on Pohnpei were valued at US$1-1.25 f.o.b. (Croft, 1990b), and Croft quoted one buyer as offering to purchase at least 200,000 sponges a year.
- Sponge farming is a *village-based - low technology fishery*, and no expensive processing equipment is required.
- *Postharvest storage* does not present a problem (similar to shell fisheries).
- *Freight costs* of dried product would be *small*.
- *Convenience. There is no required harvesting time*. Sponges can be left to grow until the growers 'feel' like harvesting. Ideal for Pacific islanders who often have obligations elsewhere.
- Similarly, *farmed stock does not diminish in value as it is left unharvested*. The farmer can 'play the market' and decide when to harvest, when to leave to grow.
- Although considerable work is required to establish the transplanted pieces of parent stock, there is *little farm maintenance required* after that.
- Sponge farming could be *integrated with other mariculture operations* such as pearl farms and seaweed farms (Wilkinson, 1989).

<u>Identified constraints to sponge farming</u>

1. Long growing time
2. Disease outbreaks
3. Insufficient wild stocks to support farming
4. Vandalism?
5. Issues associated with customary reef ownership.

Bridgeland identified present (1992) constraints to the development of sponge mariculture in the Pacific as a) the availability of sufficient 'seed' (or parent) stock; b) farm size; c) capability in collecting and handling; and d) cultural/social difficulties in farm ownership (i.e. influence of customary ownership). I add to that e) availability of suitable species.

The main import demand comes from France, the United States of America, Japan, Italy, Spain and Germany. Prices vary greatly by size, shape and appearance and quality.

Table 144 1988 retail prices in several countries are given by Josupeit (1989)

Size	France (US$)	Japan (US$)	Germany (US$)
less than 10 cm	4.77	2-10	1.10-4.20
10-15 cm	11.30	16-19.50	7-11
more than 15 cm	21.20	25.80-30	14-16.50

2.22.3 Stock status

There is no information on the status of sponge stocks in PNG waters.

2.22.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: The PNG Government should decide whether it wishes to establish a fishery for sponges. If it does so, it should undertake the following approaches.

- As for seagrasses, undertake a survey of the sponge resource in PNG. This should include an assessment of the availability and biomass of exploitable sponges to be used as aquaculture brood stock. At the same time, assess the area of solid substrate (coral, rock) in areas fairly devoid of sponges but where all other conditions appear favourable to sponge habitation, as these areas could be utilised eventually for establishment of sponge beds. The services of a consultant may be required for this.
- Assess the market suitability of local species. (Note: the harvested commercial species in the Philippines sells at the lowest price because of its very soft texture and its general unsuitability as a bath sponge: Josupeit, 1989)
- Investigate suitable areas for establishing a pilot farm. The role of a pilot farm is important for establishing interest in the fishery, undertaking training and developing farming practices relevant to the local area.
- Liaise with local villagers in the selected areas for access to customary fishing rights areas and assess their interest in participating in the fishery.
- Investigate the economic feasibility of the fishery in PNG. This would involve establishment costs, capital, operating costs, salaries, training, storage, transport, marketing and returns. (An evaluation of the Pohnpei fishery (Croft, 1990b) indicated its strong potential for success.)
- High start-up and running costs and the length of time before harvest could be impediments to initiation and development of the fishery. Seek funding for the developing fishery sufficient to support it over the several years before the product is saleable.
- Piggy-back on the expertise available from FSM and elsewhere where sponge mariculture is underway or being trialed. Shared information between developing and existing industries is essential to prevent a waste of time and other resources.
- Initiate training for a DFMR officer in gathering, transporting, planting and cleaning sponges. This officer subsequently would educate and supervise the farming villagers

how to operate their farms. Well-trained operators from the beginning will encourage the development of the industry.

- Investigate growth rates of farmed sponges under different environmental conditions with the aim of finding the most suitable sites for pilot and (later) commercial farms.
- Establish a marketing chain for farmed sponges.
- Put in place a mechanism whereby world prices for sponges can be monitored so that supply of PNG-farmed sponges can be regulated to ensure best prices are obtained and also that correct returns are made to growers.
- Protect the industry (when established) by prohibiting a) the harvest of sponges by non-farmers and b) the direct sale of wild stocks (as/for cut sponges) (Wilkinson, 1989).
- Prohibit the translocation of sponges from one atoll (or region) to another because of the risk of introducing (transplanting) exotic organisms. Hence sponge farming can only be undertaken when there is sufficient parent stock in a local area. Thus the combination is: enough seed stock + permitted farming space (as well as the usual matters of finance, transport...).
- Ensure that any sponge fishery is based only on regenerated sponge tissue. Wilkinson (1989) pointed out that because tropical sponges have a slow growth rate and exhibit low recuitment they cannot be exploited directly for commercial harvest. This has happened in the Philippines (Wilkinson, 1989) where production declined from 74 mt in 1980 to 10 mt in 1986 (Josupeit, 1989).

In conclusion, I consider that a sponge fishery could be feasible in PNG but it is better to wait until the technology and returns have been proven in other Pacific nations. Indications are that prices are not going to decline for many years. During the intervening period, *properly conducted* surveys of sponge resources could be undertaken in PNG - whenever resources are available.

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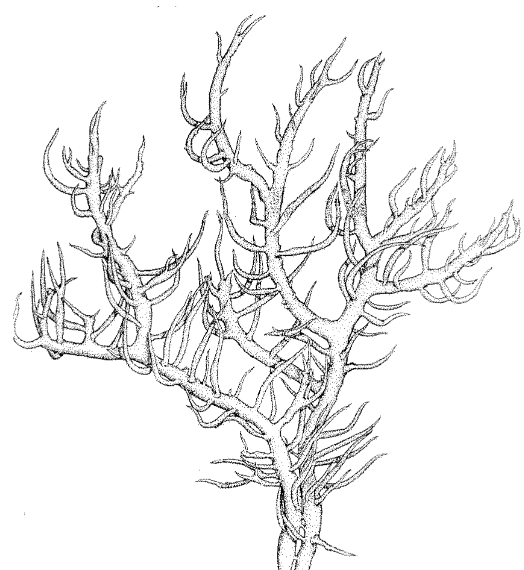
2.23 COMMERCIAL SEAWEED

2.23.1 The Resource


Eucheuma sp.

Species present: Seaweeds are algae. Algae are simply constructed plants with very diverse morphologies (South, 1993). Seaweeds include those algae normally growing attached to the substratum in marine benthic habitats and having an apparent plant body. They comprise four main groups: blue-green, green, brown and red algae (South, 1993).

The taxonomy of economically important seaweeds is difficult (South, 1993) mainly because it is based on morphological characteristics which are substantially modified by habitat. Field identifications of seaweeds are often inaccurate. There is a general lack of identification keys for western Pacific taxa, although several hundred species are recognised in the region (South, 1993). However, systematic studies continue and there have been recent taxonomic papers on economically important Pacific seaweeds - e.g. by Abbott (1988, in South, 1993) and Abbott *et al.* (1991). The importance of accurate identification of seaweeds was pointed out by Abbott *et al.* (1991), who stated that various properties of agars (e.g. in *Gracilaria*) vary with the species, thus affecting the market value of dried seaweed and the subsequently extracted colloids.

The only significant commercially important seaweed resource in the South Pacific is the red seaweed, *Eucheuma*, of which the main cultivated species if *E. alvarezii* (the 'cottoni' of industry - South, 1993). *Eucheuma* is an often cultivated genus (culture stock originating from outside the region). The main kappa carrageenan producing species (*E. alvarezii* and *E. striatum*) have been re-classified in the genus *Kappaphycus* (South, 1993).

Red algae of the genera *Gracilaria, Eucheuma* (not of use in commercial production - South, 1993) and *Hypnea*, and the green alga (or sea grapes) *Caulerpa* have been recorded from PNG (U. Kolkolo, pers. comm.).

Distribution: Seaweeds are found world-wide in shallow water, and are most diverse in temperate latitudes. Many tropical genera and species tend to be widely distributed.

There is no information on the abundance and distribution of seaweed taxa in PNG, although it is believed that - as with other tropical Pacific environments - the country's reef habitats, moderate currents, clear water and areas of shallow banks provide ideal habitats for a number of red, brown and green algae. Kolkolo (1992) indicated potential growing areas in PNG for *Gracilaria* (south-western PNG provinces) and *Eucheuma* and *Kappaphycus* (Milne Bay Province, Manus Province, East New Britain, West New Britain and New Ireland provinces).

Cultivated *Eucheuma* is raised in the Philippines, and is being farmed in a number of Asia-Pacific countries. *Eucheuma* is distributed from the Indian Ocean to the Western Pacific.

Biology and Ecology: The complex life histories and reproductive strategies of tropical seaweeds are generally poorly understood. In the tropics, seasonal growth and reproductive phenomena occur, although not always as markedly as in cooler regions. Tropical seaweeds are subjected to heavy grazing pressures, particularly from herbivorous fish such as rabbitfish (*Siganus* species) (South, 1993). Kolkolo (1992) reviewed the biology and ecology of *Gracilaria, Eucheuma* and *Kappaphycus*, and *Caulerpa*.

2.23.2 The Fishery

Utilisation: Tropical seaweeds have long been utilised by man as food, medicines, ceremonial objects and for ornaments (Smith, 1993). In Fiji, five genera of local seaweeds are widely eaten (Lewis, 1985): *Caulerpa, Hypnea, Gracilaria, Codium* and *Soleria*. The seaweeds are gathered, washed and used as a vegetable. The green alga *Caulerpa* is used as a fresh vegetable by PNG coastal villagers. There is no information on the subsistence use of other seaweed taxa in PNG (Kolkolo, 1992).

Seaweeds produce colloids which are water-soluble carbohydrates or gums. They occur in seaweeds as part of their structural components - together with cellulose - and so form an appreciable proportion (20-30 per cent) of the dry weight of seaweed. Also known as phyco-colloids, colloids are used as thickening agents for a wide range of products in a variety of industries.

Commercially important seaweed colloids are the agars (derived from red seaweeds, Agarophytes), carrageenan (derived from red seaweeds, Carrageenophytes) and alginates (derived from brown seaweeds) (Richards-Rajadurai, 1990).

Species of *Gracilaria* have considerable potential in aquaculture as well and are valuable sources of phyco-colloids. Other taxa farmed in the Philippines (Llana, 1991) are *Caulerpa* and *Enteromorpha*.

Eucheuma seaweeds are cultured commercially for the production of a colloid known as carrageenan. *Eucheuma* accounts for 80 per cent of the world supply of carrageenan (Neish, 1990, in South, 1993). *E. alvarezii* has a particularly high content of a type of carrageenan known as kappa-carrageenan. Nearly all of the world demand for this colloid is in the food industries of developed countries, where it is used as a suspending, stabilising, thickening and gelling agent in the food manufacturing industry, other industries and pharmaceuticals. There is an increasing use of semi-refined carrageenan (which is simple to produce) and a natural grade carrageenan product developed in the Philippines.

South (1993) listed the optimal conditions for the successful growth of *Eucheuma*.

Methods of farming *Eucheuma* have been well documented (Prakash and Foscarini, 1990, in South, 1993; Llana, 1991; Kolkolo, 1992; South, 1993) and three principal methods are employed in the South Pacific. All involve tying cuttings of seaweed onto lengths of monofilament lines at regular intervals.These methods are:

- the off-bottom method, where the lines are stretched between stakes driven into the substratum (recommended farm size is 300 lines);
- the floating raft method, where the lines are stretched between frames anchored on the seabed; and
- the longline method wherein the lines are stretched between floats, with anchors at each end.

Harvesting takes place every 8-10 weeks. The seaweed plants either are removed from the lines or pruned back. After maturing, the seaweed is sun dried for 3-4 days until moisture is reduced to at least 35 per cent and then it is packed in bags.

Production and Marketing: The major culture area for *Eucheuma* seaweed for carrageenan extraction is Taiwan, Philippines and Indonesia. Approximately 17,000 mt of carrageenan and 7,000 mt of semi-refined product were produced worldwide in 1989 (Smith, 1992).

Cultivation of *Eucheuma* in the South Pacific has attempted to emulate the industry in the Philippines, where *Eucheuma* has become an important fishery export. The Philippines produced 268,701 mt of fresh seaweeds in 1989, of which 240,700 mt were used for carrageenan processing (Llana, 1991). Indonesia produced an estimated 9,000 mt of fresh

Eucheuma seaweed in 1988 (Richards-Rajadurai, 1990). South (1993) listed the South Pacific countries where cultivation or trials have been attempted. In 1990, 287.4 mt of *Eucheuma* were produced by three of these countries.

In Fiji the industry has fluctuated, although seaweed growing there has been shown to be technically feasible. Production increased over the first three years of operation (1985-87), peaking at more than 200 mt/yr in 1987; but from then, production fell off to be little more 50 mt in 1992. Since 1985, five organisations have been successively involved in marketing dried seaweed from the Fiji industry (Richards *et al.,* 1994) which has been affected adversely by weather and marketing difficulties. The seaweed cultivation industry has been most viable in Kiribati although individual farms vary in their success, plants have been subject to disease, there has been adverse weather, human interference and marketing difficulties. Recently begun farming in Solomon Islands has seen small production, grazing of the seaweed by rabbitfish (*Siganus* species), inefficiency of small farms and disinterest by buyers. Farming trials in Tonga and Tuvalu have met with limited success (South, 1993) and trial farming in Cook Islands was curtailed with the destruction of culture lines by a cyclone (Richards, 1993). Federated States of Micronesia is expanding its commercial *Eucheuma* growing.

2.23.3 Stock status

There is no information on natural seaweed stocks in PNG, and no seaweed cultivation is taking place. South (1993) recommended that a comprehensive study be undertaken of edible seaweed resources in Pacific islands to determine their extent and market value, and the effects of harvesting on sustainability and the environment.

2.23.4 Management

Current legislation/Policy regarding exploitation: Kolkolo (1992) recommended that research was necessary to determine the abundance and distribution of commercially important seaweed species in the country. The technical and economic feasibility of mariculture of such species should also be investigated.

Recommended legislation/Policy regarding exploitation: Lewis (1985) and South (1993) recorded advantages of seaweed farming in tropical countries. It is low technology and the required capital is small. It can be operated as a family business and could be a useful income supplement in the subsistence sector of the community. It is compatible with traditional fishing and subsistence use of the foreshore and has little environmental impact.

Even given the above, I do not recommend that seaweed farming be commenced in PNG in the forseeable future. The reasons for this statement are:

- there is almost no information on seaweed species already growing in PNG. This information - including biology, ecology, taxonomy and distribution - would be required before a decision on what seaweed taxa to raise and where, could be made. The resources of time, money and personnel required to gather this information would be considerable and the wisdom of their use questionable in view of the uncertain commercial success of seaweed farming in PNG.
- Although seaweed farming *per se* appears to be simple, it carries a number of disadvantages and problems - as revealed by farming attempts in other western Pacific countries (see earlier). And there is no reason to believe that if PNG were to embark on a program of seaweed farming development that it could obviate all of these issues. They include:

  - the effects of weather (cyclones, strong winds, heavy rains, seasonally low water temperatures);

  - marketing difficulties;

- political and/or economic instability;

- rabbitfish (*Siganus* species) grazing;

- plant disease (e.g. fungus) and fouling;

- conflicts between user groups of the farming site;

- farms being too small, so making seaweed farming uneconomic on an individual farm basis; and

- insufficient supplies of seedstock.

- Costs of initial training and supervision of seaweed farm(er)s would be considerable, not to mention that of follow-up counselling and travel. A surer commercial measure of success now with more immediate returns, would be to deploy staff on industries such as mangrove crabs, collector shells and nearshore tunas.
- Transport, marketing and quality control issues would be heightened in PNG because of the size of the country and its lack of frequent direct trade routes.
- Traditional ownership. How would these apply to a farming activity conducted in a community's common foreshore? Further, Lewis (1985) pointed out that as seaweed is not a fish, customary rights may not apply [in Fiji] and may need to be redefined. Such redefinition would require extensive consultation and legislation, costs attendant.
- Although world demand for seaweed colloids is said to be increasing, world prices and currency fluctuations can be expected to affect the commercial gain from the industry. PNG has not demonstrated in other established fisheries (e.g. trochus) that it can monitor world fish commodity markets and effectively act as a buffer between production, price fluctuations and the grower (harvester).

Richards-Rajadurai's (1990) appraisal of the development needs of seaweed farming in the Asia-Pacific region are worthy of note:

1. simplify distribution of product;
2. increase market acceptability;
3. raise returns to growers;
4. monitor international markets and prices so as to control production and keep a tab on price fluctuations;
5. ensure there is not a glut of farms in your own country (->lower prices and quality);
6. organise growers into a cooperative? (-> seller, credit facilities);
7. distinguish different aspects of the domestic industry: eg agar v. carrageenan production;
8. expand domestic markets and import technology (-> reduce dependence on foreign markets);
9. give more attention to quality control in harvesting through semi-processing stages;
10. select species for higher growth rates, colloid yield and quality;
11. develop polyculture - e.g. seaweed + prawn farming. This can reduce the effect of crop and/or market failures; and
12. cut or prune but do not pull out plants from natural seaweed beds (->resource sustainability).

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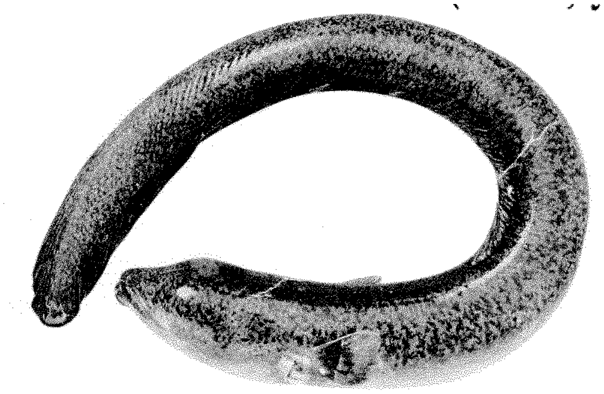
3.1 FRESHWATER EEL

3.1.1 The Resource

Species present: Six species of freshwater eel of the genus *Anguilla* are known from PNG (Kailola, 1987). Two of these - *A. reinhardti* and *A. megastoma* - are present in the outer islands. *Anguilla bicolor pacifica* and *A. obscura* are short-finned eels and *A. marmorata, A. megastoma, A. reinhardti* and *A. interioris* are long-finned eels.



Anguilla marmorata

Distribution: *A. marmorata is* recorded from the Indo-Pacific at least as far east as Fiji (Lewis, 1985) and *A. bicolor pacifica* is said to have an Indo-Pacific distribution as well. *A. obscura* ranges from West Irian to Tahiti (Ege, 1939, in Jellyman, 1991). *A. megastoma* belongs in the Pacific and does not extend further west than the Solomon Islands. *A. interioris* may be endemic to PNG. *A. reinhardti* also occurs in eastern Australia as far south as Victoria (Hall *et al.,* 1990 in Kailola *et al.,* 1993).

In the Sepik-Ramu river system only *A. bicolor pacifica* and *A. marmorata* have been recorded. *A. bicolor pacifica* and *A. marmorata* are the only species in the Sepik-Ramu river system found above 1000 m (van der Heijden, 1993a) This is their major adult habitat. They also inhabit the Sepik-Ramu floodplain. On the floodplain they inhabit rivers and creeks with muddy and silty substrates, and at high elevations they occurs in clear, fast-flowing streams over bedrock and sand (van Zweiten, 1990).

To the south of the Owen Stanley Ranges, *A. bicolor pacifica, A. marmorata* and *A. obscura* have been recorded, and *A. interioris* inhabits highlands and delta areas of the Purari River (Haines, 1983). Residents in the Upper Purari reported eels to Povlsen (1993a) from a small tributary (1,480 m altitude, 15°C) of the Dunantina River south of Henganofi village and from Kora Creek (1,560 m altitude, 14°C). Freshwater eels inhabit the Fly River, Lake Murray, the Oriomo River (Roberts, 1978) and most coastal and inland rivers and lakes (B. Shackles, pers. comm.), especially the Aramia River system.

Biology and Ecology: When mature, adult eels put on fat, become silvery in colour and migrate down the rivers to spawn in specific localities far out to sea. The oceanic spawning areas are usually in/over very deep waters. The leaf-like larvae (leptocephali) drift in regular ocean currents, changing to a more eel-like shape as they approach land. Known as glass eels, they drift with the tides into estuaries, gradually becoming pigmented brown elvers which actively migrate upstream into fresh water.

The elvers migrate upstream in shoals, and the stimuli for the migration appear to be environmental cues. Increased water flow, generating a rheotactic response from the elvers, may also be a factor contributing to the migration. The annual migration enables small eels to populate all available space along the river and the upstream waters. Each group is of about the same size and may be joined by larger elvers of young eels as they progress upstream (Jellyman, 1977). J. Glucksman observed (DFMR file, 1979) that the shoals of elvers in the lower Sepik were accompanied by small eels up to 33 cm total length and 35 g. Because several age classes are usually involved in the mass migrations, the age of elvers/juvenile eels increases with distance from the sea (Sloane, 1984, in Kailola *et al.,* 1993).

The shoals become smaller as individuals remain in suitable areas encountered en route. Juvenile eels are found throughout the Sepik-Ramu system, including highlands streams. Many eels spend their first year in freshwaters of the upper estuaries, in the lower reaches of rivers or in tidal areas. Often several separate migrations of elvers take place, the elvers moving in waves.

A. bicolor pacifica seems to migrate upstream in the main Sepik River channel between January and March. No data on the migration of *A. marmorata* is available (van Zweiten, 1990) although it may be somewhat later than the *A. bicolor pacifica* run. The elver run - originating from downstream - coincides with the wettest period of the year (DFMR file) and is usually between March and April (J. Glucksman, DFMR file). The 'run' of 2.5-7.5 cm long elvers continues for 2-3 weeks. The eels hug the banks, extending as far as 3 m towards the centre of the river. Glucksman estimated that the eels moved at a rate of 7 km/day against a current of about 6 knots.

The eels live and grow for many years in the freshwaters and in this period they are known as yellow eels or brown eels. Most eels within a population exhibit localised movements within a home range (Boseman *et al.,* in Jellyman, 1991). It is possible that most eels inhabiting fresh water mature as females: this is the case in the two species inhabiting Australia's east coast (Hall *et al.,* 1990 in Kailola *et al.,* 1993). The life cycle continues with the maturation of adult eels and their migration downstream as silver eels (Lewis, 1985) at the end of the dry season. The adult eels, 30-130 cm long, migrate downstream at the start of the wet season (October-November) travelling in the centre of the river. Silver eels do not feed; and they probably die after spawning (Beumer, 1987, in Kailola *et al.,* 1993).

No 'spectacular' (Haines, 1983: 370) upstream elver migrations take place in the Purari River system. Adult eels are present throughout the Purari River system.

3.1.2 The Fishery

Utilisation: The eels are consumed either fresh or smoked (usually smoked in the lower Sepik: J. Glucksman, DFMR file). On the whole, *Anguilla* are preferred as a food by inland national residents because of their high fat content (Coates, 1989; Mys and van Zweiden, 1990). In the upper reaches of the Sepik-Ramu river system they are the most important native fish consumed. People in the upper Sepik-Ramu eat approximately 1 kg of eels per year; the amount consumed in the upper Purari is probably lower (Povlsen, 1993b). *Anguilla* are 'taboo' to followers of the Seventh Day Adventist faith in Sepik-Ramu area (at least); and they are taboo to pregnant and breast-feeding women in upper Sepik villages. In some villages (of the upper Sepik), eels are considered to be 'men's food' (Povlsen, 1993b).

Overall, eels are important in the Highlands region and they used to form part of the bride price in some areas of the Western Highlands (A. Richards, pers. comm.). They are a highly desired food and have ceremonial significance in the Southern Highlands Province (Haines, 1982; Haines and Stevens, 1983). In the Southern Highlands, freshwater eels are the only fish harvested traditionally.

In the highlands sections of the Sepik-Ramu rivers system there is an extensive trap fishery for *A. bicolor pacifica* and *A. marmorata* (van Zweiten, 1990) where they are fished with special eel traps. They are also caught traditionally with traps in the Simbu Province (Opeari, 1983).

From the annual eel run in the Sepik River, national fishers spear the small eels (c. 25-33 cm long) but eat only a small proportion of the elvers (J. Glucksman, DFMR file). Eels are also caught with small-mesh scoop nets in the Sepik. In Yengis village on the upper Sepik, eels are fished by men using traps. The traps are lifted once or twice a week; and in Yenkis (1000 m altitude) the subsistence fishery is based entirely on the two *Anguilla* species there (Mys and van Zweiten, 1990). Of 27 villages in the Sepik River surveyed by Mys and van Zweiten (1990), *A. bicolor pacific* occurred in 100 per cent of their waters and *A. marmorata* occurred in 96.2 per cent. These two species were the most preferred to be eaten (88.5 per cent and 80.8 per cent respectively by respondents to a questionnaire).

In the upper Purari, eels are caught occasionally in several places, and in many higher altitude areas they are or were the only fishery resource. Traditionally the eels were caught in traps made of different kinds of bush material (Haines and Stevens, 1983) but now hook and line is taking over, only some older folk knowing the art of using eel traps (Povlsen, 1993a).

Production and Marketing: From lower order (c. 40-400 m altitude) streams of the Sepik-Ramu system, *A. bicolor pacifica* comprises on average 22.3 per cent by weight of the annual total catch and 1.3 per cent by number. *A. marmorata* comprises 90.3-100 per cent of total catch by weight and 2.1-100 per cent by number (van Zweiten, 1990). In high altitude (c. 600-1600 m altitude) sections of the river system, *A. marmorata* comprises 27.2 per cent of the annual catch composition by weight and *A. bicolor pacifica* comprises 39.9 per cent by weight. By number of fish caught each year they comprise respectively 9.5 per cent and 21 per cent. At mid-altitude (c. 200-600 m) *A. marmorata* comprises 21.6 per cent by weight and 8.4 per cent by number, while *A. bicolor pacifica* comprises 5.5 per cent by weight and 2.6 per cent by number. They are not caught or in such numbers the lower altitudes (van der Heijden, 1993a).

In 1993, 40 kg of live eels were exported (valued at K160) (DFMR database).

I did not find any other information on eel production and marketing in PNG.

3.1.3 Stock status

J. Glucksman (DFMR file, 1977) calculated that a sustainable yield of eels from the Sepik-Ramu river system was about 900-1,200 mt taken over a whole year based on an estimated Sepik River biomass of 30,000-40,000 mt - a biomass that is now known to be incorrect. Glucksman admitted that the potential harvest would not be realised because of the short unpredicable nature of the elver runs.

In the Western Highlands (A. Richards, pers. comm.), eels are becoming scarce and are rarely caught. At villages in the Upper Purari River system, eel numbers have decreased according to national residents. They believe that the reduction in eel numbers has occurred since the arrival of carp in the streams there (Povlsen, 1993a).

The source of eels in southern rivers is an interesting issue. Neither Roberts (1978) nor Smith and Bakowa (undated) caught eels in the Fly River system despite extensive sampling, and A. Haines rarely caught *Anguilla* in some years of sampling in the Purari - Kikori systems of the Gulf of Papua. Yet B. Shackles (pers. comm.) reported that there are quantities of eel in Fly River tributaries and the Aramia River. No elver runs are reported to take place in southern rivers (see above). Haines (1983) pointed out that the lack of deep water offshore would prevent eels from breeding in Papuan waters - hence no regular source of supply for the rivers. The alternative, he said, was that breeding only occurs off the north coast of the island of New Guinea and further, that for eels to enter the Purari watershed they would have to cross from the Sepik watershed (I understand that there are subterrestrial connections between the river systems.) The eels could possibly also emanate from spawnings in the Coral Sea or the Banda Sea to the west. Interestingly, eel (*A. obscura*) stocks derived from irregular and submarine outfall has been recorded in the Cook Islands (Jellyman, 1991) and Rennell Island in Solomon Islands (Castle, 1968, in Jellyman, 1991). Jellyman (1991) reported on the biology of *A. obscura* in a shallow depression lake in the centre of a southern Cook Islands island, the lake having no surface connection to the sea. His sample of 264 eels ranged from 337 mm to 845 mm in length. Eels are known to live for a long time (to 41 years for *A. reinhardti*: Sloane, 1984, in Kailola *et al.,* 1993). It is probably that freshwater eel populations in island lakes and southern PNG rivers are the result of irregular supply from any of the suggested nominated sources.

3.1.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Lewis (1985) summarised the potential commercial use of *Anguilla* species. He said that:

> "....world-wide, various stages of the eel life-history are fished commercially. As the upstream migrations of elvers are often predictable and involve large numbers of individuals, they can be caught moderately easily at these times and used for stocking eel farms. There is a sizeable world trade in live elvers. Adults are utilised for subsistence purposes as both yellow and silver eels but the high fat content silver eels are in strong demand for smoking. Eels may also be exported live although they have to purged prior to transporting and de-slimed before processing. The international market has a preference for short-finned eels with uniform body colouration."

Some reports say that *preference in international markets* is for the short-finned eels with uniform body colouration. Hence, *A. bicolor pacifica* would be the most acceptable of PNG's anguillid fauna. However, other reports say that long-finned species are the preference - hence, *A. marmorata* would 'get the nod'. In view of the probable market acceptance for one and not the other, <u>information should be gathered</u> *on whether the two eel species comprising the Sepik-Ramu eel run do so concurrently or at different times, and how they can be differentiated at small life stadia*. In the Philippines, *A. celebensis* and *A. marmorata* glass-eels are present at the same time in estuaries (Tabeta *et al.,* in Jellyman, 1991).

There is periodic interest in harvesting eels in PNG and selling them on the Australian and Asian markets. Enquiries have come recently from a fish farmer at Moruya, NSW (Papuan eel stocks), another in Brisbane, and Intero Pty Ltd or Kawana Waters, Qld (Sepik eel stocks). <u>Exporting live eels to Australia would be unsuccessful</u> because:

1. of quarantine restrictions; and these could also apply for chilled and smoked product;
2. Australia produces its own eels and exports them - live, chilled and smoked.

The Sepik-Ramu annual eel run has always interested would-be marketers. Even in the mid-1970s a Japanese company investigated its potential to supply live elvers to the Asian market (DFMR file). The problems they identified largely remain:

1. selective harvesting of desired sizes for individual markets could not be done;
2. *clean water for purging and for washing was not easily available*: the river water is very turbid and introduces disease risk;
3. there were *inappropriate freezing and transport facilities*.

The wet season elver migration and the dry season adult migration in the Sepik-Ramu river system are short. Two different markets would need to be available for them, and there are difficulties in securing and supporting seasonal markets - particularly for the elvers. The adult eel market could be extended with the aid of holding ponds. The supply would have to be supported by large amounts of fresh, sanitary water and good freezing and chilling facilities. Some markets may require delivery of a live product: servicing this via small ports or tiny aircraft supplied by artisanal fishers would be very difficult. Transport costs from northern PNG are inhibitive and there is a question over whether the product would be handled properly en route. Currently, export produce travels by air to international markets through Port Moresby. After purging, eels can be air-freighted successfully in a small amount of water at a chilled-down temperature of about 15°C.

Specialist markets exist for freshwater eels in Europe and Asia. In Australia, live eels fetch about A$8-10/kg. Price is dependent on size, colour and species. Wholesale prices for smoked headless and gutted eels is about A$11/kg.

Sepik elvers are most abundant and accessible from about March to April, and before they reach the Keram River mouth (approximately 10 km upstream from Angoram). *Theoretically*, a wild harvest fishery of elvers would be most successful if it were concentrated on this area, at this time. Large quantities of elvers and small eels could be retained in holding ponds and air-freighted to markets (or to grow-out ponds: see later). Eels can be caught with the traditional traps, or with fyke nets. Fyke nets are used almost exclusively in Australia (Kailola *et al.,* 1993) and Solomon Islands (SPC Newsletter #42, 1986) to harvest eels.

Information should be gathered on the age structure of eels in the southern rivers with a view to determining the origin of the eels. Sampling and stock assessment of reported areas of abundance should be performed before instigating a fishery for those eel stocks.

No management of eel stocks is suggested at this time. Depending on whether fisheries establish, and what form they take, restrictions may have to be implemented - such as bringing in licences and specifying gear types. If reports of eel quantities in Papuan rivers are correct, the fishery would be a 'fish-down' one in the first instance. Any fishery should be developed in tandem with monitoring, biological studies and stock assessments.

There are three ways in which to utilise *Anguilla* stocks in PNG. The first two of these - *wild harvesting* and *aquaculture in the form of holding pens* - have been discussed above. These methods are mainly directed at domestic and overseas markets. For hygiene, quality, supply and freight costs the overseas markets are probably unavailable.

The third way is *aquaculture with a view to restocking Highlands streams or/and (better still, in light of the dubious identification of eel stocks in the different watersheds) providing fresh or smoked eel to national consumers.*

- Eel farming has been practised for years with minimal costs in many countries: are the skills needed and facilities too difficult to obtain/apply in the PNG Highlands region? The farming would be simply 'grow-out' ponds - stocked from the elver runs of the Sepik-Ramu system. The ponds would have to be continually stocked.
- Another advantage in farming *Anguilla* in Highlands areas is that they are not exotic species - cf the FAO/UNDP current Sepik/Ramu River Stock Enhancement Project which targets introducing exotic species to PNG streams and rivers. Ten years ago, Alan Haines suggested restocking. He (1982) reported that in other parts of the world, the direct introduction of elvers to supplement natural migrations has improved production in inland waters - and that the eel harvest is largely determined by the rate of stocking (Leopold, 1980, in Haines, 1982).
- Yet another advantage is that Highlanders (and other inland PNG people) are familiar with *Anguilla* - indeed, are staunch supporters of it: it is preferred above many native fish because of its high fat quantity (8 per cent of respondents around Yonki Reservoir prefer it above all other fish, rising to 88 per cent of respondents in the Sepik-Ramu system: Mys and van Zweiten, 1990; van der Heijden, 1993b). The traditional importance of eels already has been mentioned.
- Smoking the eels would obviate the need for refrigeration and is an accepted form of fish preservation in PNG - e.g. eels and elvers from the Sepik runs are offered smoked at local markets along the river (J. Glucksman, DFMR file). A small additional market could be obtained by selling smoked eel in domestic restaurants and hotels.
- Earlier studies at Angoram have successfully investigated the possibility of catching elvers and transporting them to inland waters to either establish new stock or boost existing stocks. Small mesh nets were found to be effective.

In summary

1. investigate the species composition and seasonality of the annual Sepik-Ramu eel run;
2. investigate ways of increasing domestic marketing of eels;

3. concentrate on aquaculture (first) and wild harvesting to supply the domestic market;
4. restock rivers and streams with farmed eels.

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3.2 CARP

3.2.1 The Resource


Cyprinus carpio

Species Present: Three strains (Golden, Cantonese and Mirror) of common carp, *Cyprinus carpio*, were introduced to PNG in 1959 (West and Glucksman, 1976). Cantonese and Golden carp survived in ponds in the Eastern Highlands and Western Highlands. These varieties were also introduced to Wewak, East Sepik Province (none survived) and Simbai in the Madang Province.

Distribution: Carp are very widespread in the Highlands (Povlsen, 1993). This is partly due to the distribution of fingerlings by the national government's Highlands Aquaculture Development Center (HAQDEC) at Aiyura (Eastern Highlands Province) to pond farmers all over PNG - including Highlands areas - and also because the species has the capacity to extend its range.

Carp have escaped from ponds in the Highlands and in the lower Sepik River. Carp escaped from the ponds at Simbai during flooding (West and Glucksman, 1976) and reasonable populations of Cantonese variety carp were well established in the Keram River and the Sepik River at least from upstream of Angoram to Marienberg 20 km downstream by 1982 (Makis, 1982; Ulaiwi, 1992). Carp exhibit an affinity for shallow, recently flooded areas and are also influenced greatly by flood conditions, e.g. on the Sepik-Ramu floodplain.

Carp are also present in the southern drainage of the Owen Stanley Ranges. They were stocked in the Strickland River in the early 1960s and 1970s and also in the Fly River. Stocks in the Purari River are the result of pond escapes (P. Sagom, pers. comm.). Povlsen (1993) recorded carp from a small stream and Kurungka Creek, both tributaries of the Dunantina River south of Henganofi village (1,480 m altitude), and in the Sokozoi River, a tributary of the Asaro River (1,440 m altitude).

There are carp in Waigani swamp, Kempwelch River and other waterways in Central Province (they were stocked in some of these waterways by DFMR in the 1970s and later).

Biology and Ecology: Carp in the Sepik River prefer shallow areas of lakes and inundated floodplains. Only larger (>15 cm standard length, SL) carp are found in water depths of more than 2 m: most prefer 0.9-1.2 m water (Ulaiwi, 1992). Growth and maturity are influenced by factors such as food availability and water temperature: whereas in temperate waters spawning is seasonal, in tropical waters it is year-round - albeit spawning activity is highest in the dry season (low water period, July-October in the Sepik River). Additionally, they mature in 3-12 months in the tropics compared with 2-4 years in temperate climates (Hume and Pribble, 1980). Carp are freshwater spawners with a very high fecundity (Coates, 1989). In Sepik River mature female carp the fecundity averaged 72.6 eggs/g body weight, and there is a 1:1 sex ratio. Carp maintain a high condition factor all year in the Sepik. They are opportunistic and omnivorous in their diet (e.g. detritus, aquatic plants and benthic invertebrates, seeds).

Spawning occurs in shallow (less than 2 m) water. A 0.9 kg female can produce 100,000 eggs while a 4-5 kg female can produce 1 million eggs (Kailola *et al.,* 1993). The eggs are demersal and adhere to the substrate and aquatic plants. Growth rates of carp vary with temperature and food availability. In Australia carp probably live for 20 years, grow to 85 cm total length and to a weight of more than 15 kg (Kailola *et al.,* 1993).

European carp are active swimmers and can leap obstacles up to 1 m high and negotiate torrential flows (Merrick and Schmida, 1984, in Kailola *et al.,* 1993). These traits surely facilitate its spread in PNG. In the lowland Sepik River basin, carp spread 40-60 km a year (Ulaiwi, 1992).

Carp prefer cooler water temperatures and are more abundant in Highlands waterways. At lower (c. 80-120 m) altitudes of the Sepik-Ramu river system, carp comprised an average 11.4 per cent of the total catch by weight and 0.7 of the total catch by number (van Zweiten, 1990).

3.2.2 The Fishery

Utilisation:

Wild fishery:

Carp are caught with hook and line with aquatic insects as bait or with spears in the upper Purari (Povlsen, 1993). They are also caught with *Derris* root - for example, in the Wahgi River. Carp are also dived for using mask and snorkel in the Asaro River, Simbu Province), and are caught with hook and line at Yonki Reservoir (van der Heijden, 1993b). Gillnets are often used in lower altitude reaches of the Sepik-Ramu river system.

Carp are generally consumed fresh and they are sometimes made into `solpis' (sun-dried, hard-salted fillets) in the Sepik River.

Aquaculture:

Except for limited trout production, carp is the only fish aquacultured in the Highlands in PNG (Kovari, 1986).

The fish culture program began in about 1954. Ponds were constructed at Aiyura (where the elevation is 1,670 m) aimed at carp fingerling production. Carp farming was also carried out in the early years by mission schools and some private enterprises. After a drop in interest and a series of failures in village carp farming ventures in the 1970s, the Aiyura farm was re-established in the early 1980s with the intention of undertaking training courses, a pilot farm, an integrated fish and livestock project and a carp fingerling and distribution system. Problems identified in the earlier failure of carp farming (e.g. lack of infrastructure, expense of fingerlings and fertilizer and lack of extension and training) were intended to be addressed by the facility. Experiments on suitable feed for carp fingerlings were conducted at Aiyura in the 1980s: they revealed that sweet potato produced the highest yield in the fingerlings. Trials were also conducted on the sutability of various fertilisers for ponds.

Nowadays, carp fingerlings are supplied upon request from the Highlands Aquaculture Development Centre (HAQDEC).

Production and Marketing: According to Povlsen (1993) carp is the most important species (quantitatively) for fisheries purposes in the Highlands. Carp are commonly sold by the roadside by women and boys in Highlands areas - either the product of harvesting from farm ponds or from Yonki Reservoir and natural waterways.

In the high altitude (c. 600-1600 m) section of the Sepik-Ramu river system carp comprise 31.8 per cent of catch by weight and 46.1 per cent by number of the estimated total annual catch. At mid altitude (c. 200-600 m) the comprise 6 per cent by weight and 2.5 per cent by number; and at low altitude, they comprise 13.1 per cent by weight and 8.1 per cent by number. Van der Heijden (1993a) calculated that an estimated 42.1 per cent (= 3,436.43 mt) of the catch from the Sepik-Ramu per year is of tilapia + carp.

In a recent survey, the average size of carp harvested in 25-125 mm mesh gillnets in the Sepik was 26 cm SL (range 21.5-30 cm SL) (Ulaiwi, 1992). Catches vary seasonally, being higher in the dry season (low water, May to October).

Dietary preferences are evident among consumers. Carp are preferred as food by 3.4 per cent of 27 Sepik-Ramu river system villages responding to a questionnaire (and was the 10th most preferred fish) (Mys and van Zweiten, 1990) yet 57.95 per cent of questionnaire respondents at the Yonki Reservoir preferred carp above other fish in the reservoir, inlcuding tilapia (van der Heijden, 1993b).

Distribution of carp fingerlings from Aiyura recommenced in December 1983. In 1984, DPI recorded that 4,735 fingerlings were distributed.

Table 145 Distribution of carp fingerlings from the Aiyura fish ponds during 1984 (source: Fisheries Research annual report for 1984)

Province	Eastern H'lands	Western H'lands	Southern H'lands	Simbu	Madang	Morobe	Central
Quantity	692	980	1,200	123	600	140	1,000

(The alternative figures given in the Fisheries Research annual report 1985-1991 are probably incorrect.)

Table 146 Distribution of carp fingerlings from Aiyura for the period 1985 to 1990 is as follows (source: Fisheries Research annual report for 1985-1991)

Province	Year 1985	Year 1986	Year 1987	Year 1988	Year 1989	Year 1990	Total
Eastern H'lands	1,147	2,962	4,601	3,091	3,251	8,557	**23,609**
Western H'lands	1,865	6,150	315	40	8,024	10,240	**26,634**
Southern H'lands	174	1,600	none	1,520	4,220	3,020	**10,534**
Simbu	85	500	150	1,894	340	none	**2,969**
Enga	150	600	none	none	none	none	**750**
Nat.Cap. Dist.	none	1,200	none	none	none	none	**1,200**
Western	none	none	none	none	1,000	1,012	**2,012**
East Sepik	none	none	none	175	none	none	**175**
Central	none	60	none	13	none	none	**73**
Milne Bay	none	40	none	none	none	none	**40**
Madang	290	500	100	2,000	2,000	none	**4,890**
Morobe	1,320	4,002	1,126	1,717	3,944	13,900	**26,009**
Total	**5,031**	**17,614**	**6,305**	**10,437**	**22,779**	**36,729**	**98,895**

There is an estimated total demand for carp fingerlings of 100,000 each year (Fisheries Research annual report for 1985-1991).[1]

3.2.3 Stock status

Several recent authors (e.g. Coates, 1989; Ulaiwi, 1992) have surmised that, as with tilapia (*Oreochromis mossambicus*), the success of carp in the Sepik River may be because of access to reported `underutilised niches'. However, its history and capacity for successfully invading waterways in other countries does not necessarily support that premise. Ten years after the introduction of carp to the Sepik-Ramu, Ulaiwi (1992) reported or observed 'no negative effects' of their establishment.

[1] I have no information on distribution or production of carp fingerlings for the years 1991-93.

Interestingly, an inverse relationship exists between carp and tilapia in the Sepik-Ramu river system and in Yonki Reservoir. Both species favour similar habitats. This relationship is outlined below.

- Whereas tilapia formed 30 per cent of the catch from lower Sepik markets in 1983, their condition had dropped off and they formed only 16 per cent of the catch in 1992; *cf* carp were hardly present in markets in 1983 but formed 8.5 per cent of the catch in 1988-89 (Ulaiwi, 1992). The same relationship is demonstrated in average catch rates: over sequential fishing days carp dominate initially, followed by tilapia.
- In early 1992 in Yonki Reservoir, tilapia (*O. mossambica*) and carp comprised the total catch. Redbreasted tilapia (*O. rendahli*) were introduced to the Upper Ramu River in the second half of 1991 and by July 1992 they were represented in catches in the reservoir. In September-October 1992 an additional 28,000 fingerlings of redbreasted tilapia were stocked in Yonki Reservoir. The interaction of the three species in the reservoir may be indicated by the relative percentage of species in catches: the percentage of carp in the total catch from Yonki Reservoir decreased from 84 per cent in February 1992 to 17.4 per cent in December 1992; of *O. mossambicus* from 16.3 per cent in February 1992 to 56.5 per cent in May 1992 to 36 per cent in December 1992; and of *O. rendahli* catches rose from a very small amount in February 1992 to 46.6 per cent in December 1992 (van der Heijden, 1993b). In addition, the average weight of carp caught by fishers in the reservoir fell from about 350 g in February 1992 to about 120 g in December 1992 and the average catch per person per fishing trip fell from 3.8 carp to about 2.2 (van der Heijden, 1993b). (Seasonality in the *O. mossambicus* catches is evident.)

3.2.4 Management

There are reports that carp have negatively affected native fish stocks. In the Upper Purari, carp have reportedly displaced gobies in Kurungka Creek, a tributary of the Dunantina River (Povlsen, 1993) and native eel-tailed catfish from other streams. Based on responses to a questionnaire conducted in villages utilising fish in the Sepik-Ramu river system, 19.4 per cent of respondents in high altitude areas, 30.2 per cent in mid altitudes and 38.5 per cent in lower altitudes believed that carp had decreased the numbers of native species in their catches (van der Heijden, 1993a).

Morison and Hume (1990, in Kailola *et al.,* 1993) suggested that carp have a deleterious effect on the aquatic environment generally.

Nevertheless, the presence of carp in the rivers has - according to Povlsen (1993) - definitely improved fisheries in the area.

The case history of Australia shows that carp in the wild cannot be 'managed'. Nominal management can be implemented in farming activity, but the PNG government's approach is to spread carp as widely as possible - both from the viewpoint of supporting the availability of fish protein in the Highlands and other inlands areas, and of providing a relatively profitable and easy industry for village communities.

Current legislation/Policy regarding cultivation: To supply carp fingerlings on request. Also, to ensure there is a favourable legal framework in the village communities for aquaculture, to facilitate credit assistance, and to maintain research, extension and training programs.

Recommended legislation/Policy regarding cultivation: No change recommended at this stage.

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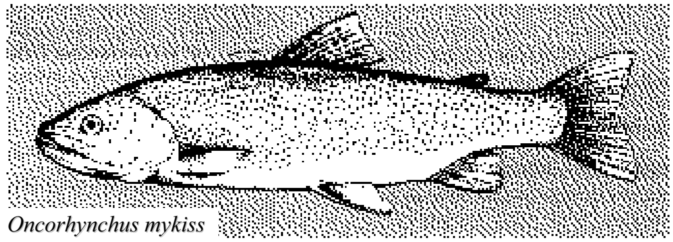
3.3 TROUT

3.3.1 The Resource



Oncorhynchus mykiss

Species present: Rainbow trout (*Oncorhynchus mykiss)* is the only species of salmonid present in PNG fresh waters. Introductions of brown trout (*Salmo trutta*) in 1964 and the early 1970s (Blichfeldt, 1974) were unsuccessful in the long term, although Blichfeldt (1974) reported brown trout in the Nebilyer River (Western Highlands Province) in 1973, and there were reports of brown trout in the Enga Province as late as the 1980s. A release of brook trout (*Salvelinus fontinalis*) from the Mendi hatchery in 1974 was not successful (Coates, undated).

Distribution: Rainbow trout are native to North America. They were first introduced to PNG in 1949 when 20,000 fingerlings were released into the Ahl River at Nondugl and the Waghi River (Western Highlands Province). In 1952, 8,000 trout fry were stocked into the Bulolo River (West and Glucksman, 1976). Stocking continued privately until 1959 and in 1964 the PNG Department of Agriculture, Stock and Fisheries took over the stocking (Povlsen, 1993a). Between 1971 and 1986 the introduction of trout into watercourses was based on fingerlings hatched and reared at two government-operated hatcheries - the Mendi hatchery in the Southern Highlands Province and the Kegesugl hatchery in the Simbu Province. The fingerlings were raised from eyed ova imported from Australia. Trout stocking into river systems was discontinued in 1991[1]. The only recorded trout stocking since 1986 took place in March 1992 with the release of 10,000 fingerlings at Weile Dam, Enga Province (Povlsen, 1993a). Information on recorded rainbow trout introductions in PNG is given by Blichfeldt (1972; 1974), West and Glucksman (1976), Sagom (1989) and Povlsen (1993a).

Based on surveys, Povlsen (1993a) concluded that the lower limit of trout in PNG highlands is 1,760 m altitude. Trout streams in the Highlands are typically fast-flowing streams with rocky and stony river beds and clear water; and usually with no macrophytes growing in them. Trout prefer fast flowing rivers and streams interspersed with deeper pools and/or stretches of slower flowing water (Blichfeldt, 1972). Water temperatures suitable for trout range over 6°C to 15-20°C (Frost and Brown, 1972) and the water temperature range in the Highlands streams surveyed by Povlsen (1993b) was 10°-15°C. Water hardness (a measure of the amount of calcium and magnesium associated with carbonate in water) in Highlands streams is low, averaging 34.2 mg/l. The pH of Highlands streams containing wild populations of rainbow trout ranges between 6.5 and 8 (Sagom, 1989). Frost and Brown (1972) stated that for trout, growth generally is good in 'hard', alkaline waters and poor in 'soft', acidic waters. In the PNG Highlands, the waters are 'soft' and slightly acidic (Povlsen, 1993c).

Povlsen (1993a) stated that large areas of the Highlands which appear to contain suitable habitat for rainbow trout, viz. Western Province, West Sepik Province and East Sepik Province, were never stocked. However, Blichfeldt (1974) noted that between 1971 and 1973, one quarter of a million rainbow trout fingerlings were stocked in Highlands waters from tributaries of the Ramu River to the Sepik River headwaters. Van der Heijden (1993a) considered that rainbow trout are present in some high altitude streams in West Sepik Province and Western Highlands Province although the contribution they make to the annual catch in the Sepik-Ramu river system is probably small (yet unknown). Villagers at Telefomin reported breeding trout from Feramin and Lake Louise, both parts of the Sepik River drainage (Coates, undated).

[1] At time of printing, I have not been advised whether this date is correct or incorrect.

In the northern drainage of the Enga Province, rainbow trout are reported to be in Lake Iviva and nearby streams, and in some streams draining into the Upper and Middle Lai River and Ambum rivers (van der Heijden, 1993a). Rainbow trout are present in the Kandep Lakes (van der Heijden, 1993b) where they are self-sustaining. Wright (1980) caught rainbow trout there in 1979 - seven years after introduction.

A breeding population of rainbow trout has occupied the Kotuni River (Eastern Highlands Province) since about 1956 (Blichfeldt, 1974). Povlsen (1993b) surveyed streams in the Eastern Highlands and Simbu provinces. In the Upper Purari, trout were reported to be present in the Omaigiha Creek, a tributary of the Kutui River (1,840 m altitude, water temperature 13°C), at Mondia Bridge (2,320 m and 10°C), Simbu River (2,320 m and 10°C), Gembogl River (2,320 m and 11°C), Karenda River near Mount Giluwe (2,220 m and 11°C) and Anggura River (1,760 m and 13°C) and Kuragamba River in Simbu Province. All are mountainous, torrential streams, clearwater or slightly turbid. Povlsen (1993a) considered that the trout populations in the Anggura and Kuragamba rivers are self-reproducing, but he made no comment on the Omaigiha Creek trout (which also appear to be self-reproducing). No stocking had occurred in any of the Upper Purari rivers later than 5-6 years earlier than his survey.

Trout are present in streams in the Goilala district (Koisipe and Woitape areas) of the Central Province where they are utilised for subsistence purposes (Tanaka, 1990).

Other river systems where trout are established are noted by Cadwallader (1991).

Biology and Ecology: Trout grow best where the water temperature is about 16°C. They reproduce successfully in clean, running, cold water when it is below that level (Blichfeldt, 1972).

Conditions and water temperatures in most Highlands rivers are close to optimal for the growth of rainbow trout (Blichfeldt, 1974). In addition, there is little competition for food. Growth rates from initial introductions are reported to be very good: Blichfeldt recorded an average weight of 2 kg (largest 4.5 kg) for trout in the Tongo River (Southern Highlands Province?) released 18 months earlier. This compares favourably with the expected growth rates for rainbow trout in North American streams (Blichfeldt, 1972) where, during the first year, trout will increase in body length by about 2.5 mm/month, and by the end of the first year, they will weigh about 0.5 kg. Maximum weight achieved is between 2 kg and 4 kg (5-8 kg in optimal conditions) (Blichfeldt, 1972). Rainbow trout usually have a more rapid initial growth rate than those of other trout species (R. Tilzey, pers. comm.). The trout move downstream as they grow.

Information on wild-harvested rainbow trout caught by Povlsen (1993b) in the Highlands is given below.

Table 147 Biological information from rainbow trout in the Highlands (source: Povlsen, 1993b)

Anggura River			Kuragamba River			Omaigiha Creek		
SL	W	CF	SL	W	CF	SL	W	CF
240	192	1.39	217	166	1.62	182	95	1.58
190	79	1.15	252	275	1.71	221	170	1.57
212	175	1.85	230	199	1.63	216	260	2.58
202	159	1.93	238	202	1.50	230	170	1.40
210	143	1.54	245	239	1.63	208	140	1.57
191	112	1.61	252	258	1.61	223	135	1.22
183	86	1.40	89	13	1.85	194	105	1.44
233	235	1.86	67	5.2	1.72	172	75	1.47
			55	2.9	1.76	172	70	1.38
						102	15	1.41
						88	10	1.47
						73	5	1.29

(Legend: SL: standard length, mm; W: total weight, g; CF: condition factor)

Povlsen (1993a) stated that a condition factor of 1.25 is generally accepted as a satifactory average condition factor for salmonid fish. The average condition factor (1.6) for trout in the sample above shows that rainbow trout in PNG are in very good condition.

No studies have been performed on the production-biomass of salmonids in tropical regions. In temperate or mountainous streams, production-biomass is generally below 60 kg/ha (because they are softwater - acidic - and infertile) (Povlsen, 1993a). Povlsen calculated the production/biomass ratio[2] from the instantaneous growth rate he calculated for the trout tabled above. In Omaigiha Creek (near Goroka) the biomass he calculated was 69.3 kg/ha and in Kuragamba Creek (Simbu Province) it was 46.3 kg/ha. This meant that the production-biomass was 86.6 kg/ha and 57.9 kg/ha respectively. Povlsen (1993a) stated that these figures compare favourably with production-biomass figures for North American studies, probably because in tropical streams there is not a winter 'low'.

Rainbow trout swim upriver to colder, highly oxygenated waters when they are ready to spawn. When a suitable place is found, the female lays its eggs in a depression in the gravel stream bed; the male fertilises them, and the female covers the fertilised eggs with gravel. The eggs hatch after about one month and, as their yolk reserves are absorbed, the young trout begin to feed on small insects. Male trout are usually capable of breeding at the end of their first year, while females normally require two years (sometimes three) before they can produce eggs. Trout breed once a year, and probably live for 5-7 years under local (PNG Highlands) conditions (Blichfeldt, 1972). Blichfeldt (1974) found that most trout matured during their second year, although some matured at only nine months of age.

Gonadal stages of the trout caught by Povlsen (1993b) were: Anggura River (sampled 9 April) maturity stages 1 and 2 (early development) in both males and females; Kuragamba River (sampled 12 September) maturity stages 1-3 (all males) and two stage 5 (running ripe) females caught downstream of the sampling area; Omaigiha Creek (sampled 4 August) maturity stages 1-3 (males and females), one stage 4 female and one stage 5 male. One male trout with running ripe testes was caught by villagers at Omaigiha Creek on 2 August.

[2]The production/biomass is the total elaboration of new tissue in a certain time period divided by the mean biomass of the population over the same time period: Gerking, 1978

Sagom (1989) suggested that spawning of wild trout in PNG occurs between July and September, and Cadwallader (1991) suggested that October-November is the main breeding season, a time when upstream migrations of large trout has been reported. Blichfeldt (1972) believed that May-August was the spawning period. However, local residents at Komea (Southern Highlands Province) reported catching roed females all year round (Povlsen, 1993a) and in the Central Province breeding may occur in May-June (Cadwallader, 1991). Povlsen (1993a) concluded that spawning of wild trout populations takes place in remote, high-altitude streams (above 2,300 m) in very sparsely human populated areas. In the Southern Highlands Province, trout are believed to breed in rivers where the temperature range is lower (10-15°C) than in rivers with a temperature range of 15-20°C where trout occur but do not appear to breed (Cadwallader, 1991).

The stomach contents of the trout sampled by Povlsen (1993b) consisted of 75.4-91.9 per cent (by volume) adult and larval aquatic insects, 0.6-6 per cent terrestrial invertebrates, 2.1-16.7 per cent plant material (e.g. fruits, seeds, plant fragments, fine organic matter) and 5.1-7 per cent of unidentified animal/other material. Differences in the food items between the sites probably reflected the availability of food items (Povlsen, 1993a). The main food items were benthic insects, of which larval caddis flies (Trichoptera) were the most abundant, comprising 30 per cent of all the stomach contents examined. No custaceans, molluscs and fish were found in any stomachs.

Wild populations of rainbow trout in PNG are considered to be free of recognised trout diseases (Copland, 1981).

3.3.2 The Fishery

Utilisation:

Wild fishery:

Rainbow trout are caught with hook and line (Cadwallader, 1991; Povlsen, 1993c) which are bought at local stores. Mainly boys and men go fishing, and baits of aquatic insects, grasshoppers, grubs and worms are used. Many people have become quite skilled trout fishermen. Also, spears are used widely to catch larger trout. Cadwallader (1991) reported that derris root and bilums are used in some areas. There is no trout stocking in rivers nowadays.

Aquaculture:

Initially, trout were introduced to PNG to provide a sportfish, mainly for expatriates. However, from the mid-1970s, trout introductions were made for local people to fish, the result of the PNG Government's drive to alleviate perceived malnutrition in the Highlands. Following the national government funded trout stockings, several Highlands provincial governments set up their own hatcheries.

In 1971 the government-run Mendi (Southern Highlands Province) hatchery received its first shipment of rainbow trout ova. The Kegesugl government trout hatchery in the Simbu Province was established in about 1984. The Mendi hatchery operated until about 1991 (see earlier footnote), while the Kegesugl hatchery closed in 1987 (Coates, undated). Both the Mendi and Kegesugl hatcheries were established for river stocking purposes - by importing eggs from Australia, hatching them and releasing fingerlings.

The first commercial ('private') trout farm in PNG was established on the Omaigiha Creek in the Kotuni area near Goroka (Eastern Highlands Province) in 1970. This in effect was funded by the government through subsidies (Coates, 1989). The Kotuni farm operated until 1984 producing fish for a minority market, and 'never showed a profit and generally a substantial loss' (Coates 1989). The Kotuni trout farm re-opened in 1989 as the Gana Trout Farm, but closed again in about 1990 because of financial problems. In 1991 the Kotuni Business Group Inc. proposed a plan for revival of the farm.[3]

A second private farm, the Nupaha Trout Farm, was established at Goroka in 1989. It was funded by the European Economic Commission and in June 1990 there were reports that it had raised 60,000 trout of marketable size.[4]

A third private farm, the Lake Pindi Yaundo Enterprise trout farm, was established at the foot of Mt Wilhelm in the Simbu Province in 1993 or 1994.[5]

Eyed (fertilised) ova are imported from Australia (either Hume Weir hatchery in NSW, or Tasmania) and hatched, and the young trout are raised to fingerling stage at the farms. Mortality at the Nupaha and Kotuni trout farms is or was high (50-80 per cent) (Masuda *et al.,* 1994). After fingerling stage the fish grow quickly, attaining the harvest size of 250 g in 8-13 months. The trout are fed with pellets manufactured in Lae.

Because trout farms are placed along natural waterways, escapes from farms into the river systems are probably inevitable and have frequently occurred (Coates, undated).

Production and Marketing: Up until 1982 the Mendi trout hatchery raised more than 720,000 trout fingerlings (Sagom, 1989). These were stocked into streams and rivers in the Simbu, Southern Highlands and Enga provinces.

About 25 per cent of trout hatched at the Kotuni farm were released into rivers of Highlands and coastal provinces (Gendua, DFMR files, 1991), the remainder being sold as marketable fish.

The production capacities were about 7 mt a year at the Nupaha trout farm and 25 mt a year at the Kotuni trout farm (Masuda *et al.,* 1994). As the Gana trout farm, Kotuni produced 10 mt of trout in 1989, either as smoked whole, filleted and whole fresh product (Sagom, 1989). Masuda *et al.* (1994) carried out an economic analysis of trout farming in PNG and determined that it costs K5 to produce 1 kg of trout. The financial feasibility of trout farming is, however, dependent on the price of fish and the production capacity of the farm: a trout farm in PNG needs to produce 6 mt of trout a year selling at K7.50/kg if it is to 'break even'.

Wild-caught trout (fresh or smoked) are offered for sale in markets in all Highlands provinces (Cadwallader, 1991). Price depends on size: 250-300 g wild-caught trout sell for K2 (*the same as similar-sized trout sold at the Nupaha commercial trout farm; cf* above). Large trout fetch prices from K5 to K12 each.

3.3.3 Stock status

A study by Povlsen (1993c) suggested that rainbow trout stocks established in high altitude streams in the Upper Purari River catchment has increased the biomass in those streams from almost zero to almost 60 kg/ha.

Villagers in the Upper Purari River catchment reported that the numbers of trout in Omaigiha Creek have declined; and also that whereas trout used to be in Yu Creek (1,800 m and 13°C) - a tributary of the Nebilyer River - they are there no longer (Povlsen, 1993b). Villagers also reported that trout numbers have decreased or the trout have disappeared in recent years in streams along the Kundiawa-Kegesugl road in the southern part of the Gembogl district, Simbu Province (Povlsen, 1993a). The most important reason for this depletion is overfishing, as trout is the only edible-size fish species in these areas.

[3] Information on the current status is unavailable.

[4] Information on the current status is unavailable.

[5] I have no more information on this operation.

Only in remote regions do significant trout stocks still exist where, because of local conditions (remoteness, sparse population) the resource is not fully exploited (Coates, undated). Blichfeldt (1974) observed that the local fishing pressure for trout in most rivers (in the Southern Highlands Province) is quite severe and Povlsen (1993a) concluded that trout in the PNG Highlands are highly vulnerable to exploitation wherever there is significant human settlement. For example, the trout population in the Anggura River, Ialibu district (Southern Highlands Province) manages to cope with fishing pressure and numbers have not decreased since the species was stocked in the early 1970s. The human population of the Ialibu district is approximately 21.6/km^2, while in the Gembogl district (where trout numbers have decreased) it is approximately 47/km^2.

Heavy fishing pressure probably prevented brook trout from establishing (Povlsen 1993a) (but see earlier).

Based on Coates' opinion (1989) that there are 148.9 km^2 of streams in the Sepik-Ramu system catchment suitable for fish production in the altitudinal range of 1,800-2,800 m, Povlsen (1993a) calculated that there was a potential trout production of 1,074 mt/year in the Sepik-Ramu catchment alone.

Povlsen (1993a) found no evidence that the presence of trout in the PNG Highlands streams had adversely affected the native fish there.

3.3.4 Management

Current legislation/Policy regarding exploitation: The DFMR (1991) supports the establishment of a Highlands Regional Cold Water Fish Hatchery and the introduction of cold-water fish species 'more appropriate' to Highlands conditions than are rainbow trout. It also promotes the subsistence production of fish.

Recommended legislation/Policy regarding exploitation:

A. The introduction of 'more appropriate' species for stocking

Rainbow trout may not be an optimal species for stocking, but it may be an important nutritional supplement. Also, trout are already in PNG. Rainbow trout in PNG waters grow quickly, have excellent condition, and are disease free. No-one has identified a more suitable species than rainbow trout for subsistence purposes at the altitude where trout occur in PNG.

According to Povlsen (1993a), the rainbow trout is one of the most productive salmonid species in low-fertile, cold-water streams and hence is suitable for PNG rivers and streams at altitudes above 1,800 m. It may be that rainbow trout are more productive than other coldwater species in the water conditions there. Two Himalayan species, viz. snow trout (*Schizothorax richardsonii*) and mahseer (*Tor* species), are being considered for introduction to the Sepik-Ramu rivers catchment. These alternative species can tolerate a wider range of environmental conditions and are expected to disperse more widely into the middle reaches of rivers. Accordingly, they would have a bigger impact than have trout on native fish fauna.

B. Trout farming as a subsistence activity.

Trout farming requires a high level of technical expertise and sound finances. Carp and eel farming are activities better suited to subsistence fish production in PNG.

Below is an overview of rainbow trout in the PNG Highlands, with recommendations for exploitation.

1. Trout have been stocked (either on purpose or by accident) in Highlands streams since 1949, i.e. for 45 years. They appear to be widespread in the Highlands provinces, and there are more streams in the PNG Highlands that could be successfully stocked with rainbow trout (Povlsen, 1993a).

2. Trout are restricted to high altitude rivers and have a minimum effect on native fish fauna, simply because few native fish fauna inhabit these high altitude rivers. Cadwallader (1991) recommended that particular river catchments be designated as reserves where the stocking of trout (and other organisms) would be prohibited.

3. Although studies elsewhere have shown that low fertility, softwater streams do not produce enough benthos to support trout production, Povlsen (1993a) argued that trout in PNG exploit other food sources.

4. Trout do not have a good dispersal ability and remain in the areas where they were introduced. They do not disperse between one river sub-catchment and another because of their temperature tolerance: i.e. they would have to descend to warmer waters and then ascend adjacent rivers. Dispersal of trout is enhanced by villagers at Koisipe (Central Province) (Cadwallader, 1991).

5. Trout stocks in PNG are disease free.

6. Trout for stocking and for commercial farming are/were imported as eyed ova from Australia. An import levy (50 per cent) applies. The eyed ova were raised to fingerling stage at the government hatcheries at Mendi and Keglsugl before stocking out. They are raised to market-sized fish at the Nupaha (and Kotuni) trout farms.

7. The PNG Government, provincial governments and aid organisations have provided substantial funds over many years to provide trout for consumption - either from catching in a river or purchasing from a farm.

8. Commercial trout farming in PNG is technically feasible. However, it is a high-risk activity, depending on high-grade pelleted food and efficient farm management (Cadwallader, 1991). The quality of pellets available in PNG is suboptimal and there is room for improvement in farm management practices. Economic factors such as high cost of feeds, transportation and marketing constrain commercial trout farming in PNG (DFMR file, 1991).

9. For trout farming to be financially viable in PNG, the fish have to retail at K7.50 or more at the farm gate. This is very expensive. Australian trout retail for K2.30/kg at the farm gate. If air freight is added, Australian trout would sell for about K10/kg (Masuda *et al.,* 1994). Tomich and Stockwell (1991, in Cadwallader, 1991) pointed out that the PNG price was more than three times the then North American farm gate price, and because there is a gobal oversupply of salmonids, PNG trout would be non-competitive on the world market. It is unrealistic for PNG to contemplate an export market for farmed trout.

10. The only market for PNG-farmed trout would be in PNG itself, where it is limited to about 5 per cent of the population: purchased mainly by hotels, tourist lodges, airlines, and mining companies. Even so, PNG private trout farmers should not be complacent, since diners determined to pay for a feed of trout may not be nationalistic nor bother to discriminate between a K7.50 and K10 price per kg. Masuda *et al.* (1994) believed that the price of PNG farmed trout would decrease as trout production and competition between farmers increased following the establishment of many new farms, but the price of feed, imported ova, the level of farm management and so on would remain the same. How much government subsidy would be involved in keeping these many farms going so that they can sell trout with a lower price tag?

11. The size of the local market for trout should determine the number of trout farms. The <u>commercial farms</u> must become more efficient and proactive, respond to market demands and <u>not rely on government subsidies</u>. Markets for farmed trout clearly have not been sought actively. Poon Catering (which services PNG's mining and oil company operations) told me that it is keen to obtain local farmed trout but cannot obtain sufficient supplies: surely an alert farm manager could have satisfied this market?

12. The PNG Government should not heavily commit itself to 'working for' commercial trout farms. It should limit its assistance to the provision of technical advice, assistance with egg supply, training opportunities and (possibly) advice on project proposals.

13. Trout provide a valuable source of protein for many people in the higher-altitude Highlands areas. People living in these areas have nutritionally fewer options than do people living at lower altitudes (Povlsen, 1993a). Where they are targeted by village fishers, trout numbers decline. Hence, restocking is expected and management is required. I understand that stocking has not been carried out officially since 1991.

14. Kroeker (1982) pointed out that improved nutrition for Highlanders is the primary goal of a river stocking program. Because 'it is not in the nature of wild trout populations to be either highly productive or very resilient in the face of excessive fishing pressure' (Kroeker, 1982), the <u>PNG government must continue stocking trout</u>, and at a level which corresponds to local needs and fishing pressure. This "put and take" concept is widely accepted in North America and Europe where fishing pressure can be excessively high (Kroeker, 1982). Support for stocking also came from the Fishery Sector review (1989) which said that 'There is clearly a role for the national government to coordinate, advise and assist [in trout stocking] so that production is maximised and duplication of effort minimised.'

15. In conjunction with this "put and take", Kroeker (1982) and Sagom (1989) suggest that villagers should be shown improved methods of fish capture and preparation so that they can maximise resource utilisation. A suite of paradoxes emerge. If the government teaches people how to better catch trout, then it will have to carry out more stocking. But the government is obliged to stock to meet local needs. Should catch quotas be imposed? Kroeker (1982) said: 'If we depend on a set of management restrictions to maintain a fish population, then we are effectively restricting the role of that population as a food source.'

16. Moreover, are management restrictions difficult to enforce? Haines (1982) pointed out that the ownership of fishing rights or waterways by individuals, groups or villagers is a deeply held traditional concept where claims of ownership are made to waterways and the fish in them. This right effectively operates as a limited-entry system. The ownership of fishing rights has positive aspects (Haines, 1982): e.g. under appropriate circumstances the owners of waterways themselves can develop and enforce management measures - as they are protecting their property. This facility can be effected with trout. Haines recorded that in 1978-79, people in the Mendi area (Southern Highlands Province) developed their own conservation measures when they became concerned that trout resources were being overexploited. The Mendi Local Government Council introduced, at the initiative of villagers, a temporary ban on trout fishing in its area. The ban was effectively enforced, basically because each person policed his own stream. The Mendi Council has more recently imposed a minimum size limit of 20 cm on trout harvested from its area (Cadwallader, 1991). Haines (1982) also pointed out that, since Highlands streams are privately owned, it is possible to increase populations of trout and other species by stream improvement. Each owner would be improving his own stock, and the activity would also reinforce traditional concepts of ownership and conservation.

17. Local and provincial governments can obtain direct revenue from trout fishing by imposing licence fees (Blichfeldt, 1972). Having well-stocked rivers can also support a tourist industry.

18. <u>The PNG Government should consider what is its main role</u>: either to make relatively inexpensive fish available to much of the Highlands population through a managed restocking program, or to subsidise commercial trout farms which supply expensive fish to a small, elite, luxury market. (Much of that market is not comprised of nationals, anyway; and trout could be imported for a little extra cost).

19. The PNG Government should not encourage the development of commercial trout farms whose financial outlook depends on subsidies. There is considerable interest among Highlands people in trout farming (Povlsen, 1993a) and there is also considerable provincial government support for the continuation of trout stocking (Fishery Sector review, 1989) in natural waters. These facts reflect the popularity of fish in the area. However, trout farming is not carp farming. It is not a subsistence level activity, expecially for people who have no tradition of farming. Trout are very demanding with regards to water quality and conditions, and food is expensive (Povlsen, 1993a). By developing an effective stocking program, the PNG government can meet the demand of Highlands people for trout while removing itself from the need to subsidise private farms.

20. A national Highlands cold-water trout hatchery should be established. It should service the purposes of supplying trout for restocking in rivers and to commercial farms, and also operate as a research and aquaculture training centre. The cost of establishing a cold-water trout hatchery would be assuaged by a) the government fulfilling its role of providing protein for its people, b) long-term savings from having trained farm managers, and, partly c) sale of fingerlings to farms and provincial governments (for stocking).

21. There is a <u>need to evaluate the status of trout stocks</u> in PNG's high altitude Highlands rivers and to investigate their biology - for example, their breeding cycle - and ecological impact. Without knowledge of which streams support self-sustaining populations, it is difficult to carry out efficient stocking practices. A thorough survey of Highlands rivers and headwaters of coastal rivers should be undertaken, and support the studies of van Zweiten (1990), Povlsen (1993a,c) and van der Heijden (1993a). An evaluation of rainbow trout in the Highlands is also important to better assess the value of importing additional species. Field studies should also be undertaken to assess the extent of utilisation of trout once stocked and appraise the socio-economic importance of rainbow trout in the Highlands (Povlsen, 1993a).

22. Importing eyed ova should gradually be replaced by local production of eyed ova. Both Blichfeldt (1974) and Cadwallader (1991) pointed out that progeny of locally grown trout would be more suited to local conditions than would trout derived from imported ova, and also that any danger of importing fish diseases from abroad would be eliminated. Cadwallader (1991) provided information on the ratio of broodstock for egg and fry production. If fingerlings were raised from local broodstock, the current 50 per cent levy (which is said to impose a financial constraint on commercial farmers: Masuda *et al.,* 1994) would fall away.

23. Cadwallader (pers. comm.) has advised that the stocking of eyed ova (rather than fingerlings) into streams through the use of Vibert boxes is not as good an option as Kroeker (1982) and the Fishery Sector review (1989) suggested. Cadwallader pointed out that the eyed ova suffer extremely high mortality as they are exposed to a wide range of invertebrate predators and physical damage when compared to hatchery raising under predator-free controlled conditions. Blichfeldt (1974) found that the cost of locally produced fingerlings at Mendi worked out at about 5 per cent of the cost of bringing fingerlings up by air from Australia: the cost of hatching fingerlings in the rivers themselves should increase savings by a comparable amount. The DFMR should investigate this operation. In general, the operation of importing eyed ova, hatching and rearing fingerlings and then stocking them in rivers is cost intensive.

24. Should a surplus of eyed ova become available from local and raised imported trout, they could be exported. As there are few places in the world where disease-free trout ova are available, PNG would have a ready market (Blichfeldt, 1974; Cadwallader, 1991). *It is at this export market that PNG should aim rather than at an export industry of farmed fish.*

<u>Summary</u>

- Establish a *national cold-water* trout hatchery.

- *Do not subsidise* private trout farms. The financial risk should be solely that of the farm owner(s).
- *Do not encourage trout farming* at the expense of carp or eel farming.
- Investigate the possibility of *raising locally-spawned trout from broodstock,* and of stocking eyed ova.
- Aim at establishing an *export market of disease-free eyed ova.*
- Take steps to *train fisheries officers* in trout farming and management.
- Recommence a *river stocking program* - but be discriminating in the selection and purpose of rivers to be stocked.
- Undertake thorough biological, ecological and socio-economic *surveys of wild trout populations and their use* in the PNG Highlands. This is a priority.

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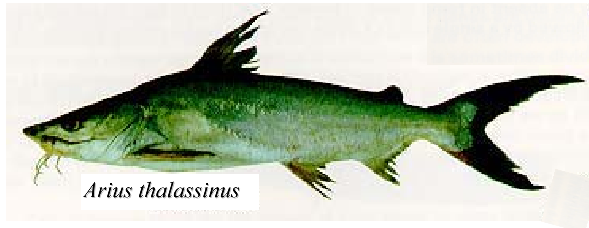
3.4 FORK-TAILED CATFISH

3.4.1 The Resource



Arius thalassinus

Species present: Thirty-three species of forktailed catfish (family Ariidae) inhabit PNG waters. However, they do not occur in the New Guinea islands (Manus, West New Britain, East New Britain, New Ireland and North Solomons provinces) nor in the Milne Bay Province. I have no record of ariid catfishes occurring in the Northern and Morobe provinces (and they are not listed in the MOMASE project's five categories).

Only eight species of Ariidae inhabit northern PNG waters: three are marine species and of them, *Arius thalassinus* and *A. bilineatus* also inhabit southern PNG waters. The other marine species in the north is *A. polystaphylodon*. The five freshwater species inhabiting the northern provinces are: *A. nox*, *A. solidus*, *A. velutinus*, *A. coatesi* and *A. utarus*.

Along all of the southern PNG coast, *A. thalassinus, A. bilineatus, A. argyropleuron*, *A. nella, Arius* species 5, *A. mastersi, A. proximus, A. armiger, Arius* species 3, *Arius* species 6 and *Arius* species 4 inhabit either marine or estuarine waters or river mouths (or a combination of these habitats). *Cinetodus froggatti*, *Nedystoma novaeguineae*, *A. danielsi*, *Arius* species 1, *A. graeffei* and *A. leptaspis* inhabit coastal waters, estuaries, tidal reaches of rivers and freshwaters. *Nedystoma dayi*, *C. carinatus*, *C. crassilabris, C. conorhynchus, A. spatula, A. taylori*, *A. berneyi*, *A. augustus*, *A. latirostris* and *A. macrorhynchus* inhabit freshwaters only. (The numbered species are undescribed taxa identified by Kailola, 1991 and new name combinations also follow Kailola, 1991).

Some of the 33 species of ariid catfish are of minor importance in fisheries because they have either a limited distribution (e.g. *Nedystoma novaeguineae*, *Cinetodus conorhynchus*, *Arius* species 5, *Arius* species 3 and *Arius* species 6) or are caught infrequently in existing fisheries (e.g. *A. polystaphylodon*).

Distribution:

Species	Distribution (Province)	Habitat
Nedystoma dayi	Western and Gulf	freshwater
Cinetodus froggatti	Western and Gulf	estuarine, inshore, freshwater
Cinetodus carinatus	Western and Gulf	freshwater
Cinetodus crassilabris	Western and Gulf	freshwater
Arius argyropleuron	Gulf and Central	marine and estuarine
Arius nella	Gulf	marine and estuarine
Arius nox	East Sepik and Madang	freshwater
Arius solidus	East Sepik and Madang	freshwater
Arius spatula	Western and Gulf	freshwater, rarely brackish
Arius danielsi	Western and Gulf	freshwater and brackish
Arius species 1	Western, Gulf and Central	freshwater, inshore, freshwater
Arius mastersi	Gulf and Central	inshore, estuaries, river mouths
Arius thalassinus	West Sepik, East Sepik, Madang, Gulf and Central	marine
Arius bilineatus	East Sepik, Western, Gulf and Central	marine and estuarine
Arius proximus	Gulf	inshore and estuaries
Arius velutinus	West Sepik, East Sepik, Madang, Western Highlands	freshwater

Arius taylori	Western, Gulf, Southern Highlands	freshwater
Arius coatesi	East Sepik and Madang	freshwater
Arius graeffei	Western, Gulf and Central	inshore, estuaries, freshwater
Arius berneyi	Western	freshwater, rarely brackish
Arius armiger	Western, Gulf and Central	marine, estuaries, tidal rivers
Arius augustus	Western and Gulf; Southern Highlands?	freshwater
Arius latirostris	Western, Gulf, Central, Southern Highlands	freshwater
Arius leptaspis	Western, Gulf and Central	inshore, estuaries, freshwater
Arius utarus	West Sepik, East Sepik and Madang	freshwater, tidal rivers, brackish
Arius species 4	Western, Gulf and Central	inshore, estuaries, river mouths
Arius macrorhynchus	Western and Gulf	freshwater

The ariid catfishes are an important group of fish in the Sepik-Ramu rivers system (Coates, 1989), Fly River system (Roberts, 1978) and the Purari River system (Haines, 1979). Roberts and Haines considered that, in the absence of other fish species, the ariid catfishes underwent an adaptive radiation in PNG's freshwaters, largely exemplified in their trophic adaptations. Haines (1983) noted where, in the Purari River, some species of ariid catfish replace each other ecologically upstream and downstream: riverine species *A. latirostris*, *A. spatula* and *Nedystoma dayi* are replaced in the delta and estuary by *A. leptaspis* + *A. proximus*, *A. danielsi* and *Arius* species 4, respectively. There are also differences in ariid species composition between the Fly and Purari rivers: e.g. whereas *A. berneyi* and *A. augustus* are common in the middle and lower Fly River (respectively), they are absent from the Purari River. Haines (1983) suggested that *A. proximus* and *A. latirostris* replace those species in the Purari. Similarly, *Cinetodus froggatti* inhabits freshwater in the Fly River but only lives in the estuarine zone in the Purari River.

Ariid catfish dominate in number of species and biomass in the Purari River system (Haines, 1983) and occupy almost all available trophic niches. Haines (1979) noted that *A. leptaspis* is the most abundant and widespread of the larger fish species in the deltas of the Gulf Province, and *A. berneyi* is perhaps the most abundant ariid in the middle Fly River.

The ariid catfishes are the most diverse fish family on the Sepik River floodplain (Coates, 1989), although the family is represented there by only five species. They are generally restricted to the main river channels and lakes: only *A. nox, A. solidus* and *A. utarus* have been caught on the floodplain (which is dry for six months of the year and inundated to a depth of 2 m for the other six months); and of these, *A. nox* most utilises the floodplain. This species exhibits modest exploitation of the floodplain and modest seasonality in its abundance and biology. All other ariid catfish tend to be restricted to lakes and/or river channels. Certain species (e.g. *A. nox*) are said to exhibit 'reverse' seasonality, by increasing feedings, condition and fat deposits in the dry season (Coates, 1989).

In the Sepik-Ramu rivers system, juveniles of *A. velutinus* migrate from lowland rivers into tributary rivers up to about 800 m (Coates, 1989). This species inhabits main river channels and is strictly confined to turbid river channels. It is the only ariid that ascends rivers to fairly high elevations (e.g. Jimmi River), where it inhabits deeper pools in low gradient rivers (van Zweiten, 1990). On the southern side, *Arius taylori* and *A. latirostris* appear to emulate the habitat preferences of *A. velutinus.*

Biology and Ecology: The most striking features of ariid catfish are their habit of oral incubation (mouth brooding) and the attendant low fecundity. Fecundity increases with increase in size of both parents and the size of the buccal cavity in larger males means they can brood more young than can smaller males. Of the five species inhabiting the Sepik River floodplain, the maximum fecundity of 170 ova (from a fish 625 mm in standard length) was recorded for the largest species, *A. coatesi* (Coates, 1988).

As a general rule, spawning takes place towards the end of the dry season and extends through the wet season (Coates (1983) reported some Sepik-Ramu rivers species in spawning condition all year), larger fish undertaking a second spawning. The male ariid catfish broods the fertilised ova and they hatch in his buccal cavity. Brooding lasts for 4-6 weeks during which the male parent does not feed. Little is known about the stimulus for spawning in ariid catfish, but some species are known to migrate (e.g. *Arius* species 1, *A. nella*) and spawning aggregations occur (recorded in *A. nella, A. bilineatus, A. thalassinus*). The fish probably attract each other by making a drumming noise with their swimbladder.

Because production of large ova takes so much reserve from female ariid catfish, ripe females are emaciated: after releasing their brood they are active feeders. The opposite occurs with male ariid catfish, who build up fat reserves before their brooding duties are required. Towards the end of the spawning period, male fish are emaciated and, after releasing their brood, feed very actively (before they may brood again). A review of ariid catfish reproduction an development is given in Rimmer and Merrick (1983).

Diet changes with size/growth. The scope of dietary items consumed by the different ariid catfish species in PNG is given below. Fecundity and ova diameter and maximum recorded size is also tabled.

Table 148 Biological information on PNG fork-tailed catfishes.

Species	Maximum size (cm)	Fecundity	Size of eggs	Diet
Nedystoma dayi	35 cm FL	10-20	5-11 mm	detritus, mud, algae; also plant material, crustaceans, insects
Cinetodus froggatti	42 cm SL	40-45	10.5-11 mm	bivalve and gastropod molluscs
Cinetodus carinatus	56 cm FL	no info.	no info.	detritus and mud; also insects, detritus, plant material
Cinetodus crassilabris	56 cm FL	29	no info.	detritus, plant material, prawns, crabs
Arius argyropleuron	46 cm TL	no info.	no info.	prawns, molluscs, detritus, mud
Arius nella	87 cm TL	no info.	15.5-19 mm	grit, sea urchins, plant material
Arius nox	28.5 cm SL	30	no info.	insects, crustaceans, detritus, plant material
Arius solidus	49 cm SL	8-90	no info.	insects, crustaceans, plant material, detritus, fish, worms, fish scales
Arius spatula	64 cm TL	no info.	no info.	*Cherax*, *Macrobrachium*; also fish, insects
Arius danielsi	55 cm FL	no info.	no info.	prawns, other crustaceans; also insects, detritus, plant material
Arius species 1	>1.2 m SL; '40 kg'	47-85	16-22 mm	fish; also prawns, crabs, plant material
Arius mastersi	51 cm SL	25-28	10.5-12 mm	prawns, crabs, fish, fish scales, detritus
Arius thalassinus	1.3 m SL	40-103	19-24 mm	fish, sea urchins, fish scales, worms, detritus, crustaceans, squid, polychaetes
Arius bilineatus	62 cm SL	18-54	15-18 mm	fish scales, detritus, sea urchins, crustaceans, fish, molluscs
Arius proximus	41 cm SL	no info.	no info.	crustaceans, gastropods, fish, fish scales
Arius velutinus	50 cm SL	25-90	no info.	plants, detritus, insects, eggs

Arius taylori	35 cm SL	no info.	no info.	fruits, insects, detritus, plants
Arius coatesi	66 cm SL	170	no info.	crustaceans, plants, detritus, insects, worms, fish, eggs
Arius graeffei	c. 50 cm SL	123	14 mm	plants, crustaceans, insects, fish scales, fish, bivalves, detritus
Arius berneyi	48 cm SL	no info.	no info.	fish scales, prawns, insects, mud, worms, fish, crabs, plants
Arius armiger	29.5 cm SL	c. 40	8-10 mm	prawns; also crabs, fish, insects, detritus, plant material
Arius augustus	94 cm FL; 109 cm TL; 20 kg	no info.	10.4 mm	fish, prawns; also insects, detritus
Arius latirostris	45 cm SL; 62 cm TL	no info.	no info.	fish, insects, arthropods, plants, debris, fruit, crustaceans, worms
Arius leptaspis	71 cm TL; 64 cm SL; >10 kg	10-70	no info.	insects, fruit, prawns, detritus, fish, bivalves, crabs, plant material, worms
Arius utarus	45 cm SL	no info.	no info.	prawns, insects, fish scales, detritus, plant material
Arius species 4	30.2 cm SL	c. 35	11-11.5 mm	fruit, detritus
Arius macrorhynchus	46.3 cm SL	no info.	no info.	plants, fruit, insects

(SL= standard length; FL= fork length; TL= total length; egg size is diameter)

The largest freshwater/estuarine species inhabiting PNG waters are therefore *Arius* species 1, *A. coatesi, A. augustus*. There are anecdotal reports that *Arius* species 1 attains 2 m in length and that *A. augustus* attains well over 1 m.

3.4.2 The Fishery

Utilisation: Ariid catfish were caught traditionally with bow and arrow and spearing in highland fisheries (Haines and Stevens, 1983). In the Western Province and Gulf Province they are caught with handlines and hooks and gillnet, using a range of mesh sizes.

Ariid catfish are considered to be highly important nutritionally within the Sepik-Ramu region. They contain large amounts of fat which is highly regarded by nationals (Coates, 1989) (However, this would be a seasonal feature - see above). Ariid catfish are among the preferred fish in upper Sepik River villages because of their high fat content (Mys and van Zweiten, 1990). For example, *Arius velutinus* is heavily fished in all the rivers it ascends. At Kemeilmin (750 m altitude) and Yenkis (1,000 m altitude) the eel-tailed catfish *Neosilurus gjellerupi* and *A. velutinus* make up nearly 90 per cent of the catch (van Zweiten, 1990).

Ariid catfish are also important to the subsistence fishery of the Sepik-Ramu rivers system as they are readily caught all year round - esecially when tilapia and gudgeons are less available (Coates, 1989). Catches of ariid catfish in the Sepik-Ramu rivers system vary considerably with season, peaking in the dry season (May-October). Generally, they dominate landings from open and deeper (> 2m) water (Ulaiwi, 1992).

Arius graeffei is harvested from Waigani Swamp and other freshwaters in the Central Province. On almost any day, pre-adult individuals are offered for sale at Koki market, Port Moresby. A considerable amount must be sold in the National Capital District each year.

Ariid catfish were among the species bought by the Baimuru Fish Plant from Gulf communities during the late 1970s and 1980s. Prices received for ariid catfishes were lower than those for other bycatch species of the barramundi fishers (e.g. threadfin salmon, jewfish).

Production and Marketing:

Southern provinces:

In a 25-day survey in early 1976 in the Purari River delta, 109.7 kg of catfish were harvested by three village communities (average weight 4.4 kg) (Haines and Stevens, 1983).

Table 149 Ariid catfish purchases by the Baimuru Fish Plant, 1981 (source: Haines and Stevens, 1983) (Artisanal catch)

Month	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	**Total**
weight (kg)	65	75	85	0	0	46	328	478	670	617	197	2,561

Table 150 Landings at the Baimuru Fish Plant, 1982-89, kg whole weight (artisanal, not catches which includes subsistence). (source: 1982-83 - Opnai 1984; 1984-89 - DFMR files).

species	1982	1983	1984	1985	1986	1987	1988	1989
all catfish	1,541	2,156	3,995	no rec	12,031	16,946	5,129	4,815
yell catfish	-	-	3,722	no rec	11,937	16,946	5,129	4,815
oth catfish	-	-	273	no rec	94	0	0	0
cpue	0.7	0.8	-	no rec	-	-	-	-

(Note: 'yell catfish'[yellow catfish] = *Arius* species 1). In late 1976, this species was the single most important commercial species at Kikori after barramundi (Haines, 1979).

Table 151 Catfish landings in the Baimuru-Kikori estuarine fishery, 1980-88, in mt whole weight. (Source: Fisheries Sector review 1989)

Year	1980	1981	1982	1983	1984	1985	1986	1987
weight (mt)	0.2	3.0	6.3	-	4.1	24.0	10.3	16.9

Northern provinces:

Ariids from the Sepik River floodplain comprise approximately 25 per cent by weight of the annual fish harvest (Coates, 1985; 1989). They are insignificant in catches from the high altitude sections of the Sepik and Ramu rivers; they are present 2.2 per cent by weight and 4.74 per cent by number in mid-altitude sections of the rivers; and are present in 12.4 per cent by weight and 13.8 per cent by number in low altitude sections of the rivers (van der Heijden, 1993). At Angoram in the lower Sepik River, ariid catfishes comprise 50 per cent by weight of native fish landings (Kailola, 1988). Ulaiwi (1992) also found that in villages in the lower Sepik river, catfish landings by weight vary from dominant (about 50 per cent) to 2.5 per cent.

In the early 1980s *A. solidus* comprised 67 per cent gillnet catches in the Sepik River and 21 per cent of Angoram market landings, ndicating its importance in the local fishery (Coates, 1983).

Of 27 villages surveyed in the Sepik-Ramu rivers system, *A. velutinus* occurred in 53.8 per cent of their catches, and was (of all waters in the system) the 4th most preferred fish (34.6 per cent) after eels and eel-tailed catfish. It comprises on average 23 per cent weight in catch in the lower altitude regions and averages 9.2 per cent numbers in catch (van Zweiten, 1990).

Marine fisheries: Ariid catfishes are a significant component of the bycatch from prawn trawling operations. They are more prevalent in trawling conducted off rivers with extensive deltas - e.g. in western Gulf Province. Ariid catfish are the most dominant fish group in the main trawling grounds between Orokolo Bay and Freshwater Bay (Kailola and Wilson, 1978). (See also Profile1.10: Trawl By-catch Species)

3.4.3 Stock status

Southern provinces:

The only information available on stock status is from surveys conducted by Alan Haines in the 1970s. His information is extracted below.

Haines (1979) reported on gillnet surveys in the Purari and Kikori rivers systems to assess the potential for riverine fisheries there. Relevant sections (giving information on ariid catfish catches only) from his Table 14 are presented below.

Table 152 Gillnet results from a 1979 survey of the Gulf of Papua riverine systems.

Locality	Date	Av. *night* catch/hr/net (kg)	% catfish component of catch	Total hrs fishing	Av. *day* catch/hr/net (kg)	% catfish component of catch	Total hrs fishing
Bevan Rapids	11/74	7.7	45	16	-	-	-
Kuku Creek	5/75	9.2	54	13	9.7	52	2.5
Kuku Creek	5/75	6.8	66	27	-	-	-
Wabo	1/77	0.8	20	84.5	-	-	-
Wabo	1/77	0.6	54	84.5	0.6	8	38.5
Kibi Creek	1/77	0.9	40	27.5	-	-	-
Anno Creek	12/74	4.5	65	15	-	-	-

(Anno Creek is the only Kikori River locality sampled where ariids were caught)

Haines' (1979) results for ariid catfish from surveys using commercial size gillnets in the Purari-Kikori delta systems (his Table 15) are given below.

Haines (1979) observed that a commercial operator would have considerably improved catch rates than those he obtained.

Northern provinces: I have no firm information on the status of ariid catfish in the Sepik-Ramu rivers system; except there is anecdotal information that their abundance has reduced following the introduction of tilapia (profile 3.5) and carp (profile 3.2).

Marine fisheries: There is no information on the status of stocks of marine ariid catfish caught in prawn trawls.

3.4.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Although ariid catfish are a 'nuisance' fish in gillnetting operations targeting higher priced species such as barramundi, they do comprise a useful commercial resource. There is reasonable potential for further development of an ariid catfish fishery in the Gulf Province at least. Landings at the Baimuru and Kikori fish plants have shown the existence of the resource beyond subsistence needs. The harvest of ariid catfish is mainly seasonal - when the fish are migrating or actively feeding prior to spawning. Ariid catfish would form a useful adjunct to a threadfin salmon + inshore shark + jewfish (Sciaenidae) fishery.

Not all of the species inhabiting the Kikori-Purari rivers system and deltas would be available for commercial harvest. The freshwater forms generally have a better flavour than the marine taxa, although all larger catfish are worth marketing.

Recovery rates of fillets from ariid catfishes are said to be poor, but with careful filleting, rates of 35-40 per cent are achievable (Kailola and Pierce, 1987). The fillets from larger catfishes are of good quality and free of small bones when retrieved, chilled and packed well (Kailola and Pierce, 1987) and should fetch good prices.

Table 153 Commercial gillnet results from a 1979 survey in the Gulf of Papua delta.

Locality	Date	Av. *night* catch/hr/net (kg)	% catfish component of catch	Total hrs fishing	Av. *day* catch/hr/net (kg)	% catfish component of catch	Total hrs fishing
Barea	1/76	1.92	20	13	-	-	-
Era delta	1/76	0.96	3	2	-	-	-
Akoma	1/76	2.1	8	4	-	-	-
Moinamu	8/76	2	5	56.5	2.8	17	10
Gauri	7/76	2.8	11	28	3.6	15	9
Era River	12/74	1.1	36	13	-	-	-
Ravikaupara	2/76	3.7	48	15	-	-	-
Ravikaupara	11/76	2.6	16	7.4	-	-	-
Alele Passage	11/74	3.5	7	14	-	-	-
Morowam	5/75	6.35	32	24	0.9	16	11
Akoma	10/75	2.1	69	51	3.3	75	46
Morowam	10/75	1.7	11	37	-	-	-
Akoma	11/76	1.1	34	18	2.8	66	9.5
Baimuru	11/74	1.8	11	13.5	0.8	69	-
Aird delta	12/74	15	4	13	-	-	-
Kaivu	5/75	2.6	51	30	1.5	72	8
Era River	12/74	3.2	98	-	-	-	-
Aird Hills	12/74	1.9	5	13	-	-	-
Upper Pie R	5/75	2.9	36	13.5	-	-	-
Ravikoupara	10/75	0.7	80	16	-	-	-
Ravikoupara	11/76	0.2	59	28.5	0.15	91	21

Ariid catfish were the most abundant product at the Baimuru and Kikori Fish plants in the 1970s. Haines (1979) observed that markets were limited and that research was needed on production of a catfish product acceptable to consumers, and on its marketing. The Sector Review (1989) added that development is constrained by high transport costs and lack of necessary infrastructure (a situation also affecting other other identified resources in the Gulf and Western provinces).

Based on the current prices received for ariid catfish fillets in southern provinces, a fishery based on that alone could not be supported. Ariid catfish can be salted and smoke-dried, but because of the oily nature of the flesh and the thick body, it is not as successful an operation as can be achieved using other fish species.

The marine species of ariid catfish forming a component of the trash from prawn trawling operations in the Gulf of Papua are generally juveniles and do not command a market. The only marine species achieving a large size in PNG waters is *Arius thalassinus* and large individuals of this species would only occur in deeper water - e.g. off the north coast provinces - where they could be handlined. However, I am not aware that these fish are fished traditionally there.

In my view, the subsistence and artisanal fisheries for ariid catfishes in the Sepik-Ramu river can bear no more expansion.

The low fecundity, mouth-brooding and spawning aggregation habits of ariid catfishes make them susceptible to overexploitation. And it is at these times when the species are most easily harvested. Where harvesting has gone unchecked at this period the resource has been largely eliminated. Along the Indian coast, for example, all-year trawling and gillnetting harvests spawning aggregations and brooding males: by harvesting brooding males the next generation is virtually eliminated. Uncontrolled harvesting in Lake Argyle (north-western Australia) seems to have caused a similar situation on the ariid catfish resource in those confined waters.

Hence, in the Sepik-Ramu rivers system, a closed season for ariid catfish should be implemented from the beginning of the wet season for 2-3 months. This time period should enable the completion of at least one aggregation, spawning and mouth-brooding cycle (large ariid catfish can spawn and brood more than once each season). After spawning, the female ariid catfish rapidly put on condition. In the southern provinces however, the resource appears very abundant as it is not affected by species introductions and fishing pressure is more dispersed.

I do not know if there are traditional restrictions on the taking of ariid catfish during their spawning period. Pre-spawning females are emaciated yet full of eggs, while pre-brooding males are in good condition and with layers of fat. In light of the value inland national fishers place on fatty fish, there may be restrictions on harvesting mature females or brooding males (whose condition gradually drops as the brooding period passes). I have no record of the large eggs being eaten by Papua New Guineans (as the eggs are in many parts of South East Asia, for example).

Stock assessments of ariid catfish in PNG would be very difficult to perform because of the difficulty in identifying the species. Only some - e.g. *Arius* species 1 - are easily identifiable. The optimal level of harvest then, is difficult to estimate. It would be worthwhile however, to monitor the harvest of the few easily identifiable species: eg *Arius* species 1, *Arius berneyi* and *Arius spatula* in the Western and Gulf provinces, and *Arius nox* and *A. velutinus* in the East Sepik and Madang provinces. Villagers in these provinces would be able to distinguish these forms (as a first step).

3.4.5 References

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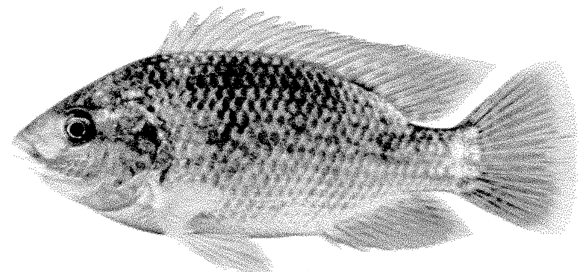
3.5 TILAPIA

3.5.1 The Resource



Oreochromis mossambicus

Species present: *Oreochromis mossambicus* (Mosambique tilapia) and *O. rendahli* (red-breasted tilapia).

Distribution: The natural distribution of tilapias is limited to Africa and the Near East. They have been introduced extensively around the world - mainly to tropical/subtropical countries - as a favoured aquaculture subject.

O. mossambicus was introduced to PNG in 1954 specifically for pond culture (although this venture was never successful because of rapid breeding and the species' preponderance for subsequent stunting). The year after its initial introduction *O. mossambicus* was introduced to the Dobel experimental ponds at Mt Hagen (West and Glucksman, 1976). Trials conducted there to assess its suitability as a species for highland pond culture were unsuccessful and highland pond culture for tilapia was never established in a large way (Povlsen, 1993). Nevertheless, in some parts of the highlands tilapia apparently did establish: there are reports from nationals that they occur in small ponds and lakes in the Eastern Highlands and Western Highlands provinces. There are reports that tilapia also used to inhabit the Dunantina River at Henganofi (Southern Highlands), but they disappeared after carp became established in the area (Povlsen, 1993).

O. mossambicus was introduced to ponds near Maprik in the East Sepik Province in 1964 (West and Glucksman, 1976). Shortly afterwards it was found in the Screw River (a tributary of the Sepik River), and the large, naturally breeding population spread through the lower and middle sections of the Sepik-Ramu river system (Redding, 1989). The tilapia population became particularly abundant in the floodplain areas of the middle Sepik such that in the mid 1970s there were enough there to support a small cottage industry based on the hard-salting and sun drying of tilapia fillets (the 'solpis' industry).

O. rendahli was introduced into some areas of the Sepik-Ramu river system in 1991 (van der Heijden, 1993a). Approximately 150,000 fingerlings of this species were released by the Sepik River Fish Stock Enhancement Project between June 1991 and October 1992 at 27 locations on the river system. Fingerlings were stocked within 10 km of eight surveyed villages at about mid-altitude - 80-200 m - of the river system. Follow-up surveys were conducted a year later at two villages near lakes where the species had been stocked. At one (Yau'umbak) *O. rendahli* comprised 4.58 per cent of fish caught by number and 1.7 per cent by weight, and at the other (Rebru) they comprised 1.05 per cent by weight and 0.27 per cent by number. [At these villages, *O. mossambicus* comprised 29.3 per cent and 8.38 per cent by weight respectively.]

O. rendahli was also stocked in the Upper Ramu River in the second half of 1991, and an additional 28,000 fingerlings were stocked in Yonki Reservoir (Eastern Highlands Province) in September and October of 1992 (van der Heijden 1993b).

In the Sepik-Ramu river system, *O. mossambicus* is present in the floodplain and the upper reaches. The species is mainly found at gradients between 0-0.05m/m. It prefers slower moving waters with fairly stable substrates (Redding, 1989). Van Zweiten (1990) collected tilapia at altitudes of 20 m to 320 m, but Allen and Coates (1990, in van Zweiten, 1990) collected it at 1,500 m and villagers reported it at 2,160 m. It is present in the Torricelli Range, the Sepik and Ramu rivers marginal floodplain and in the Upper Ramu River valley (van Zweiten, 1990).

O. mossambicus are also present in abundance in waterways of the Central Province (e.g. Waigani swamp, Sirinumu Dam, Laloki River and Brown River). They are also represented in catches landed at Voco Point in Lae (source: Hermes *et al.,* 1994) and in swamps in the Northern (Oro) and Gulf provinces (Fishery Sector review 1989). Madang landings come from the Ramu and probably other provincial waterways.

Biology and Ecology: Tilapias are of the family Cichlidae, comprising over 100 species according to some authorities. They are freshwater fish but tolerate salinity to different degrees (they are 'secondary freshwater' species). All tilapia species were considered to belong to the genus *Tilapia*, but in recent years, mouth-brooding species have been classified into *Oreochromis* or *Sarotherodon*.

In the Sepik-Ramu river basin, tilapia are restricted to the surface waters and adult tilapia are seldom found below 12 m (Redding, 1989). The general conclusion from catch data and market surveys is that during the flood season tilapia move onto the floodplain and become less accessible (to fishers). In the Sepik River basin, it is tilapia that utilises the floodplain to a far greater extent than any of the native species. Tilapia move from the floodplain to areas of more permanent water (such as ox-bow lakes) at the beginning of the dry season. The shallow water areas of the Sepik-Ramu floodplain are important feeding and breeding habitats for tilapia (Redding, 1989).

Tilapias are mouthbrooders, and have high reproductive turn-around. Just before the breeding season, the male forms a territory and makes a nest in shallow littoral areas (in the Sepik-Ramu system) of more permanent water close to the floodplain but not on it (Redding, 1989). The main nesting sites are in 0.8-1.5 m water depth at mean peak flood and are on average 1 m in diameter. The size of the nests correlates with the size of the male. The nests are constructed on fine, silty mud. Because of the changing nature of the Sepik River, there may be years of abundant nest sites and other years when competition for sites is fierce.

After the nest is constructed, the male lures a female into the nest to mate. The female holds the fertilised eggs in her mouth, where they develop. Five to seven days after spawning, hatchlings of 8-9 mm in total length hatch out, but are still brooded by the mother. About two weeks after spawning, juveniles become independent of the mother.

Tilapia grow to 300 g in lower altitudes (in the Sepik-Ramu river system) but are stunted at altitudes higher than 100 m, where they do not attain weights of more than 20-30 g and a length more than 100 mm (van Zweiten, 1990). The species attains 'normal' length in larger rivers with moderate flow and large pools up to an altitude of 80-100 m and appears to stunt in the higher altitude, smaller and faster-flowing rivers. The smallest female at stage 5 maturity found in surveys above 100 m weighed 5 g and was 67 mm long (van Zweiten, 1990) and the maximum size of fish at 240 m altitude is approximately half that of fish at 40 m altitude. The biomass and numbers of fish decrease above 120 m (van Zweiten, 1990). Tilapia apparently breed in these higher altitude rivers although it is not known what habitats are used for nesting sites.

Females move into the nesting areas during the breeding seasons for spawning then retreat to the nursery areas, further into the floodplain, to brood the young. Juveniles appear to remain hidden in the inaccessible areas of the floodplain until they reach a mean size of 125 mm. Based on overseas studies these fish are probably 2-3 years old; ie there is a delay between the peak breeding period and the emergence of recruits, although the emergence of the recruits into the fishery seems to occur at the same time as the peak breeding period (Redding, 1989). In her study of the Sepik tilapia, Redding found an increase in the catch of smaller fish between late May and late July corresponding to a drop in the mean length of tilapia on the floodplain between February and March. These phenomena suggest that the smaller fish are moving from the floodplain to the deeper water. Redding (1989) believed that dietary requirements and habitat preferences are probably the determinators of the movement of juvenile fish.

On the Sepik floodplain, tilapia feed on a variety of autochthonous material in the form of epiphytic and benthic algae, diatom species, pieces of macrophyte and detritus (Redding, 1989; Coates, 1989). In the shallow areas the diet also includes benthic diatom species whereas in the deeper oxbow lake sites the main food items include epiphytic diatom species, algae and detritus. The shallower water areas would allow access to benthic detrital aggregate, reported (by Coates, 1989) to be a preferred food of tilapia. The substrate of decaying vegetation in deeper areas is anoxic and is unfavourable to tilapia. Juvenile tilapia feed on diatoms and invertebrates, primarily insect larvae such as Cladocera (Redding, 1989). Both juveniles and adults are opportunistic feeders. Mean stomach fullness tends to decrease as the water begins to recede in March-May on the floodplain.

Brooding females do not feed during the period of egg incubation. Males feed continuously during the year while females exhibit significant differences in stomach fullness between high and low water periods (Redding, 1989). Condition in females also fluctuates with gonadosomatic index (GSI): when the GSI is high (indicating increased breeding activity) their condition is generally lower and is lowest when the GSI peaks (from survey information, in December 1981, March 1982, May 1982 and January 1983). However, females are in good condition prior to breeding. Redding considered that the general decrease in condition for both sexes at the end of the dry season is because of the reduction in food availability and the influx of juveniles feeding on the same food source.

O. mossambicus are polygamous mouthbrooders. The minimum size at maturity in females is between 141 mm and 160 mm on the Sepik River basin and 161-180 mm for males (Redding, 1989). At maturity stage 5 (ripe), most females are 181-200 mm and most males are 201-220 mm. There is usually a distinct sexual dimorphism, with the males of the same age being larger. *O. mossambicus* will reproduce prolifically given abundant food and space and it has the tendency to over-populate (this leads to overcrowding, reduced growth rates and small size at maturity). Overseas studies show that stunted populations of tilapia can occur in either food-rich or food-poor environments and where mortality rates are low (Redding, 1989).

O. mossambicus breed throughout the year in the Sepik floodplain with distinct peaks during the wet season (Redding, 1989). Fish movements, condition, feeding and breeding do not have a distinct pattern. Their rather erratic trends may be following the unpredictable nature of changes in the water level in the Sepik River where there is no precise distinction between wet and dry seasons as is normal in a monsoon climate. From GSI calculations, there are several peaks throughout the year for both males and females. Females generally show continuous breeding patterns with the GSI falling in interim periods. The main breeding periods seem to be December-January, March and May although there are smaller peaks in the GSI in August and November.

Fecundity in tilapia is low - in tandem with their habit of parental care. Ovaries contain both primary and secondary ova - probably correlated with the number of spawnings per year.

3.5.2 The Fishery

Utilisation: Between 1964 and 1974 the tilapia population in the Sepik River basin increased so rapidly that by 1974 the catch by artisanal fishers was estimated to be 10,891 mt/yr (Redding, 1989). The tilapia were fished with spears and hooks and only 18 per cent of the catch was taken with gillnets of 4-5 inch mesh. The use of gillnets has become much more widespread over the past 20 years. Tilapia are caught with hook and line in Yonki Reservoir (van der Heijden, 1993b) and almost exclusively with gillnets in Waigani swamp near Port Moresby.

People living as far away as Konedobu and Four-mile (Port Moresby) travel to Waigani swamp to fish. In 1983 nearly 30 per cent of fishers surveyed made their living from fishing in the swamp (Fisheries Research annual report 1983). The gilled and gutted catch is taken to markets in the Port Moresby district.

Ramu River tilapia is trucked to Madang and to Lae. Tilapia caught in nearby swamps are sold also in markets in the Gulf and Northern (Oro) provinces (Fishery Sector review, 1989).

Of 27 villages surveyed in the Sepik Ramu system, tilapia was present in 42.3 per cent of their waters and was the 6th most preferred fish (26.9 per cent) (Mys and van Zweiten, 1990). Tilapia are eaten in seven Torricelli Range villages (and they are among the larger of the fish species there) but - in contrast to the other large targeted species there (eels, catfish) - they do not have large amounts of fat and are therefore not as highly regarded.

In Yonki Reservoir, *O. rendahli* has only been caught since mid-1992. Whereas *O. mossambicus* is not a favourite of the local residents because of its small size and small amount of flesh [?stunted because of altitude?], *O. rendahli* is more preferred (van der Heijden, 1993b). Van der Heijden (1993b) found that 11.6 per cent of fishers at Yonki preferred to eat *O. mossambicus* and 13.8 per cent preferred to eat *O. rendahli*.

The apparent size of the tilapia resource in the Sepik-Ramu river basins engendered the 'solpis' fish fillet industry. A central marketing system was proposed and later (1974/75) realised in the establishment of the East Sepik Rural Development Project (ESRDP) through Asian Development Bank funding. Its aim was to provide a collection service for processed (salted, sun-dried) fillets for the middle Sepik and distribute and sell them throughout PNG. Despite the initial enthusiasm the industry never reached its projected levels and has since decreased in production to minimal levels (Redding, 1989). The decline in the 'solpis' industry is probably due to a combination of factors including the faulty basis of yield predictions, disinterest by nationals in fishing, the variable availability of the fish, overfishing of tilapia due to targeting, better economic return from fresh fish or tinned fish and the reduction in fishing activity due to the emergence of the aquatic fern *Salvinia molesta* (Rodwell, 1982; Redding, 1989). Another problem may have been transport costs involved in marketing 'solpis' in the Highlands region (it was trucked to Wewak, sea freighted to Lae, trucked to the Highlands).

Production and Marketing: Between 1981 and 1989, tilapia accounted for about 65 per cent of the weight of fish passing through the Angoram market (Redding, 1989). This - she suggested - shows the importance of the species in the subsistence and commercial fishery in the Sepik River basin. Coates (1989) observed that 50 per cent of landings in the Sepik River floodplain fishery consisted of tilapia. Dry season landings average about 100 times more than flood season catches (Coates, 1989). In eight years of market surveys, Redding noted an increase in the numbers of tilapia being sold in April, May, August and September.

Table 154 1979 harvest offered for sale at the Angoram market once every month, were (source: Fisheries Research annual report 1979):

Period	Nov.-April (wet season)	May-Oct. (dry season)
fresh tilapia (mt)	8.6	13.6
smoked* tilapia (mt)	17.5	25.8

(*: 'in fresh fish equivalents' - i.e. solpis x 6.7)

The prices offered averaged 8 mt/kg for salted fillets, 30 mt/kg for smoked split tilapia and 26 mt/kg for fresh whole tilapia.

Coates (1985) estimated that tilapia production from freshwater lakes in the Sepik was 8-40 kg/ha/yr. The 1989 Sector Review stated that the current (i.e. 1989) catch in the Sepik floodplain was about 4000 mt/yr comprising 50 per cent tilapia and 50 per cent catfishes and gudgeons. Van der Heijden (1993a) estimated that carp+tilapia comprise 42.1 per cent (= 3,436.43 mt) a year of harvest from the Sepik-Ramu river system. As percentage of annual catches, tilapia are present in high altitude (c. 200-400 m) catches 0.1 per cent by number and 0.1 per cent by weight, in mid altitude (c. 80-200 m) they are present in catches 7.8 per cent by weight and 8.2 per cent by number, and in low altitude (c. 40-120 m) areas they are present in catches 49.1 per cent by weight and 48 per cent by number.

In Yonki Reservoir, the weight of each *O. mossambicus* caught increased from about 30 g in February 1992 to about 100 g in December 1992 and the average number of tilapia caught per person in the same period ranged from about 0.5 to about 5 (van der Heijden, 1993b). In comparison, from July 1992 (shortly after it was introduced) the number of *O. rendahli* caught in Yonki was about 2.5 per person to December 1992 when it was about 6 per person, and the weight of each fish ranged from an average of about 30 g to about 200 g. Approximately 15 months after being introduced to Yonki Reservoir *O. rendahli* contributed 47.9 per cent to the total weight of catches from the reservoir (van der Heijden, 1993b).

Table 155 The production of 'solpis' in the Sepik in mt in the Sepl River system, 1977-88 (source: A.1977-81- Rodwell, 1982; B. ESRDP - December 1978*; C. DPI Fisheries Research Angoram, March 1979*; 1988 - Redding, 1989):

Year	1977	1978	1979	1980	1981	1988
projected wt - A.	20.7	60.8	125.2	214.6	357.7	?
projected wt - B.	-	23	68	135	-	-
projected wt - C.	-	-	35	40	-	-
realised wt	14.5/15.8*	22.3/22.6*	40.3/40.0*	20.9	10.3	2

(*: from Fisheries Research annual report 1979)

The maximum catch rate at the height of the 'solpis' industry was 93.49 g/sq m (Redding, 1989). The original projected production was 140 g/sq m (Redding, 1989) and in 1979 the DPI Fisheries Research unit at Angoram projected a yield of 70 kg/ha/yr. One reason for the overestimate of tilapia production in the Sepik floodplain is that it was based on production in Asian and African streams (Fishery Sector review 1989). The value of the 1979 product was K49,000 (Fisheries Research annual report 1979). By 1981, 81 per cent of the 'solpis' production was from four main villages on the Upper Keram River (Redding, 1989).

Fresh and smoked tilapia ('makau') are the main fish products sold every day in Lae's main produce market (Hermes *et al.,* 1994). They are sold on a 'per piece' basis (K0.20-K0.80) regardless of whether they are fresh or smoked. In a two-week period in December 1993, 33 kg of fresh tilapia and 21.4 kg of smoked tilapia were sold in the market.

There are no production figures for the tilapia catch sold in the Port Moresby district. Both fresh and smoked tilapia are sold at Koki market nearly every day of the week and they have been for at least 20 years. In 1983 it was estimated that full-time fishers earned up to K100/fortnight from the sale of catches (several species but mainly tilapia) from Waigani swamp (Fisheries Research annual report 1983).

At the Madang provincial government's landing place 11,034 kg of tilapia were brought there in 1992, and up to October 1993 tilapia comprised 29 per cent of landings (source: DFMR/PGFO Madang).

3.5.3 Stock status

Coates (1989) believed that the ability of tilapia to exploit floodplain conditions [on the Sepik-Ramu] is the major factor determining its relative (especially early) success within the river. Coates considered that the success of tilapia in the Sepik River basin suggests that the detritus in the river 'is particularly rich, or underexploited, or both'. This is - in my view (supported by Arthington (1986) and others) - is a minor contributor to success. Tilapia are successful wherever they are introduced because

- they are mouth brooders. Parental care always enhances the species' success by ensuring that most of the brood survive and they are free swimming at a larger size than are other post-larval fish in the same habitat;

- they are aggressive fish;
- they are territorial;
- they have a wide temperature tolerance;
- they breed sequentially - capable of breeding every 6-8 weeks, instead of breeding approximately once a year (related to the monsoon periods) as do native fish;

By 1989, Redding found that the existing *O. mossambicus* stocks in the Sepik River basin were limited and that they had shown a tendency to become over-exploited, even at 'modest' levels of fishing pressure. A survey of the Angoram market in that year revealed that the mean fish size appeared to be smaller than that 5 years earlier - suggesting stunting. By the late 1970s/early 1980s it was realised that catches of tilapia in the Sepik were falling (Fisheries Research annual reports 1979; 1980 & 1981).

There are large fluctuations in the abundance of tilapia in landings: catch rates in the Sepik basin show a marked seasonality as they are related to the level of water in the river and hence the floodplain (Redding, 1989). Catches are greater during the periods of low or falling water levels when most of the fish were concentrated in the deeper waters. Shallower sites adjacent to the floodplain tend to yield more fish than does the deeper roundwater (Redding, 1989). During March of each year there is a significant fall in the catch rate of both males and females. This could be due to either adult fish moving onto the nesting sites outside the area or the influx of juveniles, or a combination of both. Area and year class recruitment each year is dependent - to some extent - on the area of floodplain inundated during the wet season in previous years.

Most individuals of *O. rendahli* caught one year after stocking in the Sepik-Ramu river system were smaller than 10 cm total length (probably the F1 generation) or bigger than 19 cm total length (van der Heijden, 1993a). In contrast, Yonki Reservoir fish increased in number and size much faster over a similar time interval after stocking (van der Heijden, 1993b).

In Yonki Reservoir *O. mossambicus* and carp comprised the total catch in February-March 1992, and in July 1992, *O. rendahli* was also in the catch - less than a year after it was stocked in the Upper Ramu River (van der Heijden, 1993b). The effect of red-breasted tilapia (*O. rendahli*) on the other two species is illustrated in the table below.

Table 156 Percentages of catch in the Yonki Reservoir, 1992. (Variations in fishing periods, methods, etc - if any - not stated) (source: van der Heijden, 1993b)

Species	February 1992	May 1992	December 1992
Cyprinus carpio	84%	-	17.4%
O. mossambicus	16.3%	56.5%	36%
O. rendahli	nil	-	46.6%

In the Sepik River, van der Heijden (1993a) found that 12.8 per cent of respondents to a questionnaire living along the mid-altitude length of the river, and 19.2 per cent or respondents living along the low altitude river length believed that the presence of tilapia (*O. mossambicus*) in the river had caused a decrease in the number of native species present in catches.

3.5.4 Management

Current legislation/Policy regarding exploitation: To introduce it to suitable waterways as a means of increasing the availability of fish protein to nationals. Red-breasted tilapia were introduced as the result of research conducted by the Sepik River Fish Stock Enhancement Project (SRFSEP), who found that it utilised a different food niche to Mosambique tilapia as well as being more flavoursome (although they informed me that they had not taste-tested it!).

Recommended legislation/Policy regarding exploitation: None at present.

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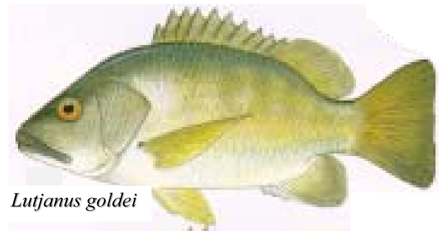
3.6 PAPUAN BLACK BASS

3.6.1 The Resource



Lutjanus goldei

Species present: The Papuan black bass is *Lutjanus goldiei*. It was formerly confused for the river roman or mangrove jack, *Lutjanus argentimaculatus*. In international sports fishing circles, Papuan black bass are called 'Papuan black snapper', New Guinea bass or Niugini bass.

Distribution: Papuan black bass inhabit streams and rivers in the West Sepik Province (Vanimo), East Sepik Province (Sepik and Ramu rivers), Madang Province (Ramu River: Allen *et al.,* 1992), all major rivers of West New Britain and East New Britain (e.g. Panimo, Pulie, Kulu, Powell, Henry Reid, Bergberg, Esis and Warangoi rivers), Popondetta (Northern Province), Central Province (Vanapa, Laloki and Kempwelch rivers), Gulf Province (Bamu and Aramia rivers, Kikori River system, Purari River system) and Western Province (Fly River). They probably inhabit Bougainville (North Solomons Province) rivers as well.

L. goldiei was believed to be endemic to the New Guinea mainland and islands but it has recently been recorded from the Ryukyu Islands (Senou and Suzuki,1992, in Allen *et al.,* 1992).

Papuan black bass inhabit brackish and fresh waters. Generally, they inhabit rivers subject to high rainfall in their catchment and hence prone to rapid rises in water level and swift flow. Hence, Papuan black bass are not in the Markham River, nor in rivers west of the Fly River, including the Bensbach River. The New Britain rivers where they occur are somewhat deep and swift to moderatley slow flowing (Stein, 1992). Coates (1989) recorded Papuan black bass from the lower Sepik-Ramu rivers as far upstream as Ambunti - 300 km from the sea. (In 1983, Coates had recorded the species as *L. argentimaculatus*). Papuan black bass occurs in oxbow lakes, floodplain habitat and lagoon/lake systems in the middle Fly River from Kiunga to Lake Bosset (Smith and Bakowa, undated). They are found only in the Seribi River (a tributary of the Kikori River) and upper reaches of the Purari River (Haines, 1979).

Biology and Ecology: In rivers draining into Galley Reach (west of Port Moresby) Papuan black bass have been caught up to 35 lb (c. 16 kg) rarely attain more than 5 kg, but in Western Province, individuals are known to reach about 30 kg. Stories of fish larger than 80 lb (c. 35 kg) have never been proven (D. Butler, pers. comm.). The International Game Fishing Association has recorded a 43 lb (c. 20 kg) fish taken from the Ok Tedi River in its "all tackle" records section. The maximum total length is about 100 cm (Allen, 1985) and fish of this size have been captured in rivers near Port Moresby.

Papuan black bass are opportunistic and omnivorous in their diet. They consume invertebrates (e.g. crabs), fish (including catfish, smaller bass and spot-tail bass), small crocodiles and mammals (D. Butler, pers. comm.). In common with many large, rivering fish, Papuan black bass are territorial fish. In areas where there is little tidal influence they remain in the one general area, but where there are large tides (e.g. in the Gulf Province rivers) they move ('run') with the tides and changing river flows and water levels. They take live bait when angled.

The fish appear to move upstream to spawn at the end of a dry period (?the dry season). D. Butler has caught large, running ripe males at these times and areas. Nothing else is recorded about the species' biology, and there is an urgent need to establish age estimates and other population estimates. Work being undertaken in 1993 by M. Huber and others based at the University of PNG remains incomplete and unpublished (M. Cappo and D. Butler, pers. comm.).

3.6.2 The Fishery

Utilisation: Papuan black bass are caught in gillnets by artisanal and subsistence fishers, and in the last ten years comprised a noteworthy component of the fish landings at the Baimuru Fish Plant in the Gulf of Papua. Other artisanal fishing methods include handlines, traps and spears. Papuan black bass are caught in conjunction with mangrove jack, thumbprint snapper (*Lutjanus johni*), spot-tail bass (*L. fuscescens*) - in New Britain - and barramundi (profile 1.2). The species was not harvested commercially in its own right until the mid-1980s, and before that it was traded as a 'mixed fish' component and called 'second barramundi' (D. Butler, pers. comm.).

Papuan black bass are the prime target of recreational (sports) fishers. In sportsfishing circles it is generally considered that pound for pound they are the strongest fish swimming in either fresh or salt water (D. Butler, pers. comm.). Recreational fishers engage in fishing 'safaris' to catch and then release these fish. The fish are caught with rod-and-reel or by fly casting using lures. Live baiting (using fish such as tilapia (profile 3.5), or prawns) is most effective at times. There is also a lodge at Arrjim Island (near Kandrian, West New Britain) from where anglers access southern New Britain rivers.

Production and Marketing: Papuan black bass are occasionally sold at the Kokopo fish market in East New Britain (source: DFMR database, Kavieng; 44 kg in 1991), and in recent years they have been sold (as black bass) in supermarkets in Port Moresby (D. Butler, pers. comm.).

In Baimuru, fish are bought from fishers for K1/kg. However, given their value to recreational anglers, the best market value for Papuan black bass is 'alive and in situ'.

Table 157 Landings of Papuan black bass at the Baimuru Fish Plant, 1984-89 (source: DFMR database):

Year	1984	1985	1986	1987	1988	1989
quantity (kg)	982	no record	2,555	1,753	795	501

3.6.3 Stock status

There is no estimate of abundance. Anecdotal reports suggest that Papuan black bass are nowhere abundant, occurring in river systems in their hundreds rather than thousands. This view is supported by sportsfishing catch-and-release rates (D. Butler, pers. comm.), and Haines (1979) recorded the species from single individuals only.

The catch figures at Baimuru have dropped, probably the result of leaving gillnets (e.g. for barramundi) set in the water.

As with other fish resources, the effect on habitat of forest clearing practices which increase water turbidity ranges from mild to severe. It is probable that Papuan black bass populations (especially those in New Britain where there is extensive logging) are being adversely affected.

3.6.4 Management

Current legislation/Policy regarding exploitation: In its 1993 statement of policies and programmes, the DFMR supported the conservation of freshwater species utilised for sportsfishing (barramundi and Papuan black bass) and recognised the value of these species as economic, social, recreational and aesthetic assets to the nation. The DFMR suggested regulation of game fish operators, and further study of the sportsfish industry.

Recommended management/policy regarding exploitation: Papuan black bass are a valuable resource for the tourism industry. Their apparently low population size and localised distribution mean that the species would not support a commercial fishery in its own right.

In view of their importance to the recreational fishery (internationally), information on the species' distribution and biology should be gathered by DFMR in cooperation with recreational sports fishing clubs and individuals. Completing logbooks on a voluntary basis would assist, and these should be carefully designed to obtain as much information as possible from fish which are released on capture. Safari captains should be encouraged to debrief DFMR. 'Biologicals' should be obtained by DFMR from whole fish brought to the Baimuru Fish Plant and fishers should be questioned regarding catching method, known fish movements, distributions and habitats.

In view of the tourism value of these fish, the interests of the clubs and 'safaris' should be protected. National fishers should be discouraged from harvesting Papuan black bass other than for subsistence food. This matter seems to be particularly relevant in the Gulf Province. There the DFMR should promote the importance of live Papuan black bass to villagers and, in association with the PNG tourism industry and sportsfishers, encourage and assist the villagers to participate in the recreational fishery.

The development of a sportfishery based on estuarine/lowland river areas would also be less expensive than 'bluewater' gamefishing (Fishery Sector review 1989). *Mobile 'safaris'* to the Gulf and Western provinces from Port Moresby could be organised with the use of house-boats, and *serviced sportsfishing lodges* (like the Bensbach Lodge) could be established. Although little specialist infrastructure is required, access would need to be negotiated with traditional owners. The income to villagers from sportsfishing for Papuan black bass and barramundi would be more than they would obtain for these fish on the shop floor - i.e. villagers where Papuan black bass occur should be encouraged to look at this fish as a re-usable resource.

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For information, Papuan black bass is recorded on video in a series called Clear Water, Big Fish (vol.1) (Rodney Clarke, Melbourne, 328 2274) and in a video simply called New Guinea Black Bass by W&G Media (Brisbane, 899 2768).

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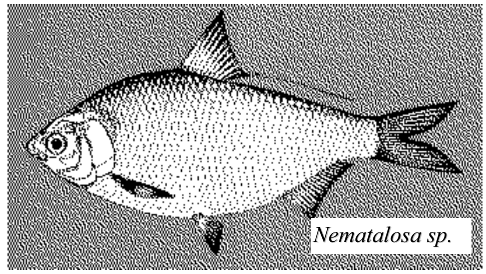
3.7 FLY RIVER HERRING

3.7.1 The Resource



Nematalosa sp.

Species present: The species of bony bream comprising the resource are *Nematalosa flyensis* and *N. papuensis*. *N. flyensis* was described as recently as 1983. Another species - *N. erebi* - also inhabits freshwaters of the Western Province but only around the Bensbach River (Kailola, 1987).

N. flyensis and *N. papuensis* are distinguished mainly on the length and number of their gill rakers, characters difficult to utilise when attempting to differentiate between the species in the field.

Distribution: *N. flyensis* and *N. papuensis* occur only in the Western Province - certainly the Fly and Strickland rivers, possibly the Bamu-Aramia rivers system.

Within the extensive floodplain system of the Fly River, *Nematalosa* species are most abundant in the flooded shallow valleys and oxbow lakes (billabongs) and are abundant in the open waters of the grassed floodplain (e.g. at Bosset) (Smith and Bakowa, undated). The oxbow lakes are deeper and serve as refuges during the dry season.

Biology and Ecology: No studies have been conducted on the biology of the two species separately. *Nematalosa* form large shoals, often in shallow water (Briggs, 1980). Because they move about a lot their distribution is patchy and they can be locally abundant. They are bottom (mud) feeders, mainly of detritus, but also feed on algae and aquatic insects (Briggs, 1980; Merrick and Schmida, 1984). *Nematalosa* comprise an important food source for larger fish - e.g. *Lates calcarifer* and some fork-tailed catfish species.

Nematalosa are short-lived species. They spawn several times each year (if not continuously) (Ok Tedi Mining Limited, 1986, in Smith and Bakowa, undated) with peak spawning activity in the early wet season (*N. erebi;* probably also *N. papuensis* and *N. flyensis* Merrick and Schmida, 1984). They probably mature at 13-15 cm length [tropical populations of *N. erebi*] and probably have a rapid growth rate. Fecundity is high, ranging up to several hundred thousand in large females (Briggs, 1980). The eggs are pelagic, less than 1.0 mm in diameter (*N. erebi*). They attain a moderately large size, to 278 cm in length (M. Wilson, pers. comm.).

3.7.2 The Fishery

Utilisation: The fish are occasionally targeted by villagers using small mesh gill nets. They may feature as a bycatch of the barramundi fishery but as gillnets used in that fishery are large, only larger fish would be caught in them. The fish are used as subsistence food.

Nematalosa spoil rapidly after capture because of their oily nature. They also have numerous fine bones. For these reasons, *Nematalosa* species are not utilised very much by local villagers.

Production and Marketing: All catch data reported by Ok Tedi Mining Limited are lumped together for the two species, *N. flyensis* and *N. papuensis.* There is no information on the quantity of herrings harvested each year. Catches vary substantially because of the sporadic occurrence of the fish shoals in different stretches of water (Smith and Bakowa, undated).

In Lake Pangua, catches of larger fish tend to dominate in March and July (M. Wilson, pers. comm.).

For the period February 1989-June 1992 a quarterly sampling program along the Fly River yielded catches of bony bream as tabled below.

Table 158 Catches of bony bream from the Fly River, 1989-92.

Station	Total number	Total weight (kg)	Mean weight (g)
Bosset lagoon	10,220	1,421	139.1
Lake Pangua	10,945	993.7	90.8
Oxbow lake 1	1,961	121.7	62.1
Oxbow lake 2	2,428	142.5	58.7
Oxbow lake 3	5,482	372	67.8
Oxbow lake 4	2,720	209.9	77.2
Fly River	1,062	119.5	112.6
Fly River	1,937	152.8	78.9

(Information such as length of set, gear and time of day is not available).

3.7.3 Stock status

The stocks are presently largely unexploited.

Nematalosa accounted for 14-72 per cent of the biomass caught in lacustrine areas sampled by Smith and Bakowa (undated) who found the largest catches were from Lake Pangua. Smith and Bakowa (undated) estimated that *Nematalosa* have the potential for a much greater sustainable harvest than has barramundi, *Lates calcarifer*.

By comparing production data for the *Nematalosa* species in the Western Province with that for *N. erebi* in South Australia, M. Wilson (pers. comm.) suggested a sustainable yield of 5,000 mt a year for the *Nematalosa* species combined. However, environmental factors - such as long periods of drought - can influence yield size.

3.7.4 Management

Current legislation/Policy regarding exploitation: There is none.

Recommended legislation/Policy regarding exploitation: Ok Tedi Mining Limited and the Porgera Joint Venture mining company have expressed interest in facilitating the utilisation of the Fly River herring stocks. A fishery based on this substantial resource would provide additional protein and income for inhabitants of the Fly-Strickland rivers basin, who comprise 96 per cent of the population of the Western Province (PNG National Statistics Office, 1982). Properly processed product could also be sold elsewhere in PNG and possibly, overseas. Dissemination and purchasing of processed Fly River herring throughout the country also could alleviate the substantial outlay by the country on canned imported fish products.

Nematalosa species need to be frozen or salted straight away after capture and are not very acceptable to the consumer in an unprocessed state. Development of an acceptable product is difficult because of their very bony naure. However, a precedent to processing bony bream has already been set - in the processing of *N. erebi* during the war, when it was canned for consumption of troops overseas (Briggs, 1980).

Trials conducted recently by Ok Tedi Mining Limited and the Australian Maritime College (in Launceston) established five products which could be developed from Fly River herring. Two of these (salted dried fish and, possibly, spicy fish slices) can be prepared at village level using a solar dryer, while the remainder (fish burgers, fish cakes and canned spicy fish) are appropriate to factory style production (F. Kow, pers. comm.). Tests showed that the products have high nutritional values.

Salted dried fish can be used for home village consumption or packaged and sold in the Highlands or elsewhere. Other products rely on the fish being frozen immediately after harvest and processing facilities should be located where there is adequate clean water and power (e.g. at Kiunga and Tabubil) and where quality could be maintained.

Several further steps should be undertaken to facilitate the establishment of a fishery for Fly River herring.

1. Unbiased sampling should be carried out with the aim of establishing population parameters such as growth and mortality, so enabling the determination of yield estimates and levels of exploitation for the two species.
2. Method(s) should be devised whereby the two species may be distinguished in the field. Information on catches of correctly determined species is needed for accurate assessment of biomass and monitoring of yields and sustainability.
3. Different fishing methods should be trialed to establish catch rates and handling strategies. For example, use of shallow drop nets or ring nets with submersible lights used overnight (M. Wilson, pers. comm..).
4. Studies of the productivity of the Fly-Strickland rivers floodplain should be conducted on an annual basis. Information from these studies would support annual estimates of *Nematalosa* biomass and annual harvest projections. Short life span, fast-growing species such as herrings and sardines (family Clupeidae) are inclined to wide fluctuations in biomass in response to environmental factors.
5. Development and availability of and support for suitable preservation techniques for handling the fish immediately on capture. These include refrigeration or brining, and salting and drying. A processing vessel - equipped with refrigeration, processing and packaging facilities - could provide this support in conjunction with a land-based freezer plant for holding processed product (M. Wilson, pers. comm.). Because the vessel could move to areas of high productivity, its use would obviate transport (and hence, spoilage) difficulties to land-based freezers.
6. Production and taste trials should be performed on identified fish products and should include realistic evaluations of quality maintenance, transport facilities, costs, shelf life, packaging and markets.
7. Discussions should be held with villagers affected by the proposed fishery to ascertain customary fishing rights, and negotiations should be undertaken with regard to access to the resource. Every attempt should be made later in the fishery's development to engage local villagers before nationals from other areas.

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