FIJI FISHERY RESOURCE PROFILES

Information for management on 44 of the most important species groups

GPA

Ministry of Fisheries Fiji
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LIST OF ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
ASEAN	Association of South East Asian Nations
AUD	Australian Dollar
BRUVS	Baited Remote Underwater Video Surveys
CCM	Members, Cooperating Non-members and Participating Territories of the WCPFC
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CL	Carapace Length
CMM	Conservation and Management Measures
CPUE	Catch Per Unit Effort
DWFN	Distant Water Fishing Nation
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EU	European Union
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organization of the United Nations
FFA	Pacific Islands Forum Fisheries Agency
FFC	Forum Fisheries Committee
FL	Fork Length
FJD	Fijian Dollar
FOB	Freight on Board
FRCS	Fiji Revenue and Customs Service
GDP	Gross Domestic Product
IGFA	International Game Fishing Association
IUCN	International Union for the Conservation of Nature
LRFFT	Live Reef Food Fish Trade
MSY	Maximum Sustainable Yield
MUS	Management Unit Species
NZ	New Zealand
NGO	Non-Government Organisation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Agency
PAFCO	Pacific Fishing Company Limited (Fiji)
RFMO	Regional Fishery Management Organisation
SCRFA	Science and Conservation of Fish Aggregation
SCUBA	Self Contained Underwater Breathing Apparatus
SPC	Pacific Community
SPR	Spawning Potential Ratio
TAC	Total Allowable Catch
TL	Total Length
TMDP	Tuna Management and Development Plan
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UBA	Underwater Breathing Apparatus
US/USA	United States of America
USD	United States Dollar
USP	University of the South Pacific
WCS	Wildlife Conservation Society
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WWF	World Wide Fund for Nature

FOREWORD

Fishery resources are vitally important to Fiji. They are significant to the country in terms of food security, employment, and exports – in addition to their recreational and social attributes. Fiji has a wide range of fishery resources, including finfish, invertebrates, and plants. By one estimate, over 350 species are harvested in Fiji.

Much of the work of the Ministry of Fisheries involves interventions to maximise the benefits from these resources and to protect them for the future. This is a complex, expensive and challenging process – and many decisions in fisheries management require detailed information on the concerned species.

Much research in Fiji has been done in the past on the animals and plants that support fishing activity. In fact, a bibliography on Fiji fisheries published 25 years ago listed over 1,400 reports on aspects of fisheries in Fiji. However, there is a problem in that the information is scattered and not readily available – and this often equates to a scarcity of knowledge on the part of people with responsibilities for the management of particular fishery resources.

I have considerable pleasure in announcing the publishing of a reference book that pulls together much of the past fisheries research in Fiji into a single volume. The *Fiji Fishery Resource Profiles* gives summary information on 44 of the most important species or species groups. For each resource covered the book has information on the species present, distribution, biology/ecology, the fishery, production/marketing, stock status, management, current legislation/policies on exploitation, and management recommendations. In short, a “one-stop shop” for fishery managers and other interested people.

I note that this book is a collaborative effort. The contributors are staff of the Ministry of Fisheries, non-government organisations, academics, the private sector, and individual consultants. I am especially pleased that efforts have been taken to encourage young researchers to produce chapters – and learn the art of putting together a major publication.

This work has been largely supported by the David and Lucile Packard Foundation – who have been very generous with their assistance to Fiji over the past 15 years. The John D. and Catherine T. MacArthur Foundation contributed to finalising the publication.

Hon. Semi Koroilavesau
Minister of Fisheries

INTRODUCTION

In 1985, the Fisheries Division of Fiji's Ministry of Agriculture, Fisheries and Forestry produced the "Fiji Resource Profiles".[1] That 90-page document catalysed the production of similar profiles for most Pacific Island countries. The Fiji profiles informed Government policy on natural resource management for some years. In 1993, the Forum Fisheries Agency (FFA) was requested by the Fiji Fisheries Division to provide technical assistance in the compilation of information on the important fishery resources of the country. FFA's Research Coordinator, Andrew Richards, worked in Fiji with Fisheries Division staff in October to November 1993 to collect relevant information. In early 1994, FFA published the 205-page document "Fiji Fisheries Resources Profiles."[2]

The 1994 publication proved to be quite useful. It served to provide summary information on 45 different categories of animal and plant fishery resources to staff of the Fisheries Division, non-governments organisations (NGOs), students, communities, researchers, and others. The profiles were especially convenient, given the limited availability of documentation on Fiji's economically important marine and freshwater organisms.

THE 1994 "FIJI FISHERIES RESOURCES PROFILES" ARE ARGUABLY ONE OF THE MOST USEFUL DOCUMENTS EVER PRODUCED TO SUPPORT THE DEVELOPMENT AND MANAGEMENT OF INSHORE FISHERIES IN FIJI.

More recently, the David and Lucile Packard Foundation has supported a portfolio of projects specifically targeted at improving the governance of Fiji's inshore fisheries. In 2016 Gillett, Preston and Associates interviewed people in the Fisheries Department, NGOs, and fisheries specialists in Fiji to determine specific problem areas that were constraining the management of inshore fisheries. Many people interviewed noted the lack of readily available reference material on the resources that support significant fisheries in Fiji. Accordingly, the Packard Foundation funded efforts to update and enhance the 1994 FFA fishery profiles.

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1 Lewis, A. 1985. Fishery resource profiles: information for development planning. Fisheries Division, Ministry of Primary Industries, Suva.

2 Richards, A., M. Lagibalavu, S. Sharma and K. Swamy. 1994. Fiji Fisheries Resources Profiles. Report 94/4, Forum Fisheries Agency, Honiara. 205pp.

This document contains 44 profiles of fishery species groups. Where information is available, profiles have sub-sections on:

- The resource
    - Species present
    - Distribution
    - Biology and ecology
- The fishery
    - Utilisation
    - Production and marketing
- Stock status
- Management
    - Current legislation/policy
    - Recommended legislation/policy
- References

It is acknowledged that the primary reference for most of the profiles is the 1994 FFA publication. Much of this document builds on the work led by Andrew Richards 23 years ago.

It should be noted that these profiles focus on information specific to Fiji. More general information on the groups of resources covered is available from a variety of sources, including FishBase (www.fishbase.org), species identification guides for the Western Central Pacific by the Food and Agriculture Organization (FAO) of the United Nations (www.fao.org/docrep/009/w7191e/w7191e00.htm), and the Pacific Community (SPC) Guide and Information Sheets for Fishing Communities in the Pacific (http://www.spc.int/coastfish/en/publications/information-sheets/kit-for-communities.html). The drawings are courtesy of the FAO.

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Some comments and caveats are made on the profiles in this document. In this regard, some features associated with fisheries in Fiji should be noted:

- In the two decades since the 1994 FFA publication there has been little assessment of inshore fishery resources on a Fiji-wide basis. Although much surveying of resources has been done at the community level by the Fisheries Department (196 sites) and NGOs (about 135 sites), there has been virtually no work from those surveys oriented towards examining the stock status of specific resources across all sites (e.g. the status of trochus in Fiji).
- For several decades the Fisheries Department surveyed municipal, non-municipal markets, other outlets and roadsides in the Central, Western, and Northern Divisions for the sales of finfish and non-finfish and published estimates of those sales in the Department's annual report. Detailed reporting of catches ceased in 2004 and summary reporting continued to 2013, with a gap for 2011 and 2012. A recent assessment of the market survey in a review of coastal fisheries in Fiji[3] stated "The statistical system that is used to provide coastal fisheries data in Fiji is now no longer functional, primarily due to the prioritisation of scarce government resources. This has resulted in a shortfall of fisheries information". The end result is that there have been no reliable production data for inshore fishery resources for more than ten years, making it impossible to monitor trends in production.
- As to exports of fishery products, the monitoring of inshore fishery exports by the Ministry of Fisheries appears to be quite inaccurate.[3,4] The Customs Department independently monitors exports using a detailed international system for classifying exports, but the fish categories that are actually declared by exporters and used by Customs are often not very informative (such as "other dried fish" and "fish fillet fresh or chilled"). This results in poor knowledge of exports of specific types of fish, and inadequate data for fisheries management.

The above three points tremendously reduces the amount of useful data for compiling these fishery resource profiles. On a different level this paucity of information limits the effectiveness of fisheries management in the country – to address this the Ministry of Fisheries has resurrected its market surveys. However, investments should also be made in export monitoring.

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3 Gillett, R., A. Lewis, and I. Cartwright. 2014. Coastal Fisheries in Fiji: Resources, Issues, and Enhancement of the Role of the Fisheries Department. Gillett, Preston and Associates for the David and Lucille Packard Foundation, Suva. 60pp.

4 Mangubhai S., Y. Nand, R. Ram, M. Fox, M. Tabunakawai-Vakalalabure, and T. Vodivodi. 2016. Value Chain Analysis of the Wild Caught Sea Cucumber Fishery in Fiji. Report No. 02/16, Wildlife Conservation Society and Fiji Department of Fisheries, Suva. 66pp.

INVERTEBRATE FISHERY PROFILES

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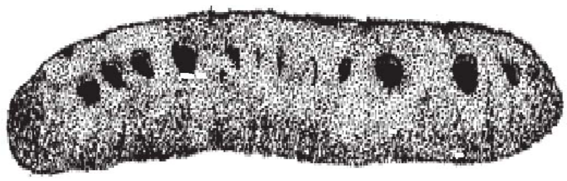
1 SEA CUCUMBERS



1.1 The Resource

Species Present: There are approximately 1,200 species of sea cucumbers (Family Holothuridae) distributed world-wide, of which at least 66 species are commercially harvested (Purcell, 2010). Pakoa *et al*. (2013) listed 27 commercially harvested species occurring in Fiji, of which 20 were important for the commercial export trade. Three additional species, **dri** (burying blackfish − *Actinopyga spinea*), *Bohadschia ocellata* and **katapila** (dragonfish − *Stichopus monotuberculatus*), were later observed drying in exporters' warehouses in 2016 (Purcell *et al*., 2016a). Fishers in Fiji reportedly do not distinguish between *B. ocellata* and *B. argus* due to their close resemblence to each other (Purcell *et al*., 2016a). Therefore, the local name for *B. ocellata* is likely that of *B. argus* – **vula ni cakau**. To date there are 30 sea cucumber species, of which 28 species are commercially important for Fiji's sea cucumber fishery (Table 1).

Table 1. Sea cucumber species present in Fiji. na: data not available. Source: Pakoa *et al.* (2013), Purcell *et al.* (2016a), Lalavanua *et al.* (2017a)

Common name	Scientific name	Local name	Value	Regional reference densities[5] (animals per ha)
deepwater redfish	*Actinopyga echinites*	**dri tabua**	High	na
spiky deepwater redfish	*Actinopyga flammea*	**tarasea**	Medium	na
stonefish	*Actinopyga lecanora*	**dri vatu**	Medium	10
surf redfish	*Actinopyga mauritiana*	**tarasea**	High	20
hairy blackfish	*Actinopyga miliaris*	**dri loli**	Medium	150
deepwater blackfish	*Actinopyga palauensis*	**dri ni cakau**	High	na
burying blackfish	*Actinopyga spinea*	**dri**	Medium	na
tigerfish	*Bohadschia argus*	**vula ni cakau**	Medium	50
chalkfish	*Bohadschia marmorata*	**mudra**	Medium	1,400
polka-dotted sea cucumber	*Bohadschia ocellata*	**vula ni cakau**	Medium	na
brown sandfish	*Bohadschia vitiensis*	**vula**	Medium	160
lollyfish	*Holothuria atra*	**loliloli**	Low	2,400
snakefish	*Holothuria coluber*	**yarabale**	Medium	350
loli's mother	*Holothuria coronopertusa*	**tina ni loli**	Medium	na
pinkfish	*Holothuria edulis*	**loli piqi**	Medium	250
white teatfish	*Holothuria fuscogilva*	**sucuwalu**	Very High	10
elephant's trunkfish	*Holothuria fuscopunctata*	**tina ni dairo**	Low	10
slender sea cucumber	*Holothuria impatiens*		Low	na

5 Assessments conducted by SPC in 2002−2012, generated threshold densities for 17 species of sea cucumbers by averaging the 25% highest densities from the Pacific. These can be used as a baseline for comparison or as a reference in the case that a site has no specific site density data available.

Common name	Scientific name	Local name	Value	Regional reference densities[5] (animals per ha)
golden sandfish	*Holothuria lessoni*	**dairo kula**	Very High	na
white snakefish	*Holothuria leucospilota*		Low	20
sandfish	*Holothuria scabra*	**dairo**	Very High	700
black teatfish	*Holothuria whitmaei*	**loaloa**	Very High	10
flowerfish	*Personothuria graeffei*	**senikau**	Low	50
greenfish	*Stichopus chloronotus*	**dri votovoto**	High	1,000
curryfish	*Stichopus herrmanni*	**laulevu**	Medium	130
Selenka's sea cucumber	*Stichopus horrens*	**katapila**	Low	na
dragonfish	*Stichopus monotuberculatus*	**katapila**	Medium	na
brown curryfish	*Stichopus vastus*	**laulevu**	Medium	na
prickly redfish	*Thelenota ananas*	**sucudrau**	High	10
amberfish	*Thelenota anax*	**basi**	Low	20

Distribution: Sea cucumbers of commercial importance are distributed globally across all latitudes, in all major ocean froms intertidal to deep-ocean and from polar to tropical. Among the commercial coastal holothuroids the Aspidochirotida (possess flattened leaf-like tentacles and are primarily deposit feeders) are predominant in the tropics, while the Dendrochirotida (possess branched tentacles and are primarily suspension feeders) are more common in temperate regions (Purcell *et al*., 2012). In Fiji, sea cucumbers are distributed throughout all the inshore coastal waters of the islands, from shallow seagrass beds and sandy bottoms, deep lagoons, reef flats, back reef slopes, and into deeper reef habitats (Bruckner, 2006).

Biology and Ecology: Sea cucumbers represent one of the five extant classes of the Phylum Echinodermata. Dating back 460 million years, they are characterised by their lack of segmentation, an endoskeleton of calcareous ossicles, and a large coelom with complex chambering giving the ambulacral or water-vascular system where respiration, locomotion and sensory function are combined. The typical morphology of sea cucumbers is a soft, cylindrical body, elongated from mouth to anus, with their ventral surface in contact with the sea floor (Conand, 2006). The body symmetry is typically pentaradial with a secondary bilateral symmetry. They are typically deposit/detritus feeders, extracting nutrition from organic matter that settles on the substrate (Preston, 1993). A study in Fiji found the movement rate for **dairo** was in the range of 2−8 m day per day, and appear to be active for around 10 hours per day (Lee, 2016; Lee *et al.*, 2018).

The alimentary canal is complete, the nervous system is not centralised and the reproductive system is simple (Hyman, 1955). The reproductive system of holothuroids consists of a single gonad, situated dorsally, and in the Aspidochirotida composed of either two tufts of tubules (Stichopodidae), or only one tuft (Holothuridae). The sexes are generally separated and show little dimorphism unless in the process of gamete maturation. In most sea cucumber species, the mature gametes are freely released into the sea water. The spawning behaviour observed in many Aspidochirotida species, involves and upright posture of males and females followed by a swaying back and forth while the gametes are being released. Holothuroids can also undergo asexual reproduction, by transverse binary fission (Conand, 1989). **Dairo** was observed spawning in Natuvu village, Vanua Levu, in November 2009 (Hair, 2011) and in October and December 2015 coinciding with spring tides (Lee *et al.*, 2018). Very little is known of the reproductive patterns of other sea cucumbers in Fiji.

1.2 The Fishery

Utilisation: Sea cucumbers have been commercially harvested since the early 1800s in Fiji (Ward, 1972 in Kinch *et al*., 2008), occasionally for the raw body wall or viscera, but mostly in order to be processed into a dry product called *bêche-de-mer* or *trepang* (Ram *et al*., 2014). Chinese and other Southeast Asians consume sea cucumbers for its health and medicinal benefits. Chinese believe that sea cucumbers have healing properties, especially for joint ailments, urinary problems and cancers (Bordbar *et al*., 2011). Apart from its medicinal properties, sea cucumbers are also a delicacy in Chinese cuisine and are of cultural importance (Fabinyi, 2012).

Bêche-de-mer is produced by a process of gutting, salt curing, boiling, smoke curing and sun drying. Purcell (2004) provides a manual[6] and training video[7] for processing sea cucumbers into bêche-de-mer. The final product should be completely dry, solid, have a straight shape, and no signs of damage (Purcell *et al*., 2016b). The aesthetics of bêche-de-mer play a large role in the value, and improper processing causes a substantial loss in value. A study in Fiji found that 10−50% of the product's value can be lost by improper processing (Ram *et al*., 2014); as a result middlemen and exporters tend to prefer buying the raw (gutted) animals from fishers and processing themselves (Purcell *et al*., 2016b). Only one species of sea cucumber is commonly consumed in Fiji; **dairo** (sandfish − *Holothuria scabra*) though Purcell *et al.* (2016c) reports that **loaloa** (black teatfish − *H. whitamei*) and **mudra** (chalkfish – *B. marmorata*) are occasionally eaten. Most sea cucumber fishers prefer to sell their catch for much needed income (Mangubhai *et al*., 2016).

Due to the economically decentralised nature of this fishery it forms an important source of income for local fishers in remote areas, including women (Pakoa *et al*., 2013; Mangubhai *et al*., 2016). Sea cucumbers are largely harvested through gleaning, free diving and diving with the aid of underwater breathing apparatus (UBA). "Lead Bombs" – small weighted harpoons – are also used to access deeper water species such as **sucuwalu** (white teatfish − *H. fuscogilva*), though this method causes some damage to the animal (Purcell *et al*., 2016c).

Production and Marketing: High demand for sea cucumbers continues to grow in line with the growth of China's and other Asian economies (Carleton *et al*., 2013; Purcell *et al*. 2018) but suppliers, including Fiji, cannot keep pace with the demand. The fishery in Fiji is characterised by heavily over-exploited stocks with most individuals below the reproductive size, a boom-and-bust history of exploitation, and increase in trade of low-value species as high-value species are depleted (Mangubhai *et al*., 2016). Fiji had already experienced two boom-and-bust cycles since 1976. The first boom in the export trade was in 1988 with a total export of approximately 700 mt and then followed by bust pattern that resulted in the much reduced total export of approximately 150 mt in 1993. However, Adams (1992) highlighted that the production values are under-reported because some bêche-de-mer are exported under the generic category of "miscellaneous molluscs".

However, after 1993 the export volume started to increase and reached its peak (another boom) in 1997 with a total export volume of approximately 800 mt followed by a bust in the following years with a total export volume of approximately 150 mt in 1999. From 1999−2012, Fiji's highest export volumes were in 2005 and 2011 with a total export volume in those years of 130 mt, lower than the 1988 and the 1997 export volume (Carleton *et al*., 2013; Ram *et al*., 2016). Between 2003−2012, annual volume of bêche-de-mer production varied significantly from a peak of 340 mt in 2005, down to 130 mt in 2009, which equates to a total value of FJD 16.5 million and FJD 5.5 million, respectively (Pakoa *et al*., 2013). In terms of species exported, Kinch *et al.* (2008) highlighted that in 1988 **driloli** (hairy blackfish – *A. miliaris*), **sucuwalu** (white teatfish – *H. fuscogilva*), **loaloa** – (black teatfish – *H. whitmaei*), **dairo** (sandfish – *H. scabra*), **drivatu** (stonefish – *A. lecanora*) and **dritabua** (deepwater redfish – *A. echinites*) were the most important species in the export trade. **Driloli** comprised 90% of sea cucumber exports in 1988 (Preston *et al*., 1988); however, between 2003−2012 the proportion fell to 6% (Pakoa *et al*., 2013).

6 http://aciar.gov.au/publication/cop026

7 Online version: www.youtube.com/watch?v=KH6u0oZoclk Downloadable files: http://scu.edu.au/environment-science-engineering/index.php/125

1.3 Stock Status

In the past ten years the sea cucumber fishery in Fiji has been evaluated in four major reports: a study conducted by the Pacific Community (SPC) under the PROCFish project (Friedman *et al*., 2010); a study by SPC on the status of sea cucumber resources and fisheries management (Pakoa *et al*., 2013); a study on the economic evaluation of sea cucumbers in Fiji with other Melanesian countries including Tonga (Carleton *et al*., 2013); and a comprehensive report compiled by the Wildlife Conservation Society (WCS) and the Ministry of Fisheries on new advances in sea cucumber research (Mangubhai *et al*., 2017). All four reports concluded that Fiji's sea cucumber fishery is extremely over-exploited and urgently requires stricter management actions.

Underwater assessment by Friedman *et al*. (2010), Pakoa *et al*. (2013), and Lalavanua *et al*. (2014, 2017a) all agreed that the sea cucumber species densities in Fiji were well below the regional reference densities[8]. Despite an export ban on **dairo** since 1988, stocks have not recovered with surveys recording densities below regional reference densities and comprising largely immature animals (Lalavanua *et al*., 2017a).

1.4 Management

Current Legislation and Polices Regulating Exploitation: As of the 1 November 2017 individuals and companies fishing for sale or for export can face a fine up to FJD 20,000 (Naleba, 2017). In 2019, Holothuria whitmaei, H. nobilis and H. fuscogilva were listed on Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES). All species listed in CITES Appendix II applies to CITES Party countries such as Fiji, regardless of the destination.

If the ban is lifted the Fisheries Act 1942 is the primary legislation regulating the sea cucumber fishery in Fiji. The Act guides the management of the fishery through a permit and licensing scheme and the key national implementing agency of the Act and management of the marine resources is the Ministry of Fisheries. The requirements in the Act that have direct implications on the sea cucumber fishery include:

1. **Legal size limits for exporting sea cucumber**
   It is stipulated in *Regulation 25B* of the Act, that no person shall export either natural or processed (bêche-de-mer) sea cucumber, of any species, less than 7.6 cm or 3 inches. The Ministry of Fisheries has proposed new 'dry and wet' size limits for sea cucumbers, in line with the reproductive biology of different species. These size limits have also been included in the draft regulations for the management of Fiji's sea cucumber fishery.

2. **Prohibition to export sandfish**
   No person shall export either in natural or processed form holothurians of the species **dairo** (sandfish − *Holothuria scabra*). Additional prohibited species are included in the draft regulations for the management of Fiji's sea cucumber fishery.

3. **Issuance of exemption on UBA**
   In 2017, the Ministry of Fisheries placed a complete ban on the issuance of exemption on the use of UBA for the harvesting of sea cucumbers (Lalavanua *et al*., 2017b) due to its large socio-economic cost to rural communities, as well as high financial cost to Fiji's government health system when admitting injured divers to the hyperbaric unit in Suva (Tabunakawai-Vakalalabure *et al*., 2017).

8 Assessments conducted by SPC in 2002−2012, generated threshold densities for 17 species of sea cucumbers by averaging the 25% highest densities from the Pacific. These can be used as a baseline for comparison or as a reference in the case that a site has no specific site density data available.

4. **Fishing Permit and Licence**
The Act requires a fishing licence – in addition to a permit – if a person intends to capture fish for trade or business. These fishing licences are granted by the Ministry of Fisheries Licensing Officers and all fishing licences expire on 31 December of each year[9]. If a fisherman violates the terms of the licence, the Ministry may choose to either revoke the licence or, alternatively, apply to court for its cancellation. Note that near shore fishing licences are granted for fishing within *qoliqoli* areas.

Management Recommendations: Fiji's sea cucumber fishery desperately needs more robust regulation to safeguard the fishery for the future. The fishery is characterised by inequity in the terms of fair distribution of economic gains in the value chain, poor bargaining powers of fishers compared to traders and exporters, gender inequalities, limited access for fishers to market-related information, lack of national standards, technological limitations, poor data collection and poor enforcement of laws such as size limits, requirements for commercial licences and the ban on the use of UBA (Mangubhai *et al*., 2016, 2017, Purcell *et al*., 2017). A 2017 policy brief from the WCS and senior staff from the Ministry of Fisheries recommended six key management strategies the Ministry should implement as promptly as possible. The six key management strategies include:

- Retain the complete ban on the issuance of exemptions on the use of UBA;
- Impose minimum legal size limits for different species groups for fresh and dried products. A management plan drafted by the Ministry of Fisheries provides updated size limits (dry and wet) to ensure adequate recruitment;
- Impose a short list of permissible species that can be harvested and exported;
- Reduce fishing capacity by significantly employing limited entry rules or very short fishing seasons;
- Develop a national and adopt (legalise) nation-wide standards for pricing of raw and dried sea cucumbers; and
- Strengthen enforcement of all regulation, especially the size limit and permissible species at the exit point of the product, which will be cost effective for the Ministry.

The policy brief also recommended that if the Ministry of Fisheries could not impose all recommendations above then it may wish to consider imposing a 5−10 year moratorium on harvesting and exporting of sea cucumbers in Fiji. In such a case the fishery should open only after this period if the results of underwater assessments show that (i) the density of sea cucumber by species is well above the regional reference densities, and (ii) 80% of those animals are above size at maturity.

9 The Offshore Fisheries Management Decree extends the period of some licenses to 3 years. 35.—(1) Every licence or authorisation issued by the Permanent Secretary shall, unless earlier cancelled or suspended under section 38 of this Decree, be valid for a period not exceeding 36 months from the date of issue.

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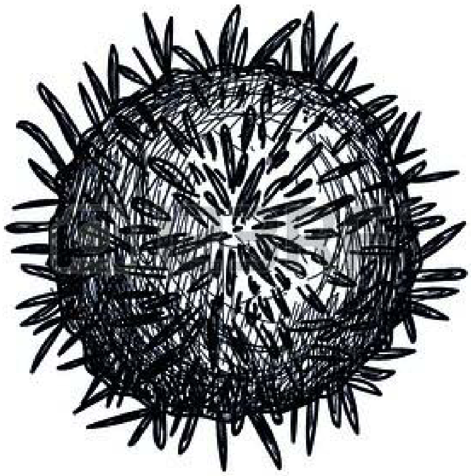
2 SEA URCHINS



2.1 The Resource

Species Present: Morton and Raj (1978) list the following sea urchins from Fiji: edible sea urchin/collector urchin (**cawaki** − *Tripneustes gratilla*), long-spined sea urchins (*Diadema setosum*), banded sea urchin (*Echinothrix calamaris*), slate pencil urchin (*Heterocentrotus mammillatus*), rock-boring urchin (*Echinometra mathaei*), flower urchin (*Toxopneustes pileolus*) and *Mespilia* sp..

Distribution: *Tripneustes gratilla, D. setosum, E. calamaris* and *T. pileolus* are widely distributed in the Indo-Pacific region, and *H. mammillatus* and *E. mathaei* are widely distributed through the South Pacific. *E. mathaei* and *H. mammillatus* are also found in the Indian Ocean, and *T. pileolus* and *E. calamaris* in Australia and Japan.

Biology and Ecology: Sea urchins are echinoderms, related to starfish and sea cucumbers. They have a calcified external shell, known as a "test", with mobile external spines. The hard tests of sea urchins can be a variety of colours from black to white, with red, green and purple common colours for various species of edible sea urchin. They move and feed with a hydraulic system that enables them to move their spines, stick to the sea floor and move their jaws (McShane, 1992). Sea urchins feed on seaweed that they break up with their jaws. Because they have no bulky muscles, much of the energy derived from food can go towards reproduction. Up to 25% of their weight can be gonads, or "roe". Sea urchins generally have a seasonal reproductive cycle, so that the quality of the roe varies throughout the year. The quality and quantity of sea urchin roe is also dependent on the amount of available food (McShane, 1992).

Sea urchins move slowly and tend to form large aggregations on reef surfaces. *E. mathaei* are usually found from midtide down at 1−8 m, in dense aggregations under thickets of branching corals or on surfaces of rocks (Shokita *et al*., 1991). Towards low water and on the outer reef face, *E. mathaei* is accompanied by *H. mamillatus*. **Cawaki** is commonly found in little exposed areas of the reef in 1−8 m of water, most often in the presence of seaweed. *T. pileolus* is found to a depth of 15 m in sheltered lagoons and rubble flats, whereas *E. calamaris* is found from 5−40 m in the interior of lagoons (Guille *et al*., 1986). Common predators of sea urchins include stingrays, pufferfish, triggerfish, and octopus (SPC, 2011).

The growth of **cawaki** is rapid; for example, the first-year growth (test diameter) has been recorded at 60−70 mm in Okinawa, Japan, and has reached 60 mm within 5 months in the Philippines (Shimabukuro 1991; Bacolod and Dy, 1986 in Lawrence and Agatsuma, 2007). **Cawaki** are reported to attain a maximum test diameter of 160 mm, which corresponds to an age of 4–5 years (Rahman *et al*., 2014). The growth rate of sea urchins generally decreases during summer months, attributed to temperature stress, and also decreases with age (Lawrence, 2007). Several studies in Lawrence and Agatsuma (2007) found populations of **cawaki** seldom live more than 2 years, though they can live up to 4 or 5 years (Rahman *et al*., 2014). A detailed account of the biology and ecology of edible sea urchins including *Tripneustus* spp., *Diadema* spp., and *Echinometra* spp. can be found in Lawrence (2007).

2.2 The Fishery

Utilisation: Lewis (1986) lists **cawaki** as an aquatic food of Fiji. Sea urchin roe is highly prized as a delicacy by Japanese consumers and is growing in popularity in western markets particularly USA and France. In 1999, Japan imported 13,700 mt of sea urchins and sea urchin products, while France consumes approximately 1000 mt each year. The majority of sea urchin roe and whole sea urchins entering the

Japanese market come from USA, Chile, South Korea, Canada, and Russia. World production of sea urchins peaked in 1995 at 120,306 mt, but production declined rapidly as a result of the decline of national fisheries in Japan, USA, and Chile. Chile now accounts for more than half of the world's sea urchin production, of which *Strongylocentrotus* spp. make up the majority (Andrew *et al*., 2002).

Production and Marketing: The Fiji Fisheries Division maintained a record of the sales of **cawaki** in municipal markets and outlets in Fiji. According to the Division's annual reports, from 1986−1989 approximately 3 mt were sold in municipal markets and outlets annually at a value of approximately FJD 0.90 per kg (Anon., 1987−1990). In 1990, sales increased significantly to 20.8 mt then dropped to 1.7 mt in 1991 and 7.6 mt in 1992 (Anon., 1991–1993) During the 1991−1992 period, **cawaki** was sold for approximately FJD 1.80 per kg. A total of 100.4 mt of **cawaki** was sold in municipal markets in 2004, a substantial increase over 1992 production levels, 97.4 mt of which was sold in Suva for approximately FJD 2.50 per kg (Anon., 2005).

According unpublished data from Fiji's Revenue and Customs Authority, 2,480 kg of "other sea urchins" worth FJD 300,294 were exported to Hong Kong in 2012. In 2013, sea urchin exports to Hong Kong, New Zealand and the USA totalled 3,236 kg and were worth FJD 196,674. In 2014, exports declined to 214 kg valued at FJD 26,196 all of which was destined to China. Prices vary considerably (FJD 20−153 per kg) between and within markets and years, which may be attributed to the quality of the sea urchin product(s).

A project aimed at developing high quality fresh-chilled sea urchin gonad products and other sea urchin products suitable for export was conducted by the Pacific Horticultural and Agricultural Market Access Program (PHAMA) in collaboration with Sai Yee Food Industries Ltd in Suva between December 2014 and June 2015. Despite developing two suitable methods to process sea urchin roe, which would extend the product's shelf life to approximately 22 and 34 days respectively, the final product failed to pass a taste panel primarily for aesthetic reasons (Lako and Wiseman, 2016).

2.3 Stock Status

There is no information available on the status of sea urchin stocks in Fiji.

2.4 Management

Current Legislation and Policies Regulating Exploitation: Sea urchins are classified as "fish" in the Fiji Fisheries Act Cap 158, but there is no legislation or policy specifically applicable to sea urchins. Unshelled sea urchin (**cawaki vali**) has been categorised as a high-risk food item by the Suva City Council and Ministry of Health, and as such its sale was banned in Suva's Municipal Market (Anon., 2010). However, the ban was lifted shortly after, upon conclusion of an investigation by the Ministry of Health (Ministry of Health, *pers. comm.*).

Management Recommendations: Sea urchins are commercially exported and are locally consumed and therefore, legislation and policies may need to be introduced to better manage the fishery. Sea urchin fisheries are commonly managed through fishery closures during spawning seasons, and minimum (and maximum) size limits. In the case of the Philippines where **cawaki** is the main species, rotational harvests are also employed in which two out of five areas are harvested every 3 years, a scheme have proven to be successful (Andrew *et al*., 2002).

Studies are required to determine the spawning season(s) of commercial sea urchins in Fiji, this is important for the management of the fishery, and for commercial operations that predominantly harvested sea urchins for their roe. In areas where sea urchin densities are very low, they may need to be artificially aggregated prior to and during spawning seasons (SPC, 2011). Stock assessment of sea urchins, primarily **cawaki** is necessary to determine stock status.

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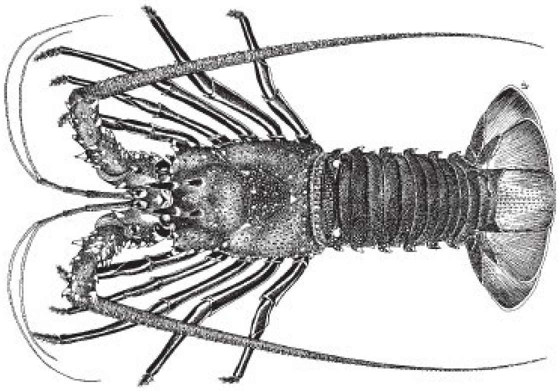
3 LOBSTERS

3.1 The Resource



Species Present: Lewis (1985) reports that the most abundant species of rock lobster in Fiji is **uraukula** or **urauvatuvatu** (golden rock lobster – *Panulirus penicillatus*). Smaller quantities occur of **uraudina** (painted rock lobster – *P. versicolor*), the whiskered lobster[10] (*P. longipes femoristriga*) and **urautamata** or **uraubola** (ornate rock lobster – *P. ornatus*). **Vavaba** or **ivinibila** (slipper lobster – *Parribacus caledonicus*) is also found in Fiji.

Distribution: Geographical distributions, keys to species identification and some biological information about the known marine lobster species are provided in Holthuis (1991). **Urakula** is the most widespread species of spiny lobster, and is found in the Indo-West Pacific and Eastern Pacific regions. Its range extends from the Red Sea, east and south-east Africa to Japan, Hawaii, Samoa and the Tuamotu Archipelago, east to the islands off the west coast of the United States, and in some localities near the continental coast of Mexico.

Uraudina 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. There are two subspecies of *P. longipes*. In the Indo-West Pacific, the subspecies *P. longipes femoristriga* (called "eastern subspecies"), inhabits waters of Japan, the Moluccas, Papua New Guinea, eastern Australia, New Caledonia and French Polynesia. **Urautamata** is found in the Indo-West Pacific region from the Red Sea and east Africa to southern Japan, Solomon Islands, Papua New Guinea, Australia, New Caledonia and Fiji. Holthuis (1991) describes the distribution of **vavaba** as being in the Indo-West Pacific region in Queensland, Australia, New Caledonia and Loyalty Islands, Vanuatu, Fiji and Samoa.

Biology and Ecology: In Fiji, **uraukula** is the most abundant of the species present, particularly on the reefs of the eastern group of islands. It occupies a limited range of habitats. It is usually found only in the shallow surf zone of reef fronts and is reported to prefer windward slopes (Prescott, 1988). In Cook Islands it is also common on the leeward side of islands. During the day, it usually remain well back in holes and crevices in the reef, while at night it comes out to feed and remains on the reef flat or seaward of the reef crest down to 4 m (Passfield, 1988). In Micronesia, it is found at depths of 0.3–4.9 m, with higher densities at 1.2–1.8 m (Smith, 1992). **Uraudina** is quite common and is present in the lagoons and sheltered waters of most islands. **Vavaba** is not generally abundant in Fiji (Lewis, 1985). **Vavaba** occupies the surge zone with **uraukula**.

Urautamata is occasionally caught from the reefs of the main and western islands, while *P. longipes femoristriga* is very rare, only a few specimens having been reported (Pitcher, 1993). *P. longipes femoristriga* occupies a habitat in clear water just on the lagoon side of active reef edges amongst dense coral growth. **Urautamata** is found in shallow, sometimes slightly turbid coastal waters from 1–8 m depth. It has been found as deep as 200 m, exposed to oceanic water, outside the Great Barrier Reef (Pitcher, 1993). Its habitat may include sandy and muddy substrates, rocky bottom near the mouths of rivers and coral reefs. **Uraudina** is found in shallow water, from the sub-littoral down to 15 m depth. Common habitats are coral reef areas, often on seaward edges of the reef plateau, and in clear water and in surf areas (Holthuis, 1991).

10 No Fijian name is known for this species

Lobsters are generally regarded as opportunistic and omnivorous scavengers, but they can be somewhat selective towards food items with higher nutritional and energy value (Pitcher, 1993). The range of food items consumed by *Panulirus* species generally includes molluscs (primarily gastropods), crustaceans, echinoderms, seagrass and algae (Phillips *et al*., 1980).

Panulirus species generally have relatively consistent and similar life cycles and breeding behaviour. Sexes are separate and easily distinguished by external characters. Male lobsters possibly attracted by a sex pheromone, mate with inter-moult females that have developing ovaries. The males deposit an acellular mass containing tubular spermatophores onto the females' sternum (Pitcher, 1993). Within a few days after mating, females extrude several hundred thousand eggs into a chamber formed by curving the abdomen over the sternum. The eggs are fertilised as the female releases the sperm by scraping the spermatophore.

The eggs are carried under the tail of the female for about a month before tiny phyllosoma larvae are released. The time of larval release in **uraukula** may be cued to the full moon, and the female may move to areas where currents are stronger and directed to carry the larvae into the oceanic environment (MacDonald, 1979 in Smith, 1992). **Uraukula** at Palau reproduce throughout the year, with about 40 per cent of females being ovigerous (bearing eggs) in any month (MacDonald, 1979 in Smith, 1992). It is likely that the same situation occurs in Fiji.

The transparent phyllosoma larvae may remain in the ocean for 4−12 months or more, passing through 10 or more morphological stages and growing to as long as 50 mm, before they moult into the puerulus stage (Phillips and Sastry, 1980 in Pitcher, 1993). This stage, when they resemble a colourless miniature adult, may last from a few days to a few months. The pueruli undergo the transition from the oceanic to the benthic environment, where they settle in or near the adult habitat and quickly moult into pigmented juveniles (Phillips and Sastry, 1980 in Pitcher, 1993). A detailed account of the complete larval development of *P. penicillatus* in culture can be found in (Matsuda *et al*., 2006) 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.

Similar to other crustaceans, lobsters 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, probably as a result of the diversion of energy into egg production with the onset of sexual maturity. In comparison, the males continue to grow relatively quickly.

The size at which lobsters become mature is a basic biological parameter that is critical for management. Carapace size at sexual maturity for **uraukula** in Palau is 10 cm and in Solomon Islands 7.5−7.9 cm (MacDonald, 1982 in Nichols, 1991; Skewes, 1990). The Pacific average asymptotic carapace length (L_∞) for male **uraukula** is 15.7 cm and for females, 12.2 cm. For **urautamata** from Torres Strait, L_∞ for males is 16.4 cm and for females, 14.9 cm, and for *P. longipes* from Tonga, L_∞ for males is 13.3 cm and for females, 11.8 cm (Pitcher, 1993).

Estimates of natural, fishing and total mortality for *Panulirus* species in the Pacific are summarised by Pitcher (1993), who also provides information on abundance of lobster populations. In the Pacific, the absolute abundance of **uraukula** has been estimated in only a few limited areas of reef slope. Figures from Solomon Islands indicate that densities were between 111−128 lobsters per km of reef slope or 46−57 per ha (Prescott, 1988). Because the area of habitat available for **uraukula** is limited to a 20−25 m wide strip of windward reef slope, stocks of this species are relatively small, and can only be expected to sustain small fisheries.

3.2 The Fishery

Utilisation: Traditionally, traps of various kinds were widely used in the Pacific to catch lobsters, but now they are used in only a few fisheries. The traps caught **uraukula** and *P. longipes*, but **uraudina** and **urautamata** almost never entered traps (Prescott, 1988). As in many of other island countries in the Pacific, **uraukula** in Fiji can be caught by spearing and hand collection on the reef flats at night, either side of a low tide. The product is typically sold as frozen tails or whole animals, tail weight as a percentage of total weight varying between approximately 40% for females of most sizes to as low as 25% for large males. Lobsters collected locally on a small scale are sold to hotels, shops, municipal markets and wholesalers; however, a substantial proportion of the catch is consumed at home or bartered in villages (Pitcher, 1993). A survey of the major seafood suppliers in Fiji determined that lobsters are very important in terms of sales to hotels and resorts (Raravula, 2013).

Production and Marketing: The total marketed production in 1984−1985 was estimated at between 70–90 mt, a substantial increase on the <30 mt per year for the preceding years (Lewis, 1985). Total marketed production of lobsters remained <40 mt per year for the years 1986−1988, before rising to approximately 90 mt per year in 1990−1991, thus repeating the pattern shown six years previously (Anon., 1987–1992). According to the Fisheries Division 2004 Annual Report 59.4 mt of **uradina** were sold in municipal markets, 59.0 mt of this being in the Northern Division's markets, and 0.12 mt of **vavaba** all of which was sold in the western division. For the same year 224.28 mt of **uradina**, 10.26 mt of **urakula**, 8.73 mt of **urautamata**, and 2.15 mt of **vavaba** were sold in non-market outlets. The majority of all non-market outlet sales were in the Western division. A 2013 study of Fiji's seafood supply chain found that four resorts in western Viti Levu and 11 food outlets in Suva (including hotel restaurants), purchased a total of 808 kg of **urau** and 303 kg of **vavaba** per month (Raravula, 2013). Based off this limited sample, the 2013 production for **urau** for Fiji was at least 9.7 mt, and 3.6 mt of **vavaba**. Thus the production of **vavaba** increased by at least a third from 2004−2013.

According to annual reports by the Fisheries Division the price of **uraudina** in 2004 was approximately FJD 16 per kg of whole animal. Raravula (2013) reports prices of FJD 13–32 per kg, depending on the quality of the lobster and market circumstances. Based on one seafood supplier surveyed, slipper lobster can fetch prices up to FJD 39 per kg (Raravula 2013). According to Fisheries Division Annual Reports exports of frozen lobster from Fiji remained <70 kg per year until 1992 (Anon., 1987–1993). It is difficult to discern whether or not lobsters have been exported from Fiji for the years 2004, 2008, and 2012−2014 as they are collectively accounted for in the category "coral and similar matter, unworked or prepared but not otherwise worked molluscs, crustaceans or echinoderms and cuttle-bone, unworked or prepared but not." (Anon., 2005, 2009; FRCS, *unpubl. data*).

3.3 Stock Status

Given the probable wide dispersal of **urakula** (*P. penicillatus*) phyllosoma larvae, maintaining areas of coral reef with healthy stocks will ensure adequate recruitment to more heavily exploited reefs. Recent work by Chow *et al*., (2011) has found no ongoing gene flow between the Eastern and Central-Western Pacific *P. penicillatus* populations. Within these areas *P. penicillatus* showed little evidence of population structuring; however the authors assert that population structuring within these areas should be investigated further "in more detail using larger sample sizes and more variable genetic markers" (Chow *et al*., 2011). In addition, **urakula** stocks may enjoy a measure of inbuilt protection because of the animal's exposed seaward reef habitat and reluctance to enter traps. Given the lack of available data for Fiji, it is not certain if Pitcher's (1993) assumption that **urakula** stocks in the Pacific will be resilient to recruitment overfishing, still holds true and a precautionary approach should be taken for the fishery.

3.4 Management

Current Legislation and Policy Regulating Exploitation: No restrictions for lobsters are prescribed under the Fisheries Act and Regulations. The harvesting of lobsters is discussed at length under the Cabinet Guidelines approved in 1984, but is not being used. Although the lobster guidelines are not currently being used, they may be useful for guiding future management and are therefore reproduced here from Lewis (1985):

1. Participation in lobster fishing activities to be restricted to Fiji nationals.
2. Fishing activities to be restricted in the first instance to uninhabited islands and reefs and only with the written approval of resource custodians; village fishermen to be involved in fishing operations to the maximum extent practicable.
3. A size limit to be imposed on caught lobster. This is to be subsequently incorporated into Fisheries Regulations. A minimum carapace length of 70 mm has been suggested for the Tongan fishery and would be a useful starting point.
4. Provision to be made for Ministry of Fisheries observers to accompany commercial scale operations as deemed necessary.
5. It may not be necessary at this stage to implement management regimes. The restriction of the resource to seaward reefs (which will often be inaccessible due to weather) and variation in vulnerability (moon phase, tidal cycle etc.) confers some measure of protection. In addition, optimal fishing methods still need to be developed. The Ministry of Fisheries should be present during the early phase of any development to obtain information relevant to management questions. The above comment refers to commercial operations. Village and small-scale fishermen will presumably continue as before, but will be subject to any size restrictions.
6. Export to be subject to inspection as required, and issue of permit. (It is to be hoped that quality standards will be set for all export items as the industry develops).
7. Participation in the fishery on a commercial scale to be restricted where possible to operations with a demonstrated capability to produce a high quality product. This will maximise the product value and hence returns to fishermen.

Urautamata (*Panulirus ornatus*) and **uraudina** (*Panulirus versicolori*) appear in Schedule 1 (Section 3) in Part 9 of the Fiji Endangered and Protected Species Act 2002. As such:

- No person must export, import, re-export or introduce from the sea any specimen without an export permit, if any person contravenes this they are liable on conviction to a first offence fine of FJD 20,000, and fines of FJD 100,000 or to imprisonment for five years in the case of a subsequent offence.
- No person must trade or breed in captivity any specimen unless the person is registered with the Management Authority. Any person who contravenes this commits an offence and is liable in the case of an individual to a fine of FJD 20,000 or imprisonment for four years In the case of any company or association or body of persons, corporate or unincorporated to a fine of FJD 100,000.
- If the above-mentioned species are bred in captivity it is listed as an animal belonging to CITES Appendix II. Permits may be granted by the Fiji CITES Management Authority.

Management Recommendations: The fishery is difficult to manage, largely because the lobster's larval stages drift in the open sea for over a year before settling on reefs as juveniles (SPC, 2011a; 2011b). As such fishery management or conservation efforts in small areas are unlikely to produce visible or immediate results, and thus management over a large spatial scale is recommended. The following management actions are recommended in SPC (2011a; 2011b):

- Restrict the total community catch of lobsters to a sustainable level (e.g. 20 kg of lobster per km of reef-face per year);
- Rotate the catching of lobsters on different areas of reef on a time scale of years;
- Ban the taking of undersized lobsters, 15 cm total length (TL) for **vavaba** (*Parribacus* sp.), and 9 cm carapace length for *Panulius* spp. (including **urau)**. Size limits used in the Pacific Islands region are provided in SPC (2005);
- Ban the use of underwater breathing apparatus;
- Ban the use of spears;
- Ban the taking of egg bearing lobsters;
- Ban fishing during spawning season(s), if spawning is limited to selected months of the year; and
- Apply local catch limits.

In discussing strategies for managing Pacific lobster fisheries, it is important to keep fishing methods simple to discourage over-capitalisation and its consequences, and taking into account traditional reef-tenure systems for village-based fishermen. Lewis (1985) and Pitcher (1993) stress 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 is provided in Lewis (1985), and more recent information relevant to this issue is available in Adams and Dalzell (1994).

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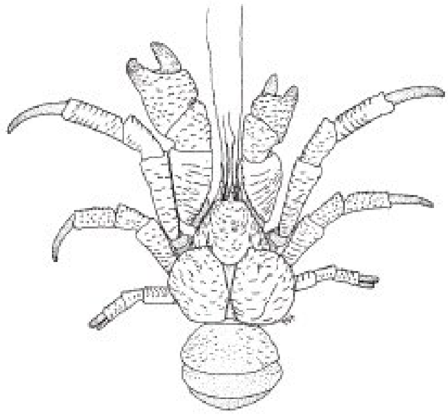
4 COCONUT CRAB



4.1 The Resource

Species Present: Wells *et al*. (1983) and Lewis (1986) note **ugavule** (coconut or robber crab − *Birgus latro*) as being present in Fiji.

Distribution: *Birgus latro* are widely distributed on remote tropical islands of the Indo-Pacific from Mauritius in the West Indian Ocean to the Tuamotu Archipelago in the eastern Pacific. The distribution of *Birgus latro* is limited to the tropical zone, with only a few populations occurring in the subtropics (e.g. Taiwan and the Ryukyu Islands of Japan, Drew *et al*., 2010). Recent population genetics research has shown that while the *Birgus* populations in Vanuatu and Solomon Islands probably constitute a single stock, the Indian and Pacific Ocean populations are likely two distinct stocks (Lavery *et al*., 1995). There was some indication that coconut crab populations in Niue and the Cook Islands are also separate independent populations from each other (Fletcher, 1993).

A 1984 mail survey of 28 countries, mainly in the Pacific and southeast Asian regions suggested that at the time, **ugavule** were abundant, to varying degrees in only six localities: Solomon Islands, Vanuatu, Chuuk (Federated States of Micronesia), Tokelau, Niue and Marshall Islands (Brown and Fielder, 1988), and New Caledonia (Kadiri-Jan and Chauvet, 1997). Coconut crabs were only common in some isolated or rare in the remaining 22 countries surveyed. A review by Drew *et al.* (2010) based on studies conducted between 1970 and 1995 found that on uninhabited islands such as Taiaro in the Tuamotu archipelago, and Igurin in the Enewetok Atoll, Mashall Islands densities of **ugavule** were 190 crabs per ha and 147 crabs per ha respectively. These values were substantially higher than of inhabited Pacific Islands such as Niue, Lifou (New Caledonia), and Christmas Island (Australia), where densities were 46 crabs per ha, 27.5 crabs per ha, and 67 crabs per ha, respectively.

In Fiji **ugavule** is common on only a few islands. **Ugavule** have also been found on Yadua and Aiwa Islands (Drew *et al*., 2010), Cikobia Island in Macuata (Nair *et al*., 2003), Kabara in the Lau Group (Seeto, 2015), Qelelevu Atoll in the Ringgold Isles (UNEP/IUCN, 1988) and in privately owned islands in northern Lau (K. Miller, *pers. comm.*).

Biology and Ecology: Ugavule are omnivorous scavengers, hiding in holes in the sand or under coconut trees and shrubs during the day, emerging at night to forage along beaches and over coral rocks. Densities of **ugavule** appear highest in areas of higher humidity, abundant food resources, and available hiding areas (Shiller, 1992). The species is the largest and least marine-dependent of the land crabs. Growth is very slow and heavily influenced by environmental factors, which is a key reason why the species cannot be commercially cultured (Shiller, 1992). Large adults may attain a weight of 4 kg and measure 200 mm in carapace width (Brown and Fielder, 1988; Lavery *et al*., 1996).

Moulting takes about a month and is carried out in a shallow hole plugged with earth forming a visible hump on the surface. Smaller **ugavule** moult more frequently and have considerably larger growth increments (up to 16%) per moult, based on these observations.

Mating generally occurs from May to September, with a peak in July to August in the Federated States of Micronesia (Reese, 1971 in Smith, 1992). The female carries the eggs under her abdomen attached to hairs. After about one month the female moves to the shore and releases the eggs into the sea. After hatching, the larvae remain planktonic for around 4 to 5 weeks before settling, developing a shell and becoming amphibious. The young crab will carry a shell for around 9 months, becoming increasingly terrigenous (Brown and Fielder, 1988). As they grow they move further inland away from the coast. Fletcher *et al*. (1990) estimated **ugavule** may live between 30 and 40 years in the wild.

A study from Hatoma Island in Japan found that 50% of females at 24.5 mm thoracic length were sexually mature, and 100% were mature at 32.3 mm thoracic length (Sato and Yoseda, 2008). **Ugavule** in Vanuatu becomes reproductively active at approximately 5 years of age (Schiller *et al*., 1991), and a thoracic length of approximately 28 mm (Fletcher *et al*., 1990). Another study from Vanuatu also estimated a 600 g **ugavule** to be 12 to 15 years old, and documented relationships between thoracic length, cephalothoracic length and weight (Helagi *et al*., 2015). Recruitment was found to be low and highly variable in Vanuatu, with successful recruitment of post-larvae and juveniles only occurring once every 5−10 years (Fletcher, 1988). Replenishment of heavily exploited populations is therefore likely to be slow.

4.2 The Fishery

Utilisation: Local inhabitants intensively hunt **ugavule** wherever they occur, as its flesh is universally regarded as a delicacy. There are no records of coconut crabs being exported from Fiji; however, they are being exploited commercially to supply local markets (Qounadovu, 2015; Seeto, 2015).

Production and Marketing: There is no information available on the production and marketing of **ugavule** in Fiji. If there is any production, it is at the subsistence level but may supply local markets, as mentioned above.

4.3 Stock Status

The status of **ugavule** stocks in Fiji is unknown, though they are thought to be generally depauperate and in need of urgent action. Extinctions of local populations are likely to have happened, but are also poorly documented. **Ugavule** are reported to persist on many of the Northern Lau islands, especially those that have no human populations (T. Adams, *pers. comm.*).

4.4 Management

Current Legislation and Polciies Regulation Exploitation: Ugavule (coconut crab − *B. latro*) is listed under Schedule 1 (Section 3), Part 10 of the Endangered and Protected Species (Amendment) Act 2016. This act regulates the international trade, domestic trade, possession and transportation of species protected under CITES. Under the Act, no person shall export/import/re-export/introduce from the sea **ugavule** without the corresponding permit. A person who contravenes this is liable for a first offence fine of FJD 20,000; and in the case of a second or subsequent offence – to a fine of FJD 100,000 or imprisonment for 5 years. No person must trade in specimens of **ugavule** without being registered with the Fiji CITES Management Authority, and a person who contravenes this is liable to a fine of FJD 20,000 or 4 years imprisonment, while a company or association is liable to a fine of FJD 100,000 (Fiji Government, 2002). This act includes laws pertaining to the transit, transshipment, and captive breeding of **ugavule**.

Management Recommendations: Establish a minimum size limit (e.g. 36 mm thoracic length applies to **ugavule** in Niue), develop seasonal and area closures when crabs are reproductively active, ban or control exports, and monitor the quantity and size of **ugavule** being caught (Helagi *et al*., 2015). Given how depleted populations are, there may be a need to set up fenced coconut crab reserves in areas with suitable habitats and access to the sea as well as restrict the capture and sale of large coconut crabs outside reserve areas, possibly with catch limits attached to licences (SPC, 2011).

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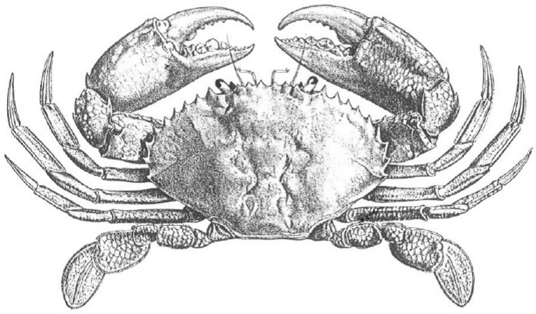
5 MANGROVE CRAB

5.1 The Resource



Species Present: The green mangrove or mud crab (*Scylla serrata*), **qari dina** or most commonly **qari***,* is listed by Lewis (1986) as the only species present in Fiji, although four *Scylla* species are currently recognised in the Indo-Pacific region (Keenan *et al*., 1998), and other members of the swimming crab family (Portunidae) are found in Fiji, in the genera *Portunus*, *Podophthalmus* and *Thalamita.*

Distribution: A comprehensive description of the Indo-West Pacific distribution of **qari** is given by Dickinson (1977) in Brown (1993). Any tropical Pacific Island large enough to sustain a fluvial delta with associated mangrove forests will support a population of mangrove crabs, although natural populations are rare east of the Pacific Plate, as with many coastal species (Brown, 1993). **Qari** are found throughout Fiji except on outlying islands where there are no mangrove stands, and occur entirely within customary fishing grounds (Lewis, 1985). The Rewa, Ba and Labasa River deltas have some of the largest stands of mangroves in Fiji (Mangubhai *et al.*, 2019) and are the main sources of **qari** supply to municipal markets and non-market outlets (Lewis, 1985).

Biology and Ecology: Qari are frequently found in areas characterised by a muddy substrate associated with mangrove vegetation, and they are characteristically found in mangrove swamps or stands. This type of habitat is typical of sheltered tropical to sub-tropical estuaries, embayments and the lower reaches of rivers and tidal streams (Brown, 1993). In a survey carried out by Lal *et al*. (1983) in Wairiki Creek near Suva, **qari** was the dominant crab species found.

Qari are sometimes found in the mud amongst mangrove roots, but more often in burrows which extend obliquely down into the mud at an angle of about 30° to the horizontal. Burrows may be up to 2 m in length, and are used as general refuges by sub-adult and adult crabs, notably during moulting. They can tolerate a wide range of temperatures and salinities, and are opportunistic feeders, subsisting primarily on slow-moving or immobile prey organisms. They tend to live in parts of the estuarine system where prey is most abundant, usually remaining buried during daylight hours and feeding at night (Brown, 1993).

Female crabs migrate offshore to spawn (Brown, 1993), with each female producing up to 5 million eggs per spawning. These hatch to produce planktonic larvae, which flow back on the tide and are recruited to the mangroves near the parental biomass (Nichols, 1991). Juveniles (20–80 mm carapace width) remain in the mangroves at low tide, while sub-adults (80−120 mm) and adults (>120 mm) migrate to intertidal habitats at high tide, retreating again at low tide (Nichols, 1991). Size at maturity for **qari** is influenced by latitude with larger size-at-maturity and maximum sizes occurring in the east coasts of sub-tropical Australia and South Africa compared to most tropical populations (Le Vay, 2001).

Studies in Queensland, Australia found mud crabs became sexually mature at about 128 mm carapace width for females and 165 mm for males (Robertson and Kruger, 1994), at around 2 to 3 years of age. At Pohnpei, there is a lunar periodicity of the seaward movements of spawning females, with a peak around the new moon (Perrine, 1978 in Smith, 1992), while in Natal, South Africa, **qari** spawn throughout the year peaking through the summer months (Robertson and Kruger, 1994). In contrast, studies from Australia suggested that peak mating activity for **qari** occurred in the spring and early autumn whilst spawning occurred only in the summer months when seawater temperature was above 22°C (Heasman *et al*., 1985 in Le Vay, 2001). Except for spawning migrations, **qari** generally do not move more than 1 km in their estuarine environment.

Because **qari**, like other crustaceans, have a rigid exoskeleton, they must periodically shed it (moult) in order to grow. Fielder and Heasman (1978) in Brown, (1993) provide a concise description of this complex process. The rate at which crabs grow depends on the moult frequency and the moult increment, the size difference between the old and new shell. While growth data of **qari** under ural conditions in tropical regions is unavailable (Sara, 2010), one study has shown that in sub-tropical climates, mangrove crabs attain a carapace width of between 8 and 10 cm in their first year, and between 13 and 16 cm in their second year (Brown, 1993). In Australian waters, **qari** can reach a carapace width of 24 cm, but monatst fall within the 15−20 cm size class/range. Males have larger, heavier claws and attain weights of 3 kg and more.

5.2 The Fishery

Utilisation: In Fiji, **qari** are caught largely by hand, hooked from burrows or caught by hand nets, hook and line, scoop nets and spears (Mangubhai *et al*., 2017). They are also taken incidentally by gillnet fishers working near mangroves. Most fishing for **qari** is done by women for household consumption or are sold live largely at municipal markets or by the roadside. Those for sale are bundled and bound in strings of 3−10 of medium-sized crabs or 10−15 for small crabs or sold individually if they are large-sized (Mangubhai *et al*., 2017). Provided they are kept in moist packing such as mangrove leaves or wet cloth, **qari** can be kept alive for up to a week, though their condition gradually deteriorates (M. Fox, *pers. comm.*). Though males and females differ in shape, claw size and quantity of meat return, there is no price differential in local markets in Fiji, where they are usually sold in strings of mixed sex. Market surveys in 2016 and 2017 in Fiji revealed that customers selected crabs mainly based on weight and size, and to a lesser degree, price, sex and origin of crabs (Mangubhai *et al*., 2017). Similarly, there is a strong though often illegal market for soft shell (moulting) crabs in some countries, but this has gained little traction in Fiji.

Production and Marketing: *Qari* are marketed in municipal markets and by direct sales to local consumers, traders, shops, hotels, restaurants and exporters. After prices remained relatively constant from the early to mid-1980s at around FJD 4.50 per kg, prices for **qari** at municipal markets increased from FJD 10 per kg in 1991−1992 to around FJD 12−13 per kg in 2004 (Anon., 1987–1993, 2004), then to FJD 25 per kg in 2016 in small municipal markets and up to FJD 40 per large sized individuals, possibly 1.5 kg at larger municipal markets (Mangubhai *et al*., 2017), while prices obtained through other outlets tend to be higher than market prices. Prices have thus roughly doubled every ten years.

Estimated sales of **qari** for the years 1982−1992 varied, with estimated sales of slightly more than 40 mt per year in 1982, and then fluctuating between 70 to 140 mt per year from 1983−1992. From 1983−1991, direct sales to shops, hotels and restaurants far exceeded sales in municipal markets. However, the municipal market share of the total increased significantly in 1991, only to drop again in 1992. The most recent reliable market survey data, for 2004, suggest that around 325 mt of **qari** were marketed that year; around 135 mt in municipal markets and 189 mt in non-market outlets. Marketed volume has effectively increased more than two-fold since 1992. Total catches in the 12 years since that time are unknown. As noted above, a similar doubling of price per kg has also occurred between 1992 and 2004.

Long-term data on exports are not available, though a recent value chain analysis of the fishery stated that 984 kg of seafood classified as crabs (unknown species) were exported to New Zealand in 2014 (Mangubhai *et al*., 2017).

5.3 Stock Status

Despite unexplained large dips in production in 1984 and 1989, production of **qari** since 1983 has been consistently high compared with production in the late 1970s to early 1980s and has increased hugely since 1992, as noted. In areas adjacent to urban centres, the stocks must have experienced heavy fishing pressure. From 1988, it had been noted that large numbers of small **qari** were being sold in markets (Anon., 1988). Although there is no trend data available post-1980s, currently crabs below the legal size limit are openly sold in some large municipal markets such as Suva (Ministry of Fisheries, *pers. obs.*), which is a source of concern for the future of the stocks, and has been for many years. Concerns for **qari** populations were noted back in 1994, with Sasa villagers in Macuata Province saying that **qari** were hard to find (Fong, 1994). However, most crab collectors interviewed in Bua Province perceived their local **qari** population to be stable (Mangubhai *et al.*, 2017), and is consistent with catch per unit effort (CPUE) data collected by mud crab fishers from 2016–2017 (WCS, *unpubl. data*).

The main threats to **qari** are overharvesting, especially of undersized animals and berried[11] females, and clearing or filling of mangrove habitat (Mangubhai *et al.*, 2019). Category 5 Cyclone Winston that passed through Fiji in February 2016, had an impact on mud crab fishers with almost half the fishers surveyed in Bua Province experiencing difficulties accessing collection sites and markets (Thomas *et al.*, 2019). Sizes of **qari** in municipal markets suggest that populations are in a healthier state on Vanua Levu, compared to Viti Levu (Ministry of Fisheries, *pers. obs.*), and is consistent with CPUE data collected by women fishers on the two islands (WCS and FLMMA, unpublished data).

5.4 Management

Current Legislation and Policies Regulating Exploitation: Regulation 19 of the Fisheries Regulations (Cap.158 as amended) provides that: “No person shall kill, take, sell or offer or expose for sale any crab of the species *Scylla serrata* (swimming crab or **qari dina**) of less than 125 mm [5 inches] measured across the widest part of the carapace or shell.”

Management Recommendations: Despite the current size restrictions, it seems that the taking and selling of undersized **qari** is common. Public awareness programmes, particularly focused on the owners of customary fishing rights, sellers and consumers, could draw attention to the undesirability of killing small crabs before they have had a chance to breed. Berried female crabs should not be caught and be allowed to spawn first before they are caught. Large-volume exports of **qari** should be discouraged, as these will impact domestic sales. Stricter enforcement of size limits is essential at municipal markets.

A national management plan for the fishery is needed to help ensure the long-term management of **qari** populations. At the same time, the draft management plan for mangroves should be passed to ensure there is no further loss of mangrove habitat in Fiji. Furthermore, bans regarding the clearing of mangroves without permits or any prior Environment Impact Assessment (EIA) should also be enforced.

Ecological surveys of **qari** populations are hampered by poor knowledge on habitat preferences and movement patterns throughout their life history, the difficulty of working with cryptic species, and the lack of a standardised stock assessment methodology (Hay *et al.*, 2005). In terms of the information required for future **qari** fishery management, the collection of a time-series of reliable catch and effort data, including locality information and a realistic measure of fishing effort which can be used to calculate a CPUE or index of population density will be more cost-effective. Market surveys should also be conducted as a cost-effective way to capture information on the volumes, sizes and sex of **qari** being sold at local markets.

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6 INSHORE CRUSTACEANS

6.1 The Resource

Species Present: The commonly consumed inshore crustaceans of Fiji according to Lewis, (1986), Choy (1982), and Yaldwyn (1973) are listed in Table 2. Diagnostic characters for each species and a detailed distribution can be found in Carpenter and Niem (1998). The mangrove crab (*Scylla serrata*) (Profile 5 MANGROVE CRAB), the coconut crab (*Birgus latro)* (Profile 4 COCONUT CRAB), rock lobsters (*Panulirus* spp.) (Profile 3 LOBSTERS), and brown land crab (*Cardisoma carnifex)* (Profile 7 BROWN LAND CRAB) are not included as they have separate profiles.

Table 2. Common inshore crustaceans of Fiji. Source: Yaldwyn (1973); Choy (1982); Lewis (1986).

Common name	Scientific name	Fijian name
brown land crab	*Cardisoma carnifex*	**lairo**
red-clawed crab	*Parasesarma erythrodactyla*	**kuka, kukadamu, kukadra**
black mangrove crab	*Metopograpsus messor*	**kukaloa**
crenate swimming crab	*Thalamita crenata*	**qarivatu**
spotted reef crab	*Carpilius maculatus*	**tavutolu, kavika**
smooth redeyed crab	*Eriphia sebana*	**motodi, taqalito**
mud lobster	*Thalassina anomala*	**mana, tola**
banded mantis shrimp, banded prawn-killer	*Lysiosquillina maculata*	**uravidi**
mangrove prawn	*Palaemon concinnus*	**moci**
giant tiger prawn	*Penaeus monodon*	**urakeirasaqa**
witch prawn	*Penaeus canaliculatus*	**uranicakau**
green tiger prawn	*Penaeus semisulcatus*	
western king prawn	*Penaeus latisulcatus*	
spiny greasyback shrimp	*Metapenaeus anchistus*	
fine shrimp	*Metapenaeus elegans*	
banana prawn*	*Penaeus merguiensis*	
blue prawn*	*Penaeus stylirostris*	

*Introduced for aquaculture in the 1970s and 1980s, but now have established wild populations (Briggs *et al*., 2004; Richards *et al*., 1994)

Distribution: The "South Pacific Island", and Western and Central Pacific distribution of the species listed in Table 2 can be found in Yaldwyn (1973) and Carpenter and Niem (1998), respectively. The species listed in Table 2 are fished within inshore habitats, including mangrove and estuarine environments; however these species may occur in other habitats during different life stages. Choy (1982), in a survey of penaeid prawns around Viti Levu, found banana prawns (*Penaeus merguiensis*) only at Raviravi in Ba Province, in the vicinity of a discontinued FAO/UNDP fish pond project. The other species listed above, with the exception of blue prawns (*P. stylirostris*), were found in the study areas (i.e. Laucala Bay near Suva, and the estuaries of the Ba and Navua Rivers, and their adjacent lagoonal areas).

Biology and Ecology: Crabs belong to the order Decapoda and can be classified into two main groups, brachyuran crabs and anomuran crabs. All crabs listed in Table 2 belong to the infraorder Bracyhura, and are benthic (Carpenter and Niem, 1998). Some species such as **lairo** (brown land crab − *C. carnifex*) and **kuka** (red-clawed crab − *Parasesarma erythrodactyla*) construct burrows, whereas **motodi** (smooth redeyed crab *Eriphia sebana*) and **tavutolu** (spotted reef crab − *Carpilius maculatus*) are cryptic, and **qarivatu** (crenate swimming crab − *Thalamita crenata*) buries itself under soft sandy sediment.

Kuka are commonly found in intertidal areas with soft sediment often on the banks of creeks and streams, and this species is commonly associated with mangroves (Lal *et al*., 1983). **Qarivatu** prefers areas near mangroves or with muddy-rocky substrates, and is of low value as it does not attain a large size (max. carapace width 8 cm) (Carpenter and Niem, 1998). **Tavutolu** is a nocturnal reef crab, cryptic during the day and emerging at night to feed. This species can grow up to 18 cm carapace length. **Motodi** is found along rocky-shores and on reefs, and can attain a maximum carapace width of 8 cm.

Little is known about the biology of lysiosquillids*.* **Uravidi** (banded mantis shrimp, banded prawn-killer – *Lysiosquillina maculata*) is the most common and widely distributed species of the genus *Lysiosquilla* in the Indo-West Pacific region (Angsinco *et al*., 1986). **Uravidi** are found in level bottom habitats in shallow water, from shore to a depth of approximately 25 m, forming simple burrows with two openings that may be up to 10 m apart. **Uravidi** attain a maximum TL of around 38 cm. 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. The modal size range of mantis shrimp in the Philippines was found to be 22.5−23 cm, at which size males weighed 125−250 g and females 180−330 g (Angsinco *et al*., 1986). They 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.

Mana (mud lobster − *Thalassina anomala*) form characteristic volcano-like mounds during their burrowing process, in which they spent the majority of their lives. The burrows are either ‘U’ or ‘Y’ shaped and often found in muddy areas behind mangroves, with mounds up to 3 m in height and burrows 2−2.5 m deep. **Mana** feed on detritus rich mud and they can grow up to 30 cm TL (Ng and Sivasothi, 2001; Dubey *et al*., 2012).

Members of the family Penaeidae are usually marine, although juveniles and young are often found in brackish water or estuaries, sometimes with very low salinities (Carpenter and Niem, 1998). Penaeids are mostly benthic and mainly found on soft bottom of sand and/or mud, but a few species (e.g. genus *Funchalia*) are pelagic and others are known to inhabit coral reefs (e.g. some members of the genera *Metapenaeopsis*). The sexes are easily distinguished by the presence of a very large copulatory organ (petasma) on the first pair of pleopods of males, while the females have the posterior thoracic sternites modified into a large sperm receptacle process (thelycum) which holds the spermatophores or sperm sacs (usually whitish or yellowish in colour) after mating. The eggs are small and numerous, and are released directly into the water and not retained on the female abdomen.

The larvae of Penaeids are planktonic and have the nauplius stage. The life cycles of species of *Penaeus* and *Metapenaeus*, the two most important commercial shrimp genera, are complex. Adults generally move from shallow coastal waters to offshore and spawn at depths between 10−80 m. The eggs hatch within 14 to 24 hours and release very small, simple larvae; the nauplii. The nauplius larva passes through several substages before it metamorphoses into the mysis stage. These larvae are planktonic and are carried by currents toward shore where they arrive as postlarvae; this occurs about three weeks after hatching when the animals are 6−14 mm long and shrimp-like in appearance. The postlarvae invade inshore brackish waters, abandon their planktonic way of life, and become bottom dwellers living in shallow littoral areas. In these rich nursery grounds they grow rapidly, develop into juveniles and, as size increases, move gradually back toward the mouths of bays or estuaries, where they become subadults. Soon the shrimps migrate offshore, continue growing and mate, and when they finally reach the spawning grounds, the mature females spawn and the cycle is repeated; most shrimps in these grounds are about 1 year-old, rarely older than 2 (or perhaps 3) years old.

Moci (mangrove prawn − *Palaemon concinnus*) grow to a maximum TL of 7 cm (females), females are capable of bearing eggs after they reach a size of 4.9 cm. This species is rarely found outside of brackish waters. **Urakeirasaqa** (giant tiger prawn − *P. monodon*), probably the most studied penaeid, attains a maximum body length of 35 cm (females) and 27 cm (males), but is commonly between 12−20 cm. The species is found from the coastline to depths of about 150 m, usually less than 30 m, on bottoms of sand, mud, or silt.

Uranicakau (witch prawn − *P. canaliculatus*) attain a maximum body length 18.2 cm (females) and 14.5 cm (males), and commonly between 10−13 cm. Found on sandy bottoms, from shallow water to depths of about 50 m. Choy (1988) studied the **uranicakau** fishery of Laucala Bay. Males of the species reached sexual maturity at about 1.4 cm carapace length (CL), all males above 2.0 cm CL were sexually mature. Females reached sexual maturity at 2.0 cm CL, resulting in an estimated age at first maturity between 4–6 months (Choy, 1988).

The **western king prawn** (*P. latisulcatus*) grow to a maximum body length 20.2 cm (females) and 16.2 cm (males) though is commonly between 10−16 cm. It is found from the coastline to depths of about 90 m, on bottoms of sand, mud, or gravel, with a clear preference for sandy substrates. Adults are buried in the substrate during the daytime and come out to feed at night. The **spiny greasyback shrimp** (*Metapenaeus anchistus*) attains a maximum body length 16.5 cm (females) and 14.6 cm (males), and is commonly between 7−14 cm. This species is found to depths of about 30 m. Fine shrimp (*M. elegans*) reach a maximum body length 11.8 cm (females) and 8.4 cm (males). Usually inhabits estuaries, ponds, and inland lagoons with low salinity, but also found at sea to a depth of 55 m, on mud or sandy-mud bottoms.

Banana prawns (*P. merguiensis*) reach a maximum body length 24 cm (CL approximately 6 cm) in females and 20 cm (CL approximately 5 cm) in males, commonly between 13–15 cm. Inhabit bottoms of sand and mud, from the coastline and river mouths to depths of about 55 m, usually less than 20 m; prefers turbid waters. Sometimes forms very dense shoals and good catches are often linked with heavy rainfall. **Blue prawns** (*P. stylirostris*) grow to a maximum body length of 23 cm, found in bottom mud and clay or sandy mud habitats, adults are predominantly marine, whereas juveniles are estuarine, this species is generally found to depths of 27 m (Holthuis, 1980).

6.2 The Fishery

Utilisation: The wide variety of crabs collected in Fiji waters are largely used for subsistence. However, **kuka** and **lairo** are also collected at an artisanal level, with **lairo** more readily sold and consumed than **kuka** which is usually caught at low tide by women and occasionally men, digging them out of their burrows using their hands or small spades (Quinn and Kanalagi, 1998). From May to October these crabs usually come out of their holes and climb up mangrove trunks and are collected by hand. **Tavutolu** is collected by hand, but only in small numbers (Carpenter and Niem, 1998), and **motodi** are occasionally collected for food but never in large numbers. **Motodi** is mildly toxic in parts of its range (Llewellyn and Endea, 1989).

Pillai (1992) notes that **mana** is considered a great delicacy by the Fijian inhabitants of the south-eastern coast of Viti Levu. However, it is seldom utilised as a food by the coastal dwellers of the north and north-west of Viti Levu, perhaps because of the difficulties associated with catching the animal. However, Fijians have devised two other methods which are described in detail by Pillai (1992). Men usually employ a trapping device, which relies on the adult **mana** tripping a “trigger” to release tension on a bent pole joined to a noose. When the **mana** comes to the entrance of the burrow, it sets off the trigger. As the pole springs up, the noose tightens quickly around the mid-section of the animal’s body, usually resulting in the animal being dragged out of the ground. Skilled trappers can set approximately 10 traps per hour, with a success rate of 80−90%. A second catching method, known as **kucokuco**, is more commonly used by women, though men may also use it. When one of the several lower accesses to the burrow is located near the base of the mound, the catcher's foot, or less commonly the hand, is pressed vigorously against it. The disturbance inside the mound created by this action drives the **mana** to the surface, where it is caught in the hands (Pillai, 1992).

Uravidi is used almost exclusively for subsistence purposes, since volumes of sales of this organism are not listed in the Fiji Fisheries Division Annual Reports. They can be caught at night with spears, snares and bait, or with night lights or in trawls. Penaeid prawns are in demand in local and overseas markets wherever they are fished, including Fiji. Smaller penaeids and **moci** are captured with small-mesh push nets in estuaries (Lewis, 1985). The larger marine prawns, particularly **urakeirasaqa** and **uranicakau** are captured during low tides at night in Fiji along estuary shorelines, using lanterns in conjunction with fine spears and scoops. This method of fishing is known as **cina**. Other fishing methods for prawns in Laucala Bay involve seining and the use of scissors nets (Choy, 1988).

Production and Marketing: Kuka are typically sold in bundles of 30–60 indivudials, and according to the Fisheries Division market survey 21.9 mt of **kukadamu** and 71.4 mt of **kukaloa** (*M. messor*) were sold in both municipal and non-municipal markets in Fiji in 2004, for FJD 2–4 per kg (Anon., 2005). Anecdotal information collected in Suva market in 2017 suggested a typical bundle of **kuka** sells for approximately FJD 5−8, all market vendors reported their **kuka** had come from Tailevu. In 2004, 22% of total **kuka** sales were at non-municipal markets. Fisheries Division Annual Reports note 3.58 mt and 2.32 mt of **qarivatu** were sold in 2001 and 2002, respectively − all of which were in the Northern Division (Anon., 2001; 2002). No other figures are available for the production and marketing of **qarivatu** in Fiji after 2002.

Tavutolo are rarely seen in municipal and non-municipal markets, occasionally small quantities are sold, often restricted to the Northern Division. The Fisheries Division Annual Reports record 0.02 mt were sold in Rakiraki in 2001 and 13.69 mt in 2002 (Anon., 2002; 2003). A 2016 market survey found 1 kg of **tavutolo** typically sells for FJD 25 per kg. Most **mana** are produced and sold in the southeast of Viti Levu, usually in bundles of 5−10 individuals tied together, at approximately FJD 15−30 per bundle (S. Lee, *pers. obs.*), a 2016 survey of municipal markets in the Central Division found **mana** were sold for approximately FJD 9 per kg, an increase from FJD 3.00−5.50 per kg in 2004 (Anon., 2005). According to the last publicly available Fisheries Department market survey in 2004, 17.45 mt and 18.16 mt of **mana** were sold in municipal markets and non-municipal markets, respectively. In 2004, approximately 88% of total sales (35.6 mt) were in the Central Division, and sales of **mana** in non-municipal markets in the Central Division decreased from approximately 43% to 40% of total sales. Anecdotal information suggests that most **mana** sold in Suva municipal markets were from Tailevu (S. Lee, *pers. obs*.). There are no figures available for the production and marketing of **Uravidi** in Fiji.

Sales of **moci** gradually increased from 9 mt in 1986 to a peak of 33.5 mt in 1991 before declining to 16 mt in 1992 (Anon., 1987−1993). By 2004 sales of **moci** were estimated at 35.9 mt (FJD 4−6 per kg), prices of **moci** appear to be unchanged (FJD 4 per kg) in 2016 according to a municipal market survey of the central division. Non-municipal market outlets accounted for 76% of total sales (35.97 mt) in 2004, the central division accounted for 65% of total **moci** sales Fiji wide (Anon., 2005).

Current market statistics do not distinguish between marine and freshwater prawns, production probably being dominated by the latter (Lewis, 1985; Richards *et al*., 1994). Choy (1988) estimated the total penaeid (marine) catch from Laucala Bay near Suva to be about 3,000−5,000 kg per annum. On local markets, prawns are sold whole and fresh, mostly to wholesale and retail outlets. Retail prices of locally caught *P. monodon* in 1985 were approximately FJD 10 per kg (Lewis, 1985). Current prices of locally caught penaeid prawns are not documented but it can safely assumed they are much higher than 1985 prices.

6.3 Stock Status

There is no information regarding the stock status of **mana** in Fiji. Heavy fishing pressure in the south-east of Viti Levu, as witnessed by the rapid increase in estimated sales and prices at markets and outlets, may have a detrimental effect on **mana** stocks. Any further degradation of Fiji's mangroves, and subsequent loss of **mana** habitat, is likely to negatively impact on the stocks of this animal. Similarly, there are no estimates of stock status of mantis shrimp in Fiji. A study in the Philippines recorded 57 mantis shrimps from 46 identified burrows in an area of 16 ha, at a density of 3.56 shrimps per ha (Angsinco *et al*., 1986). In a nearby 10 ha area, the density was 4.2 mantis shrimps per ha.

Lewis (1985) notes that Fiji's wild stocks of penaeid prawns are probably limited by the relatively small area of soft bottom habitat. Trawl surveys in 1976 and 1983 failed to locate commercial quantities, and encountered problems with rough bottom. It is likely that natural stocks will probably continue to support only a small artisanal fishery.

6.4 Management

Current Legislation and Policies Regulating Exploitation: There is currently no specific legislation regarding any of the species listed in Table 2 in Fiji. According to the Fisheries Act (Cap. 158), the species listed in Table 2 are considered "fish" under the Fisheries Act (Cap. 158), and as such the following legislation is relevant to their fisheries:

Use of poison

8. No person shall take, stupefy or kill any fish in any lake, pool, pond, river, stream or in the sea by the use of any of the- following substances or plants:
   (a) any chemical or chemical compound;
   (b) any substance containing derris;
   (c) any substance containing the active principal of derris, namely, rotenone;
   (d) any plant or extract of or derivative from any plant, belonging to the genera *Barringtonia, Derris, Euphorbia, Pittosporum or Tephrosia,* or place any of such substances or plants in any water for the purpose of taking, stupefying or killing any fish.

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Management Recommendations: Stock assessments and further research are needed to identify the breeding seasons of commercially/artisanally harvested inshore crustaceans (i.e. **kuka**, **lairo**, **mana**, and **moci**) and establish minimum size limits. Public awareness programmes, directed towards fishers in customary fishing grounds, should be produced to draw attention to the undesirability of killing small crabs or **mana** before they have had a chance to breed. For **Uravidi**, no additional management is required at present. It should be noted that degradation of near-shore habitat, such as dredging or the taking of sand for building purposes, will negatively impact on **Uravidi** stocks.

Similarly, no additional management is required for the harvesting of penaeid prawns, given the lack of an organised prawn fishery. With the continuing development of the local prawn farming industry, there is a need for care to be exercised with the importation of exotic species, to prevent the introduction of diseases and parasites (Lewis, 1985). The continuing pollution of nearshore waters from nearby urban areas will adversely affect the habitat of natural stocks of penaeid prawns.

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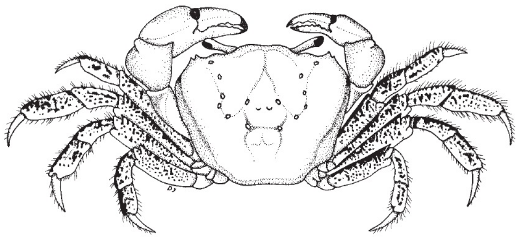
7 BROWN LAND CRAB



7.1 The Resource

Species Status: Lairo (brown land crab – *Cardisoma carnifex*) is one of several fully terrestrial crabs to occur in Fiji, and is considered the one of the largest and most common terrestrial crabs. Although **lairo** is not considered a delicacy on par with **qari** or **ugavule** (Profile 5 MANGROVE CRAB and Profile 4 COCONUT CRAB, respectively), the lower value and relatively higher abundance of **lairo** make them popular in Fiji.

Distribution: Lairo are a common species throughout the Indo-West Pacific, and are found in the coastal zone of most high-volcanic islands. In Fiji, Fulaga is noted by UNEP/IUCN (1988) as a **lairo** breeding area but spawning must occur throughout its wide Fiji range.

Biology and Ecology: Few studies have investigated the biology, ecology, and fisheries of **lairo**, a terrestrial crab, excavating deep burrows near the sea. **Lairo** burrows can be more than 1 m deep with several accessory branches and diverticula, burrows often reach the water table (Vannini *et al*., 2003). Adults construct their burrows in back mangroves or similar brackish-water habitats amongst ground cover vegetation. Although **lairo** can be found during the day, they are most active at night, during which time they feed on detritus.

The crabs emerge at dusk, around two days before the full moon and make their way to the shore. The larvae are released from the eggs into the waves by vigorous flapping of the abdomen. Release of larvae at spring tides presumably maximises dispersal along the coast (Nichols, 1991). Larvae are released into the sea and return back to land upon completion of their development. Vannini *et al.* (2003) report that juvenile (1.4–4.4 cm carapace width) **lairo** live in the burrows of adult **lairo** for at least 3 years, probably feeding on leftover food that the adult may bring in. Juvenile **lairo** may be unable to leave the wet environment of adult burrows before its aerial respiratory system is sufficiently developed. Nothing is known about when they start their own burrows, or how they avoid cannibalism while living in the adult's burrow. Males can attain a maximum carapace width of 12 cm.

7.2 The Fishery

Utlisation: Lairo are collected in large numbers wherever they are found, this species is often collected by hand at night or using baited live-traps in areas with a high density of burrows. These crabs are almost exclusively sold live, tied up in bundles.

Production and Marketing: From 1986–1992 estimated total (municipal and non-municipal market outlets) volume of sales were generally between 8–15 mt; however, there was a rapid increase from 10.5 mt in 1989 to 22.5 mt in 1990, further increasing to 58.3 mt in 1991 before decreasing to 14.7 mt in 1992 (Anon., 1986–1993). Total sales of **lairo** in 2002 amounted to 65.17 mt, in 2003 to 68.87 mt, and in 2004 to 59.46 mt (FJD 3 per kg) (Anon., 2003–2005). The Northern Division accounted for 59% of total sales in 2004, all of which were at municipal markets. This is a change from the previous 2 years when non-municipal markets accounted for a much higher proportion of sales, and in 2002 when approximately 50% of total **lairo** sold Fiji wide were through the Central Division municipal markets (Suva and Nausori). During the 1986–1992 period prices for **lairo** showed a slight upward trend reaching approximately FJD 4 per kg in 1992 and remaining stable through 2004. In 2016, **lairo** sold for approximately FJD 9 per kg (Fisheries Division *unpubl. data*). It is difficult to determine whether or not **lairo** are exported, and if so in what quantity as the Fiji Revenue and Customs Service use general categories such as "Other Crustacean" and "Crabs Frozen". However, it is unlikely **lairo** are exported, given their low value compared to **qari** (mud crab – *Scylla serrata*)

7.3 Stock Status

Unknown.

7.4 Management

Current Legislation and Policies Regulating Exploitation: **Lairo** are considered “fish” within the Fisheries Act (Cap. 158), but there is no legislation or polciies relevant to the **lairo** fishery.

Management Recommendations: Research is needed to determine stock status, spawning season(s), and size at maturity of **lairo**. Size limits may be required for the species.

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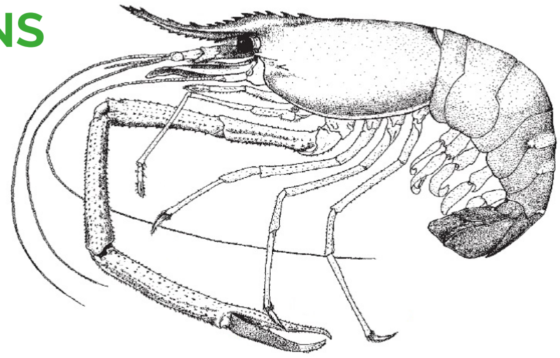
8 FRESHWATER CRUSTACEANS



8.1 The Resource

Species Present: Lewis (1985) and Jansen *et al.* (1990) note the natural presence in Fiji's freshwaters of at least 13 species of palaemonid prawns, including 11 species of the genus *Macrobrachium* (**ura**). Of noteworthy are the **uradina** (monkey river prawn *Macrobrachium lar*), **kadikadi** or **sasakadi** **(**rough river prawn *M. equidens*) and the Koua river prawn (*M. australe*). Others believed to be present include the mountain river prawn (*M. latimanus*) (Longhurst, 1970 in Holthuis, 1980) and the Noumea river prawn (*M. aemulum*), which has also been recorded in Cook Islands. The giant freshwater prawn (*M. rosenbergii*) was first introduced to Fiji in 1975 for aquaculture (Singh, 2011).

Distribution: Freshwater or long-armed prawns have an Indo-Pacific distribution from East Africa to the Marquesas (Holthuis, 1980). Within Fiji, these prawns are found in the extensive natural freshwaters and artificial impoundments.

Biology and Ecology: In order to grow, all freshwater prawns have to regularly cast their exoskeleton in a process called moulting. There are 4 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. The males of *Macrobrachium* species attain a much larger size than females, and can be readily distinguished by their larger claws and slimmer bodies. All freshwater prawns are omnivorous bottom scavengers, and are more active at night than during daylight hours (Lewis, 1985). **Kadikadi** tend to inhabit the lower parts of streams, river mouths, estuaries, and brackish waters of high salinity, the species rarely found in pure fresh water but often in sea water (near river mouths) to a depth of at least 30 m (Carpenter and Niem, 1998). **Kadikadi** larvae have about 11 stages and transform into postlarvae in 43 days. The species is known to grow to a maximum length of 9.8 cm (Carpenter and Niem, 1998).

8.2 The Fishery

Utilisation: Many of Fiji's freshwater **ura** are small, and probably only **uradina, kadikadi** and *Macrobrachium australe* are of any value as food species. No intensive fishery for freshwater **ura** exists in Fiji, though there is a substantial artisanal/subsistence fishery, usually involving women who harvest ura with push nets, hands, fine spears and traps (Lewis, 1985). Access to the **ura** fishery is weather-dependent, with heavy rains and flooding restricting the ability of fishers to access the freshwater rivers and streams, and preventing the use of certain fishing gear. *M. rosenbergii* are the most common **ura** farmed in Fiji, however production remains below 1 mt (Anon., 2015).

Production and Marketing: Most freshwater **ura** species can survive for a considerable period of time out of water, and are often sold live, wrapped in taro leaves. With a lower meat recovery rate and muddy taste compared with penaeid prawns, freshwater **ura** attract a lower price than penaeids in most markets.

Marine and freshwater prawns are not distinguished in production statistics, though *Macrobrachium* are believed to make up the bulk of the catch (Lewis, 1985). Fisheries Division Annual Reports estimated sales of **ura** increased dramatically from approximately 17 mt of **ura** per year between 1986−1988 to a peak of 72 mt in 1991, which dropped to 53 mt in 1992 (Anon., 1987−1993). The total value of **ura** sold in 1990 was approximately FJD 790,350, dropping to FJD 577,000 in 1991. By 2004 sales of **uradina** were estimated at 34.8 mt (FJD 12−19 per kg). Quantities of **ura** sold at non-market outlets were much greater than that sold in municipal markets in 2004, 90% of total non-municipal market sales of **uradina** were in the Northern Division. Of the 385 mt of **ura** sold in non-market outlets in 2004, the majority was sold in the Central (191 mt) and Western Divisions (166 mt). In 2016 **uradina** sold for a mean price of FJD 44 per kg, and **ura** for FJD 28 per kg (Ministry of Fisheries, *unpubl. data*).

Gillett (2016) noted that a substantial amount of "educated guesswork" is required when estimating production of Fiji's freshwater fisheries. After accounting for the degradation of freshwater systems and increasing value of the product, the production of freshwater fisheries is estimated at 3,731 mt for 2014, assuming the ratio of freshwater crustaceans to **kai** (*Batissa* spp., Profile 13 FRESHWATER CLAMS) sold in municipal and non-municipal markets remained constant from 2004−2017 (Gillett, 2016). An estimated 634 mt of freshwater crustaceans (17% of total freshwater production) were sold in 2017 valued at approximately FJD 7.6 million (Gillett, 2016).

There are only two records of freshwater prawns beimg exported for the years 2003, 2004, 2008, and 2012−2014: 5 kg in 2003 valued at FJD 198; and 28 kg in 2008 valued at FJD 560 (Anon., 2004; 2005; 2008; FRCS *unpubl. data*). There was however, no indication if these figures were for wild or farmed prawns. According to Raravula (2013) one resort in the Western Division purchases on average 40 kg of **ura** each month, a major seafood supplier to several resorts in the Western Division stated that **ura** from subsistence suppliers sold for FJD 15 per kg in 2012/2013.

8.3 Stock Status

The status of local stocks is unknown, though with the vastly increased production from 1989−1991, and the sharp drop in production in 1992, stocks in small streams near major urban centres subject may be severely depleted. Lewis (1985) reported that the increasing use of chemicals, which kill prawns of all species and sizes, was at that time a major source of concern. It is not known whether this illegal method of fishing is still in practice.

8.4 Management

Current Legislation and Policies Regulating Exploitation: According to the Fisheries Act (Cap. 158) freshwater crustaceans (including prawns) fall under the category "fish" as such the following regulations apply to their fishery:

Use of nets in estuaries

7. No net other than hand nets, wading nets and cast nets shall be permitted for the purpose of taking fish in the estuary of any river or stream or in the sea within 100 m [l00 yards] of the mouth of a river or stream. *(Amended by 87 of 1979)*

Use of poison

1. No person shall take, stupefy or kill any fish in any lake, pool, pond, river, stream or in the sea by the use of any of the- following substances or plants:-
   (a) any chemical or chemical compound;
   (b) any substance containing derris;
   (c) any substance containing the active principal of derris, namely, rotenone;
   (d) any plant or extract of or derivative from any plant, belonging to the genera *Barringtonia, Derris, Euphorbia, Pittosporum or Tephrosia,*

   or place any of such substances or plants in any water for the purpose of taking, stupefying or killing any fish.

Fishing in fresh water

10. No person shall kill or take fish of any kind (excluding shellfish) in fresh water in any manner other than by means of a hand net, portable fish trap, spear, line and hook.

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Management Recommendations: Given the small size of the prawns and the length of the spawning season, neither the imposition of minimum size restrictions nor restrictions on the sale of berried females would have much value. The ban on the use of poisons to kill prawns in this very valuable fishery should be strictly enforced, so that it can continue to provide income to rural Fijians. Furthermore, policy that protects the habitats of these freshwater crustaceans should be introduced, and where policy is already in-place it should be strictly enforced, such as the Environment Management Act 2005.

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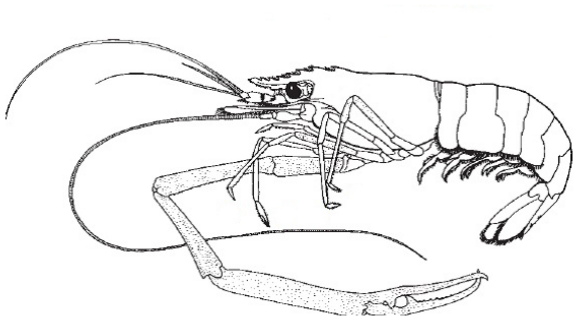
9 MONKEY RIVER PRAWN



9.1 The Resource

Species Status: Uradina (monkey river prawn − *Macrobrachium lar*) is indigenous to Fiji.

Distribution: Uradina are found throughout Fiji's streams and waterways, preferring well-oxygenated waters that are connected to the sea. Individuals are usually abundant near riffles or waterfalls, particularly where shelter such as large rocks or large tree roots is available.

Biology and Ecology: A detailed account of the biology and ecology of **uradina** can be found in Lal (2012). **Uradina** is a large palaemonid prawn indigenous to Fiji and several other Pacific Islands. They are a relatively fast growing species of freshwater prawn, with characteristics suitable for aquaculture. **Uradina** are highly sought after for the local market. **Uradina** are omnivorous bottom scavengers, and are more active at night than during daylight hours (Lewis, 1985). Plant material makes up a significant proportion of the diet of uradina, and has been identified as an important fruit-eating detritivore in Hawai'ian stream ecosystems (Larned *et al*., 2001 in Lal, 2012).

Uradina is a diadromous species, with adults occupying freshwater habitats in the upper levels of streams and creeks far inland, and larvae adopting to a marine environment in the planktonic and post-larvae stages. Early juveniles can be found in estuarine and inshore marine areas, as well as lowland freshwater bodies (Short, 2004). Larvae and post-larvae are found in marine habitats; early juveniles can be found in brackish habitats and move further upstream as they mature. Some females migrate downstream in order to release their larvae.

Uradina appear to have a 3-year life span, becoming mature between 5–9 months post-settlement (Kubota, 1972). The minimum size of an ovigerous female was 14 mm (carapace length) (Short, 2004). Ovigerous females either release larvae in adult habitats far upstream or migrate downstream and release larvae closer to the sea; currents carry newly hatched larvae to the sea (Lal, 2012). **Uradina** are able to continue mating after becoming sexually mature, however they must undergo a pre-mating moult before being able to reproduce again. They can attain 300 g in weight and grow to a maximum TL of 181 mm, with maximum sizes of developed males and females reported to be 61 mm and 195 mm TL, respectively (Short, 2004). As is the case with all *Macrobrachium* species, males attain a much larger size than females, and can be readily distinguished by their larger claws and slimmer bodies. A generalised growth curve of wild **uradina** is provided in Kubota (1972) − based on information provided, a 70 mm female would be between 9−11 months old from the time of settlement (Lal, 2012).

9.2 The Fishery

Production and Marketing: Uradina supports a substantial artisanal and subsistence fishery in Fiji. The most recent market survey by the Fiji Fisheries Department found 35.17 mt of **uradina** were sold in municipal markets in 2004; during the same year 24.63 mt was sold in non-market outlets, all recorded sales were made in the Central and Northern Division. **Uradina** fetched prices between FJD 12−19 per kg at both points of sale. In 2016 **uradina** sold for a mean price of FJD 44 per kg (Ministry of Fisheries, *unpubl. data*), an increase of more than two fold in 10 years.

9.3 Stock Status

Natural stocks of **uradina** have declined in many places areas due to over-exploitation, illegal fishing, destructive fishing methods (including the use of chlorine and other chemicals), and habitat modification as a result of pesticides, fertilisers, increased sediment load, and introduced/invasive fish species (Nandlal, 2005). There is a general consensus that wild stocks of **uradina** is heavily fished and threatened by overexploitation particularly closer to urban centres and areas with habitat alteration.

9.4 Management

Current Legislation and Policies Regulating Exploitation: There are no legislation or policy to specifically protect **uradina** - all relevant legislation can be found under Profile 8 FRESHWATER CRUSTACEANS which details the management recommendations for freshwater crustaceans.

Management Recommendations: The recommendations proposed here are identical to those proposed by Lewis (1985), that the ban on the use of poisons to kill prawns be strictly enforced. The habitats that support **uradina** should also be protected and or managed.

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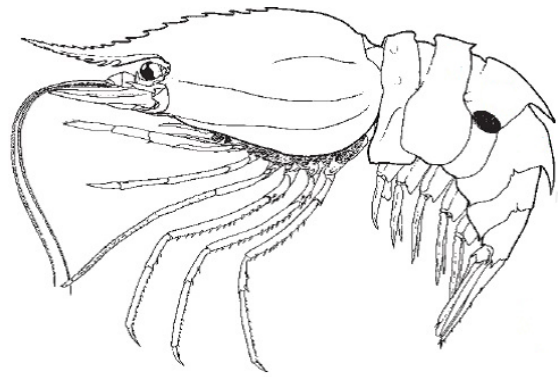
10 DEEPWATER MARINE PRAWNS (SHRIMPS)



10.1 The Resource

Species Present: The major species found in deepwater trapping surveys in Fiji are pyjama shrimp (*Parapandalus serratifrons*), striped soldier shrimp (*Plesionika edwardsii*), striped gladiator shrimp (*P. ensis*), armed nylon shrimp (*Heterocarpus ensifer*), mino nylon shrimp (*H. sibogae*), humpback nylon shrimp (*H. gibbosus*) and smooth nylon shrimp (*H. laevigatus*) (King, 1993).

Distribution: *Heterocarpus* species listed above have at least an Indo-Pacific distribution, and 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: The two divisions of the Natantian decapod crustaceans, Penaeidea and Caridea, contain the most exploited species commonly and interchangably referred to as either shrimps or prawns. Carideans include the commercially cold and temperate water shrimps of the genus *Pandalus.* Carideans differ from penaeids 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. Unlike penaeids, carideans carry fertilised eggs externally beneath the abdomen (the “tail”), which is often proportionally smaller than that of penaeids (King, 1993).

Deepwater shrimps inhabit the steep outer reef slopes of islands, and the continental slopes of large landmasses. Their distribution is relative to depth, with each particular species occupying different but overlapping depth ranges. *P. serratifrons* and *Pl. edwardsii* are widely distributed in shallower water (under 400 m), while medium-sized *Heterocarpus* species predominate in catches over 400 m. *H. sibogae*, which is commonly found in the south-western Pacific, appears to be replaced by *H. ensifer* in the eastern and northern Pacific. 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).

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. Female *H. laevigatus* reach sexual maturity between 40–43 mm carapace length (CL), 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% of female *H. laevigatus* were carrying eggs in April 1979, June and July 1980 and May 1981. 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; *Pl. edwardsii*, *H. sibogae*, *H. gibbosus* and *H. laevigatus*. Growth data for *H. laevigatus* suggest that the largest size groups in the Fiji samples are over 8 years of age at a CL_{∞} of 57 mm. Natural mortality rates for *H. laevigatus* in Fiji were estimated to be 0.66 per year or 48% per year (King, 1986). 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 (King, 1993).

10.2 The Fishery

Utilisation: Deepwater shrimps in the Pacific islands countries are caught in baited traps. Several different types of traps and baits have been used. In general, 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 lay in series on the seafloor, or a single large trap may be used these are attached to a buoy on the surface. Traps with side, rather than top entrances appeared most efficient in Fijian surveys (King, 1993).

Commercial fishing trials using a large vessel were carried out in Fiji during 1982. The mean catch rate of small (volume of 0.2−0.3 m^3) traps trialled near Suva in 450−650 m was 1.2 kg per night. In 1991/1992, some small-scale trapping of deepwater shrimps was conducted near Suva from an *alia* catamaran. The catch rates achieved at this scale were reported to be sufficient to support a commercially viable operation, but low consumer acceptance of deepwater shrimps, due to sharp shells and associated peeling difficulties, proved to be problematic (T. Adams, *pers. comm.*). Larger traps, used by commercial fishermen in Hawaii, are reported to catch at least 5 times more shrimps than small traps (Methot, 1994 in King, 1993). A commercial fishing vessel, using traps with a volume of 1.84 m^3 in a survey of the Hawaiian Islands during 1983 and 1984, obtained an average catch rate of 12 kg per trap-night (Tagami and Barrows, 1988 in King, 1993). A local company based out of Pacific Harbour reportedly catch armed nylon shrimp (*H. ensifer*) between depths of 250–500 m. As these prawns become very soft when overcooked, it is recommended they are either eaten raw or cooked quickly (never over two minutes).

Production and Marketing: There are virtually no records of production and marketing of deepwater shrimps in Fiji (FAO, 2002). King (1993) provides information on research and methods of assessment required to assess the potential for a fishery based on deepwater shrimp resources. In this account, the importance is emphasised of collecting financial information related to potential exploitation, when conducting shrimp trapping surveys. A local company sold locally caught armed nylon shrimp for FJD 49 per kg.

10.3 Stock Status

The status of the stocks of deepwater shrimp in Fiji's waters is unknown.

10.4 Management

Current Legislation and Policies Regulating Exploitation: None at present.

Management Recommendations: None required at present. The US National Oceanic and Atmospheric Administration (NOAA) and National Marine Fisheries Service (NMFS) listed *Heterocarpus* as a management unit species in 2009. Owners and operators of all vessels that fish for deepwater shrimp within the exclusive economic zones of US states, territories, and commonwealth in the western Pacific are required to purchase a fishing permit from the NMFS, which may be renewed annually, and to maintain a catch logbook issued by the NMFS. The purpose of designating *Heterocarpus* as a management unit species was to legally require fishers to record information on the harvests (and bycatch) in order to provide fishery scientists and managers with information to improve the understanding and management of the fishery (NOAA, 2014).

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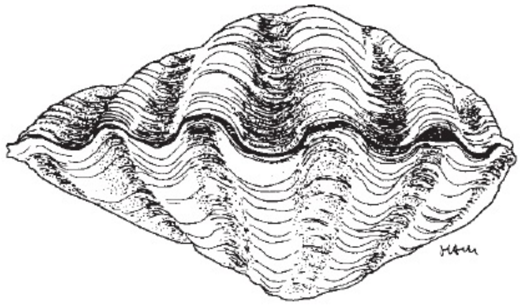
11 GIANT CLAMS

11.1 The Resource



Species Present: Table 3 lists all species of giant clam (**vasua**) that are found in Fiji. There are six species which occur naturally in Fiji; **katavatu** or **kativatu** (rugose giant clam − *Tridacna maxima*), **cega** (fluted giant clam − *T. squamosa*), **vasuadina** or **matau** (smooth giant clam − *T. derasa*), Noah's giant clam (*T. noae*, **katavatu**) (Borsa *et al*., 2014) previously confused with *T. maxima,* and the devil clam (*T. mbalavuana*), which is endemic to Fiji and Tonga (Wells, 1996). *Tridacna mbalavuana* is also known as *T. tevoroa* (Ledua and Braley, 1990); however, the older species name *T. mbalavuana* takes priority (Wells, 1996). **Teke ni ose** (bear paw clam – *Hippopus hippopus*) though naturally occuring has a very limited extant range within Fiji (Seeto *et al*., 2011).

Table 3. Giant clams (**vasua**) found in Fiji. The FAO common name is used. Source: Carpenter and Niem (1998)

Common name	Scientific name	Fijian name
Rugose giant clam	*Tridacna maxima*	**katavatu, kativatu**
Fluted giant glam	*Tridacna squamosa*	**cega**
Smooth giant clam	*Tridacna derasa*	**vasuadina, matau**
Noah's giant clam	*Tridacna noae*	**katavatu**
Devil clam	*Tridacna mbalavuana* (also known as *T. tevoroa*)	**tevoro**
Crocus giant clam	*Tridacna crocea* *	**katavatu**
Giant clam	*Tridacna gigas* **	**vasuamatau**
Bear paw clam	*Hippopus hippopus* ***	**teke ni ose**

* Not recorded as naturally occurring (Wells, 1997), but reported to have been introduced (Parry- Jones, 2003).
** Previously considered extinct in Fiji (Lewis, 1985), this species has been reintroduced to certain areas (N. Kuridrani, *pers. comm.*).
*** Thought to be extinct in Fiji (Lewis, 1985), however recently rediscovered on Bukatatanoa and Navatu reefs in southern Lau (N. Kuridrani, *pers. comm.*).

Distribution: The natural range of **vasuadina** does not extend east of Palau in the northern tropical Pacific, but in southern waters extends as far east as Tonga (Munro, 1993). **Vasuadina** (up to 62 cm in length) is only found in clean, full-salinity seawater on sandy areas of the inner reef slope close to living coral. It can live in a range of depths down to 25 m. The geographic range of **cega** extends from the western Indian Ocean to Polynesia (Lucas, 1988). **Cega** (up to 40 cm) is usually found closer to shore than **vasuadina**, on rubble and in reef cracks. *Tridacna maxima* (**katavatu**) is the most widely distributed species of giant clam, with a geographic range extending from the Red Sea to the Tuamotus in French Polynesia. *Tridacna maxima* (up to 30 cm) is most often found on reef tops, firmly attached or burrowed into the coral to withstand the battering of the surf. *Tridacna maxima* is generally restricted to shallow areas (<10 m) (Van Wynsberge *et al*., 2017).

Tevoro is reported to occur in the eastern Lau group of Fiji, the northern Vava'u and Ha'apai islands of Tonga (Lucas *et al*., 1991), around Tongatapu Island in Tonga (L. Bell in Richards *et al*., 1994) and in New Caledonia (Tiavouane and Fauvelot, 2017). It inhabits relatively deep water (>20 m) compared to other giant clam species and is apparently intolerant of shallow conditions (Lucas *et al*., 1991). **Tevoro** is able to rely on phototrophy at greater depths than **vasuadina**, both species (at their normal depths) attain most of their nutrition requirements through phototrophy compared to **vasuamatau**, which primarily relies on filter feeding (Klumpp and Lucas, 1994).

T. crocea is widely distributed from the tropical eastern Indian Ocean to the western Pacific, from the Andaman Islands to Fiji; north to Japan and south to New Caledonia and Queensland. The species can be found deeply burrowed in coral masses or coral heads on reef flats, they occur to approximately 20 m deep in clear waters (Carpenter and Niem, 1998a). *Tridacna noae* is recently recorded from Viti Levu (Borsa *et al*., 2014) but its abundance and distribution relative to *T. maxima* has not been assessed. All comments in this profile dealing with *T. maxima* are therefore assumed to refer to both species.

Biology and Ecology: Cega seems to favour fairly sheltered lagoon environments adjacent to high islands, but in the closed atoll lagoons of Polynesia, it appears to be excluded by *T. maxima*. **Vasuadina** appears to be characterised by preferentially inhabiting clear offshore or oceanic waters away from high islands with significant run-off of fresh water. All species are depth-limited by their symbiotic algae (Munro, 1993).

Giant clams are facultative phototrophs, being essentially planktotrophic but able to derive all of the maintenance requirements from their symbiotic algae. However, it is likely that they will attain their optimal growth when their nutrition is supplemented by phytoplankton or dissolved organic matter extracted from sea water (Munro, 1993). All giant clams are protandrous hermaphrodites, becoming simultaneous hermaphrodites in later years (Munro, 1993). *Tridacna maxima* appear to mature as males at around 6 cm, with 50% of individuals fully mature (male and female) at 10−11 cm and 100% fully mature at 14 cm and above (Lewis *et al*., 1988). During spawning sperm are released first, followed by eggs some hours later.

Giant clams are highly fecund, with millions of eggs being released. Settlement of the planktonic larvae occurs approximately 11 days after fertilisation, metamorphosis shortly after and shell formation after 50 days (Lewis, 1987). In the central tropics there is no evidence of any seasonality in reproduction (Munro, 1993). Spawning can be readily induced, making *T. maxima* and other tridacnid species amenable to culture (Lewis, 1987). The reproductive activity of giant clams in semi-closed atolls and lagoons is linked to temperature changes and water renewal; spawning of *T. maxima* in French Polynesia (detected by gonad maturity indices in June and July 2014) were timed with high oceanic water inflow and a decrease in lagoon water temperature (Van Wynsberge *et al*., 2017).

Lewis (1987) states that the growth of *T. maxima* throughout its range is relatively slow. Lewis *et al.* (1988) stated the maximum size of *T. maxima* in Fiji is 33 cm. Growth rates vary considerably between seasons and environmental conditions. Representative von Bertalanffy parametres are around K= 0.068−0.145 and L_∞ = 19.7−24.7 cm for wild *T. maxima* (Gilbert, 2005; Van Wynsberge *et al*., 2017).

Information on mortality rates in the early juvenile stages is very sparse owing to the extreme difficulty in finding specimens of wild juveniles (Munro, 1993). Mortality after adult size (10 cm) is reached is assumed to be very low, the thick shell and partial embedment conferring considerable protection. Estimated annual survival rates for adult *T. maxima* are 81% in an unexploited population and 75−78% in an exploited population (Lewis, 1987). Waters *et al*. (2013) report survival rates of 15% for 1 year-old giant clams (mean shell length 14.4 ± 0.36 mm) and 40% for 3 year old clams (mean shell length 50.2 ± 0.64 mm) in the Cook Islands. Giant clam mortality rates in semi-enclosed areas increase during times of low water renewal, which is associated with low oxygen supply (Van Wynsberge *et al*., 2017). *Tridacna crocea* commonly grow to a shell length of 11 cm, but are known to attain a maximum shell length of 15 cm (Carpenter and Niem, 1998).

Judging by the rarity of juveniles in most populations and their cryptic nature, it is likely that recruitment is very erratic and limited. Giant clams are highly vulnerable to stock depletion, which will result in a collapse in the fertilisation rates and consequent reduction in recruitment rates. If a coral 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 recovery of giant clam stocks could take hundreds of years (Munro, 1993).

11.2 The Fishery

Utilisation: Domestically giant clams are harvested primarily for subsistence purposes, being taken almost exclusively for their meat, with the heavy shell commonly utilised as an ornamental item. For the export market most trade is in the form of clam shells, either single or in pairs, or made into curious and souvenirs, and live specimens for aquariums (Cumming *et al.,* 2002). The meat comprises 15–20% of the total weight and is composed of a tough mantle (60% flesh weight) and the adductor muscle (15% of flesh weight or 22 per cent of total weight). Meat weight varies between 12–20% of total weight, the percentage decreasing with increasing size. The gonad is frequently retained but the dark-coloured kidney is discarded (Lewis, 1985; 1987). **Vasuadina** is the species most commonly collected, since it is of large size and is easily spotted lying unattached on the sandy seabed.

Production and Marketing: From 1978 to 1984, the annual harvest of giant clam flesh brought to market for urban consumption was about 10 mt per year (Richards *et al*., 1994). It was estimated that with purely local artisanal fishing, the total harvest of giant clam meat in 1984 was approximately 50 mt, comprising 20 mt collected for export, 10 mt collected for sale in local commercial markets and 20 mt collected for subsistence purposes. From 1986 to 1992 sale of giant clam flesh at municipal and non-municipal markets averaged 19 mt annually, peaking in 1991 at 30.5 mt before declining to 9.7 mt in 1992 (Anon., 1987–1993). According to the most recent Fisheries Annual Report that contains market data (Anon., 2005) sales of giant clams (*T. maxima* and **vasuadina**) in municipal markets totaled 12.64 mt, the vast majority of sales taking place at Suva municipal market. Non-municipal markets accounted for 15.48 mt of giant clams (*T. maxima* and **vasuadina**) sales in 2004, the majority of these sales occurred in the Western Division.

In 1985, prices paid to harvesters on landing ranged from FJD 6–11 per kg for muscle and FJD 0.60–1.50 per kg for mantle while whole flesh prices varied between FJD 1–3 per kg (Lewis, 1985). In 1992, the price of **vasuadina** in municipal markets averaged FJD 3.70 (up from FJD 2.36 in 1991) and the price of *T. maxima* averaged FJD 3.17 (up from FJD 2.48 in 1991) (Anon., 1992; 1993). The 2004 prices ranged between FJD 3.00–8.25 per kg, *T. maxima* fetching prices in the lower end of that range (Anon., 2005). A 2016 market survey (Ministry of Fisheries, *unpubl. data*) of municipal and non-municipal markets found **vasuadina** was sold for an average of FJD 6 per kg. According to their company website, Great North Seafood Ltd, located in Labasa, Fiji sells giant clam meat for FJD 15 per kg, and exports the shells.

Export volume of giant clam shells and live specimens was relatively consistent from 1993–2003 (CITES Trade Database[12]), averaging 8.15 mt per year. Live specimens of *T. crocea*, **vasuadina***,* and *T. maxima* made up the bulk of this quantity. It is likely these live specimens were exported for the aquarium trade. In 2002 the CITES Secretariat in Geneva recommended all signatory countries including the USA, suspend trade with Fiji. This suspension included *Tridacna* spp., export however continued to the USA and Japan. The suspension was a response to Fiji having defaulted on the terms of CITES that it signed in 1998 (Cumming *et al*., 2002). This may account for the reduced export volumes of *Tridacna* spp. post–2003. The suspension was lifted shortly after the enactment of the Endangered and Protected Species Act 2002. Between 2003–2009, Fiji exported 223 kg of giant clam. Exports of giant clams from 2009–2015 are provided in Table 4.

12 https://trade.cites.org (accessed: 07.2017)

Table 4. Gross exports of *Tridacna* species from 2009−2015. If no 'quantity type' was specified, the quantity was assumed to be kilograms (kg). Source: CITES Trade Database

Scientific name	Fijian name	Gross exports (kg)		
		Live	Shell	Meat
Tridacna derasa	**vasuadina**	0	4,797	0
Tridacna gigas	**vasuamatau**	0	3,718	1
Tridacna maxima	**katavatu**	0	188	0
Tridacna squamosa	**cega**	12	2,529	0
Tridacna spp.		44	3,376	0
Tridacna crocea	**katavatu**	0	0	0
Total		**56**	**14,608**	**1**

11.3 Stock Status

As giant clams are sedentary, large and easily collected, the resource is very vulnerable to exploitation. Fiji's stocks of *v***asuamatau**, the largest species, have been wiped out, and stocks of **vasuadina** are depauperate. Lewis (1985) states that due to low level but continuous artisanal harvesting of **vasuadina** over hundreds of years, and estuarine influences creating unsuitable habitats, this species is scarce around the larger inhabited islands. **Tevoro** and **teke ni ose** are now restricted to the eastern Lau Group, likely a result of ecological factors combined with serial overfishing.

In the Eastern Division, poaching and commercial harvesting have decimated the stocks on some reefs. These may recover, but **vasuadina** takes at least 4 years to reach reproductive capability, and perhaps 7 years to reach average size, so it will take at least 5 years of non-exploitation before these reefs again become fishable. Divers using UBA and gleaners targeting sea cucumbers opportunistically collect giant clams (West, 2014), likely eliminating any depth refuge that had previously existed. From the 1980s giant clams were considered overfished throughout their Indo-Pacific distributions (Lucas, 1994), given their inclusion as by-catch in the sea cucumber fishery it is likely that stocks of giant clams in Fiji have been decimated recent years. The SPC PROCFish assessment of Fiji, which surveyed sites in Dromuna and Muaivuso on Viti Levu, Mali and Lakeba in Vanua Levu confirm that stocks of giant clams were significantly depleted in 2003 and surveys in 2009 showed signs of further depletion (Friedman *et al*., 2010).

The majority of research and surveys focusing on wild giant clams was conducted between the 1980s and early 1990s. Since then, research has largely focused on mariculture. The Ministry of Fisheries has maintained the giant clam research programme on Makogai Island, which began as a quarantine station in 1983. The Makogai research station cultured *T. gigas*, *T. maxima*, **vasuadina**, **cega** in their land hatchery and ocean nursery, and **teke ni ose** in their ocean nursery prior to Tropical Cyclone Winston (February 2016). Following the cyclone **vasuamatau** and *T. maxima* are still cultured in the land hatchery, and **teke ni ose** is no longer cultured (N. Kuridrani, *pers. comm.*). **Vasuadina** is currently the main species cultured on Makogai Island, with the giant clams produced reportedly to be used for re-stocking reefs. To receive stock for reseeding reefs, a community or hotel with a marine protected area must write a letter of request for stock to the Director of Research or Fisheries, within the Ministry of Fisheries. If approved, project officers from Makogai are sent to assess the area and formulate a management plan before giant clams are provided for reseeding. With no long term monitoring in place, there is insufficient information to undertake a cost-benefit analysis and assess success rates. However, given the length of the program and the low densities of giant clams, restocking programs have not resulted in the recovery of any species to date.

11.4 Management

Current Legislation and Policies Regulating Exploitation: According to the Fisheries Act Cap. 158 are:

25A. No person shall export from Fiji tridacnid clam (giant clam) (**vasua**) flesh, including adductor muscle or mantle tissue, of the following species: (a) *Tridacna derasa* (**vasuadina**); (b) *Tridacna squamosa* (**cega**); (c) *Tridacna maxima* (**katavatu**).

However, the "Director of Fisheries or any person appointed by him may exempt any person, in writing, from any of the provisions 25(A)…if evidence is supplied demonstrating that the fish covered by such regulations originated from artificial spawning methods".

All species of giant clam (Family: Tridacnidae) are included in Appendix II of CITES (IUCN, 2017) as such they are included in the Endangered and Protected Species Act 2002 and under Regulation 5 of the Offshore Fisheries Management Act. Therefore all species of the Family Tridacnidae (inclusive of the genera *Tridacna* and *Hippopus*) are protected. *Tridacna balavuana* (also known as *T. tevoroa*), is listed under Part 8 of Schedule 1 (Section 3) of the Endangered and Protected Species Act 2002. The act outlines laws, legislation pertaining, and permits pertaining to species listed under CITES.

Because of the vulnerability of the resource, exploitation guidelines were drawn up in 1984 and approved by Cabinet. There are as follows:

- Harvest and marketing of the resource is to be restricted to Fiji nationals;
- Harvesting is to be carried out at the written invitation of traditional custodians and only on uninhabited islands and reefs in the first instance. Village fisherman are to be involved in (commercial) fishing operations to the maximum extent possible;
- Size limits for the (then) three species are to be established and strictly observed by harvesters; these size limits are to be subsequently incorporated into the Fisheries regulations;
- Provision is to be made for Ministry of Fisheries observers to accompany collecting vessels as deemed necessary;
- Notice is to be given in writing by collection vessels of islands/reefs to be visited, together with the written approval of the custodian;
- Details of catches are to be supplied on a per-reef basis or as directed by Ministry of Fisheries;
- Management regimes for particular areas are to be determined by consultation between collectors and Ministry of Fisheries. Possible options include quota (wet weight), selective harvesting (as is done with tree thinning, for example) and reserved sectors where no harvesting would be allowed;
- All exports are to be subject to optional inspection and compulsory licence. A list of approved exporters is to be drawn up;
- Processing of material prior to export is to be strongly encouraged and preference on issue of export licences given to persons processing product;
- The export of *muscle only* is to be discouraged, unless markets can be found for the remainder of the edible portion;
- Consideration is to be given to the utilisation of the shell itself, which is currently discarded; and
- Although it remains essentially a matter between the collector and resource custodians, Fisheries Division should do all it can to ensure a fair price be paid, and that harvesting itself is done by them.

The Guidelines were designed mainly to put the decision to exploit the resource or not into the hands of the local custodians of the fishing rights, under whose jurisdiction all the clam stocks of Fiji lie, and to enable Ministry of Fisheries to keep track of harvesting so that management advice can be given. Many of the Guidelines were superseded in December 1988 when Cabinet passed a new regulation banning the export of giant clam meat - Regulation 25A of the Fisheries Regulations (Cap.158) provided above.

Management Recommendations: Prohibit the export of wild giant clam shells, of all species, as large quantities of giant clams are being commercially harvested for their shells and the meat sold locally. This undermines any conservation or restoration efforts to increase wild giant clam stocks. A management plan should be developed to ensure the recovery of giant clams in Fiji, and restocking efforts should be reviewed and updated to ensure effectiveness.

An assessment survey should be conducted to ascertain the present state of the wild stocks of giant clams in Fiji - with special attention placed on assessing the relative abundance and distribution **katavatu** as the two species (*T. crocea* and *T. noae*) have been previously confused. Because of the intensive surveys of natural giant clam stocks conducted in Fiji from 1984−1988 under the auspices of the ACIAR International Giant Clam Project, there is an excellent set of baseline data from which to make comparisons.

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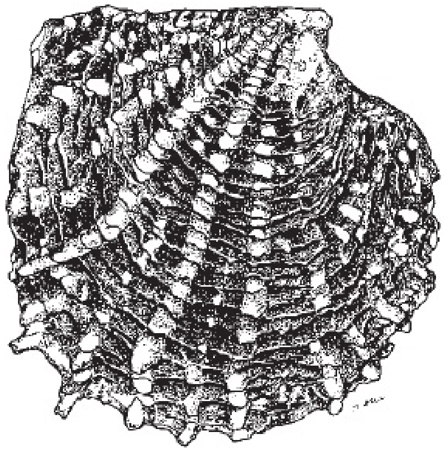
12 BLACK-LIP PEARL OYSTER



12.1 The Resource

Species Present: Civa (black-lip pearl oyster – *Pinctada margaritifera typica*) is the dominant commercial species in Fiji (J. Hunter, *pers. comm.*). Based on 1992 survey results and interviews with shell dealers in Fiji, Murray (1992) concluded that there are now no stocks of gold-lip pearl oyster (*P. maxima*) in the country. **Melamela** (penguin wing oyster – *Pteria penguin*) are also found in Fiji waters; however it does not constitute a wild harvest fishery like *P. margaritifera*, but is instead occasionally harvested for ornamental use.

Distribution: The **civa**, the black-lip pearl oyster (*P. margaritifera*) 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.

Biology and Ecology: Civa occurs in lagoons, bays and sheltered reef areas to around 40 m depth, but is most abundant just below low-water. Strong byssal threads attach the oyster to rocks or other oysters. In Fiji, Murray (1992) notes that there are two main habitat types for **civa**; shallow lagoons similar to those found in French Polynesia and the Cook Islands, and inshore reef systems where the reef-tops are accessible at low spring tides.

Pearl oysters are non-selective filter-feeders. High turbidities may exclude **civa** from closed lagoons or from areas of heavy terrestrial run-off, while strong currents promote faster shell growth. Temperature limits the **civa** to warmer tropical regions. Lagoon water quality influences sizes, growth rates, shell quality and shell colour (Sims, 1993).

Civa generally reach maturity at 2 years of age. Initially, the majority are males, but protandric sex changes usually result in an even sex ratio by the fourth or fifth year. Temperature is the main influence on sexual development and spawning patterns. Spawning is usually not limited to distinct seasons and protracted spawnings may occur throughout the year. **Civa** usually exhibits two periods of maximum spawning in Cook Islands, from August–September and the following February–March (Sims, 1988; 1993). A study of recruitment patters of **civa** in Savusavu Bay, Vanua Levu, noted that the months of February–March were the most successful for spat collection (Vilisoni, 2012). While an increase in temperature favoured spawning of **civa**, a decrease in temperature favoured **melamela**. **Melamela** in Savusavu Bay exhibited high recruitment numbers (spat collected) between January–September (Vilisoni, 2012).

The planktonic larval stage in **civa** may extend to 4 weeks. The larvae are obligate planktotrophs after 1 or 2 days and have relatively narrow physiological tolerances. Larvae settle out onto suitable available substrate but retain some motility before beginning to secrete byssal threads. Age-fecundity patterns, density-dependent 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 spatfalls 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. Representative von Bertalanffy parametres are around K= 0.52 and L_∞ = 155 mm for cultured **civa**. The rapid initial growth results in shell diametres of between 100–120 mm after 2 years. 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 gastropods is the main cause of natural mortality in adults. Recent estimates of annual natural mortality (M) for **civa** range from 0.1−0.2. 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).

12.2 The Fishery

Utilisation: Natural pearls are rarely found in **civa** and the fisheries are based on the value of the mother-of-pearl or pearl-shell itself, which is used in the manufacture of buttons, inlay and usually jewelry work. Black pearls are produced naturally only from the black-lip pearl oyster and because of their rarity and colouration, attract top prices. Cultured black pearls are also much sought-after and half-pearls or "blister pearls" are marketed for use in pendants, brooches and rings. Since the introduction of pearl culture to French Polynesia and the Cook Islands in the mid−1970s the industry has experienced massive growth. Cultured pearls are currently the Pacific region's most valuable aquaculture commodity valued at USD 176 million in 2007, round 'black' South Seas Pearls produced in French Polynesia from *P. margaritifera* accounted for 98% of the 2007 production value for the Pacific (Chand *et al.*, 2011). The cultured pearl industry in the Cook Islands is worth USD 5 million and is the second largest source of revenue for the country after tourism (Adams *et al.*, 2001). **Melamela** is cultured in Tonga for mabé pearls (half pearls). The size of the industry in French Polynesia dwarfs the industries of Fiji and Tonga. A value chain analysis of cultured pearls in Fiji can be found in Chand *et al.* (2011).

Free-diving and reef gleaning are still the main methods used in most Pacific fisheries for taking black-lip pearl shell, including Fiji. Sims (1993) states that hard-hat and hookah diving machines were once widely used throughout the South Pacific, but their use is now generally prohibited. In Fiji, the rapid increase in the use of hookah appears to be directly related to the rate at which pearl shell resource depletion occurred. Murray (1992) noted that in the 6 months prior to February 1992, two Suva-based companies had sold 200 hookah diving machines for commercial fishing purposes, with further orders for 85 more units – though it is likely that some of these were also used for harvesting sea cucumbers (Profile 1 SEA CUCMBERS). Murray (1992) estimated that there were approximately 300−350 hookah units currently in operation in Fiji. Wild harvest fisheries for **civa** are largely non-existent in the present day, except for spat, which are sold to pearl farms. According to the 2008 Fisheries Division Annual Report, 9 pearl farms were in operation (8 in the Northern Division, 1 in the Western). However, only two farms recorded exports for that year: J. Hunter Pearls in Savusavu Bay; and Valili Pearls in Matuku Bay. The 2014 Fisheries Division Annual Report (Anon., 2015) stated that 5 pearl farms were in operation, together with 12 community-based spat "farms", all of which are based in the Northern Division. J. Hunter Pearls currently dominates Fiji's cultured pearl industry. The collection of **civa** spat by villages is largely subsidised by the Ministry of Fisheries; equipment and training are provided, and sales negotiated by the Ministry.

Production and Marketing: Sims (1993) states that notable quantities of **civa** are produced in Fiji, in comparison with other countries in the Pacific. Prior to 1960, fishing for *P. margaritifera* and *P. maxima*[13] in Fiji was practised at an artisanal level, with mainly a local trade in shell (Murray, 1992). Murray (1992), in interviews with village divers, found that shells are taken by free diving to 2.5 m and by reef gleaning on reef tops and reef edges an average of 2−4 days per week, depending on tides. Informants told Murray (1992) that in the 1960s to 1970s, a village person could collect 30−50 **civa** per day, falling to 20−30 per day in the 1970s to late 1980s, but by the early 1990s the average number of **civa** collected declined to 1−4 per person per day. 10 **civa** taken per person per day was considered exceptional by the 1990s (Murray, 1992). From 1975−1985, Fiji's annual mother-of-pearl shell exports fluctuated between 9−30 mt per year, with an average of 18.6 mt per year (Richards *et al.*, 1994). Exports peaked in 1988 at 57.5 mt, followed by a drop to mid−1970s export levels in 1991−1992 (Anon., 1989; 1992; 1993).

13 Considered extinct in Fiji (Murray, 1992)

The peak in exports in 1988 is thought to have been caused by several factors. Economic necessity within villages, combined with increased access to bank finance permitted many divers and fishermen to acquire fishing boats and equipment. This enabled them to search previously inaccessible areas of reef. Gleaning of reef tops for edible shellfish maintained the fishing pressure on shell stocks. Both buyers and sellers were encouraged by newly opened trade opportunities and increasing world market prices for mother-of-pearl, from approximately FJD 4 per kg in 1986 to FJD 14 per kg in 1990 (Murray, 1992).

Civa is also sold in municipal markets and non-market outlets, the shells, either carved into jewellery or polished, can be found in handicraft markets and stores catering to tourists. High local sales in 1988 and 1990 were followed by very low or zero reported sales in subsequent years (Anon., 1989–1993). Only 0.08 mt, 0.26 mt, and 1.08 mt of **civa** were sold, in 2002, 2003 and 2004 respectively. Fisheries Division Annual Reports record no sales of **civa** in 2001 (Anon., 2003–2005). A jewellery company in Suva, Fiji purchases approximately 50 kg of **civa** shells per year from a cultured pearl farm in Savusavu. The shells are allowed to dry for at least a year in a cool shaded area, before they can be processed into jewellery or ornamentals. Prices for the shell range between FJD 2–10 per kg (P. Frey, *pers. comm.*). J. Hunter Pearls sell **civa** meat, which is harvested from **civa** oysters that are not seeded or reseeded to form pearls, the meat of pearl-oyster adductor muscle has excellent flavour and texture (Sims, 1988). Vacuum packs of **civa** meat sell for FJD 100 per kg and between 2–3 kg can be harvested per day during pearl harvest season (May and October).

12.3 Stock Status

Murray (1992), following an extensive **civa** survey, concluded that Fiji's wild **civa** stocks were very depleted, and in some areas, exhausted. He ascribed the poor condition of the stocks to heavy fishing pressure and in some locations, environmental stress caused by water-borne agricultural chemicals and general pollution of inshore areas land-derived effluent. Of the areas surveyed, Murray (1992) stated that the reefs surrounding Raviravi had the most abundant mother-of-pearl resources, and estimated that the standing stock of **civa** in west Vanua Levu was between 50,000–70,000 shells. Passfield (1995) in Gillett *et al*. (2014) based on surveys of Western Vanua Levu, Beqa Island, Totoya Island, and Makogai Island for **civa** and **melamela** stated that the abundance of **civa** was low at all the survey sites, too low to support an expansion of pearl farming in the areas surveyed. Bao and Drew (2016) reported that populations of common molluscs (including **civa**) in Nagigi, Vanua Levu have declined significantly; this decline is apparent only amongst older fishers suggesting a shift in baseline perceptions of biodiversity and abundance. It is assumed that wild populations of **civa** within Savusavu Bay have recovered significantly due to the high abundance of **civa** broodstock in the bay as a result of commercial pearl farming operations there.

12.4 Management

Current Legislation and Policies Regulating Exploitation: Regulation 21(b) of the Fisheries Regulations (Cap.158 as amended) provides that "No person shall take, be in possession of, sell, offer or expose for sale or export any shell of the species *Pinctada margaritifera* [**civa**] (pearl oyster shell) of which the nacre or mother-of-pearl measures less than 100 mm [4 inches] from the butt or hinge to the opposite edge or lip."

Management Recommendations: As it is near-impossible to distinguish between cultured **civa** and wild **civa**, market controls would be problematic. Rather, strenuous efforts should be made to reduce water-borne pollution entering Fiji's coastal zone.

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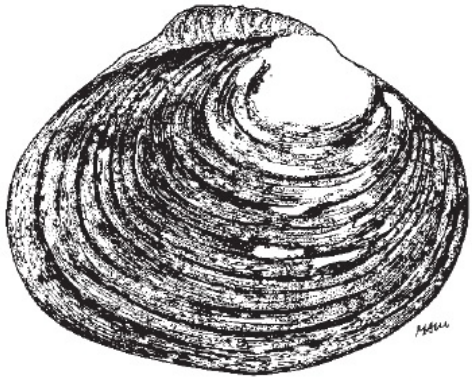
13 FRESHWATER CLAMS



13.1 The Resource

Species Present: The freshwater mussel known locally as **kai** (*Batissa violacea*) has three ectomorphs: **kai buli** which is fat and mostly round; **kai bukivula** which is thin and has an oval shell with eroded umbo[14]; and **kai dina,** an intermediate between **kai buli** and **kai bukivula** found on sandy substrate in moderate current (Anon., 1975; Kuridrani-Tuqiri, 2015).

Distribution: *B. violacea* is reported as occurring in southeast Asia, Australia, Indonesia and Fiji. Within Fiji, it is common in the following rivers: Rewa, Navua, Sigatoka, Nadi, Ba, and various Tailevu rivers (Viti Levu) and Labasa, Waikoro, and Dreketi (Vanua Levu) (Lewis, 1985).

Biology and Ecology: Kai is found on the sandy or muddy beds of rivers, restricted to the lower freshwater reaches of rivers, between the upper limit of tidal influence and the upper limit of saltwater penetration (Lewis, 1985). The clam is free living, burrowing to 10 cm in riverbeds and capable of substantial movement. Spawning in **kai** occurs in March−May, with a peak in April. The larvae are partially incubated within the shell, and are capable of only limited movement, so the influence of floods and tides on settlement is critical. Growth rates are in the order of 2 cm per year, with larger specimens growing to 8−9 cm (300 g) (Anon., 1975; Lewis, 1985). Between 20−75% of a river bed may be occupied by **kai**, the location of productive beds being influenced by river flow rates and sediment deposition patterns. Densities of **kai** in the Rewa River were approximately 79 individuals m^{-2} (Naqasima, 1996), and compared to 270 individuals m^{-2} (mean biomass 684 g m^{-2}) in the Ba River (Ledua, 1996).

13.2 The Fishery

Utilisation: Kai is very important as a subsistence food in Fiji and was traditionally used for bartering and as a gift for friends (Anon., 1975). It forms the basis of a fishery that is operated almost entirely by women (Kuridrani-Tuqiri, 2015). Clams are located in shallow parts of the riverbed using hands and feet. Diving, using mask and snorkel, is also practiced but deeper parts of the rivers are generally not fished Lewis (1985). **Kai** fisherwomen, usually mature women assisted by younger women, routinely harvest for 3−4 hours a day, 2−4 days a week. Generally the closer a harvesting area is to a market the fewer days are spent harvesting; this is likely because more **kai** are required to cover the additional transport costs to distant market places. A day's harvest of **kai** may vary between 20−80 kg (Anon., 1975). As the fishing grounds are communally owned, harvesters can harvest anywhere within their demarcated area. **Kai** harvested in 2015 had a mean size of 71 mm in the Rewa River, 32 mm in the Ba River, 53 mm in the Sigatoka River (Kuridrani-Tuqiri, 2015).

The clams are invariably sold live either in markets or to middlemen who visit **kai**-producing villages on a weekly basis. Providing they are kept wet, **kai** can be kept alive in bags for up to a week, and up to two weeks in regularly changed water. There is considerable water loss but little meat loss during such storage, so **kai** may be extensively transported around the larger islands. Though much of the **kai** from the Toga and Rewa Rivers is sold in the Suva, Nausori and Davuilevu **kai**-selling centres, the market has been extended to the islands of Lomaiviti, particularly Koro Island (Lewis, 1985; Bibi, 1991). The raw meat recovery from **kai** is approximately 20% and roughly 650 g of cooked meat can be recovered from 5 kg of **kai** (Lewis, 1985). The clam is prepared in several ways for consumption; boiled with salt, boiled with coconut cream (**vakalolo**), curried, deep-fried or made into soup. The shells are not currently utilised commercially.

14 *umbo* (plural umbones or umbos) is the vaguely defined, often most prominent, highest part of each valve of the *shell* of a bivalve or univalve mollusc.

Production and Marketing: A value chain analysis of Fiji's **kai** fishery can be found in Kuridrani-Tuqiri (2015). The **kai** fishery is one of the most valuable village-level fisheries in Fiji, and **kai** forms the major component (by weight) of non-fish products sold in municipal markets and non-market outlets throughout the country. In 2015, there were approximately 500 harvesters spread between 27 villages and two settlements involved in the **kai** fishery. Prior to 1985, approximately 1,300 mt was marketed annually, mainly through municipal markets, though this does not include the substantial subsistence production (Lewis, 1985). There was a sudden, unexplained increase in total sales to over 1,800 mt in 1992, due mainly to an increase in market sales (Anon., 1993). Marketed production levels of **kai** from 2001−2004 is provided in Table 5. From the Fisheries Department Annual Report (2004), 2,527 mt of **kai** was marketed in 2004; Of this approximately 2003 mt was sold in municipal markets, 67% of which (1,349 mt) was sold in Western Division municipal markets in Lautoka, Nadi, Sigatoka, and Ba (in order of decreasing volume). Anecdotal information on current **kai** prices in Suva market suggests the standard price for **kai** was FJD 5 for a 2 litre container filled to the brim. **Kai** are separated by size when possible (WCS and Ministry of Fisheries, *unpubl. data*). Kuridrani-Tuqiri (2015) reports the same quantity being sold in Sigatoka Town for FJD 12. **Kai** sold for FJD 1.03 per kg in a 2016 market survey by the Ministry of Fisheries.

Kuridrani-Tuqiri (2015) noted that a small portion of **kai** is processed (often cooked or boiled) − these are primarily sold to supermarkets or exporters. Hotels in Viti Levu purchased approximately 10 kg of shelled **kai** per week (0.52 mt annually), however there are few hotels that purchase **kai**. Approximately five processors were identified in Kuridrani-Tuqiri (2015) who supplied on average 20 kg of **kai** (without shell) to supermarkets, and 100 kg per week to two exporters based Sigatoka and in Lami. Exports range between 20−100 kg of **kai** (without shell) per week; the main markets are Australia and New Zealand.

Table 5. Estimated annual **kai** production (mt) in Fiji. The mean price (FJD per kg) is provided in parentheses. Source: Anon., 2002–2004

	2001	2002	2003	2004
Municipal market	1,089.37 (0.78)	1,143.71 (0.67)	634.45 (0.94)	2,003.49 (0.81)
Non-municipal market	535.48	884.72	418.57	523.89
Total	**1,624.85**	**2,028.43**	**1,053.02**	**2,527.38**

13.3 Stock Status

Despite concerns about possible damage to **kai** habitat by dredging, pollution and overfishing, **kai** stocks in 1985 appeared to be in good condition (Lewis, 1985). Although there have been no **kai** stock assessment surveys, the stability of market sales tends to confirm that this is still the case. Individuals in deeper water constitute a relatively unexploited buffer stock in the large rivers, and increased siltation has probably expanded the area of suitable habitat.

13.4 Management

Current Legislation and Policies Regulating Exploitation: As **kai** are considered “fish” within the Fisheries Act (Cap. 158) the use of chemical compounds to kill or stupefy **kai** is banned.

Management Recommendations: Because of its importance as an affordable source of protein for low income earners and provider of direct income to villagers, every concerted effort should be made to conserve **kai** stocks. Regular market surveys should be conducted to monitor the size-frequency of **kai**, and measures taken to minimise damage to **kai** habitat from water-borne pollution and uncontrolled dredging. A study on the **kai** fishery should be conducted as soon as practicable, and baseline data collected on areas that supply the largest volume of **kai** (i.e. the Rewa, Sigatoka, and Ba rivers).

As **kai** are filter feeders the Food Safety Act 2003 and Food Regulation 2009 should be enforced in order to improve or maintain the quality and safety of the product for consumers. As **kai** exports on a commercial scale are relatively recent, these exporters and the communities that supply them should be monitored to ensure food safety and that stocks are not overfished. Conditions for **kai** vendors in municipal markets should be improved in order to maintain a safe and quality product; this can be done by demarcating areas with proper drainage and an accessible supply of clean water in places where **kai** are sold.

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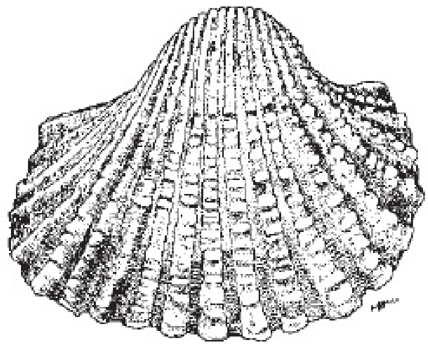
14 OTHER BIVALVES



There are several species of edible bivalve in Fiji (Table 6). **Vasua** (giant clams) and **kai** (freshwater clam) are the subject of separate profiles (Profile 11 GIANT CLAMS and Profile 13 FRESHWATER CLAMS, respectively). Ark shells (Family: Arcidae) form a very important fishery in many countries, often with different species dominating the ark shell fishery of different countries. Though Carpenter and Niem (1998) list several species of ark shells extant in Fiji, **kaikoso** (*Anadara antiquata*) is the species commonly eaten in Fiji (Naqasima, 1996) thus likely make up the majority of local sales. The Fijian name **kaikoso** appears applicable to several closely-related species, as such the literature cited and examples, are from various closely-related species of ark shell.

14.1 The Resource

Species Present: This profile contains eleven species of common bivalves consumed and traded in Fiji listed. A more extended list of species is provided in Table 6.

Table 6. Edible bivalves in Fiji. Source: Parkinson (1982), Lewis (1986), Carpenter and Niem (1998)

Common name	Scientific name	Fijian name
jewel-box shell	*Chama* sp.	**bu, su, sobu**
antique ark	*Anadara antiquata*	**kaikoso, qeqe**
granular ark	*Anadara granosa*	**kaikoso**
ventricose ark	*Arca ventricosa*	**kaikoso**
hazelnut ark	*Arca avellana*	**kaikoso**
decussate ark	*Barbatia foliate*	**kaikoso**
hardshell clam	*Periglypta puerpera*	**kaidawa, kaibakoko**
venus shell	*Gafrarium tumidum*	**kaitakadiri, qaqa**
littleneck clam	*Tapes literata*	**kaivadra**
coconutscraper cockle	*Vasticardium* sp.	**kaininiu, sakaro**
surf clam	*Atactodea striata*	**sigawale, silawale**
mangrove mussel	*Modiolus agripetus*	**kuku, boro**
mangrove oyster	*Crassostrea mordax*	**dioniveitiri**
thorny oyster	*Spondylus ducalis*	**kolakola, saulaki**
pigmy pearlshell	*Pinctada martensi*	**civaciva, civare**
squamose scallop	*Chlamys squamosa*	
royal cloak scallop	*Gloriapallium pallium*	
slipper cupped oyster	*Crassostrea iredalei*	

Distribution: Most of the bivalves listed in Table 6 have a wide distribution in the tropical Indo-Pacific. Paulay (1987) states that **bu** (jewel-box shell − *Chama pacifica*) is known to occur from Australia and Borneo in the west to the Tuamotu Islands in the east. In Fiji, **kaikoso** are common wherever conditions (substrate and salinity) are suitable (Squires *et al.*, 1973).

Biology and Ecology: Many of these species are found in the lagoon, on the reef ridge and some in deeper waters. Species such as **kolakola** (thorny oyster − *Spondylus ducalis*) and **dioneveitiri** (mangrove oyster − *Crassostrea mordax*) are cemented to the substrate, with entire loss of the byssus. **Bu**, a cemented sessile heterodont, appears to be restricted to larger lagoonal habitats (Paulay, 1987). They attach by deeply conical right valve, with the smaller left valve forming a lid on top. A study of **sigawale** *(Atactodea striata*) in New Caledonia noted that sexual differentiation begins at a shell length of 2 cm, and the species has an extended or continuous breeding period (Baron, 1992). However sexual activity peaks in the hot season. **Sigawale** are found in the littoral zones of sandy beaches, but distribution along a beach is often patchy.

A study of **kaikoso** from Laucala Bay near Suva, found that they were patchily distributed from low water mark downwards, mostly in turtlegrass (*Zostera* sp.) (Butler, 1983). Density of **kaikoso** varied from 0.2 ± 0.8 to 2.2 ± 3.1 individuals per m² of substrate. Large **kaikoso** were usually on their own.

In a separate study in Laucala Bay, smaller **kaikoso** were more abundant near the shore, whilst larger animals were more abundant in deeper water. Abundance was greater where there was both sand and mud present, but large specimens were found in muddy areas (Chand, 1980 in Butler, 1983). From this information, Butler (1983) concluded that **kaikoso** is a species which recruits into sand/seagrass areas, though it can live in mud when older. It lives in areas where the sediment is dynamic, due to floods and other causes. In a survey at Wailoaloa Beach near Nadi, found that the **kaikoso** beds extended along the beach just offshore from low water mark, to approximately 65 m from shore (Squires *et al*., 1973). **Kaikoso** were not uniformly distributed, but aggregated in groups up to 46 per m², with an average of 7.2 individuals per m². The average weight of the **kaikoso** specimens sampled was 25 g. **Kaikoso** from Laucala Bay may grow from settlement to a length of 20 mm in less than a year, and from 20−40 mm in 8 months or less, though another 4 years may be required for the shells to reach 60 mm (Butler, 1983). **Kaikoso** have separate sexes and reach reproductive maturity when they are about 1 year old and approximately 20 mm long (SPC, 2011).

Because the closely related *A. antiquata* are reported to reach 90 mm in length (Cernohorsky, 1972 in Butler, 1983), Butler (1983) suggests that none of the animals in his samples were more than two-thirds of their maximum length, which could be explained by the intense collection by people throughout the Suva area. Butler (1993) surmised that **kaikoso** from Laucala Bay recruit several times a year, but discontinuously and at fluctuating densities. Animals above about 20 mm in length had visible gonads at all times. In India, *A. granosa* spawns throughout the year, and can have 2−4 reproductive cycles per year. First maturity is attained at 20 mm for males and 24 mm for females (Narasimham, 1988).

14.2 The Fishery

Utilisation: Lewis (1986) lists the bivalves in Table 6 as being utilised for subsistence purposes by Fijians. These bivalves are usually harvested by gleaning, often by hand. These bivalves are also listed in Fiji Fisheries Division Annual Reports as being sold in municipal markets and non-market outlets. **Sigawale** are collected by hand or by using small digging tools to uncover the animals from the littoral zone of sandy beaches.

Kaikoso is an important food item in Fiji, being taken by subsistence fishermen, sold in markets or exchanged for agricultural produce in rural areas (Squires *et al*., 1973). There are several ways in which Fijians collect **kaikoso**, including “dabbling” with the feet and raking with the fingers. Another method is to look for the shell gape at the water’s edge on a rising tide, while another is to walk where mud is exposed at low water, spotting half-covered animals (Butler, 1983). **Kaikoso** fishing at Wailoaloa Beach near Nadi was observed involving fisherwomen that waded out from the beach, feeling with their toes for shells in the muddy sand (Squires *et al*., 1973). The women fished as far out as they could stand with their heads above water, at about 1.5 m depth. Since the outer edge of the **kaikoso** bed is approximately 2.5 m deep at a distance of 60 m from the shore, only part of the bed was fished. Though there was some variation in the time spent fishing, the average catch was approximately 2 kg of **kaikoso** per fisherwoman per day.

Civaciva are often found as biofoul on pearl-farms in Savusavu bay (S. Lee, *pers. obs.*). **Civaciva** are often collected while cleaning the mesh panels that contain the pearl oysters. Once enough **civaciva** are collected (>1 kg) they are thrown into a large mesh bag and shaken vigorously in the sea, this effectively cleans the **civaciva** shell of any unwanted growth. The organism is kept alive by submersion in the sea until ready for consumption. Most, if not all of the **civaciva** harvested is consumed the same day by workers on the pearl farm.

Production and Marketing: Apart from **kai** (Profile 13 FRESHWATER CLAMS) there are several species of molluscs sold in small amounts in municipal markets and non-market outlets. Estimated sales (mt) of these molluscs for the years 2001−2004 are listed in Table 7. The last year when the Fisheries Division published the details of their market survey was in 2004. From annual sales of <110 mt per year for the period 1986−1991, the sales of **kaikoso** in 1992 exceeded 250 mt (Anon., 1987–1993). After years of negligible sales of **kaikoso** in non-market outlets, approximately 10% of total **kaikoso** sales were made through outlets in 1992 (Anon., 1993). The mean price of **kaikoso** in municipal markets rose gradually from FJD 0.28 per kg in 1986 to FJD 0.57 per kg in 1991, before falling to FJD 0.43 per kg in 1992 (Anon., 1987–1993). The approximate value of the fishery in 1992, excluding subsistence catches, was FJD 109,302. Market prices for the various bivalves have risen very gradually or remained constant over the period 1986−1992, generally selling at less than FJD 1.00 per kg; by 2004 prices had risen to a mean of FJD 1.13 per kg (Anon., 2005). In 2004, 70% of total **kaikoso** sales were at the Suva municipal market, where k**aikoso** were sold for a mean of FJD 0.85. Suva municipal market accounted for the majority of **kaikoso** sales (by quantity) during the 2001−2004 period (Anon., 2002–2005). In 2017, **kaikoso** and **kaidawa** were sold in heaps at the Suva municipal market, with the quantity per heap is measured by filling a one or two litre container to the brim (S. Lee, *pers. obs*.). A 2 litre container of **kaikoso** sold for FJD 5.00, and a 1 litre container of **kaidawa** sold for FJD 5.00. The majority of sales listed in Table 7 were in the Central Division.

According to Fiji Fisheries Division Annual Reports (Anon., 2007–2009) there is an oyster, mussel, and scallop export industry in Fiji. It is not known if this industry still operates in 2017, and if so at what capacity as no Fiji Revenue and Customs Service export data were published in the Fisheries Division Annual Reports post-2008. The quantity and value of these exports are provided in Table 8. “Scallops live fresh or chilled” were valued between FJD 15−17 per kg, “Other scallops frozen, dried” between FJD 3−7 per kg, “Mussels live fresh or chilled” at FJD 13.52 per kg, and “Mussels frozen, dried” between FJD 1−5 per kg. Parkinson (1982) notes that there are only three species of scallop (Family: Pectinidae) in Fiji; *Chlamys ratula*, *Chlamys squamosa*, and *Gloriapallium pallium*. The abundance of these species is very low, therefore “Scallop” likely constitutes a mis-identified bivalve, possibly **vasua** (Profile 11 GIANT CLAMS) adductor muscle.

Table 7. Estimated sales (mt) of various species of edible molluscs in markets and outlets for the years 2001−2004. na = not available. Source: Anon., 2002–2005

Fijian name	2001	2002	2003	2004
kaikoso	227.15 (0.63–1.20)	215.95 (0.54–0.83)	134.79	286.08 (0.50–2.80)
kaidawa	5.04 (0.79–0.93)	7.6 (0.50–1.00)	4.08	29.51 (0.50–0.90)
oyster	na	na	na	2.27 (4.09–6.39)
kuku	0.98 (0.69–0.77)	1.95 (0.35–0.60)	0.75	0.95 (0.80–3.33)
kolakola	na	0 (0.77)	na	1.01
civaciva	na (6.00)	0	9.35	na
kaivadra	1.64 (0.49–0.78)	na (0.63–0.78)	1.64	na
sigawale	5.86 (0.44–0.63)	2.56 (0.43–0.75)	1.16	na
qaqa	7.4 (0.42–0.65)	4.68 (0.48–0.65)	0.71	na
qeqe	1.96	1.2 (0.35–0.40)	na	na
bu, su, sobu	na	na	na	na

14.3 Stock Status

There is no information on the stock status of these bivalves in Fiji. From estimated sales figures, sales of **kuku** suffered a distinct decline from 1986−1992, while sales of **qaqa** and **kaivadra** have dramatically increased from previous levels (Anon., 1987–1993). Other species, such as **kaidawa** and **sigawale** have had relatively constant sales over the same period. Bao and Drew (2016) report that populations of common bivalves (**civaciva**, **kaikoso**, **sigawale**, and **bu**) in Nagigi, Vanua Levu have declined significantly; this decline is apparent only recognised amongst older fishers suggesting a shift in baseline perceptions of biodiversity and abundance. There is no information available regarding the status of **kaikoso** stocks in Fiji. It is likely that a substantial proportion of its habitat is in deep water which is out of reach of traditional harvesting methods. Consideration should be given to re-surveying the previously surveyed sites at Laucala Bay and Wailoaloa Beach, to determine the present abundance of **kaikoso** in these areas. Due to habitat destruction/degradation and fishing pressure the abundance of **kaikoso** is expected to have declined since the 1980s.

Table 8. Exports quantity (mt) of oysters, mussels, and scallops for the years 2006−2008, value (FJD) provided in brackets below export quantity. “Fresh” refers to “Live, fresh or chilled”, and “Preserved” refers to “Frozen, dried”. Source: Anon., 2007−2009

Bivalve	2006		2007		2008	
	Fresh	Preserved	Fresh	Preserved	Fresh	Preserved
Scallop	na	24.78 (289,659)	0.03 (513)	43.08 (240,629)	0.58 (8,982)	152.07 (497,619)
Mussel	1.36 (18,442)	na	na	220.26 (268,590)	na	413.85 (1,945,635)
Oyster	na	na	na	na	0.11 (110)	na

14.4 Management

Current Legislation and Policies Regulating Exploitation: None at present.

Management Recommendations: Measures should be taken to minimise damage to **kaikoso** habitat from water-borne pollution and uncontrolled removal of beach sand. The Pacific Community (SPC) information sheets recommend the following management options and measures for kaikoso fisheries:

- Ban the use of all fishing methods other than hand gleaning;
- Establish closures during the spawning season, which is roughly the start of the rainy season in December in Fiji;
- Establish permanent no-take areas;
- Work with local authorities to minimise damage to ark clam habitats; and
- Establish rotational harvesting, if the fishing area is sufficiently large.

There needs to be greater emphasis on the proper identification of export products.

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15 TROCHUS

15.1 The Resource

Species Present: Sici or **Ieru** (trochus − *Rochia nilotica* known previously as *Trochus niloticus*[15]) is a relatively well-studied animal, with two bibliographies published (Gail and Devambez, 1958; Nash 1987). Izumi (1987) reviews Japanese trochus research between 1937−1939. A comprehensive summary of trochus biology, fisheries, and management in the Pacific Islands is given in Nash (1993). The closely-related **tovu** (white-based topshell − *T. pyramis*) is common in Fiji (Lewis, 1985).

Distribution: The natural distribution of **sici** is on tropical reefs from the Andaman Islands in the Indian Ocean to the islands of Fiji and Wallis in the Pacific (Bour, 1990). Since the late 1930s, however, **sici** has been successfully introduced into many areas in Micronesia and Polynesia (Gillett, 1991).

Biology and Ecology: Trochus prefer to live on the ocean side of reefs where the wave action is greatest. The larger shells are generally found in 0.6−6 m of water, and the smaller **sici** on the inter-tidal reef-flats (Bour, 1990). Though on some islands they are found in the deeper waters beyond the reef (Sims, 1988a), **sici** are rarely found below 12 m.

The sexes are separate but cannot be determined by any secondary external sexual features. The sex ratio is usually 1:1. 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 at each new moon but with different females – each female spawns about every 2−4 months (Bour, 1990). The fecundity of females increases with age, with small, newly mature females of around 7 cm basal diameter producing approximately 500,000 eggs while females of 13 cm basal diameter produce up to 3 million eggs (Sims, 1988a). The fertilised eggs become planktonic larvae after 9−10 hours, and settle out as juveniles on the reef flat after a few days.

In the presence of suitable substrate (a primary algal film or coralline algae such as *Porolithon*), larval settlement occurs at 50−60 hours post-fertilisation, but may be prolonged to 10 days in the absence of suitable substrate in which to settle. Metamorphosis (loss of velar cilia) may be completed as little as 3 days after fertilisation. This provides evidence that populations may be largely self-seeding on the scale of individual reefs.

Sici show rapid growth during the first 3−4 years, the rate being strongly determined by environmental conditions. Sims (1988a) states that **sici** attain a basal diameter of 8 cm after about 3 years. Subsequent growth is much slower; 110 mm basal diameter being reached at an age from 5−8 years. The maximum size generally attained by **sici** is about 150−155 mm diameter, though larger specimens (>163 mm) have been recorded. Longevity is not known, but results of growth studies suggest that **sici** lives for 10−15 years, and possibly longer (Nash, 1993). The rate of annual natural mortality of **sici** is around 0.08 (Bour, 1988). Hermit crabs are probably a significant **sici** predator (Sims, 1988b).

15 Williams *et al.* (2008) have suggested a revision of the taxonomy to *Tectis niloticus*.

15.2 The Fishery

Utilisation: Trochus has been commercially harvested in the Pacific Islands since the early 1900s (Gillett *et al.*, 2020). The Fiji fishery is likely to have developed after the end of World War II when world demand for mother-of-pearl shell surged. A trochus button factory in Levuka operated for most of the 1950s, but closed in the late 1950s when shell button prices fell due to competition with plastic buttons (Gillett *et al.*, 2020). **Sici** is eaten as a subsistence item in Fiji, the shell being boiled to extract the meat which generally comprises 15% of the live weight. It is also collected for the production of quality mother-of-pearl buttons and for ornamental purposes. Shells of the 7−10 cm size range are most sought after for commerce. In the manufacture of buttons, blanks are cut from the shell, following the whorls around. The blanks are later buffed and polished, while the residual shell can be further processed to produce mother-of-pearl chips.

The processing of **sici** involves the fairly simple production of blanks followed by the more sophisticated processing into finished buttons. A good explanation of blank, button, and by-product processing is given in Carleton (1984). In 1985, two local companies established button-blank factories which between them were anticipated to process 300−350 mt of **sici** shell per year, to substitute for exports (Lewis, 1985). In 1989, Fiji had four button-blank factories, with another one planned, but in 1992 only one was operating at a reduced level (Adams *et al*., 1992). In early 2017, there was one button-blank factory operating consistently and one operating sporadically. Both were located in the Suva area. Gillett *et al*. (2020) report that the largest trochus processor had 17 blanking machines in late 2019, but only six were operating and those were only used part-time. The operations of the sporadic operator are a mystery, but it is unlikely that he the business was still functioning in late 2019.

In southeast Asia there are markets for fresh, frozen, dried and canned **sici** meat, and markets in the traditional medicine trade for the thin operculum. Collection of **sici** is by hand, usually by walking on the reef flat at low tide, or by free diving (Lewis, 1985).

Production and Marketing: Production of **sici** shell for export fluctuated markedly in Fiji for the period 1969−1985, from a high of 547 mt in 1973 down to 166 mt in 1979. After remaining relatively steady at approximately 250 mt per year for the period 1985−1987, export of **sici** shell peaked in 1988 at nearly 400 mt (Anon., 1986–1989). Fiji Fisheries Division estimated that the total **sici** shell harvest in Fiji in 1988 may have exceeded 600 mt (Anon., 1989). The price paid for **sici** in the late 1980s and early 1990s ranged from FJD 5−14 (Anon., 1987–1993).

Gillett *et al*. (2020) report that information on recent sici exports is available from the Ministry of Fisheries export permit and Revenue and Customs Service export databases (Table 9). The export information below is inconsistent and conflicting, and is totally inadequate for making estimates of annual **sici** harvests in the country. Nevertheless, on face value of the above data, the 2014–2018 average export of trochus blanks in the Customs data (24 tonnes/yr) equates to about 195 tonnes of raw trochus. Adding that quantity to the 2011–2018 average export of raw **sici** (34 tonnes/yr) suggests that in recent years the annual **sici** harvest is about 230 tonnes/yr (Gillett *et al*., 2020)

Table 9. Fiji's Exports of **Sici** from the (a) Fisheries Department's Database, and (b) from the Revenue and Customs Service export database.

(a)	2011	2012	2013	2014	2015	2016	2017	2018
Trochus shell (kg)	0	44,900	87,400	3	19,800	64,000	19,000	36,002
Trochus button & blanks (pcs)	0	0	0	1,000,000	0	4,950	18,047	4,556

(b)	2014	2015	2016	2017	2018
Trochus button & blanks (kg)	5,304	4,199	55,451	54,187	2,768
Trochus button & blanks (FJD)	$358,501	$215,605	$621,050	$504,678	$189,888

In recent years, the harvest of **sici** in Fiji has been a by-product of the sea cucumber fishery. Sea cucumbers, being much more valuable than **sici**, are a major activity of many commercial divers – with **sici** being taken opportunistically or when diving for sea cucumbers is unfavourable.

A World Bank study presented information on regional and global **sici** production (Gillett, 1995). It stated that **sici** now occurs in all but four of the twenty-two Pacific Island countries. Twelve countries actually harvest **sici**, with six countries (Solomon Islands, Papua New Guinea, Fiji, New Caledonia, Vanuatu, and FSM) producing 87% of the total. In recent years the annual harvest of **sici** from the Pacific Islands region is estimated to have been about 2,300 tonnes, or about 59% of the world's total production of 3,900 tonnes. Gillett *et al.* (2020) estimated that in the last 25 years, world **sici** production has fallen from about 3,900 tonnes to 2,020 tonnes, a drop of almost 50%. In 2020 the Pacific Islands region was responsible for about 69% of the global production of **sici**.

There has not been much net change in the buying prices for **sici** (i.e. prices paid to fishers) in the last two decades. Gillett (1995) reports that in 1994 the average price paid was FJD 6.25, while in early 2017 the largest **sici** processor was paying between FJD 6.00–6.50 for raw **sici** (N. Yuen, *pers. comm.*). World Bank (1997) states "The price paid for trochus domestically appears strongly related to the number of buyers. Efforts to increase the number of buyers bidding for trochus where there are presently few is probably the simplest mechanism to improve local prices".

In 1994 the factory gate buying price for **sici** in Fiji was US$4.60 per kg. in the late 2010s the factory gate buying price for **sici** in Fiji has been F$5/kg (US$2.40). **Sici** buyers pay less for low quality shell (i.e. very large or worm damaged) and less if purchasing occurs away from Suva. In early 2019 **sici** meat was being sold for US$7.20/kg at a retail shop in Labasa (Gillett *et al.*, 2020).

15.3 Stock Status

The vulnerability of **sici** to overfishing across all countries where it occurs is probably due to a combination of factors: **sici** inhabit a clearly-defined and easily accessible zone on coral reefs (the intertidal and shallow subtidal area on the windward side of the reef); with only a little practice, the shell is easily found despite the inconspicuous coloration of the shell; and larval dispersal is probably limited (Nash, 1993). The latter means that heavily-depleted populations will only slowly regenerate, since recruitment is primarily localised; recruitment from other reefs is likely to be only slight.

The export substitution that was expected to occur with the establishment of button-blank factories in Fiji did take place to some extent (Adams *et al*., 1992). However, with the 1988 peak in raw shell exports and the additional demand from button factories, recruitment overfishing may have occurred on heavily fished reefs, followed by a steady decline in major stocks. There have been no stock assessment surveys for **sici** shell in Fiji (Richards *et al*., 1994). However, in examining historical Fiji **sici** information it appears that there have not been any large scale surveys of **sici** in the country and stock status information is limited to trends in production estimated largely from raw **sici** export data, combined with ideas on the amounts of **sici** consumed by the local button factories. There is also anecdotal information from the fishers and processors on the changing abundance of **sici**. The trends and anecdotes suggest a heavily exploited resource that nonetheless continues to produce moderate harvests.

15.4 Management

Sici management across the Pacific uses a variety of measures. This includes area closures, seasonal closures, minimum size limits, maximum size limits, moratoriums, sanctuaries, total allowable catches, and individual transferable quotas. In addition, reef reseeding has been attempted in several countries, and deserves some mention. **Sici** re-seeding is often perceived as an appealing alternative to restrictive management measures, but in reality those measures will still be needed. Through lack of proper management, excess fishing pressure results in **sici** depletion. Simply adding to numbers of **sici** on the reef does not address the cause of over-exploitation; after re-seeding, without restrictive management, over-exploitation is likely to re-occur. Despite this, **sici** re-seeding continues to be viewed by many countries as an easy alternative to management, rather than a possible complement (Gillett, 1995)

In the early-1990s a ban on the export of raw **sici** (i.e. unprocessed shells) was introduced in Fiji under the authority of the Customs Regulations 1986, which indicates that exemptions from this ban could be authorised by Permanent Secretary for Commerce, Industry Tourism, and Civil Aviation. In 1993 and 1994 110 tonnes of unprocessed shell were recorded by Customs as being exported (Gillett, 1995). The 2010 revision of the Customs Regulations still has a ban on unprocessed **sici** shells[16]. The issue of banning the export of raw **sici** was explored in a World Bank study (see box).

Bans on Exporting Raw Trochus. Source: Gillett (1995)

Several studies examining the Pacific Island trochus shell trade have recommended that blanking be carried out within the countries where the shell is harvested. Substantial benefits to countries may be obtained from trochus processing. These include employment, skill and entrepreneurial development, and benefits/linkages to many other sectors of the economy. There are also more subtle merits such as ease of monitoring the compliance to trochus size regulation at a few factories (as opposed to a much larger number of exporters) and more flexibility in marketing strategy. There are, however, drawbacks to the processing of trochus in Pacific Island countries. In almost all cases where factories have been proven to be feasible over the long-term, there has been some type of discouragement on the export of raw trochus in order to assure raw product availability to the factories. This has included high taxes on the export of raw trochus (30% in the Solomon Islands), export bans with discretionary exemption (Vanuatu, Fiji), and total bans (French Polynesia). This restriction results in reducing the number of buyers competing for trochus in a country, the price of trochus falls, and factories obtain their trochus supplies at considerable less than prevailing world prices. Fishermen, however, receive less for their trochus catches. It has been stated that raw trochus export bans result in village fishermen subsidising urban factories. It is also possible that in the present market structure, overseas buyers may actually pay more for raw trochus than the product of local processing of the same amount of raw trochus. Reconciling the desire for industrial development with maximising income to the fishermen is complex, involving many considerations which will be different for each country. Specific recommendations on the trochus processing issue would not therefore be applicable to all countries in the Pacific Islands region.

16 www.frcs.org.fj/wp-content/uploads/2012/11/Customs_-Prohibited-_Imports_-and_-Exports_Regulations-_Revised.pdf

Sanctuaries to conserve the stocks of **sici** have been established in several countries (Nash, 1993). Since the larval stage of **sici** is no more than a few days (see above), larvae are unlikely to disperse widely. The effectiveness of sanctuaries for repopulating areas that are exposed to fishing will depend on direction and strength of water currents, and the proximity of the fished stocks to the sanctuaries. They will only be an effective fishery conservation tool if they are situated in suitable **sici** habitat, and are not fished.

Current Legislation and Policies Regulating Exploitation: Regulation 21(a) of the Fisheries Regulations (Cap.158 as amended) provides that " No person shall take, be in possession of, sell, or expose for sale or export any shell of the species *Trochus niloticus* [**sici**] (trocas shell) measuring less than 90 mm [3.5 inches] across the whorl." Exporters of **sici** shell are required to be licensed and are subject to inspection. As mentioned above, there was a ban on unprocessed **sici** shells, but it appears that the ban stopped with the enactment of the Endangered and Protected Species Act 2002.

Management Recommendations: Reviews of **sici** management in the country have suggested changes in the management regime: (a) A maximum size limit of 12 cm measured across the widest part of the shell should be imposed because over-size **sici** are of little use for button manufacture but produce many eggs, and (b) point-of- export inspection for compliance with the size limits.

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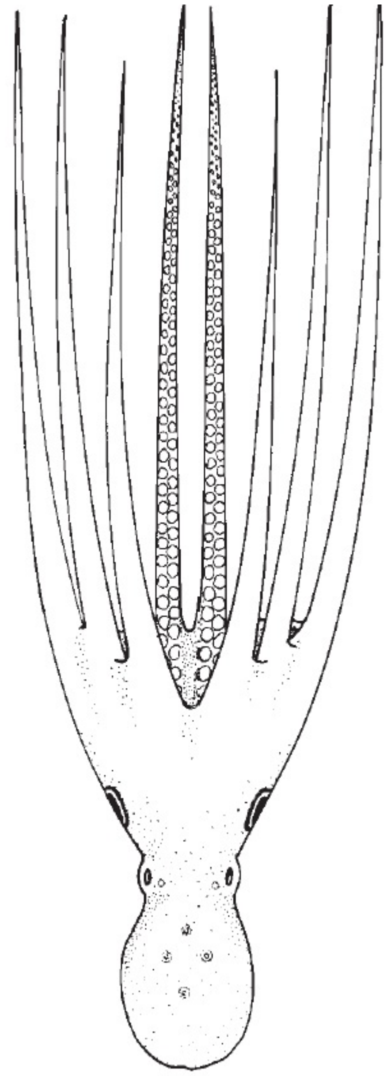
16 CEPHALOPOD MOLLUSCS



The Class Cephalopoda is a diverse marine group that includes octopus (Order Octopoda), squids (Order Teuthida), nautilus (Family Nautilidae), and cuttlefish (Family Sepiidae). These exclusively marine animals are characterised by bilateral body symmetry, a prominent head, and a set of arms or tentacles modified from the primitive molluscan foot. The class contains two, extant subclasses: Coleoidea, which includes octopi, squid, and cuttlefish − cephalopods lacking a shell; and Nautiloidea, which contains the genus *Nautilus*. Though cephalopods are a diverse and widespread group of animals, this profile focuses predominantly on those that constitute important fisheries in Fiji − octopus and bigfin reef squid. Given the wide distribution of many species of oceanic and deepsea squid it is very likely that more species exist within Fiji's waters than stated below. A detailed description of the world's known cephalopds can be found in Jereb and Roper (2005).

16.1 The Resource

Species Present: Lewis (1986) includes **kuita** or **sulua** (octopus − *Octopus* spp.) and **kuitanu** or **suluanu** (bigfin reef squid − *Sepioteuthis lessoniana*) in the poster "aquatic foods of Fiji". The day octopus (*O. cyanea*) is widely distributed throughout the Pacific, and likely makes up the majority of octopus sold in Fiji's local markets; The white-striped octopus (*O. ornatus*) also occurs in Fiji's waters but is not as common (Carpenter and Niem, 1998). At least one oceanic squid is commonly recorded from Fiji's waters, the purpleback flying squid (*Symplectoteuthis oualaniensis*). A species of giant squid, the diamondback squid (*Thysanoteuthis rhombus*) have been caught and trialled for its potential as a fishery in southern Fiji (Sokimi, 2014). **Natila** or **sulua dausoko (**Nautilus − *Nautilus pompilius*) are known throughout Fiji waters on outer reef slopes, where suitable habitat is available. Carpenter and Niem (1998) note the presence of broadclub cuttlefish (*Sepia latimanus*) in Fiji waters.

Distribution: The class Cephalopoda is distributed throughout the world's oceans. **Kuitanu** often form schools in the clear waters around coral reefs, whereas **kuita** can be found from intertidal reefs to depths of at least 25 m (Carpenter and Niem, 1998). The purpleback flying squid (*S. oualaniensis*) is widely distributed in the warm waters of the Indo-Pacific region. In Fiji, it has been taken during surveys at several sites; south of Cape Washington, south-east of Kadavu and east-south east of Qelelevu (Brown, 1979).

Diamondback squid have been caught south of Suva and north of Kadavu Island (Sokimi, 2014), the species occur circumglobally in tropical and warm subtropical oceanic waters but is nowhere abundant (Carpenter and Niem, 1998). Lesser quantities of neon flying squid (*Ommastrephes bartramii*) were also caught in association with diamondback squid. Nautili are generally restricted to deeper continental shelves and slopes of the Indo-West Pacific (Carpenter and Niem, 1998). Baited remote underwater video systems (BRUVS) documented nautili in the Beqa Passage (Barord *et al*., 2014). Nautili were also caught in numbers along the along the Suva Reef slope between depths of 200–600 m, nautili were most abundant at 500 m (Zann, 1984).

Biology and Ecology: A review of the different reproductive strategies in cephalopods can be found in Rocha *et al*. (2001). Most **kuita** are benthic animals, usually having cryptic habits, hiding in crevices, empty mollusc shells and seagrass beds during the day and hunting at night, **kuita** are well known for their camouflage behaviour (Hanlon *et al.*, 2008). While *Octopus* spp. are generally known to be nocturnal, studies have also observed social behaviour particularly foraging carried out during the day, the day octopus (*O. cyanea*) exhibit peak activity at dusk and dawn (Carpenter and Niem, 1998; Miesel *et al*., 2006). The day octopus reaches sexual maturity in less than 5 months and has a life span of 1–2 years (SPC, 2011). Many species lay relatively large eggs which are brooded by the female during a prolonged incubation period. Most brooding species have a direct development and hatchlings almost immediately adopt the benthic life of the adults (Roper *et al*., 1984). The day octopus are known to attain a maximum mantle length of 16 cm, TL >1 m, and weight up to 6 kg (Carpenter and Niem, 1998).

Kuitanu is a neritic species occurring from the surface down to at least 100 m depth. The spawning season depends on prevailing hydrographical conditions, and can be quite extended. Finger-shaped egg capsules containing 3−7 eggs are attached in clusters to seaweeds, twigs, stones and corals in coastal waters. Males attain sexual maturity at 10–14 months and females at 12−17 months. **Kuitanu** typically live for 2.5 years. Maximum dorsal mantle length is 36 cm, corresponding to a weight of 1.8 kg. Males outnumber females in the upper size classes. This species preys primarily on prawns and fishes, and occasionally on stomatopods and crabs (Roper *et al*., 1984).

Symplectoteuthis oualaniensis (no Fijian name known) is an oceanic species occurring from the surface to probably 1,000 m depth. It is known to carry out diurnal vertical movements between the surface at night and deeper layers during the day, though it may inhabit the surface sea layers during the day as well as the night (Roper *et al*., 1984). This species is characterised by a yellow patch (photophore) on the antero-dorsal surface of the mantle. The females mature at 20−24 cm maximum length and have a life-span of slightly more than one year. It 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 large diamondback squid (no Fijian name known) are a monotypic oceanic species generally caught in the top 50 m of the water column (Carpenter and Niem, 1998). Adults are slow swimmers and are often observed in monogamous, pairs (male and female) although groups of up to 20 have been observed elsewhere. Females spawn gelatinous, sausage-shaped egg masses, 15−20 cm in diameter and up to 1 m long, which have been found near the surface. Females are thought to be multiple spawners, their spawning season lasting perhaps a few months. The species are known to attain a maximum maximum length of 85 cm though commonly to 60 cm maximum length, and a maximum weight 24 kg.

Nautili are known to live more than 20 years, making them the longest lived of extant cephalopods, they exhibit no somatic growth after reaching maturity at 12−15 years (Barord *et al*., 2014). *N. pompilius* reach maturity at a shell length of 131.9 mm (males) and 118.9 mm (females), the species has an apertural growth rate of 0.61 mm per day (about 22 cm per year) (Dunstan *et al*., 2010). The family contains the only living cephalopod with an external shell throughout their life cycle. Septae divide the shell into chambers, which provide buoyancy to the animal; the animal lives in the newest chamber and is protected by a hood (Carpenter and Niem, 1998). Nautili usually occur beneath the photic zone, usually at depth of about 50−500 m, and are primarily associated with coral reefs. Their habitat is limited by depth implosion limits of 800 m, surface temperature limits of 25ºC and a nektobenthic life style, living in close association with reef slopes and ocean floors rather than in the mid-water or surface waters (Barord *et al*., 2014).

16.2 The Fishery

Utilisation: Kuita are an important subsistence food for Fijians, as are **kuitanu** (Lewis, 1986). Both species are taken by reef gleaning. **Kuita** holes are often identified by shell litter at the opening. Spears and sticks are used mainly by women and children while reef gleaning to evict kuita from their holes at low tide. **Kuitanu** has been successfully reared in aquaculture experiments (Choe, 1966 in Roper *et al*., 1984). **Kuita** are commonly found through municipal markets in Fiji, where they are usually sold partially smoked (**kuita vesa**). **Kuitanu** are rarely found in municipal market outlets, therefore production is likely restricted to the subsistence level. The months of July−October are noted as the peak season for **kuita** in Fiji according to the traditional Fijian calendar (**vula vakaviti**).

Symplectoteuthis oualaniensis is reported to be fished commercially in Okinawa and Taiwan. This species may be taken by automatic squid-jigging machines, though often only the tentacles are landed as the body breaks off during the fishing operation. The edible quality and size consistency of *S. oualaniensis* from Fiji was rated "less than optimum" for the Japanese market (Brown, 1979) mainly because of the large inedible photophore on the dorsal surface. Surveys of Fiji's flying squid resources conducted in 1979 and 1981, though optimistic about the possibility of commercial exploitation, have not led to the establishment of a commercial fishery (Brown, 1979; Takeda and Hamilton, 1981) because of the low commercial value of the species, amongst other considerations.

Nautili are of commercial value as food and in the specimen shell trade. Nautili are also collected live for aquaria and research. They are caught using baited traps and nautilus shells are occasionally found on beaches throughout Fiji. In Fiji the shells, if in good condition are sold for the curio trade. The broadclub cuttlefish (*Sepia latimanus*) are not reported in any catch or landings data for Fiji. If caught this species is likely confused with **kuitanu**.

Production and Marketing: Sales of **kuita** in Fiji's municipal and non-municipal markets for the years 1986−1992 averaged 6.8 mt per year with very little fluctuation (Anon., 1987–1993). The weighted mean price for kuita in municipal markets during 1992 was FJD 3.52 per kg, a slight increase on the price for previous years which has varied between FJD 1.62−3.08 per kg. Sale volume and weighed price of **kuita** from municipal and non-municipal markets for the years 2001−2004 is provided in Table 10. The general trend is an increase in quantity and value of **kuita** sold. No **kuitanu** were recorded in Fisheries Division market surveys, with the exception of June 2016 in the Central Division municipal market (Fisheries Division market survey, *unpubl. data*). The squid sold in municipal markets, particularly Suva and Nausori are most likely squid bait from longliners - likely the argentine squid *Illex argentinus* (A. Lewis, *pers. comm.*). The majority of **kuita** are sold in Northern Division municipal markets, followed by Central and Western markets. A 2016 market survey of the Central Division recorded a mean price of FJD 7.13 per kg for **kuita**, and FJD 4.00 per kg for **kuitanu**. Anecdotal information from Suva municipal market noted prices of **kuita** ranged from FJD 15−30, while price increased with size/quantity of product there was no discernable difference in price between raw or smoked product (S. Lee, *per obs.*).

Table 10. Production (mt) and mean value (FJD per kg) of **kuita** and **kuitanu** from municipal and non-municipal outlets in Fiji. Value provided in brackets below production quantity. Source: Fisheries Division Annual Reports (Anon., 2002−2005)

	2001	2002	2003	2004
kuita*	7.38 (3.89)	19.25 (4.86)	32.16 (4.50)	40.34** (5.18)
kuitanu	na	na	na	na

* Production quantity of **kuita** and **kuita vesa** (smoked octopus) combined, market surveys of previous years did not distinguish between the two.

Fisheries Division Annual Reports indicate that from 2001−2008 Fiji had a **kuita** and **kuitanu** export industry, though exports quantities varied considerably. It is unclear whether or not **kuita** are currently exported from Fiji, and if so in what quantity as they may be collectively grouped into the customs category "Coral and similar matter, unworked or prepared but not otherwise worked molluscs, crustaceans or echinoderms and cuttle-bone, unworked or prepared but not" (FRCS *unpubl. data*, 2012−2014). Export volumes and value of **kuita** and **kuitanu** from Fiji are provided in Table 11 below.

There does not appear to be a current fishery for diamondback squid or nautilus in Fiji. Export of diamondback squid in Fiji is economically non-viable given the low market price (particularly in Japan), however it may be of interest on the local market particularly to restaurants and hotels (Sokimi, 2014). No production values of nautilus were available for Fiji.

Table 11. **Kuita** (octopus) and **kuitanu** (squid) export volume (mt) and value (FJD). Source: Fisheries Division Annual Reports (Anon., 2004−2009)

Description	2003	2004	2005	2006	2007	2008
Octopus	na	na	34.23 (164,970)	70.73 (315,413)	66.10 (1,000,602)	6.60 (569,233)
Squid	na	12.66 (222,429)	0.46* (62,819)	22.92 (213,180)	na	na

* Recorded as "Other cuttle fish"

16.3 Stock Status

The status of the stocks of **kuita** and **kuitanu** in Fiji is unknown. **Kuita** were reported to be abundant on Fiji's reefs following Cyclone Kina in late 1992 to early 1993. It is thought that this was due to the destruction of their holes on the reef by strong wave action generated by the cyclone (J. Seeto, *pers. comm.*). The stocks of *S. oualaniensis* are thought to be considerable (Takeda and Hamilton, 1981). Diamondback squid (*T. rhombus*) fishing trails in Fiji recorded a catch per unit effort (CPUE) of 0.23 squid per hook, catch composition was 95% diamondback squid and 5% neon flying squid (*Ommastrephes bartramii*). For comparison CPUE was 0.083 and 0.125 squid per hook in the Cook Islands and New Caledonia, respectively. Catches in the Cook Islands and New Caledonia had a approximately one diamondback squid to one neon flying squid (Sokimi, 2014). According to Sokimi (2014) diamondback squid stocks in the Pacific Islands region are currently unexploited, however previous experience with diamondback fisheries in Okinawa, Japan have shown that the species appear to be abundant when first fished but stocks are fragile and are quickly overfished.

BRUVS in Beqa Passage recorded an attraction rate of 0.79 nautili per hour, which equated to a population abundance of 0.21 individuals per km^2 (Barord *et al*., 2014). The same study recorded abundances of 13.60, 0.34, and 0.03 individuals per km^2 at Osprey Reef and Great Barrier Reef, Australia, and Bohol Sea, Philippines, Osprey Reef represented an unexploited stock; Bohol Sea represented a heavily exploited stock. However the authors of the study note that this may be an overestimation given the ability of the animal to locate food over great distances. The study concluded that given the low density of nautili, their ease of capture, and late maturity, stocks can be easily overfished in a relatively short time span.

16.4 Management

Current Legislation and Policies Regulating Exploitation: The pearly nautilus shell (*Nautililus pompilius* - **natila**, **sulua dausoko**) is listed under Part 9, Schedule 2 (Section 3) of the Endangered and Protected Species Act 2002. In 2016 *Nautilius pompilius* was added to Appendix II of CITES (Uhlemann *et al*., 2016), as such any exports should appear in the CITES Trade Database in the near future. There is no specific legislation or policy regarding other species mentioned above in this profile.

Management Recommendations: Brown (1979) was of the opinion that there could be a considerable demand for squid as bait, particularly in the event of the development of a local bigeye tuna fishery (ika shibi). Given the cryptic nature of **kuita** it is difficult to survey to determine stock status, therefore sales (and exports) should be closely monitored in order to track the status of the fishery. Destructive fishing practices such as breaking open corals should be banned. SPC (2011) recommend establishing reserves in which the capture of **kuita** is banned, and in areas where space allows rotational harvest strategies can be established where each are is fished one year at a time – given the fast growth of **kuita,** a 1–2 year rotation would be sufficient enough to allow **kuita** to reproduce in the reserve.

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17 OTHER MOLLUSCS AND COLLECTOR SHELLS

17.1 The Resource

Species Present: There are several species of edible molluscs (Table 12) and collector shells listed by Lewis (1986), Jansen *et al*. (1990), and Parkinson (1982), respectively. Fiji has over 800 species of shells that are of interest to collectors, and several endemic or unique shells. These shells are from the classes Gastropoda (sea shells), Pelecypoda (bivalves), Scaphopoda (tusk shells) and Cephalopoda (nautilus) (Lewis, 1985). Fiji is particularly rich in cone shells (*Conus* spp.), cowrie shells (*Cypraea* spp.), mitre shells (*Mitra* spp.) and auger shells (*Terebra* spp.). The Fiji area supports a large number of other shell families which have market potential, such as olive shells (*Oliva* spp.), cerith shells (*Cerithium* spp.), stromb shells (*Strombus* spp.) and murex shells (*Murex* spp.) (Parkinson, 1982).

Table 12. Edible molluscs listed by Lewis (1986) and Jansen *et al.* (1990).

Common name	Scientific name	Fijian name
Turban shell	*Turbo chrysostomus*	**lasawa**
Top shell	*Tectus pyramis*	**tovu**
Spider shell	*Lambis lambis*	**yaga, ega**
Red-lipped stromb	*Strombus luhuanus*	**tivikea, gwerativi**
Stromb	*Strombus gibberulus*	**golea, gerra**
Horn shell	*Cerithium nodulosum*	**siciyarayara, durulevu**
Polished nerite	*Nerita polita*	**madrali**
Moon snail	*Polinices flemingiana*	**drevula**
Chiton	*Acanthozostera gemmata*	**tadruku**
Seahare	*Dolabella* sp.	**veata, kotia**

Distribution: Most of the edible molluscs listed in Table 12 have a wide distribution in the tropical Indo-Pacific. *Strombus luhuanus* is known from Indonesia to Papua New Guinea and Fiji (Hinton, 1972). Collector shells are found throughout Fiji, however particularly good records are available for Suva Harbour, the Suva-Sigatoka coastal strip and Yasawa Islands, which were surveyed by a team of divers in 1981 (Parkinson, 1982).

Biology and Ecology: Many of the species listed in Table 12 are found in the lagoon, on the reef ridge and some in deeper waters. **Tovu** (turban shell – *Tectus pyramis*) and **lasawa** (top shell – *Turbo chrysostomus*) graze or browse on coralline or small succulent algae on and below the coral line, their wide radulas being well adapted to scouring and sweeping. **Tovu** is usually found in concavities and under ledges near the reef margin, or beneath coral boulders. **Lasawa** is common near the reef edge (Morton and Raj, 1978). **Siciyarayara** (horn shell – *Cerithium nodulosum*) is found principally in muddy flats and mangrove areas, where it burrows into the substrate. Shells of the family Strombidae, such as **yaga** (spider shell – *Lambis lambis*), **tivikea** (red-lipped stromb – *Strombus luhuanus*) and **golea** (stromb – *S. gibberulus*) are mostly confined to the soft expanses of rubble-flats (Morton and Raj, 1978). A detailed account of the biology and ecology of Nautilus can be found in Profile 16 CEPHALOPOD MOLLUSCS.

Collector shells (Table 13) can be found in every type of marine habitat, from coral reefs to volcanic sand and silt or mud. Most shells are habitat specific, and there are many examples of specialisation of habitat. Terebra shells and olive shells are seldom, if ever, found away from sand, and some species of these are confined to black volcanic sand while others prefer white coral sand. Stromb shells and cassid shells are generally most prolific in shallow waters, though some cassids have been found in very deep water. Some species of muricid are found on intertidal mangrove roots, while others are taken in depths of over 180 m. Mitrids occur in colonies on shallow patches of sand and on intertidal coral reefs (Hinton, 1972). Some shells are herbivorous, such as strombs, or carnivorous, such as *Murex* spp., which prey on other molluscs. Cone shells are also carnivorous, and may be divided into three groups, according to their food preference - piscivorous (kill and eat fish), molluscivorous (eat molluscs including other cone shells) and vermivorous (eat small marine worms) (Hinton, 1972).

Table 13. Distribution of species recorded in Fiji by family or family grouping of possible interest to collectors. Source: Parkinson (1982)

Group	Family or family grouping	Number of species found
Cones	Conidae	28
Augers	Terebridae	26
Mitres	Mitridae/Costellariidae	22
Olives	Olividae	11
Cowries	Cypraeidae	11
Dog whelks	Nassariidae	8
Ceriths or horn shells	Cerithiidae	8
Strombs	Strombidae	4
Turrids	Turridae	2
Murexes	Muricidae	1
Tritons	Cymatiidae	1
Turbans	Turbinidae	1
	Total	123

17.2 The Fishery

Utilisation: Lewis (1986) lists the molluscs in Table 12 as being utilised for subsistence purposes by Fijians. These are also listed in Fiji Fisheries Division Annual Reports as being sold in municipal markets and non-market outlets. Collectors' shells are collected by a variety of methods, the most common being by hand on areas of sand and coral at low tide. Shells in deeper water can be collected by free diving, or by trained divers using SCUBA or hookah diving equipment. Optimum results are usually obtained at night by the use of torches, as this is when the shells are most active, and when they often leave their cover. Care should be taken to collect only perfect shells without breaks, scars or blemishes, as imperfect shells have a greatly reduced value (Lewis, 1985). Parkinson (1982; 1987) gives detailed descriptions of specimen shell collection methods.

Larger shells, except for cowries (Family: Cypraeidae), can be boiled to extract the meat, but smaller species should either be buried in sand where they will decompose, or preserved in methylated spirits. Once they have been properly cleaned, shells are easily stored and transported. They are a readily marketable commodity for villagers in remote islands who may have few other sources of revenue (Lewis, 1985).

Production and Marketing: There are several species of molluscs sold in small amounts in municipal markets and non-market outlets. Between 1986−1992 **yaga**, **golea**, **tovu**, and **madrali** constituted the majority of edible mollusc sales in municipal and non-municipal markets in Fiji, in descending order of quantity sold (Anon., 1987–1993). **Yaga** sales gradually increased from 4.04 mt in 1986 to a peak of 14.69

mt in 1991, before declining substantially to 5.66 mt in 1992. **Golea** exhibited a similar pattern; increasing from 2.48 mt in 1986 to a peak of 8.66 mt in 1990 before decreasing to an average of approximately 2.5 mt for the 1991−1992 period. The quantity of **tovu** sold between 1986−1992 remained at approximately 2 mt per year, peaking at 2.72 mt in 1992.

Approximately 3 mt of **madrali** were sold from 1986−1987. However, quantities remained at a mean of 0.46 mt between 1988−1992, only 0.07 mt of **madrali** were sold in 1992 (Anon., 1987–1993). **Tivikea**, **kalokalo**, and **lasawa** sales for the period 1986−1992 rarely exceeded 0.5 mt per year, with the exception of 1988 during which sales of **tivikea** and **lasawa** reached 9.78 mt and 1.45 mt, respectively (Anon., 1987−1993). Market prices for the various molluscs have risen very gradually or remained constant over the period 1986−1992, generally selling at less than FJD 1 per kg. Quantities and value of edible molluscs sold in municipal and non-municipal markets for the period 2001−2004 are provided in Table 14. During both the 1986−1992, and 2001−2004 periods, almost all sales were at municipal markets. For some molluscs such as **siciyarayara** and **drevula**, production and utilisation appears to be solely at the subsistence level. Anecdotal information collected from Suva municipal market in 2017 showed cooked **yaga** meat was packaged into 0.5 liter containers and sold for FJD 5 each (S. Lee, *per. obs.*).

Table 14. Quantity (mt) of edible molluscs sold in municipal and non-municipal market outlets, value (FJD) given in brackets. Source: Fiji Fisheries Division Annual Reports (Anon., 2002−2005)

Fijian name	2001	2002	2003	2004
lasawa	1.55	na	3.11	15.37
tovu	2.66	1.31	na	na
yaga, ega	5.56	2.92	5.56	26.59 (1.51–7.25)
tivikea, gwerativi	9.88	0.34	na	na
golea, gera	7.02	3.86	4.59	10.38 (0.62–3.00)
siciyarayara, durulevu	na	na	na	na
madrali	4.17	3.75	3.57	2.71 (0.70)
drevula	na	na	na	na
tadruku	2.56	1.92	0.54	2.28 (1.00–3.55)
veata, kotia	3.33	2.28 (ca. 3.00)	na	na

Most of the collectors shells marketed in Fiji are sold through the many stalls and shops that cater to the tourist industry. Shells are also sold at the municipal markets throughout Fiji and at handicraft centres in the major towns. Large ornamental shells such as *Murex ramosus*, *Lambis chiragra* and the larger cowries may be sold directly to tourists by villagers, especially in the Mamanuca and Yasawa Island Groups, Western and Northern Viti Levu and on Taveuni. It is not possible to estimate exactly how many shells are sold each year, or what the total value of these shells would be, but a conservative estimate would be several hundreds of thousands of dollars per annum (Parkinson, 1982; Lewis, 1985). The collecting and marketing of shells worldwide is of major importance. Markets for shells can be found in most of the countries of Europe, Japan, United States, Australia, New Zealand and many others.

Prices for collector shells are determined by supply and demand. Prices range from as low as FJD 0.10 for some of the more common cowries, strombs, cones and olives, to as high as FJD 9,000 for some of the exceptionally rare shells (Parkinson, 1987). A catalogue of sea shells of the Pacific region, together with prices quoted by shell dealers as of December 1986 is provided in Parkinson (1987). Current information on prices is available from reputable shell dealers. Anecdotal information collected from Suva municipal market in 2017 found a small selection of collectors shells were on sale; a small cowrie approximately 7 cm length sold for FJD 1 each, stromb shells sold for FJD 1−5 each depending on the size and condition of the individual shell (S. Lee, *pers. obs.*).

17.3 Stock Status

There is no information on the status of the stocks of the edible molluscs in Fiji. Estimated sales figures suggest **madrali** suffered distinct declines from 1986−1992. Fong (1994) reports that, due to over-exploitation mainly for subsistence and big feasts, Sasa villagers (Macuata Province) have said that **yaga** are hard to find. Additionally, Bao and Drew (2016) report that populations of common molluscs (edible molluscs and some collector shells) in Nagigi, Vanua Levu have declined significantly. This decline is apparent only amongst older fishers suggesting a shift in baseline perceptions of biodiversity and abundance.

17.4 Management

Current Legislation and Policies Regulating Exploitation: None at present pertaining to edible molluscs. Regulation 22 of the Fisheries Regulations (Cap.158 as amended) provides that "No person shall take, sell or offer or expose for sale or export any shell of the species *Charonia tritonis* (**davui**). Regulation 23 of the Fisheries Regulations (Cap.158 as amended) provides that "No person shall take, sell or offer or expose for sale or export any shell of the species *Cassis cornuta* (giant helmet shell)." Several molluscs are listed in the Endangered and Protected Species Act 2002 (Table 15), this act contains legislation pertaining to the permitting, possession, sale, collection, and transport of various species. There are no other laws or regulations in Fiji specific to the collection of marine shells.

Management Recommendations: No changes to current legislation recommended at present. Closer monitoring of sales, particularly of edible molluscs particularly **yaga, golea,** and **lasawa** are needed in order to determine stock status. As the majority of work on collector's shells was published in the 1980s, a market survey is recommended in order to determine the state of this fishery. Lewis (1985) reccomended that only perfect shells should be collected, so that a breeding nucleus always remains to perpetuate the species. Every effort should be made to conserve the nearshore environment, the habitat of many species of shells, as the destruction of this habitat will adversely affect the present shell stocks.

Table 15. List of molluscs and their designation within the Endangered and Protected Species Act 2002.

Common name	Scientific name	Fijian name	Section
Giant lamp shell	*Cassis cornuta*	**buli cina**	Part 8, Schedule 1 (Section 3)
Giant triton shell	*Charonia tritonis*	**davui**	Part 8, Schedule 1 (Section 3)
Cakobau's cone shell	*Conus fijiensis*	**viro kei bau**	Part 8, Schedule 1 (Section 3)
Sacred cone shell	*Conus fijisulcatus*	**viro tabu**	Part 8, Schedule 1 (Section 3)
Great cone shell	*Conus gigasulcatus*	**viro levu**	Part 8, Schedule 1 (Section 3)
Jolivet's cone	*Conus joliveti*	**viro i joliveti**	Part 8, Schedule 1 (Section 3)
Golden cowry	*Cypraea aurantium*	**buli kula**	Part 8, Schedule 1 (Section 3)
Des forges cowry	*Cypraea desforgesi*	**buli i foresi**	Part 8, Schedule 1 (Section 3)
Summer's cowry	*Cypraea summersi*	**buli kata**	Part 8, Schedule 1 (Section 3)
Bullmouth helmut	*Cypraeacassis rufa*	**buli tagane**	Part 8, Schedule 1 (Section 3)
Truncate spider shell	*Lambis truncata*	**ega levu**	Part 8, Schedule 1 (Section 3)

Pearly nautilus shell	*Nautililus pompilius*	**natila, sulua dausoko**	Part 9, Schedule 2 (Section 3)

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18 CORAL

18.1 The Resource

Species Present: Fiji has a wide variety of reef-building and soft corals. Having 354 species of corals (comprising 342 Scleractinian species within 72 genera, and 12 non-Scleractinian species within 5 genera) have been recorded. The fishery is comprised of companies exporting live coral and rock along with other reef organisms for the international aquarium market. The live corals are referred to as ornamental corals. There are 242 CITES-listed coral species in Fiji, of which four are non-scleractinian corals, and all subject to collection quotas (Lovell and McLardy, 2008). According to the CITES Trade Database for 2016, 46 genera of corals were exported from Fiji. The black coral fishery has been defunct since 1998 and is not considered a viable fishery resource.

Distribution: Species of ornamental corals are part of the natural fauna of coral reefs throughout Fiji. There have been several surveys of Fiji's coral reefs (Ryland, 1981; UNEP/IUCN, 1988; Spalding *et al.,* 2001; Lovell and Sykes, 2004; Mangubhai *et al.,* 2019). Lovell and McLardy (2008) reported on the coral species throughout Fiji with comment on the sustainability of collection with quantification of the degree of impact.

Biology and Ecology: Corals may be divided into two main types, hermatypic and ahermatypic, depending on whether their tissues contain single-celled symbiotic algae known as zooxanthellae. Hermatypic, or reef-building, corals contain zooxanthellae and ahermatypic corals do not. The zooxanthellae, through photosynthesis, provide nutrition as well as removing excretory products from the corals and enhancing their ability to deposit their limestone skeletons. This enables successful reef growth in an environment of physical and biogenic erosion (Veron, 2000).

Ahermatypic corals are not restricted to sunlit waters and can grow at any depth, with all their nutrition being derived from the capture of plankton. Some ahermatypes, notably *Tubastrea*, *Dendrophyllia* and *Balanophyllia*, are often found in caves or other places where lack of light prevents the vigorously growing hermatypes from displacing them.

Their capacity to form complex colonies by asexual multiplication of polyps allow for the development of hundreds or thousands of individuals. Many can grow to enormous size, achieve great age, produce enormous quantities of larvae, grow fast enough to out-manoeuvre competition for substrate and catch plankton on a large scale. Some fast-growing "staghorn" *Acropora* species can increase their branch lengths by up to 220 mm per year. Other corals produce sturdy colonies able to withstand strong wave action or expansive colonies, maximising their surface area to survive when light is limited. Some *Porites* species may grow only 3−10 mm per year to produce massive growth forms of many metres, rapid growth being sacrificed for long-term endurance and stability. As well as asexual duplication of polyps, all corals devote a substantial part of their available energy to sexual reproduction, using a wide range of methods. Broadcast spawning is the most common and effective, particularly after natural disasters such as a flood or cyclone (Veron, 2000).

18.2 The Fishery

Utilisation: A summary of trends, and review of management and sustainability in the international trade in hard corals from 2000−2010 can be found in Wood *et al.* (2012). In the past corals were harvested in Fiji for lining local septic systems and the curio trade (Lovell, 2001; Cumming *et al.*, 2002). Massive corals of the genera *Goniopora* and *Alveopora* are occasionally exported for medical use in bone replacement. Black corals were harvested for jewellery purposes. A detailed account of the collection of coral and other benthic reef organisms for the marine aquarium and curio trade in Fiji can be found in Lovell (2001).

Fiji is the world's second largest exporter of live reef products for the aquarium trade, and the Pacific's largest exporter. The trade involves the export of wild-caught and cultured hard corals as well as soft and gorgonians corals, natural and artificial live rock. (UNEP-WCMC, 2015). Additionally, "live sand" is reef sand with resident interstitial fauna and flora. In 1990, Fiji began exporting "live rock". It is a calcium carbonate reef rock pieces (15–35 cm in diameter) covered with coralline algae, and associated fauna and flora. In 2005, Fiji began exporting "cultured live rock" (Bazilchuk, 2006). Cultured live rock is made from concrete composed of limestone rubble and pumice formed into various shapes, and deposited in offshore reef areas for 12−18 months where biofouling by coralline algae and other reef organisms gives it a natural reef rock appearance. Both rock types, serve as habitat in aquaria with ecological functions of the natural reef.

Cultured coral are propagated through the fragmentation from larger colonies. The branches are broken off and set in a cement base, placed on subtidal racks and allowed to grow to a commercial size. Quality of specimens varies, the non-commercial colonies are utilised by Walt Smith International's Aquaculture Development for the Environment to repopulate the local reefs in areas where the villagers have cared for the growing corals.

Collection of corals for Fiji's aquarium trade is mostly contracted out to local divers within a village's customary fishing grounds. Collectors fill orders for specific species and quantities, using snorkelling gear and a small chisel to carefully extract corals from the substrate to avoid damage to the specimens. To fit the hobbyist aquariums, corals are limited to <15 cm diameter in size. Coral pieces are carefully transported to the holding facility where every attempt is made to provide physiologically optimum water quality and lighting. They are then trans-shipped by air to holding facilities in foreign countries (Lovell, 2001; Cumming *et al.,* 2002).

Of the 37,238 pieces of live coral exported from Fiji in 2016, the ten most shipped corals are listed in Table 16. The most numerous were the branching *Acropora* species which represent almost 1/3 of the exports and almost nine times the next most numerous genus export. The live rock quantity represents the progressive reduction in quota, leading to phasing out wild-caught collection completely.

Table 16. The top ten coral exports from Fiji in 2016.

2016 coral and live rock exports	Pieces
Acropora	13,010
Pocillopora	1,492
Fungia	1,364
Stylophora	1,347
Montipora	1,205
Lobophyllia	1,170
Seriatopora	1,104
Favia	1,007
Catalaphyllia	969
Turbinaria	921
Live rock	140,947 kg

Production and Marketing: Prior to 1985, production of ornamental corals in Fiji was limited to the small quantities gathered by the tourist market and for private collection. In early 1985, a licence was issued to a local company to extract and export coral, mostly in Bau waters of the Central Province (Viala, 1992). There are currently four companies actively operating in Fiji; two export live coral and two only live rock. Walt Smith International is exporting cultured corals and cultured live rock (Mangubhai *et al.,* 2019) and is responsible for exporting more than half of Fiji's aquarium products. Along with Aquarium Fish Fiji, they are currently the largest shippers of ornamental coral and fish. Walt Smith International's main collection area is located off the northwest coast of Viti Levu; Aquarium Fish Fiji's main collection area is within the Beqa lagoon (Lovell, 1999; 2010).

Coral exports from Fiji accounted for approximately 10% of corals and 60% of live rock in the international trade over the period of 2000–2010. In 2010 Fiji supplied 69% of live rock in international trade (Wood *et al.,* 2012). In 2010 the US accounted for 62% of imports whereas European countries accounted for 33%.

Fiji is a party to CITES having adopted the treaty in 1998. In 2002, the CITES Secretariat in Geneva recommended that all signatory countries, including the USA, cease trade with Fiji in CITES-listed species. The suspension included giant clams (*Tridacna* spp.), stony corals (Scleractinia), organ pipe corals (*Tubipora* spp.), black corals (Antipatharia), fire corals (*Millepora* spp.), and lace corals (Stylasteridae) (Cumming *et al.,* 2002). This was due to the Fiji Government not enacting the required CITES legislation in a timely manner. The suspension was lifted shortly after the enactment of the Endangered and Protected Species Act 2002.

18.3 Stock Status

Lovell and McLardy (2008) reported on the coral subject to collection versus all coral numbers within the Walt Smith International and Aquarium Fish Fiji collection areas in 2006. More information is required on the distribution and abundance of commercial coral species, their rates of regeneration and the current state of the stocks in the coral extraction areas.

18.4 Management

A detailed review of the status and management of corals in Fiji can be found in UNEP-WCMC (2015b) and Lovell (2008; 2010). The wild-collected live rock is being phased out through the reduction of quotas issued under CITES. The coral and live rock exports are covered under Appendix 2 of CITES and are subject to an annual quota, non-detriment findings and a fisheries management plan.

Current Legislation and Policies Regulating Exploitation: According to Skyes and Morris (2009), as cited in UNEP-WCMC (2015), relevant legislative measures in Fiji include the Endangered and Protected Species Act (2002), Fisheries Act (1992), and the Environmental Management Act (2005). These are administered by the Ministries of Fisheries and Environment. The aquarium trade must comply with the Endangered and Protected Species Act (2002), which lays down the export permit requirements for CITES-listed species.

Regarding the legislation for tourism, according to the Endangered and Protected Species Act (2002) "A visitor may export not more than a total of only 2 items of specimens of either Helioporidae (blue coral), Antipatharia (black coral), Tubiporidae (organ-pipe coral), Scleractinia (stony coral), Milleporidae (fire coral) or Stylasteridae (lace coral) as a personal effect under Section 20 of the Act only if (a) the visitor acquired the specimens legally; and (b) the specimens were beach-washed." Selling ornamental corals to tourists is banned in Fiji (Cumming *et al.,* 2002).

The national management plan for the aquarium trade in Fiji was reviewed in detail by Lovell (2008; 2010). Although there are only four active companies, five companies are licensed to operate in Fiji, with a moratorium preventing any additional companies into this industry. Licences to operate are required by the Ministry of Fisheries and only one operator is allowed per area. Collection is not allowed to occur in tourism areas, subsistence fisheries areas, and Marine Protected Areas (MPA). Only CITES approved coral species are allowed for collection, and collection must be within the national quota. Companies that contract collectors are required to develop Collection Area Management Plans. CITES requires a non-detrimental finding for the collection of species to show that they are not threatened with extinction within its range. Mariculture of coral is from fragmentation so it does not comply with the CITES requirement of F2 (second filial) generation-rearing which would avoid the quota requirement.

The CITES coral quota established in 2003 lists 55 CITES-designated taxa, comprising 27 genera and 28 species of scleractinian coral, and 3 genera and 2 species of non-scleractinian corals. Eleven taxa have a zero-export quota, and therefore not allowed for export. 27 genera are not contained in the quota and are not allowed for export. In 2016, 37,238 pieces of live coral were exported. These represented 45 genera drawn from 242 species for collection of the 354 currently identified from Fiji. (Lovell, 2008; 2010; UNEP-WCMC CITES Trade Data Base, 2016). As collection sites for aquarium items are within customary marine tenure areas, customary law requires negotiated access which may involve village benefits such as employment and goodwill payments (UNEP-WCMC, 2015b).

Management Recommendations: Lovell (2010) stated that there are problems with aquarium trade management in Fiji. These included:

- The CITES conservation mindset is appropriate for large, rare animals, but is applied to those which are highly abundant and reproductive;
- There is consensus amongst the coral exporting industry and scientists that CITES quotas need to be revised and based on science. Nand (2008) recommends quotas distributed to companies should be based on the geographic range, abundance, and diversity of species within a company's collection area.
- Management bias, due to NGOs with a conservation agenda, neglecting the sustainable nature and benefits of the fishery;
- Compliance is expensive in terms of fees, employees time, preparation of annual reports, and permitting administration;
- Loss of trade due to periodic bans and constraining quotas; and
- Site-specific corals should be given a lower export quota; whereas highly abundant reproductive corals should have a high quota.

Furthermore Nand (2008) states "as there are only two live coral trading companies operating in Fiji, the quotas should be assigned per company. This would allow upgrading coral quotas and promote sustainable management for each company."

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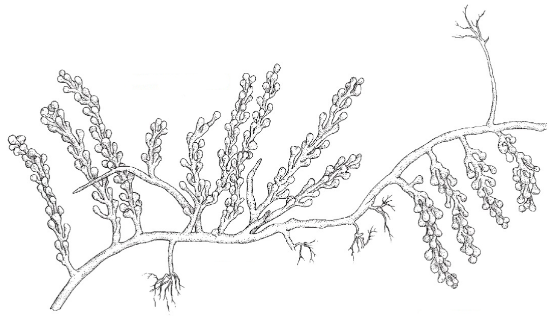
19 EDIBLE SEAWEEDS



19.1 The Resource

Species Present: Presently 8 species of seaweeds in Fiji are harvested for consumption, or sale for later consumption. These are listed in Table 17. The preferred species in Fiji are **nama** (*Caulerpa* spp.), **lumicevata** (*Hypnea* spp.) and **lumiwawa** (*Gracilaria* spp.) (South, 1993a).

Table 17. Names of seaweeds commonly harvested in Fiji. Source: Lewis (1986), South (1993a; 1993b), Novaczek (2001), ACIAR (2019)

Family	Common name	Fijian name	Scientific name
Chlorophyta (green algae)	Seagrapes	**nama, na**	*Caulerpa racemosa*
	Seagrapes	**namakeibelo**	*C. racemosa* var. *occidentalis*
	Seagrapes	**namawawa**	*C. oligophylla*
	Seagrapes	**namalelevu**	*C. macra*
	Seagrapes	**nama**	*C. chemnitzia*
	Reindeer limu	**totoyava, sagati**	*Codium bulbopilum*
	Tubular green weed	**lumiboso**	*Enteromorpha* sp.
		lumiboso	*Ulva meridionalis*
Rhodophyta (red algae)	Maidenhair	**lumicevata, lumivakalolo**	*Hypnea cornuta*
	Glassweed	**lumiyara, lumiwawa**	*Gracilaria verrucosam*
		lumiwawa	*Hydropuntia edulis* (previously *Gracilaria edulis*)
	Goldenweed	**lumitamana**	*Solieria robusta*
	Spiny sea plant	**lumikarokaro**	*Acanthophora spicifera*

Distribution: Sea grapes are widely distributed in the tropical Pacific (Shokita *et al*., 1991) and are found throughout Fiji. At Dravuni Island, Fiji, South (1991) recorded five species of *Caulerpa*, with three varieties of *C. racemosa* (var. *peltata, uvifera* and *macrophysa*), *C. cupressoides* var. lycopodium, *C. serratula*, *C. taxifolia* and *C. urvillianav. Hypnea* and *Gracilaria* are also abundant throughout Fiji (South, 1993a). Molecular studies have helped to revised the nomenclature of seaweed species (Table 17). What was previously recorded as *Caulerpa racemosa* now known as *Caulerpa oligophyllia* (most common), *Caulerpa macro* or *Caulerpa chemnitzia* (least common). All three species grow together in some areas. Other species are *Hydropuntia edulis* (previously known as *Gracilaria edulis*), *Hypnea cornuta* and *Ulva meriodionalis* (very similar to *Enteromorpha* sp.) (Paul *et al*., 2020).

Biology and Ecology: *Hypnea* and *Gracilaria* are found in sheltered back-reef areas, protected from the destructive effects of wind and waves (South, 1993a). *Caulerpa* spp. are a purely marine stenohaline algae, which will die even in slightly brackish seawater, so the salinity of the surrounding seawater should not be lower than 30 parts per thousand (Trono, 1988). In the genus *Caulerpa*, thalli appear superficially as if they have differentiated leaves, stems and roots which are green in colour. Seaweeds of this group are characterised by having many nuclei in one cell, like a single closed tube full of cytoplasm. Reproduction may be sexual or vegetative, the latter likely being an adaptation to a less favourable environment. Under favourable conditions, branches of *Caulerpa lentillifera* (found in Japan, not Fiji) grow at approximately 2 cm per day, a characteristic that is exploited in cultivation (Shokita *et al*., 1991).

19.2 The Fishery

Utilisation: Throughout the Pacific Islands and southeast Asia, several species and varieties of seaweed are utilised as fresh food, mainly through the gathering of natural stocks (Trono, 1988). In Fiji, edible seaweeds form an important part of the diet; it appears that Fijians have a long tradition in the collection and consumption of seaweeds. It is likely that the commercialisation of edible seaweeds coincided with the expansion of the cash economy (South, 1993a), and the expansion of seaweed exports coinciding with an increase in connectivity between harvest sites and markets, and air traffic to Southeast Asia and western markets.

Nama is a subsistence food in Fiji, traditionally eaten fresh as a salad, to accompany other food. It is often prepared by marinating it in lemon juice, then adding grated coconut (**lolo**), some finely chopped chili, and canned fish. **Lumicevata** and **lumiwawa** may be prepared in any of several ways prior to consumption. Plants are cleaned and washed, then mixed with chopped onion, **lolo**, chili and canned fish, and then cooked. The seaweeds add a characteristic flavour and act as a thickening agent (South, 1993a). In Okinawa, Japan and Cebu, Philippines several species of *Caulerpa* are cultivated commercially (Shokita *et al*, 1991). Considerable quantities of sea grapes in the fresh, brine-cured and salted form have been exported to Japan and Denmark from the Philippines and the prospects of mass production of this seaweed are promising (Trono, 1988).

Production and Marketing: Collecting, marketing and preparing edible seaweed in Fiji is largely an activity of Fijian women and girls. It is community-based, with the work being shared among family and village groups. Seaweed harvested from the lagoon and reef on a weekly basis is stored for eventual sale in markets at the end of the week. At least 150 harvesters are involved in Fiji, and it is projected that supply does not meet local demand (Morris *et al*., 2014). Seaweed crops in Fiji go directly to market with a three-day shelf life due to the current post-harvest methods (Morris *et al*., 2014).

Experienced Fijian **nama** harvesters normally collect only the upright shoots called fronds, leaving the stolons to regenerate more shoots. Harvesting strategy includes rotation of collecting areas over at least a 3 to 4-week cycle, to promote regeneration. Good harvesting sites are protected by the villagers and appear to have been harvested over many generations. **Lumicevata** and **lumiwawa** are harvested by hand and stored in sacks prior to sale, either immersed in seawater or kept damp in the shade. Plants are often entangled with debris, and a considerable amount of time is spent cleaning them before they are marketed (South, 1993a).

Nama fronds are sold in portions (heaps), at prices ranging from FJD 2−4 per heap, each heap weighing roughly 250−300 g (Morris *et al*., 2014). Some vendors may exclusively collect and sell **nama**, but normally **nama** sales are combined with those of other seaweeds and non-fish products such as shellfish. A single harvester can earn up to FJD 200 per week (Morris and Bala, 2016). The greatest sales take place on Fridays and Saturdays at Suva, Nausori, Nadi and Lautoka (South, 1993a). According to Fiji Fisheries Division Annual Reports from 1987−1990 previous average sales of approximately 10 mt per year for all species were recorded, production and sale of edible seaweed in 1991 jumped to 36 mt valued at FJD 50,000, falling to 20 mt in 1992 (Anon., 1987−1993). Approximately 75% of Fiji's **nama** crop is harvested in the Yasawa Islands, and the remaining 25% coming from Labasa, Tavua, and Rakiraki (Morris *et al*., 2014). Production across the ten sites surveyed by Morris and Bala (2016) ranged from 5−2,100 kg per week, with an average of 323 kg per week.

Table 18. Total seaweed sale volume at municipal and non-municipal market outlets. Mean municipal market price in FJD per kg given in brackets to the right of quantity. Source: Fisheries Division annual reports 2002−2004 (Anon., 2003–2005), Morris *et al.* (2014)

Fijian name	2002	2003	2004	2012
nama	58.88 (3.91)	40.17	102.50 (3.86)	110 (2.00–4.00)
lumicevata	13.70 (3.51)	7.2	16.17 (3.45)	na
lumiwawa	na	2.96	3.71 (1.73)	na
sagati	0.47 (2.75)	0.4	na	na
Total	**73.05**	**50.73**	**122.38**	**110**

An ACIAR project on “Diversification of Seaweed Industries in Pacific Island Countries” from 2015 to 2017 estimated an an edible seaweed volume of 10 tonnes per annum passing through the Suva market. The total annual value of edible seaweed traded in the marketplace was estimated at FJD100,000. There was variability between months, with but peaked in the cooler months of May to June, and November to December. There was some evidence that the supply of seaweed was interrupted by cyclone and flood events. Seaweed prices ranged from FJD9 to FJD17 per kilogram depending on the species.

Detailed studies of Fiji’s *Caulerpa* (**nama**) supply chain can be found in Morris *et al.* (2014) and Morris and Bala (2016). Seagrapes are the main edible seaweed in Fiji. Up to 16 villages sell seaweed at the Suva municipal market, dominated by three harvest sites - Gunu (Yasawa Islands), Rakiraki, and Man (Mamanuca Islands). This seaweed fishery supply chain is almost exclusively women. Markets for **nama** are scattered throughout the major population centers of Viti Levu and Vanua Levu. Sixty-five percent of Fiji’s **nama** crop is sold in Suva’s Municipal Market, with the remaining 35% distributed between Fiji’s six major municipal markets. Most harvested stock on Viti Levu is sold direct to wholesalers and market vendors, whereas in Vanua Levu harvesters tend to retail their own stock. 110 mt of *Caulerpa* (**nama**) was harvested in 2012, valued at FJD 255,330 (Morris *et al*., 2014).

Seaweed farming was introduced to Fiji in the late 1980s, in early 1997 the Fisheries Division began a seaweed farming project for rural communities. *Kappaphycus alvarezii* (**cottoni**) is grown on standing lines, sold to local companies, dried, baled and then exported to Asian markets. Data from the Fiji Fisheries Division Annual Reports suggests 60.97 mt was produced through this project in 2008; the vast majority (50.69 mt) was produced in Ono-i-Lau, followed by Kadavu (7.57 mt). In 2012 a total of 43.13 mt was produced valued at approximately FJD 44,100; 74% of total seaweed production in 2012 was in the eastern division (Ono-i-Lau and Namuka-i-Lau). *Kappaphycus alvarezii* is not mentioned in Table 17 as it is not eaten, carrageenan is extracted from it. The carrageenan is used for various industrial processes such as a thickening and stabalising agent.

Aquaculture production of *Caulerpa* species has been trialled in Fiji, Samoa and Australia. *Caulerpa racemosa* has many nutritional and growth traits (e.g. frond length) that suggest it may have potential for commercial production (Tikiobua 2017; Paul *et al.*, 2014)

According to Fiji Revenue and Customs Service export data from 2012−2014, seaweed was exported to Hong Kong, Philippines, Vietnam, USA and New Zealand, with the bulk of exports destined for Asian markets primarily Vietnam and the Philippines (FRCS, *unpubl. data*). In 2008, 91,270 kg of “Seaweed and other algae for human consumption” was exported, worth FJD 131,557 (Anon, 2009). Exports of “Seaweed and other algae for human consumption” increased from 22,270 kg (FJD 40,856) in 2012 to 42,672 kg (FJD 89,856) in 2013, decreasing in 2014 to 24,768 kg (FJD 45,512) (FRCS, *unpubl. data*). It is interesting to note that despite exports of “Other seaweeds and other algae fit for human consumption” making up a small portion of Fiji’s seaweed exports (largest quantity was 600 kg in 2013, valued at FJD 12,159), per kilogram they are higher value than “Seaweed and other algae for human consumption” i.e. approximately FJD 20 per kg compared to FJD 2 per kg, and the majority of exports have been to the USA and New Zealand. The differences in price, quantity, and destination indicate that "Seaweed and other algae for human consumption" is likely *Kappaphycus alvarezii* (cottoni), which is an introduced species of seaweed farmed in Fiji. The product is dried and compressed into bales prior to export.

19.3 Stock Status

There is no information available to indicate stock status of the various species of edible seaweeds. The current sale of seaweed collection, sale and consumption for both the local and export markets may be impacting adversely on stocks, and this is worthy of investigation. Morris *et al.* (2014) states, "as harvesting *Caulerpa* is limited to a few main sites this means the industry is vulnerable to loss of product. This loss may be due to the combined impacts of unsustainable harvesting and natural phenomena such as storm surges and cyclones, resulting in the sites becoming unproductive."

19.4 Management

Current Legislation and Policies Regulating Exploitation: None at present. "Seaweed (**lumi**) in coconut milk" and "Ready to eat sea grapes (**nama**)" was temporarily banned from being sold at the Suva Municipal Market citing health concerns by the Suva City Council and Ministry of Health (Anon., 2010), however the ban was lifted shortly after upon conclusion of an investigation by the Ministry of Health (Ministry of Health, *pers. comm.*). **Nama** was also temporarily banned for sale in Lautoka City and Nadi Town municipal markets during the same time period (Lasaqa, 2010).

Management Recommendations: Given the increasing harvest of edible seaweeds in Fiji and their importance in the cash economy, the crop's sustainability should be determined, and sustainable harvesting methods applied to all sites (South, 1993a; Morris *et al*., 2014). Given the current export industry in Fiji the species of seaweed being exported need to be recorded; the practice of not discriminating between seaweed products by both Fiji Revenue and Customs Service and the Ministry of Fisheries makes differentiating between wild harvest and cultured seaweed difficult. Fiji Fisheries staff should adopt practices similar to Samoa fisheries staff such as frequent data collection, recording which village vendors are from/where the seaweed was sourced, how much seaweed they are selling on the day, the species/local name and the price (Morris *et al*., 2014).

SPC (2011) recommends leaving a replanting part of each plant, such as only harvesting the upright shoots of nama and leaving the stolons (runners) to regenerate, and establishing rotational harvesting; closing areas off for two months at a time. Legislation could be adopted which prevents mechanical or motorised harvest methods that may be destructive to the stolons and habitat of seaweeds. More information is needed on **lumicevata** (*Hypnea pannosa*) and **lumiwawa** (*Gracilaria* sp.), as the vast majority of recent studies have focused on **nama** (*Caulerpa* spp.).

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FINFISH FISHERY PROFILES


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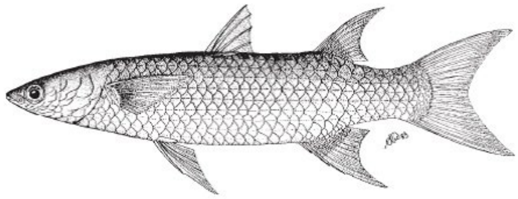
20 MULLET



20.1 The Resource

Species Present: Fifteen species of mullet (Family Mugilidae, Order Mugiliformes) are present in Fiji waters (Table 19). **Kanace** is the generic Fijian name for mullet, although specific names may apply to some species.

Distribution: Table 19 lists the Indo-Pacific distribution of mullet species found in Fiji. Mullets occur in all tropical and temperate seas, usually nearshore. Most species are euryhaline, inhabiting brackish water lagoons, estuaries, and spend time in freshwater habitats, particularly at earlier life stages. Mullet can be found to depths of 20 m, but are most commonly seen near the surface (Carpenter and Niem, 1999).

Biology and Ecology: Most mullet graze on algae and diatoms, feeding on detritus that collects 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 (Thomson, 1951 in Kailola *et al*., 1993). **Kanace** may also consume insects, fish eggs and plankton (Myers, 1991).

Because of their feeding habits, mullets are usually found in association with shallow sand, mangrove, seagrass, and/or reef habitats, with **koto** (flathead mullet − *Mugil cephalus*) being one of the most common species in mangrove areas (Sasekumar *et al*., 1992; SPC, 2011). The majority of species can tolerate a wide range of salinities, some ranging into purely freshwater while a few species are found on coral reefs (Myers, 1991). **Kava** (squaretail mullet − *Liza vaigiensis*) forms large schools, frequently in mangrove areas while **kanace** (fringelip mullet − *Crenimugil crenilabis*) occurs in schools, in sandy lagoons and on shallow seaward reef flats. Mullet are reported to spawn in large aggregations after dark (Randall *et al*., 1990).

Anon. (1988a) reports that the breeding season for **kanace** in Fiji is early summer (October−December), while in the west and north of Viti Levu, spawning migrations were reported to occur in mid-late December (A. Sesewa, *pers. comm.*). Sadovy (2004) reports **koto** spawning around the new moon during August and September, and a study on the biology of mullets in Tonga suggest **koto** and *Liza* spp. are reproductively active between July−September, with spawning commencing in the third quarter of the year, during the cooler months. Some Tongan fishermen report that spawning of some mullet species extends from September−March (Langi *et al*., 1992).

In Australian waters, female **koto**, depending on size, produce between 1.6 and 4.8 million pelagic eggs, averaging 0.6 mm in diameter (Grant and Spain, 1975 in Kailola *et al*., 1993). Knowledge of larval biology in **koto** is limited to laboratory studies. Post-larval **koto** first enters Australian estuaries when 20–30 mm long (Chubb *et al*., 1981). The fish form schools of a few hundred individuals after entering the estuaries, and move to shallow nursery areas, which may be located from the lower estuaries to freshwater reaches of tidal creeks (Thomson, 1955 in Kailola *et al*., 1993).

In Australia, juvenile **koto** reach an average size of 15 cm fork length (FL) 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 to 35 cm. New research from Fiji suggests the size at maturity (i.e. the size when 50% of fish become adults) for *Crenimugil crenilabis* is 32.2 cm, with 95% of fish mature by 38 cm (Prince *et al*. 2018). **Koto** in Australian waters are reported to reach a TL of 76 cm and a weight of 8 kg (Thomson, 1951; Grant, 1982 in Kailola *et al*., 1993). Langi *et al*., (1992) report that in Tonga both **koto** and *Liza* spp. exhibit sexual size dimorphism, with females growing larger than males. The largescale mullet *(L. macrolepis)* can grow to a TL of 60 cm, though commonly they are found at 26 cm TL (Carpenter and Niem, 1999b).

Table 19. Species of mullet found in Fiji, and their Indo-Pacific distribution. Source: Carlson (1975), Lewis, (1984, 1985), Randall *et al*., (1990), Myers (1991), Carpenter and Niem (1999b), Seeto and Baldwin (2010)

Common name	Scientific name	Fijian name	Indo-Pacific distribution
sharpnosed river mullet	*Cestraeus oxyrhynchus*		Indo-West Pacific from Indonesia to Fiji; north to Philippines, south to New Caledonia
lobed river mullet	*Cestraeus plicatilis*		Celebes, New Caledonia, Vanuatu, and Fiji
fringelip mullet	*Crenimugil crenilabis*	**kanace**	Widespread throughout tropical Indo-Pacific, from Red Sea and Madagascar to Tuamotu Islands; south to Lord Howe Island and north to southern Japan
diamond mullet	*Planiliza alata*		South and east Africa, Madagascar, Timor Sea, New Guinea, to Tonga
largescale mullet	*Planiliza macrolepis*	**keteleka, buileka, ketetuku**	Common throughout most of the Indo-Pacific from East Africa and Red Sea to Marquesas and Tuamotu islands; north to Japan and Marianas Islands
otomebora mullet	*Liza melanoptera*	**molisa**	Indo-Pacific from East Africa to the Marquesas Islands; north to South China Sea and south to tropical Australia and Tonga
greenback mullet	*Planiliza subviridis*		Indo-Pacific from Red Sea to Samoa; north to Japan, where it is rare
squaretail mullet	*Ellochelon vaigiensis*	**kava**	Throughout the Indo-Pacific from East Africa to Tuamotu Islands; north to southern Japan, south to southern Great Barrier Reef and New Caledonia
Broussonnet's mullet	*Mugil broussonneti*		Very difficult to determine due to paucity of records. Perhaps ranging from south China through South Pacific.
flathead mullet	*Mugil cephalus*	**koto, uralo**	Worldwide in tropical, subtropical and warm temperate waters, although less abundant in tropics, and apparently rare in Indonesia
acute-jawed mullet	*Neomyxus leuciscus*	**kanace**	Central Pacific, from southern Japanese and Hawaiian island in north; south to Tubai and Ducie Islands; rare in Marianas Islands.
hornlip mullet	*Plicomugil labiosus*		Widespread throughout tropical Indo-Pacific, from the Res Sea and Madagascar to Samoa; north to southern Japan and south to the Great Barrier Reef
bluetail mullet	*Crenimugal buchanani*	**tabutale? molisa?**	Indo-Pacific from South Africa through parts of Indonesia to parts of Melanesia and Micronesia; north to the Marianas Islands and southern Japan
longarm mullet	*Osteomugil cunnesius*		Reliable reports are rare due to earlier taxonomic confusion (*M. ophuysenii*). Assumed widespread from Red Sea to Western Pacific
kanda	*Osteomugil engeli* (prev. *M. kandavensis*)	**sevou**	Widespread across Indo-Pacific, from Africa to Marquesas and Tuamotu Islands; north to southern Japan; introduced to Hawaii
bluespot mullet	*Moolgarda seheli*	**kanace, sevou**	Widespread throughout Indo-Pacifi, from East Africa and Red Sea to the Marquesas Islands; north to Japan and Hawaii, and south to southern Queensland and New Caledonia

20.2 The Fishery

Utilisation: Mullet roe − commonly from **koto** − is a delicacy in Italy and the Mediterranean and in Japan (Taiwan Today, 2012; Gulf Seafood News, 2015) as well as Middle East countries. Fiji does not appear to have a fishery specifically targeting mullet for their roe. Mullet are an important food fish in Fiji, both for artisanal and subsistence use. The optimum fishing season for mullet is August−September, though they can be caught all the year round. In the early months of the year, the large post-spawners have very dry flesh, and the new generation is not yet mature (Anon., 1988b). Throughout Suva Lagoon and undoubtedly other parts of Fiji, it is common to see gill nets stretched around the periphery of mangroves, or across river mouths as drift nets to catch a variety of mullet species.

Gillett (1996) investigated the market for dried mullet in Fiji. The main market for dried mullet was in western Viti Levu; the product is almost exclusively sold in municipal markets, vendors and consumers both of Indo-Fijian decent. The product is commonly sold as an individual fish in a plastic bag sealed by a knot, at a retail price of about FJD 9−13 per kg; high prices caused by low supplies of fish are often due to wet weather hindering the drying process. Retailers in western Viti Levu reported purchasing small volumes of 4−20 kg at a time. Although the product is popular in western Viti Levu, the main area of production and consumption appears to be Labasa in Vanua Levu. This was probably a result of productive mangrove areas for capturing the desired species, ample sunshine for drying the fish, and an abundant Indo-Fijian population (primary fishers and consumers). Muncipal markets in Nadi and Lautoka still sell dried mullet in the same manner reported by Gillett (1996).

Production and Marketing: Approximately 11 mt of dried fish (mostly mullets) was exported from Fiji in 1987, of which 10 mt went to Hong Kong, FOB[17] prices for dried fish exports appear to be around FJD 4 per kg (Anon., 1988b). Artisanal production of mullet has fluctuated somewhat in recent years. Table 20 shows production (weight) and value of Fiji's artisanal mullet fishery for the years 2002−2016. According to Fishery Division Annual Reports, production from 1986−1992 generally ranged between 320−662 mt per year, with the exception of 1988 during which the catch weight markedly increased to 1,087 mt (Anon, 1987−1993). After the 1988 spike in production, catch weight decreased to approximately 345 mt for the next two years. Watling and Chape (1992) theorises the decrease in production post−1988 may be a reflection of the local bans on the use of gillnets during the past 1983−1986 period or a result of over-fishing. In 2002 total production reached approximately 450 mt, decreasing to 320 mt in 2004.

It is interesting to note that a substantial proportion (about 61%) of all mullet sales for the period 2002−2004 occurred in the Central Division alone. The apparently higher production in the Central Division maybe due to available habitat; mullets are closely associated with mangroves and seagrass beds (Sasehumar *et al*., 1992; SPC, 2011). Market value in 1986 was FJD 2.09 per kg increasing to FJD 2.41 per kg in 1992. From 1989–1991 market value of mullet was substantially higher; FJD 3.10, FJD 3.42, and FJD 6.56, respectively.

20.3 Stock Status

Overfishing by commercial fishermen residing in urban centres may be partly responsible for the observed decline in mullet landings (Lal, 1984). The introduction of cash economies and efficient gear in rural areas has also led to depletion of certain fish species, including *Mugil* spp.. Anecdotal evidence from village elders in Kubulau recall plentiful mullet runs; however current stocks stocks have declined to the point where these annual mullet drives no longer occur (Askew *et al*., 2011 in Fox *et al*., 2012). It is likely that habitat destruction and overfishing have severely impacted sought-after mullet stocks throughout Fiji.

17 Freight On Board – the cost of delivering/transporting the goods is borne by the seller

Table 20. Production (mt) and value (FJD per kg) of mullet in the artisanal fishery in 2002–2004, and 2016. Mean market price from the Central Division provided in brackets below production value. na = data not available Source: Fisheries Division Annual Reports, (Anon., 2003–2005), Ministry of Fisheries (*unpubl. data*)

Fijian name	2002	2003	2004	2016
kanace[18]	450.44 (3.56)	395.02 (4.43)	320.37 (4.26)	na. (7.10)
kava	9.69 (3.94)	6.76 (4.83)	3.66 (4.50)	na
koto	24.54 (4.32)	14.95 na.	13.31 (4.85)	na
molisa	111.97 (2.78)	21.65 (3.12)	79.65 (3.21)	na
Total production (mt)	596.64	438.38	416.99	na
Mean value (FJD per kg)	3.65	4.13	4.21	7.10

20.4 Management

Current Legislation and Policies Regulating Exploitation: The Sixth Schedule of the Fisheries Act (Regulation 18) lists 200 mm as the minimum length for fished **kanace** (*Mugil* spp.). There may also be traditional controls on fishing for mullets in some locations, e.g. there is no fishing allowed during the breeding season at Fulaga Island in Lau, perhaps indicating a sensitivity of local stocks to overfishing. The following pieces of legislation are relevant to the fishing of mullet:

Fish fences

6. It shall be competent for the Fisheries Officer: –
   (e) to determine the location and distance between fish fences or other similar obstructive devices of a permanent or semi-permanent nature;
   (f) to order the removal of a fish fence or other similar obstructive fishing device.

Use of nets in estuaries

7. No net other than hand nets, wading nets and cast nets shall be permitted for the purpose of taking fish in the estuary of any river or stream or in the sea within 100m [l00 yards] of the mouth of a river or stream. *(Amended by 87 of 1979)*

Stretched measurement for nets

12. For the purposes of these Regulations, stretched mesh shall be measured by taking two diagonally opposing knots of the mesh of the net and drawing them apart until the remaining two knots of the mesh just touch each other.

Mesh of hand nets

13. The mesh of a hand net may be of any size.

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

18 comprised of several species

Meshes of other nets

15. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Fish fences

16. In every fish fence constructed with cane or reed screens there shall be at the inmost point in each terminal trap or pan a section not less than 1 m [3 feet] in length, and of the full height of the fence wherein the can or reeds shall be placed not less than 50 mm [2 inches] apart, or wherein the cane or reed screen shall be replaced by netting or cord, galvanised wire or expanded metal, the mesh of which shall measure not less than 50 mm [2 inches] across the smallest diameter, In fences constructed entirely of wire netting or of expanded metal, the mesh of the netting in the traps or pans shall measure not less than 50 mm [2 inches] along the shortest diameter. *(Amended by 87 of 1979)*

Management Recommendations: Local bans on the use of gillnets to catch mullet appear to be effective in boosting local stock numbers. While the introduction of further management measures by the government are not proposed, scientific information and advice (as well as certain basic best management practices) should be provided by the Ministry of Fisheries to local leaders who have imposed bans on the use of gillnets, or are considering doing so. These leaders should strongly enforce ANY current bans on gillnets and prevent fishing of spawning aggregations and mullet runs where appropriate. Given the migratory nature of mullet, a no-take area is unlikely to benefit the fish, and management measures must sensibly consider the migration route/movements taken by mullet.

SPC (2011) caution that a ban on gill nets and fence traps during the time of spawning migrations of mullet may be unreasonable as mullets, are not easily caught by other fishing methods. Rather the number and size of fence traps and the lengths and locations that gillnets are used should be restricted, preventing fishers targeting mullet in areas where they are most vulnerable.

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21 EMPERORS

21.1 The Resource

Species Present: Lethrinids (Family Lethrinidae) are commonly called "emperors". Eighteen species of lethrinids are known from Fiji waters (Table 21), but three species, **kawago** (spangled emperor − *Lethrinus nebulosus*), **sabutu** or **cabutu** (yellow-tailed emperor − *L. atkinsoni*) and **kabatia** (thumb-print emperor − *L. harak*), comprise about 80% of the total landings of these fish in Fiji (Dalzell *et al.*, 1992). **Kabatia** has been selected as an important species in Fiji, and as such will be covered in more detail in Profile 22 THUMBPRINT EMPEROR.

Distribution: The 40 or so species of lethrinids are restricted to the Indo-Pacific, except for one species, which occurs only in the eastern Atlantic (Randall *et al.*, 1990). The Indo-Pacific distributions for the lethrinids taken in Fiji are described in Table 21.

Biology and Ecology: Lethrinids are bottom-feeding, carnivorous, coastal fishes, ranging primarily on or near reefs and seagrass beds, though their preferred habitat is sandy or rubble substrate. They may be found in clear to turbid water. The reefs which they frequent can be shallow, coralline reefs or deep, rocky reefs. They can be solitary or schooling, and do not appear to be territorial, often form large aggregations while spawning (Carpenter and Allen, 1989).

Lethrinids generally possess large, strong jaws and their food preference is correlated with the type of lateral jaw teeth, and also the length and angle of the snout found in a particular species (Carpenter and Allen, 1989). The omnivorous diet of lethrinids includes hard-shell invertebrates, soft-shell invertebrates and fishes, with combinations of these food items found in many species. Food items most commonly reported for emperors are polychaetes, crabs, shrimps, gastropods, bivalves, squid, octopus, sea urchins, sand dollars, starfish, brittle stars, and fish. In Australian waters, spangled emperors eat mostly bivalve molluscs, then gastropod molluscs and sand dollars (Kailola *et al.*, 1993). Feeding in most species is done at night, though many species forage coincidentally or purposefully during the day. Diurnal feeding migrations are reported for some species.

Lethrinids are sequential protogynous hermaphrodites, that is, when sexually mature they are initially females and later in life they change sex. This is why males tend to be generally larger than females and there is usually a sex ratio slightly in favour of the more abundant smaller females. It is likely that sexual transformation occurs over a wide range of sizes (Carpenter and Allen, 1989; Wright, 1993). There are very little data on the actual spawning and fecundity in any species of lethrinid. The Science and Conservation of Fish Aggregations (SCRFA) maintains a database of spawning aggregations for a range of species that can be accessed at www.scrfa.org.

Generally smaller species of lethrinids such as **kabatia** have longer spawning seasons whereas larger species such as **kawago** have shorter well-defined spawning seasons (Taylor and McIlwan, 2012). Fishermen in Palau observed that spawning was preceded by local migrations at dusk to particular areas near a reef, either in a lagoon or on the outer edge of a reef (Johannes, 1981). Spawning occurs in large aggregations while swimming in circles near the surface, or at the bottom of reef slopes. This activity is reported to be at a peak around the time of the new moon. **Kawago** are reported to spawn between May−October in Australian waters, peaking in June−July (McPherson *et al.*, 1985; Walker, 1975 in Kailoloa *et al.*, 1993; Williams and Russ, 1994).

Lethrinid eggs are pelagic, normally ranging in diameter from 0.6 mm to 0.9 mm in diameter. Hatching usually occurs 21−40 hours after fertilisation, the newly hatched larvae varying in length between 1.3−1.7 mm (Carpenter and Allen, 1989). Juvenile lethrinids of all species appear to live in shallow, inshore areas such as seagrass and mangrove areas, the fish moving to deeper water as they age (Kailola *et al.*, 1993; Williams and Russ, 1994).

Table 21. Lethrinid species occurring in Fiji waters, with Indo-Pacific distribution patterns. Previously used scientific names are shown in parenthesis. Source: Carlson (1975), Lewis (1984), Carpenter and Allen (1989), Dalzell *et al.* (1992), Carpenter and Niem (2001), Lasi (2003), Seeto and Baldwin (2010)

Common name	Scientific name	Fijian name	Indo-Pacific distribution
spangled emperor	*Lethrinus nebulosus*	**kawago**	Widespread Indo-West Pacific, including Red Sea and Persian Gulf, East Africa to southern Japan and Samoa
yellow lip emperor	*L. xanthochilus*	**kacika, kasika**	Widespread in the Indo-West Pacific, including the Red Sea, East Africa, Central Indian Ocean, Indonesia to the Ryukyu Islands, south to Queensland, and the Caroline Islands to the Marquesas
orange spotted emperor	*L. erythracanthus* (*kallopterus*)	**belenidawa**	Western Indian Ocean to the Central Pacific, f rom East Africa, Seychelles, Chagos and Maldives, to Thailand, Philippines, Ryukyus, Micronesia, North-East Australia, Samoa, Society Islands and Tuamotus
smalltooth emperor	*L. microdon* (*elongatus*)	**motonilase, leu**	Red Sea, Arabian Gulf, East Africa to Sri Lanka, to the Ryukyu Islands and Papua New Guinea
longface emperor	*L. olivaceous* (*elongatus, miniatus*)		Widespread Indo-West Pacific, including the Red Sea, East Africa to the Ryukyu Islands, to Samoa and Polynesia
Pacific yellowtail emperor	*L. atkinsoni* (*mahsena*)	**sabutu, cabutu**	Indonesia, northern Australia, Philippines to southern Japan, widespread throughout the Western Pacific to the Tuamotus
slender emperor	*L. variegatus* (*latifrons*)	**kabatianicakau**	Red Sea, East Africa to the Ryukyu Islands and New Caledonia
black-blotch emperor	*L. semicinctus* (*variegatus*)	**kabatia**	Eastern Indian Ocean and Western Pacific, including Sri Lanka, Indonesia, northern Australia, Ryukyu Islands to Marshall Islands and Solomon Islands
thumbprint emperor	*L. harak*	**kabatia**	Indian Ocean and Western Pacific, including the Red Sea
orange striped emperor	*L. obsoletus* (*L. ramak*)		Widespread Indo-West Pacific, including the Red Sea, East Africa to the Ryukyu Islands, Tonga, and Samoa
yellow-striped emperor	*L. ornatus*		Eastern Indian Ocean and Western Pacific, from Sri Lanka to the Ryukyu Islands, Papua New Guinea and North-East Australia
spotcheek emperor	*L. rubrioperculatus*	**kabatia**	Widespread Indo-West Pacific, including East Africa to southern Japan and the Marquesas
redspot emperor	*L. lentjan*		Widespread Indo-West Pacific, including Red Sea, Persian Gulf, East Africa to the Ryukus and Tonga
humpnose bigeye bream	*Monotaxis grandoculis*	**bu, mama**	Widespread in the Indo-West and Central Pacific from Hawaii and south-eastern Oceania to the east coast of Africa and Red Sea and from Australia northwards to Japan

Common name	Scientific name	Fijian name	Indo-Pacific distribution
bluelined large-eye bream	*Gymnocranius grandoculis* (*robinsoni*)	**mama**	Widely distributed in the Indian Ocean and western edge of the Pacific Ocean, from East Africa to southeastern Oceania and Australia northward to Japan
Japanese large-eye bream	*Gymnocranius euanus*		Western Pacific Ocean including southern Japan, South China Sea, western Australia to the Great Barrier Reef of Australia, Coral Sea, New Caledonia, and Tonga
striped large-eye bream	*Gnathodentex aurolineatus*		Widespread in the Indo-West and Central Pacific (excluding Hawaii) from the Tuamotu Islands to the east coast of Africa, and from Australia northwards to Japan

Lethrinids are relatively long-lived fishes; the average maximum observed age reported for 9 species is 17 years, and the range of maximum observed age is 7−27 years. In Australian waters, **kawago** are reported to live up to 25 years, achieve sexual maturity at 28 cm standard length, reach a maximum TL of 86 cm and attain at least 4.4 kg in weight (McPherson *et al*., 1988; Walker, 1975 in Kailola *et al*., 1993). In Fiji, size at maturity ranges from 23.2–42.0 cm depending on the species (Table 22, Prince *et al.* 2018, 2019). Population dynamics of emperors have been studied widely and the von Bertalanffy growth curve parametres L_∞ (asymptotic length) and K (coefficient of growth) are known for populations of over 15 species. Dalzell *et al.* (1992) provide preliminary estimates of L_∞ for Fijian lethrinids, calculated from length-frequency data and estimates of K for these species based on the growth parametres of emperors from elsewhere in the Indo-Pacific. These estimates are presented in Table 22 together with total mortality (Z), natural mortality (M) and fishing mortality (F) estimates for several Fijian emperor stocks.

Table 22. Growth and mortality estimates for Fijian lethrinid stocks. L_{50}=length 50% of fish are adults, L_{95}=length 95% of fish are adults, Z=total mortality, M=natural mortality, F=fishing mortality, TL=total length, SL=standard length, FL=fork length. Source: Carpenter and Allen (1989), Dalzell *et al.* (1992), Letourneur *et al.* (1998), Lasi (2003), Grandcourt *et al.* (2010), Gumanao *et al.* (2016), Prince *et al.* (2018. 2019)

Fijian name	Scientific name	L_{50} (cm)	L_{95} (cm)	L_∞ (cm)	K	Z	M	F	Length-weight relationship
kabatia	*L. harak*			33.7	0.47	1.72	1.03	0.68	$W=0.0178 \times FL^{3.026}$
kabatia	*L. harak*	23.2	29.0	28.5	0.90	1.52	0.75	0.77	$W=0.0192 \times TL^{2.91}$
sabutu	*L. atkinsoni*			42.0	0.30	0.86	0.74	0.14	$W=0.0216 \times FL^{3.00}$
sabutu	*L. atkinsoni*	25.3	33.0	35.3	0.36	2.11	0.55	1.56	$W=0.0184 \times TL^{2.91}$
kawago	*L. nebulosus*	41.2	50.0	59.0	0.17	0.53	0.44	0.08	$W=0.0204 \times FL^{2.975}$
	L. ornatus			32.2	0.51	2.14	1.12	1.03	$W=0.0293 \times SL^{3.067}$
kabatia	*L. semicinctus*			28.2	0.68	2.31	1.39	0.92	$W=0.0134 \times FL^{3.072}$
kabatia	*L. rubrioperculatus*			50.0					$W=0.017 \times FL^{3.026}$
kacika	*L. xanthochilus*	39.0	48.0	60.0	0.16	0.54	0.44	0.14	$W=0.0240 \times FL^{2.915}$
	L. obsoletus	26.0	31.0	30.0	0.28	1.10	0.53	1.56	$W=0.0148 \times TL^{3.01}$
motonilase	*L. microdon*			70.0	0.57				$W=0.021 \times FL^{2.90}$
	L. olivaceus	51.5	64.0						
mama	*G. grandoculis*			80.0					$W=0.0336 \times FL^{2.87}$
bu	*M. grandoculis*	34.6	42.0	60.0					$W=0.0239 \times FL^{3.011}$

21.2 The Fishery

Utilisation: Lethrinids are caught in Fiji for subsistence and commercial use. **Kawago** is one of the most highly prized food fishes in Fiji, and it is keenly targeted by commercial fishermen. Fishing gears used to capture lethrinids in Fiji are gill nets, seine nets and hand lines (Dalzell *et al*., 1992). A University of the South Pacific (USP) survey of 46 villages in 22 districts across 10 provinces in Fiji in 2008/2009 found that lethrinids (emperors) were still the most common group of fish encountered in landed catches (USP, 2009). Though there is some bias caused by the varying number of species within each fish group/family the study illustrates the importance of lethrinids to Fijian communities.

Production and Marketing: Lethrinids form an important part of the marine fish production from Fijian waters. In 1986, lethrinids were the single most important family in the inshore commercial catch, with 867 mt marketed, valued at approximately FJD 2 million. From 1986−1995 the general trend was a decrease in catch weight coupled by an increase in market value. Between 1995−2002 landings of emperors increased almost two-fold further increasing to 1,113 mt in 2004 valued at FJD 5.73 million (Table 23). The mean price of lethrinids appears to increase by up to 40% every decade. It is interesting to note that the majority of lethrinids sold prior to 2002 were in the Western Division, whilst the vast majority of post-2002 landings were in the Northern Division (Anon., 2003−2005), possibly reflecting changes in abundance and stock levels or just expanded fishing areas. Prior to 2002 the vast majority of lethrinids were sold in non-municipal market outlets, whereas during the 2002−2004 period there was a shift towards more municipal market sales. Production (mt) and mean municipal market price (FJD per kg) of lethrinids in Fiji's municipal and non-municipal market outlets is provided in Table 24 for 1995, 2002−2004 and 2016.

Table 23. Production measured as catch weight (mt), average market value (FJD per kg) and market value (FJD'000) of emperors in the artisanal fishery from 1986−2004. na: not available. Source: Anon. (1986−2004), *Ministry of Fisheries (*unpubl. data*)

Year	Catch weight	Average market value	Total market value
1986	867	2.32	2,012
1987	864	2.80	2,418
1988	882	2.95	2,598
1989	739	3.45	2,547
1990	682	4.14	2,821
1991	512	3.96	2,030
1992	584	3.23	1,886
1995	510	4.17	2127
2002	932	5.32	4,958
2003	892	5.19	4,629
2004	1113	5.15	5,732
2016*	na	7.27	na

Table 24. Production (mt) and mean municipal market price (FJD per kg) of lethrinids in Fiji's municipal and non-municipal market outlets. Mean municipal market price provided in paratheses below production. NM=non-municipal market outlet, MM=municipal market outlet. na = not available. Source: Fisheries Division Annual Reports (Anon., 1996, 2003–2005; *Ministry of Fisheries, *unpubl. data*.)

Fijian name	1995		2002		2003		2004		2016*
	NM	MM	NM	MM	NM	MM	NM	MM	NM
bu	0.99	0.10	0.20	0.82	0	0	7.12	9.12	na.
	(1.94)		(na)		(na)		(4.84)		(na)
motonilase	46.66	9.98	22.47	118.35	60.77	69.27	75.91	90.95	na.
	(4.60)		(5.24)		(4.87)		(5.20)		(7.02)
kabatia	76.56	25.12	24.1	181.59	44.85	124.96	76.35	100.85	na.
	(3.73)		(4.26)		(4.20)		(4.12)		(7.18)
kacika	25.18	2.28	7.25	101.12	28.84	88.63	51.05	87.13	na.
	(4.26)		(5.51)		(4.95)		(4.82)		(7.01)
kawago	86.25	17.98	28.87	28.87	55.90	132.81	92.99	172.85	na.
	(5.17)		(5.92)		(5.94)		(6.09)		(6.95)
mama	15.82	1.37	2.82	68.04	21.02	54.12	45.09	65.30	na.
	(4.84)		(5.23)		(5.29)		(5.10)		(na)
sabutu	177.84	16.45	25.29	313.18	44.60	104.64	83.81	140.09	na.
	(4.92)		(5.68)		(5.72)		(5.70)		(8.20)
belenidawa	6.87	0.80	4.06	4.12	1.63	40.96	9.77	4.44	na.
	(4.26)		(5.42)		(5.36)		(5.34)		(na)
sabutukula	0.03	0.07	0	0.44	na	19.18	0	0.08	na.
	(5.50)		(na)		(na)		(na)		(na)
Total production	436.2	74.15	115.06	816.53	257.61	634.57	442.09	670.81	na
Mean value	(4.36)		(5.32)		(5.19)		(5.15)		(7.27)

21.3 Stock Status

Dalzell *et al*. (1992) used length-frequency data collected from 1982−1987 to make some preliminary estimates of population parametres of Fijian lethrinid stocks, based on comparative studies. Exploitation ratios calculated from these parametres showed that, in the late 1980s, stocks may still have been approaching the point of optimal exploitation. However, the gradual decline in catches since then may indicate that stocks are presently over-exploited. The increase in catch weight post−1995 is likely a result of the fishery spreading into new areas (i.e. from the Western to Northern Division) rather than Fiji's lethrinid fishery recovering to approximately 1986 levels (867 mt). The lack of Fisheries Division market surveys after 2004 make assessing the current state of the fishery difficult. Despite the limited information, Gillett *et al*. (2014) stated that the finfish in many areas of Fiji are overexploited, therefore it is unlikely that coastal fisheries production (of which lethrinids form a majority) can increase markedly. A USP study in 2008/2009 found that 74% of all lethrinids (emperors) caught were immature (i.e. smaller than the length at first maturity) (USP, 2009). Although this may be due to gear selectivity, it can be taken as evidence of impaired capacity to reproduce (Gillett, 2014). Prince *et al.*, (2019) found the spawning potential ratio (SPR) for *Lethrinus obsoletus* was 5%. Below 20% SPR the supply of young fish to the population is expected to decline over the succeeding years, while 10% SPR is commonly called 'SPR crash', below which populations are likely to decline rapidly and, if not corrected, is likely to result in local extinction.

21.4 Management

Legislation/Policy Regarding Exploitation: The Sixth Schedule of the Fisheries Act (Regulation 18) lists minimum lengths for several lethrinid species (Table 25).

Table 25. Minimum lengths of several lethrinid species listed in the Fisheries Act (Reg. 18). Note the current size limits are below the size at maturity.

Common name	Fijian name	Min. Length (mm)
spangled and long-nosed emperors	**kawago, motonilase, musubi**	250
black-blotch, thumb-print, and red-eared emperors	**kabatia**	150
yellow-tailed emperor	**sabutu**	200

As some species of lethrinids are taken by use of nets, the following legislation is relevant to the fishery:

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Furthermore, the use of poisons is prohibited (Fisheries Act).

Management Recommendations: Difficulties in setting optimum mesh sizes for nets and introducing minimum permissible sizes to control a fishery where a large range of different sized fishes are caught, are discussed in Dalzell *et al.*, (1992). As a follow-up to the study conducted by Dalzell *et al.*, (1992), a detailed contemporary investigation of the status of all lethrinid species should be carried out, given their predominance and value in the marketed catch.

In the meantime, support should be given by the authorities to local resource owners who have successfully rehabilitated local stocks of reef fish by the imposition of bans on gillnets and SCUBA diving equipment. There is need to revise the minimum lengths of lethrinids as recent data suggests the current size limits are below the length at first maturity (Prince *et al.*, 2018) and one species, *L. obsoletus* has a low SPR (<10%) (Prince *et al.*, 2019). Given that some species of lethrinids form spawning aggregations during certain times of the year, there should be permanent bans on fishing in areas where these spawning aggregations occur provided spatial and temporal permancence can be demonstrated. Furthermore lethrinid fisheries or the sale of lethrinid species could be closed/ banned during their spawning season(s) (SPC, 2011).

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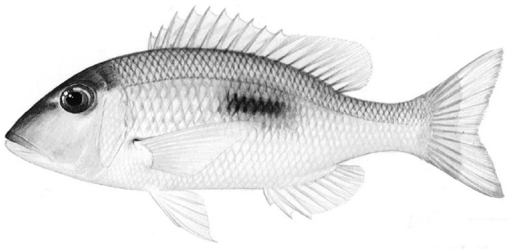
22 THUMBPRINT EMPEROR



22.1 The Resource

Species status: Kabatia (thumb-print emperor − *Lethrinus harak*) is one of the most common species of lethrinids marketed in Fiji. Production values listed in Table 26 are likely well below the actual levels as a substantial quantity of **kabatia** is utilised at the subsistence level throughout Fiji. There are several other species with 'thumb-prints' that are also called **kabatia**, however *L. harak* is the main species.

Distribution: Indian Ocean and West Pacific, including the Red Sea, East Africa, Seychelles, Maldives, Sri Lanka, Andamans, Indonesia, the Philippines, southern Japan, northeast Australia, Papua New Guinea, the Caroline Islands, to Fiji and Samoa (Carpenter and Niem, 2001). In Fiji **kabatia** is widespread and can be found in shallow sandy, coral rubble, mangrove, lagoon, channel, and seagrass areas inshore and adjacent to coral reefs.

Biology and Ecology: Kabiati are often observed in small schools though larger individuals can be solitary in nature, and are closely associated with reef flat, seagrass, and mangrove habitats. As juveniles **kabatia** inhabit mangrove habitats eventually moving into deeper waters further from the coast as adults, having a restricted home range and exhibiting high levels of site fidelity. Lethrinids in general are bottom-feeding fish that eat sea snails, crabs, sea urchins, worms, and many other animals that live on the sea floor. Some larger species also feed on other fish (SPC, 2011). A study of **kabatia** in Suva Lagoon found the largest components of the species' diet (in descending order) were echinoderms, crustaceans, gastropods, and bivalves (Lasi, 2003).

Descriptions of the early juvenile colour patterns of several lethrinids from the Great Barrier Reef, Australia can be found in Wilson (1998). Juveniles of **kabatia** (<9 cm) are closely associated with seagrass and mangrove habitats, and can be found in high abundance (relative to other lethrinids) on the inner and mid-shelfs of reefs (Wilson, 1998). Mangrove habitats play a predominant role in the early life of **kabatia** – a study in Tanzania found that 82% of adult **kabatia** had spent their juvenile stages in mangroves (Kimirei *et al*., 2013). During this phase, **kabatia** are likely opportunistic bottom feeders.

The species are protogynous hermaphrodites; females reach sexual maturity at 1−2 years and transition to males beginning at age 3 or 4 (Ebisawa and Ozawa, 2009). Length at 50% maturity (L_{50}) for female **kabatia** in Guam is 21 cm (Taylor and McIlwan, 2012), whereas in Fiji it is 24 cm based on TL (Lasi, 2003), and L_{95} is 29cm (Prince *et al.*, 2018). A study of **kabatia** from the Suva Lagoon found no significant seasonal pattern in spawning, and it therefore assumed **kabatia** in Fiji spawn throughout the year (Lasi, 2003). Although lunar patterns are not known for Fiji, **kabatia** in Guam have been documented making "nightly spawning migrations between full moon and last quarter of each lunar cycle, coinciding with a strong ebbing tide" (Taylor and Mills, 2013)

Kabatia grow to a maximum TL of approximately 50 cm, however, they are most commonly seen between 20–30 cm (Carpenter and Niem, 2001). The maximum reported age for this species is 15 years (Carpenter and Allen, 1989), though Lasi (2003) records 12 years as the maximum age in Suva Lagoon. **Kabatia** generally have high site fidelity and small home ranges, their home range expanding with increasing body size. The species have also been observed making nightly spawning migrations (Taylor and Mills, 2013).

22.2 The Fishery

Kabatia was the most targeted species of finfish by villagers in Nagigi in Vanua Levu, and is generally highly sought after throughout Fiji (Golden *et al*., 2014). The species is caught mostly by shore seine, gill nets, and handline. Women in Fijian communities tend to make up the majority of fishers targeting **kabatia**.

Production and Marketing: Kabatia are predominantly marketed as fresh whole fish, often tied into bundles of a varying number of fish of the same species − the smaller the fish the more individuals in a bundle. According to Fisheries Division Annual Reports in 1995, 101.68 mt of **kabatia** were sold in Fiji, of which 75% was through non-municipal market outlets (Anon., 1996). By 2002 this figure had risen to 205.69 mt with only 12% through non-municipal market outlets, and in 2003 to 169.81 mt (26%), and 2004 to 177.19 mt (43%) (Anon., 2003−2005). The market value of **kabatia** has nearly doubled from FJD 3.73 in 1995 to FJD 7.18 per kg in 2016 (Anon., 1996; Ministry of Fisheries, *unpubl. data*).

Exports: No available records; if exported, likely in small quantities for personal use or gifts.

22.3 Stock status

There is general consensus that stocks of **kabatia** in Fiji are overfished and that a large portion of the catch is now immature (USP, 2009; Gillett, 2014; Golden *et al*., 2014). There are an increasing number of women targeting juvenile **kabatia** from mangrove forests and adjacent mudflats, as well as on coral reefs (Thomas *et al*., 2020). This is further supported by a study by Prince *et al.* (2019) that found the spawning potential ratio for **kabatia** was 10%. Below 20% SPR the supply of young fish to the population is expected to decline over the succeeding years, while 10% SPR is commonly called 'SPR crash', below which populations are likely to decline rapidly and, if not corrected, is likely to result in local extinction.

22.4 Management

Current Legislation and Policies Regulating Exploitation: Relevant policy/legislation regarding **kabatia** fisheries are contained within the Fisheries Act. In summary, a minimum size limit of 15 cm applies to **kabatia**, and the use of nets is regulated as outlined in Profile 21 (section 21.4) EMPERORS.

Management Recommendations: Based on studies of **kabatia** in Fiji, a minimum size limit of 25 cm FL is recommended (WWF, 2017; Prince *et al*. 2018). A minimum size limit based on the L_{50} but several centimetres less should allow enough of the female population to transition into males, theoretically avoiding the issue of significant reductions in the number of males through size selective fishing mortality. On the other hand, a maximum size limit would protect the largest and oldest **kabatia** females, which make a disproportionately large contribution to spawning − ovary weight and FL relationship becomes curvilinear (Taylor and McIlwain, 2010).

Ideally, the use of nets to catch **kabatia** should be severely regulated or completely banned, as this method is unselective and offers no protection to small, immature **kabatia**. However, such a ban would be difficult to enforce and therefore the use of and enforcement of size restrictions is urged. Strong enforcement of the current policy and legislation is required to protect **kabatia** stocks.

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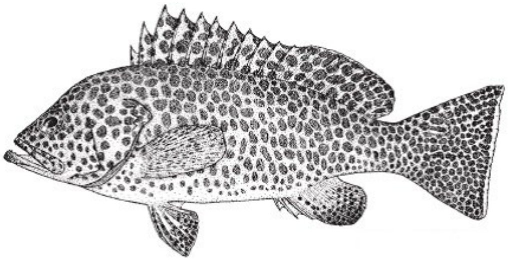
23 GROUPERS



23.1 The Resource

Species Present: Groupers (**kawakawa** – *Epinephelus* spp.) and trout/coral groupers (**donu** – *Plectropomus* spp.) belonging to the Family Epinephelidae (formerly Serranidae) are high-value food fishes and very important commercially in Fiji, and globally. The high market demand for, and commercial use of medium to large size species (Table 26) has put intense fishing pressure on many species leading to population declines. The smaller, mainly *Cephalopholis* but also some *Epinephelus* species are important subsistence species. In Fiji, there are about 25–30 grouper species taken in the commercial and subsistence fisheries, with about 10 commonly taken. However, given morphological similarities among a number of species and a range of different names applied to some species (Table 26), there is some confusion over the exact number of species. Examples include *Plectropomus maculatus*, sometimes recorded even though the species is not known to occur in Fiji, and it is very likely that this is the similar *P. areolatus* which is not listed in the same surveys, but is relatively common in Fiji. Likewise, *E. tukula* and *E. bontoides* are unlikely to occur in Fiji, although they are sometimes listed as present. *E. tauvina* is widely mis-identified and is mainly disregarded today in any species lists. In addition, when comparing species lists, attention needs to be paid to changes in species names. For example, *E. polyphekadion* was, until very recently, referred to as *E. microdon* (Craig *et al*., 2011).

Table 26. Species reported in in Fiji from market surveys and underwater surveys. Size/age of sexual maturation and maximum size/age are provided where known. IUCN global conservation status is indicated as threatened (T), near-threatened (NT), least concern (LC) or data deficient (DD) (IUCN Red List[19]; Craig *et al*., 2011). Size of sexual maturation/transition and maximum length/age are from the best available information, and may not exactly reflect growth and size parametres in Fiji due to regional variations (with the exception of local data from Prince (2017) and Prince *et al*., (2018), (2019)). SL=standard length; TL=total length; FL=fork length. L_{50}=size when 50% of fish are adults or reached size at maturity

Common name	Scientific name	Fijian name	Size (age) of sexual maturation/ transition (cm)	Max. length (cm)	IUCN
camouflage grouper	*E. polyphekadion***	**kasala, kawakawa, kerakera, votoqa.**	L_{50}=42.9 TL, L_{95}=50.0 TL	90 SL	NT
brown-marbled grouper	*E. fuscoguttatus***+	**delabulewa**	L_{50}= 59.2 TL, L_{95} = 69.0 TL; sex change at 68 TL	120 TL	NT
speckled blue grouper	*E. cyanopodus***+	**revua, rogoceva**	32 TL (female) 52 TL (male)	120 TL	LC
white-spotted grouper	*E. coeruleopunctatus*	**soisoi, kasala, seilagi, kasalatuiloa**	32 TL (female) 35 TL (male)	76 TL	LC
Malabar grouper	*E. malabaricus***	**soisoi, votosiga moala, kavu ni cakau**	45–50 TL	150 TL	NT
green/ orangespotted grouper	*E. coioides***+	**kawakawa-ni-tiki**	L_{50}=58.5 TL, , L_{95}=70.0 TL; 2–3 yrs	114 TL/ 22 yrs	NT

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Common name	Scientific name	Fijian name	Size (age) of sexual maturation/ transition (cm)	Max. length (cm)	IUCN
giant grouper	*E. lanceolatus***	**kavu**	129 TL	270 TL	VU
honeycomb grouper	*E. merra*+	**senikawakawa**		32 TL	LC
highfin grouper	*E. maculatus*	**kasala-votose**	L_{50}=39.7 TL, L_{95}=48.0 TL Lives at least 8 yrs	60.5 TL	LC
squaretail coral grouper	*P. areolatus***	**donu, batisai, donuvolavola**	L_{50}=43.5 TL, L_{95}=52.0 TL	73 TL	VU
leopard coral grouper	*P. leopardus***+	**donu, droudrou, donu damu**	L_{50}=43.8 TL, L_{95}=54.0 TL 14–19 years	120 TL	NT
black-saddled coral grouper	*P. laevis***+ (*small aggregations*)	**donuloa, donu tuimuri, loia, lola**	L_{50}=49.8 TL, L_{95}=67.5 TL 3 yrs; sex change at 8 yrs	130 TL	VU
yellow-edged lyretail	*Variola louti*	**varavaranitoga**	L_{50}=35 TL, L_{95}=42.0 TL	81 FL/ >15 yrs	LC
peacock grouper	*Cephalopholis argus*	**kawakawaloa, kialo, tikilo**	28–40 TL*	50 TL/14–40 yrs	LC
tomato hind	*C. sonnerati*	**kialo sedamu, varavarasedamu**	30 SL	57 TL	LC
tailstriped hind	*C. urodeta*	**kialo buisea, kialo ni daveta**	17 TL	28 TL	LC
coral hind	*C. miniata*	**kialo ni cakau, kasala selagi**	25 TL	45 TL	LC

Mainly deepwater species	Species that need confirmation
C. aurantia	*Cromileptes altivelis** *(rare; eastern and southern Fiji?)*
C. igarashiensis	*C. leopardus*
C. sexmaculata	*E. bontoides*
E. morrhua	*P. maculatus*
E. miliaris	*E. tukula*
E. magniscuttis	*Gracila albomarginata*
Saloptia powelli	*V. albimarginata*
Hyporthodus octofasciatus	

* FishBase (Froese and Pauly, 2017)
**Species that aggregate to spawn
+ Species that undergo sex change

Distribution: All of the groupers commonly taken in Fiji have a broad geographic distribution in the Indo-Pacific region; none are endemic to Fiji and most are widely distributed around the islands. Species differ in their primary habitats and movement patterns, as well as, in some cases, according to size classes.

Biology and Ecology: Groupers are predatory, reef-associated fishes ranging in maximum size, which in Fiji ranges from about 30 cm to about 2 m. They occur from shallow waters, including coral reefs and mangrove areas, to coastal lagoons, reef margins, channels, patch reefs, and outer reef slopes (Craig *et al*., 2011). The biology of groupers makes most species more vulnerable to overfishing than most other reef fishes (Sadovy de Mitcheson *et al*., 2013). Compared to many other reef fishes, most groupers have a relatively long life (up to several decades), and some can take almost 10 years to mature. These characteristics alone make them easier to overfish than many other species in the coral reef ecosystem because their populations have a relative low replacement rate (low productivity). In addition, some species change their sex, from female to male, as they grow and some reproduce by forming short-term seasonally specific spawning aggregations over a few weeks in one or several months of the year. Once discovered, it is very easy to wipe these aggregations out, as observed in the case of Mali passage in northern Vanua Levu.

Two species are used to characterise the two major grouper genera – *Plectropomus* and *Epinephelus* species (Sadovy and Colin, 2012). The leopard coral grouper, *P. leopardus,* is a relatively common grouper and faster growing and shorter-lived than most *Epinephelus* species. As such it can tolerate higher fishing pressure. It aggregates to spawn in multiple small brief aggregations each year which are consistent in time and locations. *P. areolatus*, by contrast has an aggregating habit more like that of *E. polyphekadion*. Juveniles feed on benthic crustaceans and adults are piscivorous. Like many groupers the species is a protogynous (female to male) sex-changing species; it changes sex at around seven years of age. Unlike most other aggregating groupers adults probably do not travel far from their resident reef to the spawning area. The species is considered to be Near Threatened globally because of marked declines in its fisheries in many areas. This species is favoured by Chinese consumers and fetches particularly high prices in this market.

The camouflage grouper, *E. polyphekadion* is representative of medium and larger members of the genus and is found in coral-rich areas, feeding on crustaceans, fishes and molluscs. It can live up to several decades and takes many years to become sexually mature. Spawning occurs in large (100s to 1,000s of individuals) aggregations that form at regular but few locations around outer reef channels. Such aggregations form over about 10 days leading up to the full moon period in Fiji with spawning at the full moon after which the fish quickly leave the site. Timing of spawning varies somewhat around Fiji but occurs for 1 or 2 months each year in each spawning site between June−October in most areas (Fox *et al*., 2012). The species is easy to catch in these large predictable aggregations and is very vulnerable to fishing, especially night-time fishing using SCUBA; most of the annual catch is taken at this time. Because of overfishing of its aggregations in many places, the species is listed as Near Threatened globally on the IUCN Red List; its aggregations have been declining around Fiji for many years due to overfishing.

Groupers produce pelagic eggs and larvae which settle out of the plankton 1 to 2 months after spawning. The distance from spawning to settlement is not known for Fijian groupers and larvae could settle close to where they have been produced or many kilometres away. The tiny fish settle into reef or mangrove areas, according to the species, and are often quite secretive or cryptic, so are not often seen. As they grow larger, they may move into deeper waters, the lagoon, outer reefs, reef channels or, for some deepwater species, to outer drop-off areas down to several hundred metres (Craig *et al*., 2011). Understanding these patterns is important for management considerations since their life history may depend on extensive reef areas over time. Adults of all species studied to date tend to establish home range areas where they spend much of their life sheltering and feeding. The exception to this is for some of the larger groupers that aggregate to spawn (reproduce) each year requiring them to undergo seasonal migrations of many kilometres from their home reefs to their spawning areas; these usually occur along outer reefs and reef channels. An individual *E. polyphekadion* that was tagged at Naiqoro Passage in Kadavu Island, was found to move at least 15 km away from the seasonal spawning aggregation site before it was caught (Sadovy de Mitcheson, 2011).

23.2 The Fishery

In Fiji waters groupers are mainly taken by hook and line (shallow and deep-water species) and by spear gun during both day and night; in some areas like northern Vanua Levu spear is used illegally with UBA. Occasionally trolling is used. Smaller groupers and juveniles might also be taken by several gears used in shallower inshore waters particularly gillnets. Seasonal spawning migrations of several species (Table 26) are well-known to local fishermen, who make, or once made, good catches at these times. Grouper flesh is firm and of excellent flavour. Chinese are the main buyer for *P. leopardus* and *E. fuscoguttatus* while Indo-Fijians prefer *E. polyphekadion*. The main targeted species is plate-sized chilled *P. leopardus* for the Chinese market, both domestic and export, with smaller species (like *E. merra* and *Cephalopholis* spp.) or individuals of larger species more commonly retained for subsistence.

Production and Marketing: Data on annual national grouper landings have not been collected in recent decades although there are several different sources of information that can be used to indicate the order of magnitude of the catches. Partial information comes from market data in 2014, 2015, and 2016 collected from retail outlets between Suva and Nausori, which recorded annual sales of **donu** and **kawakawa** of 33.23−45.44 mt in the Central Division (Ministry of Fisheries, 2017). Given that the substantial volumes of grouper are taken in other Divisions, especially the Northern Division, and the outlet data do not include direct sales from fishers to the service industry, exports, subsistence use, or deepwater groupers (see Profile 34 DEEPWATER BOTTOM FISH). National grouper landings must therefore be substantially higher than these reported volumes. Several studies conducted over the last decade can be integrated to provide indications of the relative importance of groupers in catches and markets and this information used to provide an estimate of grouper production.

One of the most thorough recent assessments of Fiji's coastal fishery (artisanal and subsistence) is that of Starkhouse (2009), who estimated total artisanal and subsistence coastal finfish (these did not include exports) at 6,401 mt and 10,405 mt respectively. Market data collected by Fiji's fishery officers in 2016 and 2015 from the Western Division reported groupers to be 5–6% by weight of all marketed fish. Surveys conducted between 2010 and 2013 on fisher catches (3,433 fish sampled in Nakodu, Tuatua, Kiobo communities) and market sales (2,929 fish sampled over 7 months from Suva, Laqere and Bailey Bridge markets) showed that 5.8% of village catches and 10% of market sales were groupers (by number of fish) (WCS, *unpubl. data*). These studies suggest that the relative importance of groupers in coastal artisanal and subsistence catches is between 5−10%. Using the conservative value of 5% groupers as a proportion of all catches and applying the artisanal and subsistence figures of Starkhouse (2009) suggests that as much as 600−800 mt of grouper could be landed annually (i.e. 16,806 mt x 5%), not including exports or deepwater species. Using an approximate market price of USD 5−10 per kg (see below; price varies according to destination) suggests that groupers could be worth (gross value) in excess of USD 4 million.

Groupers are 'Grade A Fish' (of three market grades in Fiji), the top grade in terms of value, and are subject to heavy and growing demand. According to semi-structured interviews conducted in 2016−2017 (Ministry of Fisheries and SCRFA, *unpubl. data)* prices paid directly to fishers by middlemen in recent years were FJD 6–8 per kg, to middlemen or fishers selling directly at markets FJD 11−22 per kg, and at export, hotels and restaurants for FJD 18−22 per kg. These are top prices for fishes in Fiji and reflect both declining availability and high market demand. Fishers were typically paid the same whether the fish were exported or sold domestically. **Donu** is priced more highly than **kawakawa**. Interviewees indicated that many Fijians can no longer eat grouper because of the price, and middlemen reported that availability of grouper was increasingly limited. Increasing demand is also coming from restaurants and hotels (both domestically and driving export trade) that have specific preferences for certain fish species and sizes, the latter typically from 20−35 cm. These sizes are close to or below the size of sexual maturation of many species (Table 26).

Exports: The Fiji Customs Department classification system for fish categories is not informative (e.g. broad categoies used such as "other dried fish" and "fish fillet fresh or chilled") and there is misclassification (e.g. "trout live", 'salmonids' or "other flat fish") which means that specific coastal fish taxa are poorly recorded. While data from the Minsitry of Fisheries's export permit system showed live rock, ornamental fish, and beche-de-mer are significant exported coastal fishery commodities (Gillett *et al*., 2014), reef fish exports appear in very low numbers due to poor record keeping. For example*,* in 2014 the export database of the Fiji Fishery Department indicated that less than 18 mt of reef fish (211 kg of fish steak + 17,420 kg [reef fish]) were exported; according to interviews these are likely to include mostly grouper, emperors, snappers and possibly parrotfish. Exports of almost all categories of coastal fisheries products have increased in the period 2007–2013 (Anon., 2014).

Yet, other data suggest much higher export volumes for groupers than reported above. Frozen/chilled groupers were exported to the USA in quantities up to 17 mt annually in the late 1990s and early 2000s when this trade ceased according to USA import figures (NMFS, 2014); these were likely to be deepwater species (Stone, 2005). Over a similar time period, the export trade in live reef fishes for the luxury seafood market in Hong Kong and mainland China was introduced, mainly focusing on shallow-water groupers of the genera *Plectropomus* and *Epinephelus* (Ovasisi 2006), but was stopped in the early 2000s. Maximum annual reported exports of live groupers were 21 mt in 2003, with 1−2 tonnes of groupers sold weekly (52−104 mt annually) – but not all exported – from Bua Province alone (Yeeting *et al*., 2001).

While the live grouper export trade was stopped due to concerns about overfishing, in recent years exports of frozen/chilled groupers have been growing (Y. Sadovy, *unpubl. data*), Semi-structured interviews in 2016−2017 (Ministry of Fisheries and SCRFA, *unpubl. data*) with the five known exporters suggest that about 70 mt is exported annually, mainly to Hong Kong (where frozen/chilled fish has become more acceptable and is fetching higher prices), and also to South Korea, the USA and New Zealand among other destinations. These exports are not comprehensively reported to or recorded by the government according to the interviews. For example, independent data from one major exporter strongly suggest seasonal patterns of exports highlighting the practice of targeting seasonally occurring spawning aggregations when large numbers of several grouper species become readily available (Fox *et al*., 2012; Sadovy de Mitcheson and Ramoica, 2015).

23.3 Stock Status

There have never been any national level stock assessments for groupers. Over the last 15 years several studies and analyses have shed some light onto the changing status of Fiji's grouper stocks. Studies have included underwater visual census, fisher interviews and catch surveys, market surveys as well as field studies on specific spawning aggregations. Collectively and consistently, these studies indicate declines in catches and catch per unit effort, reduced sizes marketed, shifts in dominant species marketed, and a general erosion of spawning potential in more heavily fished areas. The results confirm that Fiji is facing a crisis of sustainability in groupers and stands to lose significant food security and economic benefits from this valuable resource, with the possibility of local extinctions of some species in all but the more remote parts of the country, unless action is taken soon.

Northern Vanua Levu is a particularly important source of groupers in Fiji and several studies clearly show declines in some species. A detailed assessment was conducted in 2016 to examine the Spawning Potential Ratio (SPR)[20] of *E. polyphekadion* and *P. areolatus* in Macuata Province*.* Consistent with villager impressions, the results of the rigorous assessments, based on fish length measurements, showed that these species were being fished heavily, at about 4–5 times the level that would maximise their sustainable yields (Prince, 2017; Prince *et al*. 2019). Prince *et al*., (2019) found spawning potentials were below the 20% minimum SPR that would stabilise the populations of: *Epinephelus coeruleopunctatus* (SPR=7%), *E. coicoides* (SPR=4%), *E. fuscoguttatus* (SPR=14%), *E. maculatus* (SPR=4%), *E. polyphekadion* (SPR=3%), *P. areolatus* (SPR=5%), *P. laevis* (SPR=18%), *P. leopardus* (SPR=17%). Without management these numbers are set to decline further (Prince *et al*., 2019, 2017). Community members in the study villages noted that these species had become

20 The metric of reproduction assessed is called spawning potential (SPR) is a measure of reproduction based on the concept that without fishing a fish population can complete 100% of its natural potential for spawning. Fishing, however, reduces a population's SPR, because on average fish get caught before completing their natural life span. From comparative studies, we know that down to around 30% of SPR, fish populations retain the ability to rebound from fishing and rebuild populations to the carrying capacity of the reef. Around 20% of SPR populations have the ability to stabilise but not rebuild. Below this level, long-term ongoing decline to local extinction is expected (Prince, 2017)

rare and few catches are made during the daytime, and that spawning aggregations had either declined or stopped altogether (Prince, 2017). These findings are consistent with a 2015 interview survey focused on the outer reefs of northern Vanua Levu where spawning aggregations of several groupers were found to be declining and at least one historically important site, at Mali Passage, is no longer viable (Sadovy, 2006; Sadovy de Mitcheson and Ramoica, 2015).

The only other stock assessment on groupers was also in the Northern Division, conducted in response to concerns over high pressure by traders in the late 1990s and early 2000s to export live groupers to Asia, particularly to Hong Kong (see Profile 32 LIVE REEF FOOD FISH). Concerns that exports were exceeding sustainable yields of particularly favoured species led to cessation of the live fish fishery in the early 2000s (Yeeting *et al*., 2001; Sadovy, 2006). By 2008 the live reef fish food trade (LRFFT) was operating in just one village in Bua Province with about 25 fishers involved (Teh *et al*., 2009). Attempts were made to manage this fishery but there was concern that spawning aggregations of *Plectropomus* spp. were being targeted and that catches were declining (Yeeting *et al*., 2001; Teh *et al*., 2009). Moreover, calculations of standing grouper stock from underwater censuses indicated that catches were already too high to be sustained by natural rates of productivity (Yeeting *et al*., 2001).

In terms of importance in coastal finfish catches over three decades or so, groupers have apparently declined, possibly by 2−3 fold (as percentage of total catch) as determined by reviewing five independent surveys:

1. In a fishery report covering the period 1986–1992, annual 'Rock cod' (= *Epinephelus* species according to the report) landings in the artisanal (commercial use only) fishery ranged from 302–601 mt and made up about 15% of the 6 most important landed coastal finfish taxa (by weight) (Richards, 1994).

2. In a 1996 publication, Serranidae comprised 12.6% of catch in Fiji, more than elsewhere in Pacific (of 14 countries studied), and was the third most important coastal fish taxon landed in Fiji (Dalzell *et al*., 1996).

3. In fisher catch surveys conducted between 2002 and 2009 Friedman *et al*. (2010) reported groupers to average 9.8% from catches in four communities around Fiji (Dromuna, Muaivuso, Mali and Lakeba), with underwater surveys recording smaller groupers with average sizes 20−30 cm total length.

4. In 2008−2009 groupers represented about 5.7% of the 2,802 catches (by weight) surveyed in 46 villages across 10 provinces and was the seventh most important taxon taken, estimated from USP (2009).

5. Surveys by Fiji fisheries officers in the Western division recorded that groupers comprised 6–8% of all fish surveyed (by weight) in 2015 and 2016 (Ministry of Fisheries, *unpubl. data*).

Indications of declining grouper catch rates (catch per trip) are evident from several hundred fisher interviews conducted between 2003 and 2015 around Fiji focusing on coastal reef fisheries in general and on groupers in particular (Ministry of Fisheries and SCRFA, *unpubl. data*). The interviews addressed current and past remembered reef fish and grouper catches and showed that, in historically more heavily fished areas like Viti Levu and the Yasawas, groupers were much scarcer in catches than previously observed. Echoing these findings, there was little evidence of grouper spawning aggregations in these areas, suggesting that these had largely disappeared (a clear sign of overfishing). In northern Vanua Levu and Vanuabalavu in the Lau group, while groupers were still caught, spawning aggregation catches were declining, with the exception of recently discovered sites where fishing efforts have been intensifying in recent years, especially northern Vanua Levu (Sadovy 2006; Kuridrani. 2008; SCRFA/Fiji Fisheries Dept. *unpubl. data* 2003−2005, 2016−2017; Sadovy de Mitcheson and Ramoica, 2015).

Field surveys and interviews in Kadavu and northern Vanua Levu were used to study several aggregation sites with a long history of fishing. These studies showed declining catches of *E. polyphekadion*, *P. areolatus* and *E. fuscoguttatus*, with one aggregation at Mali Passage evidently no longer viable. Naiqoro Passage, an aggregation site in Kadavu had much reduced numbers compared to past experiences of local fishers (Sadovy de Mitcheson, 2011; Sadovy de Mitcheson and Ramoica, 2015; SCRFA database[21]).

21 http://www.scrfa.org/database/

23.4 Management

Current Legislation and Polices Regulating Exploitation: In addition to possible protection gained in no-take marine protected areas, groupers have a minimum legal size of 25 cm TL (Fisheries Act Cap 158). There are several measures being proposed that will contribute towards reducing pressures and assisting recovery if they can be effectively enforced: (i) the Minstry of Fisheries is considering protecting several aggregating grouper species during their annual spawning season from June–September; (ii) the protection of key aggregation sites (e.g. Naiqoro Passage, eastern Kadavu;) (iii) updating the size limits for reef fish species like groupers for Fiji, based on new research being conducted on the size at maturity.

Management Recommendations: Several measures are needed to stem loss of spawning stock biomass, reduce declines and promote recovery:

- The minimum size of catches and commercial use (including exports) should be increased to protect the size of maturity of different species (Prince *et al.*, 2018);
- The spawning aggregations of *E. polyphekadion, E. fuscoguttatus, E. cyanopodus, P. areolatus* and *P. leopardus* should be protected by seasonal and/or spatial measures during the reproductive season to allow these species to spawn as soon as possible, and at all times, without exception; this measure appears to have considerable support – as seen through the 4FJ campaign[22];
- Assessments of the stocks of major grouper species and those of particular concern should be conducted, most notably for *E. polyphekadion, E. fuscoguttatus, E. cyanopodus, E. merra, P. areolatus* and *P. leopardus*. While formal stock assessments would be challenging, evaluations based on simple techniques would contribute to a better understanding of key species;
- Domestic trade should be documented to species level for the main groupers of interest in all Fisheries Divisions;
- The results of these assessments could be used to develop a National Management Plan for Groupers to determine exploitation policy for this species;
- Exports of grouper should be stopped or tightly controlled until it can be determined what export level is sustainable. An appropriate export code is needed for 'groupers' to better track export trade;
- Should exports continue, an export tax for groupers should be introduced to ensure greater economic benefits to Fiji;
- The use SCUBA for spearing is illegal but still occurs in parts of Fiji; the stopping of this and night-time fishing would greatly reduce illegal fishing and reduce fishing pressure;
- Training in species identification and a species guide should be issued to fishery officers collecting data on groupers given extensive and sometimes confusing use of common and scientific names; and
- Species for which there is conservation concern, such as *E. cyanopodus* should be closely monitored or put under moratorium until recovery.

22 http://www.4fj.org.fj

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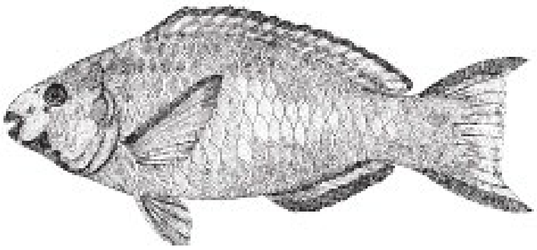
24 PARROTFISH



24.1 The Resource

Species Present: Parrotfish belonging to the family Scaridae, get their name from the parrot-like beak appearance of their teeth and their often bright colouration. The generic Fijian name for parrotfish is **ulavi**, though some communities refer to plainly coloured parrotfish as **ulavi** and colourful ones as **rawarawa** (Prince, 2017). **Ulurua** (steephead – *Chlorurus microrhinos*) is also confused with **kalia** (green humphead parrotfish as well as *Bolbometopon muricatum*) sometimes. *Cetoscarus bicolor* is known locally as **ulavidraniqai**, and *Chlorurus sordidus* is known as **karakarawa**. To avoid confusion, the common name "parrotfish" is used throughout this profile to refer to all members of the family Scaridae. Approximately 40 species of parrotfish are found throughout Fiji's waters (Froese and Pauly, 2017), though only four of these are commonly consumed (Table 27). Detailed information on **kalia** is provided in Profile 25 GREEN HUMPHEAD PARROTFISH.

Table 27. Species of parrotfish found in Fiji and their maximum total length (TL). Source: Bellwood (2001), Fishbase (Froese and Pauly, 2017)

Common name+	Scientific name	TL (cm)
green humphead, or bumphead	*Bolbometopon muricatum*	120
Carolines	*Calotomus carolinus*	54
spinytooth	*Calotomus spinidens*	30
bicolour	*Cetoscarus bicolor**	90
spotted	*Cetoscarus ocellatus*	80
Bleeker's	*Chlorurus bleekeri*	49
Indian	*Chlorurus capistratoides*	40
Pacific slopehead	*Chlorurus frontalis*	50
heavybeak	*Chlorurus gibbus*	70
palecheek	*Chlorurus japanensis*	31
steephead	*Chlorurus microrhinos**	70
knothead	*Chlorurus oedema*	42
daisy	*Chlorurus sordidus**	40
steephead	*Chlorurus strongylocephalus*	70
candelamoa	*Hipposcarus harid*	75
Pacific longnose	*Hipposcarus longiceps*	60
marbled	*Leptoscarus vaigiensis*	35
filament-finned	*Scarus altipinnis*	60
chameleon	*Scarus chameleon*	31
yellowbarred	*Scarus dimidiatus*	40
sicklefin	*Scarus falcipinnis*	60
rusty	*Scarus ferrugineus*	41

Common name+	Scientific name	TL (cm)
festive	*Scarus festivus*	45
yellowfin	*Scarus flavipectoralis*	40
Forsten's	*Scarus forsteni*	55
bridled	*Scarus frenatus*	47
blue-barred	*Scarus ghobban*	90
globehead	*Scarus globiceps*	45
highfin	*Scarus longipinnis*	40
dusky	*Scarus niger*	40
darkcapped	*Scarus oviceps*	35
common	*Scarus psittacus*	34
Quoy's	*Scarus quoyi*	40
rivulated	*Scarus rivulatus*	40
ember	*Scarus rubroviolaceus*	70
fivesaddle	*Scarus scaber*	37
yellowband	*Scarus schlegeli*	40
greensnout	*Scarus spinus*	30
tricolour	*Scarus tricolor*	26
roundhead	*Scarus viridifucatus*	45
red	*Scarus xanthopleura*	54

+ Each common name is always followed by "parrotfish", for simplicity this has been omitted from the list of common names above.
* Commonly taken as food fish (SPC, 2008a)

Distribution: Parrotfish occur throughout the tropical waters of the world's oceans. They are found on or in the vicinity of coral reefs, and are most abundant in shallow waters to a depth of 30 m (Bellwood, 2001). The highest diversity of parrotfish can be found in southeast Asia, within the Coral Triangle, and this diversity decreases eastward across the Pacific.

Ecology and Biology: Parrotfish are a diverse group of herbivorous reef fish. They feed by scraping algae off rocks or dead corals. The ingested material is ground into a fine slurry of sand, algae and any other degradable material ingested is consumed, the rest is excreted. Sand expelled by parrotfish contributes a substantial amount to the sand budget of reefs (Perry *et al*., 2015).

Throughout the day parrotfish are very active, but as night approaches they retreat into crevices or holes where they wrap themselves in a transparent cocoon of mucous and sleep. The mucous cocoon acts as a sort of 'mosquito net' protecting the fish from parasites (Grutter *et al*., 2011), and has been found to contain antibiotics (Videler *et al*., 1999). This cocoon has also been postulated to act as a early warning system against predators and to mask the scent of the fish from predators (Shephard, 1994; Winn and Bardach, 1956 in Videler *et al*., 1999).

Parrotfish are protogynous hermaphrodites with two distinct colour phases (Hawkins and Roberts, 2003). Almost all species of parrotfish start off as females – during this time they are often dull coloured with very simple patterns (initial phase/IP). Bellwood and Choat (1989) describe the juvenile (intermediate) phase colouration of several species of parrotfish. Later in life they change to males, and their colouration becomes more vivid (terminal phase/TP). Some species reach sexual maturity within two to three years, and live for five or six years. However, larger species are reported to grow for much longer (at least 15 years) and at a much slower rate. Some species of parrotfish form large spawning aggregations in order to reproduce, these are often on the outer reef slopes or in channels (SPC, 2011). New research from Fiji suggests the size at maturity for a number of species are as follows: *Chlorurus microrhinos* (L_{50}=37.5 cm, L_{95}=45.0 cm), *Scarus ghobban* (L_{50}=32.9 cm, L_{95}=36.0 cm), *S. globiceps* (L_{50}=27.0 cm, L_{95}=39.0 cm), *Scarus niger* (L_{50}=24.9 cm, L_{95}=28.0 cm), *S. rivulatus* (L_{50}=29.2 cm, L_{95}=34.0 cm), *S. rubroviolaceus* (L_{50}=36.9 cm, L_{95}=40.0 cm) (Prince *et al.*, 2018), *Cetoscarus ocellatus* (L_{50}=39.5 cm, L_{95}=47 cm) (Prince *et al.*, 2019).

24.2 The Fishery

Utilisation: In Fiji, parrotfish are commonly utilised at the subsistence and artisanal level (Friedman *et al*., 2009). They are a highly popular food fish, and can be consistently found throughout Fiji's municipal markets often dominating catches from distant islands (Gillett and Moy, 2006). The flesh is relatively soft and does not keep well, and therefore these fish are almost exclusively marketed fresh and whole. Parrotfish are taken by gill nets or by spear. Spearfishing is often at night when the fish are sleeping; the majority of parrotfish are taken by spearfishing (Gillett and Moy, 2006).

Production and Marketing: Parrotfish are considered a "Grade C" fish that fetches a relatively low price compared to other reef fish notably groupers (Family Serranidae) and snappers (Family Lutjanidae). Throughout Fiji parrotfish are commonly sold in bundles, the fish are strung together often with fish of the same species, these bundles weigh approximately 2−3 kg and are typically sold for FJD 25 per bundle at the Suva Municipal Market (S. Lee, *pers. obs.*). Table 28 lists the volume and value of **kalia** and **ulavi** sales in Fiji's municipal and non-municipal market outlets for the years 2003, 2004 and 2016 for the Central Division municipal market. The majority of these sales (by volume) occurred in the Northern Division, followed by the Central, and Western Divisions. A major seafood exporter in the Northern Division reported exporting 1.2 mt of parrotfish to New Zealand, where the fish are sold for about NZD 10 per kg.

Table 28. Production volume (mt) and value (FJD per kg) of **kalia** and **ulavi** sold in Fiji's municipal (MM) and non-municipal market outlets (NM). Value is provided in parentheses. Source: Anon. (2004−2005); Ministry of Fisheries (*unpubl. data*)

Species	2003		2004		2016
	NM	MM	NM	MM	MM
kalia	79.47	86.44 (4.23)	77.62	43.49 (4.11)	(na)
ulavi	77.22	55.94 (3.47)	115.51	126.63 (3.80)	(8.06)

24.3 Stock Status

In 2002, 2003, 2007, and 2009 the PROCFish programme surveyed four sites in Fiji; Mauvuso and Dromuna on Viti Levu, and Lakeba and Mali on Vanua Levu (Friedman *et al*., 2009). The survey recorded high landings of parrotfish for subsistence and artisanal/commercial purposes. A common trend for all sites was a high abundance and biomass of parrotfish, however the fish observed were all of small sizes – below L_{50}, the length at which 50% of individuals are sexually mature. The small sizes of these fish are indicative of fishing impact (Hawkins and Roberts, 2003; Friedman *et al*., 2009); a decreasing proportion of large/mature fish landings is characteristic of recruitment overfishing.

Based on length-based spawning per recruit stock assessment of fish landed in Macuata Province, Prince (2017) calculated the spawning potential ratio (SPR) of 26% for **rawarawa** (*S. rivulatus*), slightly above the replacement level of 20%. The study states that "fishing pressure is too high to be sustainable and spawning potential is declining towards the bare minimum needed just to replace the existing adults," and therefore management action should be taken immediately. Communities in Macuata also noted that larger *S. rivulatus* are becoming rare, most likely due to the overfishing of juvenile *S. rivulatus*, which the community thought was a different species (and referred to it as **ulavi**) due to the different colouration (Prince, 2017). Prince *et al.*, (2019) found an SPR of 10% for *Cetoscarus ocellatus* and for *Hipposcarus longiceps*, and an SPR of only 1% for *Scarus rivulatus*, suggesting urgent management action if required. Overall, stocks of parrotfish throughout Fiji are in decline and can be considered overfished (Gillett *et al.*, 2014). Size limits are needed for parrotfish to ensure the long-term sustainability of the fishery.

24.4 Management

Current Legislation and Policies Regulating Exploitation: The Fisheries Act (Cap. 158) indicated the minmum legal size for parrotfish (*Scarichthys* spp.) as 25 cm. The use of poisons and chemicals to stupefy fish is illegal, and as some parrotfish are taken by nets the following legislation applies:

Stretched measurement for nets

12. For the purposes of these Regulations, stretched mesh shall be measured by taking two diagonally opposing knots of the mesh of the net and drawing them apart until the remaining two knots of the mesh just touch each other.

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

The Fisheries Act gives special status to “spearing”, exempting commercial spearfishing from requiring a fishing licence, Gillett and Moy (2006) discussed this in further detail. The use of underwater breathing apparatus is banned, though exemptions can be granted by the Permanent Secretary or any person appointed by him in writing.

Restriction of the use of underwater breathing apparatus

4. (1) Subject to regulation 5, no person shall:
   (a) in any way collect, take, or dive for fish using underwater breathing apparatus;
   (b) be in possession of underwater breathing apparatus for the purpose of collecting, catching and diving for fish.
   (2) Any person who contravenes the provision of this regulation shall be liable to a fine of four hundred dollars or imprisonment for a term of six months or to both fine and imprisonment.

Management Recommendations: Minimum size limits may not be beneficial to some species of parrotfish as some species change sex from female to male as they grow. If only large individuals can legally be caught, catches will be made up almost exclusively of males leaving an excess of females in the population (SPC, 2011). Spearfishing for commercial purposes should require a fishing licence – the exemption in the Fisheries Act should be removed or at the very least revised to reflect this. The ban on use of underwater breathing apparatus to take fish should be strongly enforced. SPC (2011) recommends a ban on the following:

- Fishing during times of forming spawning aggregations;
- Fishing for parrotfish using spears at night; and
- The use of small-mesh gill nets.

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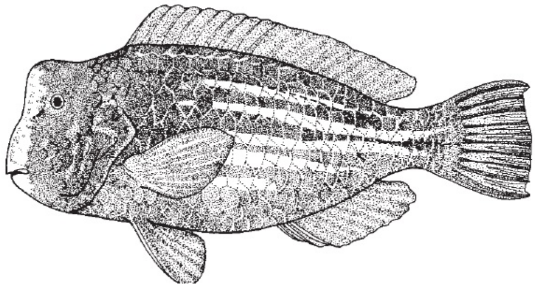
25 GREEN HUMPHEAD PARROTFISH



25.1 The Resource

Species Status: Kalia (green humphead parrotfish – *Bolbometopon muricatum*) is the largest member of the family Scaridae. Traditionally these fish received special status and were reserved for large feasts, however, they are now fished for commercial purposes.

Distribution: This species is patchily distributed throughout the tropics of the Indo-Pacific and Indian waters. Closely associated with reef systems, juveniles can be found in lagoons, while adults prefer clear outer lagoon and seaward reefs to depths of at least 30 m (Bellwood, 2001; Aswani and Hamilton, 2004).

Biology and Ecology: Kalia share many aspects of their biology and ecology with other species of parrotfish. However, they are slow growing and longlived, and play a significant role in bioerosion of carbonate reef structure (Bellwood *et al*., 2003). They have been observed to take approximately six bites per minute, with a bite volume of 1.66 cm^3; this equates to an individual **kalia** removing an estimated 2.33 m^3 or 5.69 mt of carbonate each year (Bellwood *et al*., 2003). **Kalia** feed on live coral and benthic algae; live coral is consumed in order to obtain the symbiotic algae contained within.

Based on observations of a spawning aggregation on the Great Barrier Reef, **kalia** form large spawning aggregations of about 100 individuals, with the smallest fish in the spawning aggregation being 60 cm TL (Gladstone, 1986 in Chan *et al*., 2012). In the Solomon Islands the size of maturity for **kalia** is 62 cm FL (Hamilton, 2003), and these fish are known to return to the same spawning grounds year after year (Chan *et al*., 2012). A description of **kalia** reproductive ecology by Muñoz *et al*. (2014) is paraphrased below:

Spawning activities of **kalia** occured in the morning around the full and last quarter moon, with the aggregation size peaking just prior to, and following, the full and last quarter moon, respectively. There was an observed distinct spawning break that lasted 4 days, afterwards the fish returned to the site and resumed normal spawning and courtship behaviour. The mating system was lek-based[23], with males arriving early to the spawning site and vigorously defending small territories – this defence included head-butting between large males. Females arrived later in large schools causing a substantial change to the sex ratio during the morning spawning period. Successful males paired off with females and swam into the upper water column where they would spawn. Densities at the aggregation site averaged 10 fish per ha, peaking at 52 fish per ha.

In the Solomon Islands **kalia** reportedly prefer recruitment from lagoons, suggesting areas without lagoons are unlikely to support large populations of the species (Aswani and Hamilton, 2004; Hamilton, 2004). Juveniles have a dark grey-brown colouration on their body and fins, with small brown dots on their head, dorsum and vertical finsl distinct series of pale white dots on their body in 2−3 rows of 4−5 dots (Bellwood *et al*., 1989). **Kalia** are assumed to have a wide range, however they are restricted to coral reefs, and exhibit a home-ranging behaviour within their range. These fish are commonly seen travelling in schools of up to 50 individuals during day time, and sleeping together in schools at night (Chan *et al*., 2012).

23 Males engage in competitive displays called “lekking” in order to entice visiting females

Kalia grows up to 120 cm TL, weighing over 50 kg (Hamilton, 2003). They are slow growing, with the Von Bertanlanffy Growth parameter for this species calculated as K=0.063 and L_∞=157.75 cm (Couture and Chauvet, 1994). However, this value needs to be recalculated as this was based off a maximum age of 16 years, and new information suggests this species lives up to 40 years (Hamilton, 2003). A more recent study obtained the following values; K=1.36, L_∞=694 mm based off a maximum age of 33 years (Choat and Robertson, 2001).

25.2 The Fishery

Utlisation: Historically, **kalia** were captured in daytime using **yavirau** or 'leaf drives' − a traditional method of fishing where a net of twisted coconut leaves is used like a seine net to encircle a shallow area of back reef within the lagoon. In these 'leaf drives' the fish are often driven into a fish fence/trap. Caught in the same manner as other parrotfish, they are particularly susceptible to spearfishing at night as this species tends to sleep in schools in sheltered crevices and caves (Gillett and Moy, 2006).

Production and Marketing: Fisheries Division Annual Reports show that 165.91 mt of **kalia** were sold in local markets in 2003, decreasing to 121.11 mt in 2004. Prices for this period were between FJD 4.11−4.26 per kg. The lack of production and marketing data on this species in Fiji makes it difficult to elaborate on the status of this fish since 2004. Production levels are likely very low considering this fish is now considered very rare and had not been caught since the 1990s at 12 sites in the Lau group – sites considered to be lightly exploited for Fiji.

Kalia is considered a 'Grade A' fish – unlike other species of parrotfish, which are considered 'Grade C'. As such, **kalia** fetches higher prices than other species of parrotfish. A prominent seafood exporter based in the Northern Division reported purchasing **kalia** for FJD 4.10 per kg in 2002, this price increased to FJD 7–8 per kg in 2016. A considerable amount of **kalia** taken in Fiji waters is exported to New Zealand where it is sold in slices for approximately NZD 14 per kg. An estimated 700 mt of **kalia** was exported from 2013−2016 (Ministry of Fisheries, *unpubl. data*).

Exports: Exports are allowed with the provision of a permit granted by Permanent Secretary or any person appointed by him in writing. However, it is more likely that **kalia** are mixed with other species of parrotfish and are simply mis-labelled, or generically labelled. The Fiji Revenue and Customs Service (FRCS) export data use generic categories such as "chilled fish" and "frozen fish". The Ministry of Fisheries has indicated that the chilled and frozen reef fish export industry in Fiji is growing; if **kalia** are exported they are likely included in one of these generic categories.

25.3 Stock Status

Kalia is considered locally extinct in most areas of Fiji. A survey of several islands in Fiji's Lau group (Moala, Matuku, Totoya, Kabara, Marabo, Vuaqava, Fulaga, Namuka, Komo, Oneata, Lakeba, Vanuavatu, Tuvuca, and Cicia) reports that **kalia** were previously abundant; however, at six islands the fish had not been caught since the 1990s, and at four islands **kalia** were considered rare (Dulvy and Polunin, 2004). The Lau group is relatively unexploited or lightly exploited for Fiji, and therefore **kalia** is likely to be even less abundant in other parts of the country, particularly those closer to urban centers.

25.4 Management

Current Legislation and Policies Regulating Exploitation: There is no specific legislation or policy regarding **kalia**, and the same rules for parrotfish apply to this species (see (1.24.4). **Kalia** is listed in Schedule 1 (Section 3) of the Endangered and Protected Species Act 2002, this act regulates and controls the international and domestic trade of species listed within. This species is listed as Vulnerable in the IUCN Red List of Threatened Species (Chan *et al.*, 2012).

Management Recommendations: Given the how susceptible **kalia** are to overfishing, and how few fish are found in the wild across Fiji, the commercial capture and trade of this species should be banned. Furthermore, designation and design of Marine Protected Areas (MPAs) should encompass crucial habitat for this species i.e. large lagoons, coral reefs with large forereefs, their spawning grounds, and known sleeping areas.

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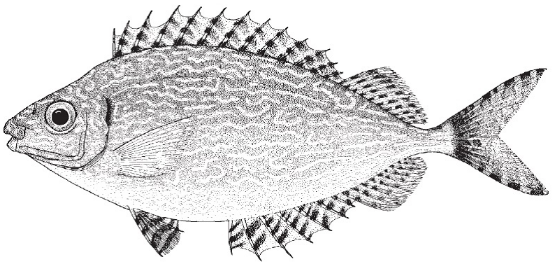
26 RABBITFISH



26.1 The Resource

Species Present: The siganid fauna of Fiji is remarkably diverse, with about 15 species in the genus *Siganus* recorded as present in Fiji waters (Woodland, 2001; Froese and Pauly, 2017), these are presented in Table 29. **Nuqa** is the generic Fijian name for siganids.

Table 29. List of *Siganus* spp. occurring in Fiji, and their Fijian names, and maximum length (cm). Source: Woodland (2001), FishBase – Froese and Pauly, 2017

Common name	Scientific name	Fijian name	Max. length (cm)
streamlined spinefoot	*Siganus argenteus*	**mulu, nuqa roro**	46
white-spotted spinefoot	*S. canaliculatus*		25
blue-spotted spinefoot	*S. corallinus**		30
barred spinefoot	*S. doliatus**	**nuqa roro**	25
mottled spinefoot	*S. fuscescens*		40
streaked spinefoot	*S. javus*		55
golden-lined spinefoot	*S. lineatus*		45
masked spinefoot	*S. puellus*		38
peppered spinefoot	*S. punctatissimus*		35
gold-spotted spinefoot	*S. punctatus**	**nuqa ni cakau**	45
little spinefoot	*S. spinus*	**nuqanuqa**	23
blotched foxface	*S. unimaculatus**		22
bicoloured foxface	*S. uspi* [1]*+	**nuqa roro**	25
vermiculated spinefoot	*S. vermiculatus*	**nuqa ni vei dogo**	45
fox-face rabbitfish	*S. vulpinus**		25

+ Endemic to Fiji
* Juveniles of this species are also harvested for the aquarium trade (Fatherree, 2013)

Distribution: Nuqa are found throughout the tropical Indo-Pacific and eastern Mediterranean, though they are invasive in the Mediterranean. They mainly inhabit inshore areas from brackish nearshore environments such as seagrass beds and mangroves through lagoons and out to the reef edge. *S. lineatus* commonly occurs around estuaries, seagrass flats, and mangroves. *S. uspi* is endemic to Fiji, though strays have been recorded from New Caledonia (Woodland, 2001).

Biology and Ecology: Nuqa are primarily herbivorous; larvae feed on zooplankton and phytoplankton. As the fish mature their feeding preference changes from finer algae during juvenile stages to coarser seaweeds and encrusting algae, and sometimes seagrasses, as adults (Woodland, 2001). Most species of **nuqa** can be found in pairs or schools, some pairs being permanent though spawning between permanently pairing species has not been recorded. The fin spines of **nuqa** contain poison glands that can inflict painful wounds (SPC, 2011). Many species of **nuqa** are brightly coloured when juvenile, some retain this colouration as the mature while others obtain a subtler camouflaged colouration. **Nuqa** are also known for changing their colouration at night or when agitated (Fatherree, 2013).

Nuqa have separate sexes and a relatively fast growth rate reaching sexual maturity within a year or two, which corresponds to a FL of approximately 15 cm. Spawning is often in large aggregations at sites with access to the open sea (SPC, 2011). The spawning months for *S. vermiculatus* and *S. spinus* are October−December fo Fiji (Sadovy, 2004). Fertilised eggs attach to the sea floor, the hatched larvae float in the sea for up to two months before metamorphosing into juveniles. Juveniles arrive at shallow seagrass beds in dense schools resembling bait balls. January in Fijian is known as **vula i nuqa levu**, translated as month when the **nuqa** arrive in great numbers (Parkinson, 1999), and this corresponds to the arrival of juvenile **nuqa** to inshore habitats. *S. vermiculatus* in Fiji is relatively well studied and its biology and life cycle are discussed in Gundermann (1983). Prince *et al.*, (2018) found the size at maturity for three species commonly found at local markets were as follows: *Siganus doliatus* (L_{50}=20.4 cm, L_{95}=22.0 cm), *S. punctatus* (L_{50}=24.1 cm, L_{95}=26.0 cm), *S. vermiculatus* (L_{50}=24.2 cm, L_{95}=27.0 cm)

26.2 The Fishery

Utilisation: Given the diurnal nature of **nuqa** (Woodland, 2001), and sheltered inshore areas they inhabit these fish are easily taken by spearfishing at night (Gillett and Moy, 2006). Gill nets and beach seines are used to catch schools of **nuqa,** smallmesh nets and cast nets are used to catch the "bait balls" of juvenile fish (SPC, 2011). **Nuqa** can also be caught by hook and line as most species will take animal bait (Woodland, 2001). Fishing **nuqa** during their spawning aggregations is a common practice in Fiji (Sadovy, 2004). **Nuqa** are an important food fish in Fijian coastal communities.

Several members of the genus *Siganus* are brilliantly coloured; most as juveniles, while some retain this colouration and pattern as adults. As such several species are targeted for the aquarium trade (Table 29). Given their herbivorous nature, fairly well documented biology and ecology, and the high abundance of juveniles during recruitment periods multiple species of **nuqa** (*S. canaliculatus*, *S. guttatus*, *S. virgatus*, *S. spinus*, *S. punctatus*, *S. fuscescens*, and *S. javus*) have been identified as potential candidates for aquaculture in the region. Several attempts have been made to culture these fish in captivity (Teitelbaum *et al*., 2009), dating back to at least 1974 in Fiji (Lichatowich and Popper, 1975). In a multispecies system sharing fish ponds with *Chanos chanos, Mugil* spp., and *Liza* spp., using chicken manure to encourage the growth of algae, *S. vermiculatus* exhibited growth rates in the range of 137−190 g in 130 days (Lichatowich and Popper, 1975). *S. vermiculatus* have spawned in captivity in Fiji, with spawning induced by injecting the fish with a synthetic hormone. However, survival rates of larvae were very low in the range of 0–9%, partly due to large temperature fluctuations in earthern ponds (Popper *et al*., 1976).

Production and Marketing: Fishing for **nuqa** happens at the subsistence and artisanal level in Fiji. **Nuqa** are considered a "Grade A" fish and usually fetches relatively high prices in the domestic market, however a large portion of the catch are for subsistence use. Fisheries Division Annual Reports show that 123 mt of **nuqa** were sold at municipal and non-municipal market outlets, for a mean value of FJD 5.14 per kg (ranging from FJD 3.66−7.83 per kg). This increased to 156 mt in 2004 sold at a mean value of FJD 4.96 per kg (ranging from FJD 3.40−6.83 per kg). The majority of these sales occurred in the Northern Division and approximately half were in non-municipal market outlets. Based off an unpublished market survey of the Central Division, the market value of **nuqa** has increased to a mean of FJD 8 per kg, interestingly the value shows no decrease during the fish's spawning season (October−December).

26.3 Stock Status

An extensive study by USP in 2008/2009 of finfishing by Fijian communities found that 43% of **nuqa** landed were below the size at first maturity (USP, 2009). The large proportion of immature fish in the landings should be taken as evidence of impaired capacity to reproduce, suggesting stocks are overexploited (Gillett *et al*., 2014).

From length-based spawning per recruit assessments of *S. vermiculatus* in the traditional fishing ground of Cokovata in Macuata Province, the population's current spawning potential ratio is approximately 31%, slightly above the replacement level of 20% required to stabilise the population (Prince, 2017). Therefore, stocks of *S. vermiculatus* in this particular area appear to be relatively healthy; however this assessment was based on a sample size of 366 fish furthermore the author cautions that the analysis is based on data collected in the last 5 years. As fishing pressure rapidly intensifies the assessment results for this species should be treated as a warning sign that management needs to act swiftly. Trends in the number of fishing licences issued per division show a rapid increase in the number of commercial fishers in the Northern Division, which is indicative of increasing fishing pressure.

Given the results of the above mentioned assessments, reports of high landings during **nuqa**'s spawning season, and habitat destruction, it is safe to presume that stocks of **nuqa** are in decline.

26.4 Management

Current Legislation and Policies Regulating Exploitation: The Fisheries Act lists the minimum legal size for **nuqa** as 20 cm. Regulation 8 of the Fisheries Act states that:

"No person shall take, stupefy or kill any fish in any lake, pool, pond, river, stream or in the sea use any of the following substances or plants: (a) any chemical or chemical compound, (b) any substance containing derris, (c) any substance containing the active principal of derris, namely rotenone, (d) any plant or extract of or derivative from any plant, belonging to the genera Barringtonia, Derris, Euphorbia, Pittosporum or Tephrosia (duva) or place any such substances or plants in water for the purpose of taking, stupefying or killing of any fish."

As **nuqa** are often taken by net the following regulations (taken from the Fisheries Act) also are applicable:

Use of nets in estuaries

7. No net other than hand nets, wading nets and cast nets shall be permitted for the purpose of taking fish in the estuary of any river or stream or in the sea within 100 m [l00 yards] of the mouth of a river or stream. *(Amended by 87 of 1979)*

Stretched measurement for nets

12. For the purposes of these Regulations, stretched mesh shall be measured by aking two diagonally opposing knots of the mesh of the net and drawing them apart until the remaining two knots of the mesh just touch each other.

Mesh of hand nets

13. The mesh of a hand net may be of any size.

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

Meshes of other nets

15. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Juvenile **nuqa** arriving to inshore habitats may be collectively grouped as "whitebait" as this term simply refers to the juveniles or fry of several fish species. Therefore, the following regulation could also apply to **nuqa**:

Nets for sardines and whitebait

16. Nets for taking sardines and whitebait may have a mesh size of not less than 30 mm [1.25 inches], wet and stretched, but their overall dimensions shall not exceed 10.5 m [35 feet] measured along the cork line and 1.5 m [5 feet] from the cork line to the ground rope. It is prohibited to join two such nets together. Such nets may not be used to take fish other than sardines or whitebait. *(Amended by 87 of 1979)*

Management Recommendations: It is suggested that there be a ban on the capture and trade of **nuqa** during the spawning months from October–December. In addition there should be education/public awareness on the unsustainable nature of fishing spawning aggregations. If the minimum size limit as per the Fisheries Act were enforced this should protect most species of **nuqa** until they are sexually mature. Action should be taken to fully protect all known spawning aggregation sites and critical habitats. SPC (2011) discusses other management measures such as banning gill nets, the use of marine protected areas, and banning night spearfishing.

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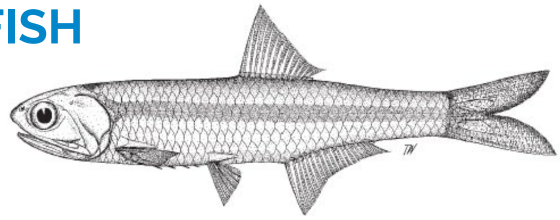
27 SMALL COASTAL PELAGIC FISH



27.1 The Resource

Species Present: The small coastal pelagic fishes of primarily lagoons and reefs are a heterogenous group not included in Profile 29 LARGE COASTAL PELAGIC FISH because of their generally smaller size (<75 cm maximum size). These smaller coastal pelagics are typically schooling species, including the large number of baitfish species utilised in the pole-and-line tuna fishery. Along with assorted small predators, and the chub or Indian mackerels, these are the main species groupings making up the category. As the pole-and-line fishery is no longer active in Fiji, the detailed information provided in the 1993 profiles is retained but considerably condensed, and the chub mackerels (**salala** - *Rastrelliger* spp.) are featured separately as an exemplar species – Profile 28 CHUB MACKEREL. Table 30 lists selected smaller coastal pelagic and baitfish species occurring in Fiji.

Garfish or half beaks, scads and mackerels comprise the medium-sized species groups in the category, and their juveniles may also contribute to baitfish catches. Other species could be added to this; for example, the large number of smaller carangids (especially *Carangoides*), midwater-feeding fusiliers (*Caesio, Pterocaesio*), coastal flying fish and others, but have not been included for the sake of brevity and clarity.

There are a variety of small pelagic schooling fishes from a number of families, which are commonly given the collective name of “baitfish” and have been used as live bait in the pole-and-line fishery. Sharma and Adams (1990) list the seven species groups which dominate the baitfish catch in Fiji (Table 30). Note that many species do not have distinct Fijian names as they are not traditionally taken or were known to Fijians.

- Sprats − blue sprats (*Spratelloides delicatulus*), with smaller quantities of silver sprats (*S. gracilis*).
- Sardinellas − spotted sardinella (*Amblygaster sirm*), with a small proportion of smooth belly sardinella (*S. clupeoides*), plus several less common species.
- Herring − gold-spot herring (*Herklotsichthys quadrimaculatus*) and the less common white herring (*Pellona ditchela).*
- Silversides − Two main species, *Atherinomorus lacunosus*, still widely known as *Pranesus pinguis*, and the more desirable *Hypoatherina ovalaua,* plus many others.
- Mackerels − *Rastrelliger kanagurta* predominates, with the more estuarine *R. brachysoma* contributing in some areas. The lesser known *R. faughni* also occurs. Cardinals − *Rhabdamia gracilis*, with smaller amounts of *R. cypselurus.*
- Anchovies − Various species dominate this grouping in different areas at different times, including *Encrasicholina heteroloba*, *E. devisi*, *E. punctifer*, *Stolephorus indicus*, and *Thryssa baelama*.

Other species, notably fusiliers (Caesionidae), weak herring (*Dussumieria* spp.), and scads (*Selar* spp., *Decapterus* spp.) also make occasional contributions to the catch.

Distribution: The coastal pelagics, as mobile species with well developed dispersal capabilities are widely distributed throughout Fiji in various coastal habitats. The selected carangids, garfish and mackerels are good examples of this. The distribution of abundant baitfish assemblages is mediated by the presence of shallow water lagoons, mostly on the north-west side of Viti Levu and Vanua Levu, and the numerous rivers and streams on the larger islands, which empty into the sea throughout the year. Although over 100 defined baiting areas were used from time to time by pole-and-line vessels, probably less than half of these were regularly visited. Access to sites may also be restricted by traditional owners from time to time, or in some cases permanently.

Table 30. Selected small coastal pelagic fishes in Fiji. Source: Lewis *et al.* (1983), (1984), (1985), FishBase, Carpenter and Niem (1998b), (1999a), (1999b), (2001a), (2001b)

Common name	Scientific name	Fijian name	Max. length (cm)
Carangidae			
bigeye scad	*Selar crumenophthalmus*		30
yellowtail scad	*Decapterus macrosoma*		35
shortfin scad	*Atule mate*		30
Hemirhamphidae			
slender garfish	*Hyporamphus dussumieri*	**busa, buse**	35
barred garfish	*Hemiramphus far*	**busa, buse**	45
Scombridae			
Indian mackerel	*Rastrelliger kanagurta*	**salala**	35
chub mackerel	*R. brachysoma*		35
slender chub mackerel	*R. faughni*		25
Selected baitfishes			
Engraulidae			
gold anchovy	*Encrasicholina devisi*		8
blue anchovy	*E. heteroloba*		9
ocean anchovy	*E. punctifer*		9
Samoan anchovy	*Stolephorus apiensis*		7
Commerson's anchovy	*S. commersonii*		10
Indian anchovy	*S. indicus*		15
little priest	*Thryssa baelama*		15
Pristigasteridae		**Vaya**	
white herring	*Pellona ditchela*		16
Clupeidae			
spotted sardinella	*Amblygaster sirm*		23
smooth belly sardinella	*A. clupeoides*		17
rainbow sardine	*Dussumieria elopsoides*		20
gold spot herring	*Herklotsichthys quadrimaculatus*	**daniva**	14
Fijian sardinella	*Sardinella fijiense*		12
blacktip sardinella	*S. melanura*		12
blue sprat	*Spratelloides delicatulus*	**caru, caca**	10
silver sprat	*S. gracilis*		10

Common name	Scientific name	Fijian name	Max. length (cm)
Atherinidae			
hardyhead	*Atherinomorus lacunosus*		11
Fiji silverside	*Hypoatherina ovalaua*		7
slender silverside	*Stenatherina temmincki*		11
Apogonidae			
flesh cardinal	*Rhabdamia cypselurus*		6
slender cardinal	*R. gracilis*		6
Caesonidae			
green fusilier	*Gymnocaesio gymnoptera*		14
banana fusilier	*Pterocaesio pisang*		21

Catch data for this large number of sites have been grouped into 8 zones (Table 31) which reflect some administrative boundaries as well as some internal consistency in habitat type (Sharma and Adams, 1990). A comparison between the two major zones: "mainland" (north and south Vanua Levu, Central Viti Levu) and "island" (Ovalau, Lomaiviti and Northern Lau) showed anchovies and mackerel to be more abundant at "mainland" sites, and sprats and cardinal fish at "island" sites, with sardines and herrings showing little spatial variation (Sharma and Adams, 1990). In 1992, the majority of the baitfish catch was made from Vanua Balavu (45.7%). The other important baitfishing sites were the islands off western Viti Levu (10.6%), Kia Islands (8.0%), Gau Island (7.5%), Beqa Island (7.6%), Ovalau Island (4.3%) and Kadavu Island (2.7%). The remainder was caught at many different locations within Fiji, but effort at each site was low (Anon., 1994).

Table 31. Characteristics of the major baitfishing zones. Source: Sharma and Adams (1990)

Zone	Characteristics	Important sites
Levuka	Deep lagoon within fringing reef with cannery nearby.	Levuka, Rukuruku, Nasova
Lomaiviti	Sheltered lagoon anchorages on lee side of islands.	Sawaike, Nawaikama (Gau), Nabuna (Koro), Namena, Makogai
Central	Mainland bays, plus the extensive Beqa lagoon.	Lami Bay, Serua, Deuba, Vaga Bay, Malumu Bay
Kadavu	Large sheltered harbours in south. Lee shore in north.	Galoa, Soso, Yaruva, Namara, Kavala
Southern Vanua Levu	Deep mainland bays.	Kabulau, Naisonisoni, Savarekareka, Vatulele, Valaga Bay (Savusavu)
Northern Vanua Levu	A large area inside the Great Sea Reef and amongst various islands.	Kia, Bekana Harbour, Mali Is. Harbour, Savusavu Bay, Cukuni Is., Udu Point, Mali Is.
Eastern Vanua Levu	Sheltered waters in lee of islands and reefs.	Qamea, Kioa, Viani Bay
Northern Lau	Vanua Balavu lagoon and smaller island lagoons.	Qilaqila, Vanuabalavu, Qelelevu, Wailagilala
Southern Lau	Island lagoons	Moala, Yagasa, Ogea, Matuku, Oneata
Western Viti Levu	Shallow bays in Viti Levu's lee	Nawala Point (Nadi), Momi Bay
Western Vanua Levu	As for Northern Vanua Levu, but access difficult	Rukuruku Bay

Biology and Ecology: The majority of baitfish species are planktivores, although scads, mackerels and the larger anchovies will feed on small fishes and crustaceans (Dalzell, 1993). They occupy a range of habitats from estuarine waters, coral reefs and lagoons to the open ocean. Tropical small pelagic fishes may be separated into three groups, based on life history parametres as shown in Table 32 (Conand, 1987; Lewis, 1990 in Dalzell, 1993). Lewis *et al.* (1983a) describe biological characteristics of the two major species of the bait fishery; *H. quadrimaculatus* and *S. delicatulus*. However, very little data on the age, growth and mortality of these species are available. Dalzell *et al*., (1987) found that *H. quadrimaculatus* and *R. gracilis* are annual species that live for 10–12 months, while *S. delicatulus* lives for only 6 months. With a short life span and high natural mortality, many of these fish will die before completing their growth. It would therefore pay to fish these species relatively hard so as to catch them before they die of natural causes (Gulland, 1983 in Dalzell, 1993). In common with other apogonids, *R. gracilis* is a mouth brooder, and is likely to have a low fecundity.

Williams and Clarke (1983) recorded **daniva** *(H. quadrimaculatus*) only in shallow water during the day, with both juveniles and adults moving into deeper waters at night where feeding occurs. In Fiji it approaches a maximum length of 13 cm. In New Caledonia waters, it is recorded as having a single spawning peak from October to November. It is sometimes severely toxic to humans in the form of clupeotoxism and has caused deaths in Fiji.

Little is known of the biology of *S. delicatulus* in Fiji. Known locally as **caru** or **caca** in some areas, blue sprats occur in small schools, usually in clear, deep lagoon waters. The species attains 7 cm in length and its maximum life expectancy is about 6 months (Sharma and Adams, 1990). Lewis *et al,* (1983) suggest this species has a protracted spawning period between October and June, and possibly throughout the year.

27.2 The Fishery

Utilisation: The many species of Fiji's baitfish resources are variously utilised by subsistence, artisanal and commercial fisheries. Pole-and-line tuna vessels, which undertook the vast majority of commercial skipjack tuna (*Katsuwonus pelamis*) fishing in Fiji, relied on adequate supplies of live bait to stimulate the feeding behaviour which results in tuna biting feather lures. Species such as *Rastrelliger* spp. are important in the artisanal fishery, while several species are utilised by traditional fisheries. As noted, many of the baitfish species do not have Recognised Fijian names and are not utilised on a subsistence basis (Sharma and Adams, 1990).

In the commercial fishery, the bait is usually captured at night in shallow coastal waters using the *bouke-ami* method. The catch consists mainly of very small fish with large numbers of juveniles of some species. Baitfish are attracted to the vicinity of the boat by submerged and overhead lights, which are then scooped by nets and then placed in a bucket, before being transferred alive to onboard bait tanks, ready for use in fishing. Most vessels prefer to catch bait late at night, to begin tuna fishing at dawn, due to the high rate of baitfish mortality in bait tanks (Sharma and Adams, 1990).

The Fiji pole-and-line fishery gradually declined for economic reasons during the 1990s, with the Ika Corporation fleet ceasing operations in 1997. One or two privately-owned vessels continued operations until 2001, when the fishery finally wound up (Gillett, 2011). Despite strong demand for pole-and-line fish in the international market place, the fishery is unlikely to resume.

Table 32. Biological characteristics of tropical small pelagic fishes. Source: Dalzell (1993)

Type	Length of life cycle	Maximum length (cm)	Time to sexual maturity	Spawning period	Batch fecundity (number of oocytes per g of fish)	Species
Type 1	short (<1 year)	7–10	3–4 months	Extended	500–1,000	stolephorid anchovies - *Encrasicholina heteroloba*, *E. devisi*, *E. punctifer* sprats - *Spratelloides gracilis*, *S. delicatulus*, *S. lewisi* silverside - *Hypoatherina ovalau*
Type 2	annual (some surviving to 2 years)	10–24	Towards end of 1st year	Restricted and seasonal	300–500	herrings and sardines - *Herklotsichthys* spp., *Amblygaster* spp., *Sardinella* spp. larger anchovies - *Thrissina* sp., *Stolephorus* spp. sharp nosed sprats - *Dussumieria* spp.
Type 3	2–5 years	20–35		Restricted and seasonal	400–600 flying fish: 50–100	round scads - *Decapterus* spp. big eye scads - *Selar* spp. small mackerels - *Rastrelliger* spp. flying fish and half beaks - Exocoetidae and Hemiramphidae

Production and Marketing: The subsistence catch of baitfish is unknown. A summary of the baitfish catch and effort by pole-and-line vessels for the years 1976–1990 is provided in Sharma and Adams (1990), and reproduced in Table 33 together with data from 1990–1992. No comparable data appear to be available for the last years of the fishery (i.e. 1993–1997).

Table 33. Baitfish catch and effort by locally operating pole-and-line boats from 1976−1992. One bucket weighs roughly 2 kg. Source: Sharma and Adams (1990)

Year	Catch (buckets)	Nights	Sets	Sets/Night	Buckets/Set
1976	41,249	436	681	1.56	60.57
1977	60,116	840	1,259	1.50	47.49
1978	46,987	755	1,041	1.38	45.14
1979	29,302	1,005	1,231	1.23	23.80
1980	54,302	1,068	1,314	1.38	41.30
1981	80,485	1,777	2,482	1.32	32.42
1982	78,901	1,741	2,294	1.30	34.39
1983	57,947	1,363	1,837	1.40	32.00
1984	54,988	890	1,210	1.50	45.00
1985	33,305	735	1,068	1.40	31.00
1986	25,679	570	799	1.40	32.00
1987	42,261	800	1,122	1.40	38.00
1988	43,836	566	799	1.40	55.00
1989	32,281	398	574	1.40	56.00
1990	65,881	1,030	1,634	1.58	40.30
1991	59,154	838	1,310	1.56	45.10
1992	123,815	1,764	3,057	1.73	40.50

27.3 Stock Status

Sharma and Adams (1990) reported that catch rates remained fairly stable over the period 1976–1990 and an average of 38 buckets of bait were caught per set. Analysis of the catch data shows that baitfishing effort to date has not yet been sufficiently intense to create a levelling off of catches at higher effort levels. With many suitable areas in Fiji as yet unfished, they were of the opinion that there was probably scope to increase existing catches by moving into new areas. The 1992 catch made by the 11 different boats in the fishery (97 boat-months of operation) was the highest recorded since the commencement of the fishery in 1976, with the highest number of nights fished (Anon., 1993).

27.4 Management

Current Legislation and Policies Regulating Exploitation: The management of Fiji's baitfish resources which lie almost entirely within customary fishing areas and is the mainstay of the Fiji pole-and-line tuna fishing fleet, was one of the priority tasks of Fisheries Division during the 1980s and 1990s. Since the bait requirements of pole-and-line fishing occasionally come into conflict with local interpretations of customary fishing rights, the concept of "goodwill" payments or royalties for use of customary fishing grounds gradually became an accepted practice.

In early 1992, a royalty payment system was initiated to compensate traditional fishing right owners for the removal of baitfish and the operation of commercial pole-and-line vessels within their areas. An interim rate of FJD 10 per night per vessel was set, until such time as the results of the Baitfish Research Project were available. From records supplied to Fisheries Division by the commercial vessels, it has been possible to assess how many nights of baitfishing has occurred at different fishing rights areas during the course of a year. This has facilitated the allocation of royalty payments to the rightful owners, using boundaries supplied by the *iTaukei* Lands Trust Board.

During 1992, a total of FJD 17,290 was collected from pole-and-line fishing companies to cover royalty payments due to the 56 customary fishing rights areas where baitfishing took place. This amount was transferred to the Central Fijian Treasury (Anon., 1993). Despite these measures, many of the preferred baiting grounds in the Lau group were closed to commercial operations by the traditional resource owners, who require further compensation for the taking of baitfish.

Management Recommendations: The results of the Baitfish Research Project, which commenced in 1991 to address concerns from resource owners about the effects of commercial baitfishing operations on fish stocks in baiting areas, played a major part in framing updated recommendations for this fishery. Project fieldwork in 1992 sought to gather information towards:

- Identifying fish species which are predators of the major species caught in the baitfishery in order to assess interactions between the commercial baitfishery and the subsistence fishery.
- Assessing the level of fishing effort and the major fishing activities with the subsistence fishery.
- Identifying the areas within Fiji where baitfishing effort is presently low, but might offer potential for the commercial capture of baitfish

House-to-house questionnaire surveys were carried out during 1993 in order to assess fishing activities within the subsistence fishery. Areas covered include the islands of Beqa, Gau, Kia, Vanua Balavu, Waya and Yasawa. The conclusions of the work were as follows (Anon., 1995):

- There was limited interaction between important species in the subsistence and artisanal catches, and the capture of baitfish by pole-and-line vessels. The most serious interactions were identified as being the capture of reef fish by crew members while they were in the lagoons at night;
- There was no evidence that overfishing had occurred on the baitfish stock in Fiji and the baitfishery would be able to support the existing levels of fishing effort; and
- There were lagoon areas in Fiji that were infrequently used by commercial vessels for baitfishing, identified as offering alternative locations for these operations, as they were found to support good populations of baitfish. By the strategic deployment of FADs, pole-and-line vessels could be encouraged to shift some of their fishing effort away from those heavily-utilised areas to these underutilised areas.

Compensation payable for each night's baitfishing, as approved by Cabinet in 1992 continued to be paid up until the ultimate demise of the main pole-and-line fishery for economic reasons in 1997.

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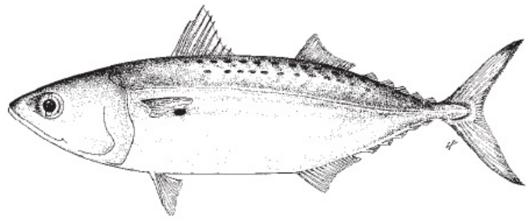
28 CHUB MACKEREL



28.1 The Resource

Species Present: Three species of **salala** (chub or Indian mackerel) occur in Fiji waters; the Indian mackerel (*Rastrelliger kanagurta*), the chub mackerel (*R. brachysoma*) and the slender chub mackerel (*Rastrelliger faughni*). The first named pair of species are sufficiently abundant to be important in their own right to Fijian fisheries (Sharma and Adams, 1990). Fishing for Indian and chub mackerel is sufficiently important in Fiji to be considered separate fisheries.

Distribution: Chub mackerel are distributed widely in the Indo-Pacific Region. In Fiji, *R. kanagurta* is generally more common in clearer reef waters than *R. brachysoma*, which is found closer to the shore (Lewis, 1985). Both species occur within customary fishing right areas, and are often found in large rippling schools at the surface.

Biology and Ecology: Both species are consumerers of phytoplankton and zooplankton, straining the surrounding waters with well-developed feathery gill rakers borne by the gill arches (Bal and Rao, 1984 in Dalzell, 1993). The slender chub mackerel reportedy takes the largest zooplankton, with the Indian mackerel mostly larval crustaceans, and the chub mackerel microzooplankton with a high phytoplankton component. The mackerels form schools which are often seen rippling at the surface in sheltered waters. They are relatively small species, growing quickly to a size of approximately 30 cm FL and a weight of 500 g. In New Caledonia, *R. kanagurta* is reported to have an L_∞ of 23.7 cm and K of 3.0 (Conand, 1988 in Dalzell, 1993).

These small mackerels spawn in their second year of life, during the summer months, typically at a size of 20 cm or slightly less. In New Caledonia, *R. kanagurta* has been observed spawning in September (Conand, 1988 in Dalzell, 1993). *R. kanagurta* appears to reach maturity at a larger size than *R. brachysoma*. Mackerel are an important source of food for predatory fish such as **walu** (Spanish mackerel − *Scomberomorus commerson*) and **saqa** (trevallies − *Caranx* spp.) (Lewis, 1985).

28.2 The Fishery

Utilisation: Most individuals of both *Rastrelliger* species are caught in the 15–25 cm length range. Gears for the capture of *Rastrelliger* throughout its Indo-Pacific range make use of its schooling habit and/or attraction to lights. They include a variety of purse seines, surround gillnets, lift nets and fish traps. In Fiji, gillnets are used to surround schools of **salala** sighted at the surface, a procedure generally requiring moderately calm water to locate the rippling schools. **Salala** are also taken incidentally in set gill nets, and in the Western Division, sizeable quantities were taken by the illegal use of dynamite. In Fiji these two species are generally consumed fresh with small quantities hot-smoked (Lewis, 1985).

Production and Marketing: The flesh of **salala** is quite dark and oily, and is marketed fresh, frozen, smoked, salted, dried and canned in various countries. The volume of sales of **salala** through municipal and non-municipal markets in Fiji for the years 1985–1992 are shown in Table 34. The two **salala** species are not distinguished in the records. Northern Division provided most of the catch sold through non-municipal markets during that period. The catch is seasonal, with the May−September period producing most of the artisanal catch. Total sales have declined appreciably in recent years, with 1992 sales in both municipal markets and non-market outlets dropping to half of the 1991 figures. Nominal annual small pelagic fisheries production for the period 1976−1986, gives an average figure of 1,349 mt for landings of mackerel in Fiji (FAO, 1990 in Dalzell, 1993). The average price per kg of **salala** in earlier years has ranged from approximately FJD 2–3 and FJD 3–4 in 2004 (Fisheries Division, *unpubl. data*). Available data for 2016 (Central Division) suggest the price exceeded FJD 7 per kg, or nearly double the 2004 price.

The most recent national production estimates, for 2004, show some increase from the 1992 figures, 82.26 mt from municipal markets and 96.36 mt from non-market outlets, with most sales in the Western Division, as opposed to the Northern Division in earlier times. There are no reliable production data since 2004. Small quantities of juvenile **salala** (estimated 5–20 mt per annum) were previously caught by the tuna pole-and-line boats during the course of baiting operations. They are not a preferred tuna bait species, as they quickly swim away from the vessel, and were not specifically targeted (Lewis, 1985).

Table 34. Sales of **salala** (mt) in municipal markets and non-market outlets from 1985−1992 and 2004. Source: Lewis (1985), Anon. (1986–1992, 2004).

Year	Municipal markets (mt)	Outlets (mt)	Total Sales (mt)
1985	134.93	410.17	545.10
1986	91.46	195.97	287.43
1987	47.94	203.16	251.10
1988	58.78	162.66	221.44
1989	82.14	322.14	404.28
1990	64.99	299.33	364.32
1991	34.36	218.54	252.90
1992	16.74	110.12	126.86
2004	82.26	96.36	178.62

28.3 Stock Status

The status of Fiji's **salala** stocks is unknown. Decreases in catch from year to year, such as that noted from 1991 to 1992, could be due to many reasons and such natural fluctuations in the abundance of small pelagics are not unusual. The 2004 figures, with a slightly higher catch than 1992, may indicate possible stability in catches over that time frame. There are no reliable market data since that time (i.e. for over 10 years), and catch trends are unknown. It was noted that prices have nearly doubled in that time, but that is the case for many inshore species and does not necessarily reflect decreasing abundance.

28.4 Management

Current Legislation and Policies Regulating Exploitation: The Sixth Schedule of the Fisheries Act (Regulation 18) lists 20 mm as the minimum length for fished **salala**. This approximates the size at first maturity and seems appropriate, but is presumably not rigorously enforced. In November 1991, the section of the Fisheries Act concerning dynamite fishing was amended (*Decree No.46 of 1991, s3*), as follows:

- Fishermen will face fines of up to FJD 500 (up from FJD 50) and an optional jail term of three months for basic fisheries offences, but fishermen convicted of using explosives or dynamite face a FJD 1,000 fine (up from FJD 100) and a mandatory six-month jail term for a first offence.
- Second-time offenders will face fines of up to FJD 2,000 (up from FJD 150) and face a mandatory jail term of one year (up from nine months).
- Third-time offenders face fines of up to FJD 5,000 (up from FJD 200) and a jail term of two years (up from one year). The previous penalty was a fine of FJD 100.

Management Recommendations: None required unless more efficient gears are introduced. Customary fishing resource custodians should be encouraged to enhance the sustainability of this resource through application of the existing legislation relating to gillnet mesh size, legal minimum size and the illegal use of explosives. They are one of the few examples of a "single species" fishery in Fiji, with all the handling and marketing advantages that this confers.

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29 LARGE COASTAL PELAGIC FISH

29.1 The Resource

Species Present: The large coastal pelagics are a diverse group of predatory surface fishes, with maximum sizes mostly exceeding 75 cm. They inhabit coastal lagoons, reef margins channels, and outer reef slopes. More than 20 species are included in the group mostly belonging to the following four families:

- **Carangidae** − the genera *Caranx* (trevallies), *Gnathanodon* (golden trevally) *Scomberoides* (queenfish), *Megalaspis* (finny scad), and *Trachinotus* (darts, swallowtail); the numerous species of the genus *Carangoides* are generally smaller and often omnivorous, so are not included; other smaller carangid species are included in Profile 27 SMALL COASTAL PELAGIC FISH (e.g. *Selar*, *Selaroides);* however, the large but uncommon *Alectis* (diamond trevally) species are not included.
- **Sphyraenidae** − the genus *Sphyraena* which includes three large species generally called barracuda (**ogo**), and numerous smaller species called seapike (**silasila**)
- **Belonidae** − the commonest and largest of several species in the family occurring in Fiji waters (**saku,** *Tylosurus crocodilus*); others (e.g. *Tylosurus* spp. occur in Fiji but not included)
- **Scombridae** − only three species of this large family included here, on the basis of their size and nearshore habitat − **yatunitoga** (dogtooth tuna), **walu** (Spanish mackerel), and **salalanitoga** (double-lined mackerel). Other scombrids are included in the Profiles 37 OCEANIC TUNA, and Profile 27 SMALL COASTAL PELAGICS.

The species included in this profile, and the maximum length in centimetres to which they commonly grow, are presented below in Table 35. Most of these species were included in the 1993 profiles. As it will not be possible to provide detailed biological, ecological and other data on all the species listed, **walu** (Spanish mackerel – *Scomberomorus commerson*) has been selected for the provision of more detailed description (Profile 30 NARROW-BANDED SPANISH MACKEREL).

Distribution: Most of the large coastal pelagic species have wide distributions in the Indo Pacific, with several circumtropical (e.g. *Sphyraena barracuda*). Within Fiji, most occur throughout the group in various coastal habitats, with the great barracuda occurring in brackish water and rivers as juveniles and sometimes far offshore as adults. Information on the micro-distribution within Fiji of several of the species listed in Table 35 is available in Lewis *et al.* (1983) which describes trolling surveys which took place over 7 months from 1981−1982 in four fishing "zones"; "mainland reef", "mainland island", "offshore reef complex" and "offshore island reef". Lewis *et al.* (1983) also includes results of a brief trolling survey which was undertaken in late 1982 at Vanua Balavu in the northern Lau Group.

During these surveys, **walu** contributed significantly to the catch in two mainland zones and good catches of this species were made in Vanua Balavu. **Ogo** were commonly taken in all zones fished and were the most abundant group overall in terms of both numbers and weight. In the mainland reef zone, *S. qenie* was the dominant species, whereas in the offshore zones, *S. barracuda* predominated.

Among the trevallies (**saqa**), *C. ignobilis* topped the catch by weight in all zones, particularly in the offshore reef complex. *C. papuensis* was common in the mainland zones but was replaced by *C. melampygus* in the offshore zones. *C. plagiotaenia* made a minor contribution to the catch in all areas. *Gymnosarda unicolor* and *Grammatorcynus bilineatus*[24] assumed some importance in the offshore reef complex and offshore island complex. **Saku** and queenfish were taken only occasionally in all areas.

24 Wrongly called *bicarinatus* in earlier work, a large species which occurs in Australia (shark mackerel) but does not occur in Fiji.

Table 35. Names of some reef associated fishes in Fiji. Source: Lewis *et al.* (1983); Lewis (1984), Lewis (1985), Fish Base, FAO species identification guide Western Central Pacific.

Common name	Scientific name	Fijian name	Max. length (cm)
Carangidae			
great trevally	*Caranx ignobilis*	**saqa (gen.), saqaleka**	170
bigeye trevally	*C. sexfasciatus*	**kodromatalevu**	78
tille trevally	*C. tille*		80
brassy trevally	*C. papuensis*	**wainikodro, kodro**	75
bluefin trevally	*C. melampygus*	**tauta, saqanivatu**	100
golden trevally	*Gnathanodon speciosus*	**vilu**	110
queenfish	*Scomberoides lysan*	**votonimoli, lai**	110
finny scad	*Megalaspis cordyla*		80
snub-nosed dart	*Trachinotus blochi*	**lalitarawau, qawaqawa**	110
black-spotted dart	*T. bailloni*	**iribuli, qawaqawa**	70
Sphyraenidae			
great barracuda	*Sphyraena barracuda*	**ogo**	200
yellow-tail barracuda	*S. jello*		150
dark-finned barracuda	*S. qenie*	**ogo, sasanitoga**	170
bigeye sea pike[25]	*S. forsteri*	**dulutoga, silasila**	75
Belonidae			
longtom, needle fish	*Tylosurus crocodilus*	**saku**	130
Scombridae			
Spanish mackerel	*Scomberomorus commerson*	**walu**	235
dogtooth tuna	*Gymnosarda unicolor*	**yatunitoga**	180
mackerel tuna	*Euthynnus affinis*	**yatu**	80
double-lined mackerel	*Grammatorcynus bilineatus*	**salalanitoga**	80

Biology and Ecology: Trevallies (**saqa**) are powerful mid-water swimmers which frequently occur in large schools and may roam for considerable distances. They are common on the edges of reefs, particularly along steep outer reef drop-offs. The great trevally (*C. ignobilis*) grows to 170 cm and may weigh over 50 kg. Finny scad are often encountered in large rippling schools in reef passes or on outer reef slopes, whereas darts and queenfish are more typically inshore species often found near mangroves and beaches. *Caranx papuensis* size of maturity is 33.0 cm (Prince *et al*. 2018).

The common longtom (**saku,** *T crocodilus*) is circum-tropical, with larger fish being outer reef-associated or found over reef slopes. The species grows to at least 130 cm and 10 kg. Barracuda (**ogo**) frequently occur in small to large schools as sub-adults, often on the edge of outer reef drop-offs. However, *Sphyraena barracuda*, the largest species of **ogo**, is often encountered alone (Randall *et al*., 1990). Lewis *et al*., (1983) reported that the largest specimen of **ogo** taken during the troll survey in Fiji waters was 135 cm in length, weighing 19.5 kg, but much larger examples are known, up to at least 35 kg. The smaller sea pike (several species) occur in lagoons and near reefs in large numbers, often in schools.

25 Similar small –medium species occurring in Fiji include *flavicauda, helleri*, and *obtusata,* as well as the medium size chevron *barracuda (S. putnamae)* growing to over 80cm but often around 60 cm. The small species are rarely distinguished and their taxonomy is uncertain

Walu are considered later in this document in detail, as the featured species of Profile 30 NARROW-BANDED SPANISH MACKEREL. Double-lined mackerel (**salalanitoga)** are typically found in broken reef areas where they can be caught in good numbers using daisy chains − multi-hook trolling rigs. Dogtooth tuna are mostly solitary as adults, cruising reef dropoffs at varying depths, and rarely moving far from the reef. Specimens up to 100 kg have been taken in Fiji. Mackerel tuna are a schooling neritic species which can range into the oceanic realm, but occur in smaller schools or even solitary when inshore.

Large coastal pelagics are voracious predators that feed on a variety of fishes, as well as squid and other epipelagic invertebrates. This renders them susceptible to capture by trolling, perhaps the commonest fishing method for large pelagics. **Saku** often skip along the surface in pursuit of prey or to escape predators, which occasionally causes problems for fishers, especially at night. Some carangid species such as **vila** (*Gnathanodon speciosus*), along with many of the *Carangoides* species, eat mainly molluscs and crustaceans, and are not truly pelagic.

Saqa, like most species in the group 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). The 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). Spawning of **ogo** in Fiji waters may occur in late spring /early summer, as with many pelagic species in Fiji, the mature fish either moving offshore to spawn or becoming unavailable to fishing gear with the onset of maturity (Lewis *et al*., 1983). The juveniles of *S. barracuda* are found in estuaries throughout the Fiji Group (Lewis, 1985). **Saku**, unlike other large pelagics, attaches its large eggs to floating debris or seaweed, after which they drift and eventually hatch, often on the substrate.

Movement of most large coastal pelagics has been little studied, relative to oceanic pelagics, but they are assumed to be relatively sedentary and in contrast with oceanic species, reef-associated pelagic fish appear to maintain long periods of reef residence as juveniles and adults. Any extensive movement which occurs is likely to be longshore, rather than across open water. Significant displacement of planktonic larvae is however possible, depending on the length of the planktonic phase, as is drift of weed to which eggs are attached, in the case of **saku**. No information is available on stock structure of large pelagics in Fiji, although the case of **walu** is discussed later.

29.2 The Fishery

Utilisation: Large **saqa** may be taken by trolling close offshore and night handlining inshore, while smaller individuals are taken by gillnets in estuaries (Lewis *et al*., 1983). Night handlining inshore may be successfully used for *C. ignobilis*, *C. sexfasciatus* and *C. tille*, but *C. papuensis* is rarely taken by this method. Darts and queenfish, usually caught in gillnets, do not make up significant landings but the silvery scaly leathery skin is often sought after for various applications (e.g. fishing lures and decoration). Trevallies are rarely reported as ciguatoxic in Fiji, whereas as some species, particularly *C. ignobilis* have been incriminated elsewhere (e.g. New Caledonia).

Ogo are readily taken on trolled lures and baited hooks, with smaller individuals of *S. barracuda* and seapike (**silasila**) being caught in large numbers on baits intended for larger reef fish. Juveniles may be taken with gillnets in estuaries and nearshore areas. The yellow-tailed barracuda (*S. jello*) has a reputation in Fiji of being ciguatoxic, more so than *S. barracuda*, which has this reputation elsewhere (Lewis *et al*., 1983). The great barracuda has been responsible for an occasional attack on humans in some areas, but striking at shiny objects in murky waters, rather than deliberate attacks.

Saku, usually taken incidentally in gillnets or when trolling, have limited market acceptability in some places because of their green bones. They are regularly implicated in injuries to fishermen when netting at night, when they leap and skim the surface to avoid capture, or are startled by lights.

Mackerel tuna and double-lined mackerel (**salalanitoga**) are not common in the market place, and dogtooth tuna are rarely taken by other than recreational fishers and spearfishermen. Dogtooth tuna have been recorded as ciguatoxic in other locations but this does not seem to be the case in Fiji.

Production and Marketing: Market surveys of commercial landings in municipal markets and a range of other outlets, undertaken by the Ministry of Fisheries in three of the four administrative Divisions, have been the basis of production estimates since the early 1980s, but do not include subsistence catches nor production from the less densely populated Eastern Division where commercial fishing occurs at much lower levels. The detailed results of the market surveys have not been available since 2003 and are believed to no longer provide reliable production estimates, based on market sales. Analyses of production and marketing are therefore historical, and current estimates of production are urgently needed.

Table 36 shows the annual production of **ogo**, **saqa** and **walu**, the three main categories of large pelagics, for 1986–1992, with an increase over time in all cases, almost exclusively in the non-market outlets. Sales of all three groups show marked inter-annual fluctuation during that period, as noted. **Ogo** sales reached historical highs in 1992, but annual sales volumes fluctuated widely. **Saqa** sales had been high since 1990, as had **walu** sales since 1989, but **walu** sales dropped sharply in 1992, causing some possible concern at that time.

The 1992 and 2004 sales were also compared, to examine trends in production. Both **ogo** and **walu** sales in 2004 were at 70% and 55% respectively of historical high sales during the period 1986−1992, whereas **saqa** were at 87%. **Saqa** sales during 2004 actually exceeded those of 1992. The drop in overall sales of the three groups between 1992 and 2004 was small (11%). It is not clear if the same species were included in the 2004 totals compared to those included earlier analyses eg **saqa, ogo** but nonetheless provide a useful comparison. No data are available since 2004, and the current sales trajectories since 2004 are unknown.

In 1986, the market prices for **ogo**, **saqa** and **walu** were approximately the same, at FJD 2.00 per kilogram. Since then, the average prices for all three groups generally rose steadily, although rising more steeply for **saqa** and **walu**. Comparison of the 2004 prices with 1992 suggest that **ogo** prices have increased by 30% (to FJD 4.1), **saqa** prices by 17% (to FJD 4.50), and **walu** by less than 5% (FJD 5.65). No average price information is available currently (2016) 2004 sales data for other large pelagics confirm the relatively minor nature of production - **saku** 31.82 mt, dogtooth tuna 9.56 t, **salalanitoga** 23.47 t, **votonimoli** (dart) 8.17 mt and mackerel tuna 30.4 mt - and it assumed that these minor levels of production continue to prevail to the present day.

Table 36. Weight (mt) of **ogo**, **saqa** and **walu** sold through municipal markets and outlets for the period 1986–1992. Source: Anon. (1986−1992).

Year	Municipal markets (mt)			Non-municipal market outlets (mt)			Total sales (mt)		
	ogo	saqa	walu	ogo	saqa	walu	ogo	saqa	walu
1986	61.52	71.43	5.44	106.70	230.52	208.94	168.22	301.95	214.38
1987	62.08	83.72	17.55	89.81	179.59	184.56	151.89	263.31	202.11
1988	57.18	58.51	14.46	151.11	191.41	156.82	208.29	249.92	171.28
1989	58.36	49.97	5.77	162.91	288.59	357.87	221.27	338.56	363.64
1990	65.40	41.72	6.32	370.12	390.70	462.30	435.52	432.42	468.62
1991	74.20	45.18	7.03	212.10	447.45	554.82	286.30	592.63	561.85
1992	70.85	49.07	6.73	452.22	374.30	375.12	523.07	423.37	381.85

Table 37. Sale volume (mt) of the three main large pelagic groupings for 2004 relative to 1992. Source: Department of Fisheries Annual Report 1992;2004.

Year	Saqa		Ogo		Walu	Total sales (mt)
1992	423.37		523.07		381.85	1,328.29
	Bft*	Saqa+	Ogo	Silasila		
2004	177.96	338	289.41	67.74		
	515.96		357.15		306.29	1,179.4
Difference (2004–1992)	+93t		(-166t)		(-75.5t)	(-148.89t)

* bluefin trevally *(C. melampygus)* but presumably includes other spp.
+ includes saqa, saqadole and saqaloa

29.3 Stock Status

Stock status of all large coastal pelagic species remains unknown, and most have not been well studied in Fiji, even including the iconic **walu** (see Profile 30 NARROW-BANDED SPANISH MACKEREL). As production levels (and prices) have remained relatively stable over time, and no obvious changes in the fishery have been noted, the default position is that most stocks are relatively healthy, given the group's assumed low-medium vulnerability (high fecundity and productivity, rapid growth rates, little evidence of aggregations/migrations for spawning increasing vulnerability).

29.4 Management

Current Legislation and Policies Regulating Exploitation: The sixth schedule of the Fisheries Act (Regulation 18) lists minimum lengths for **ogo** (300 mm) and **saqa** (300 mm). There is no legislation covering the take of **walu,** despite earlier proposals to institute a minimum size limit of 700 mm FL, and increase minimum net mesh size from 64 to 76 mm to protect juveniles (Lewis, 1985). None of the large coastal pelagic species are included in any of the Annexes of the Endangered and Protected Species Act 2002, amended 2017.

Management Recommendations: With the widespread use of gillnets, **ogo** and **saqa** smaller than the recommended minimum size limits are routinely taken, but the schedule is not enforced. A minimum size limit of 700 mm forklength is recommended for **walu.**

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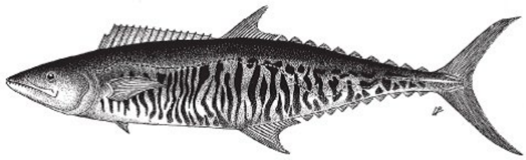
30 NARROW-BANDED SPANISH MACKEREL



30.1 The Resource

Species status: Walu (*Scomberomorus commerson*) is the only species of Spanish mackerel (Tribe: Scomberomorini) to occur in Fiji, although 5 species occur in Australia and Papua New Guinea. They enjoy iconic status in Fiji because of their appearance, size, and desirability for eating.

Distribution: Spanish mackerel have a wide distribution in the Indo-Pacific, from South Africa to Samoa, Fiji representing the most easterly regular occurrence of the species in any quantity. The widespread spatial and habitat distribution within Fiji is described in the earlier section. It is noteworthy that in the Lau group, **walu** are well established only in Vanua Balavu, the sole island which has significant mangrove stands, which provide the productive inshore nursery habitat for juveniles.

Biology and Ecology: Considerable new information on **walu** biology and ecology has become available since the 1994 profiles were compiled, for example in northern Australia (east coast, Torres Strait and Western Australia) and Oman. Some of this information is included in this profile where appropriate, as there has been no further research carried out in Fiji.

Walu are an epipelagic, continental-shelf species, rarely found in waters deeper than 100 m, and are commonly associated with coral reefs, rocky shoals and current lines on outer reef areas and offshore waters, but extending to inshore shallow waters of low salinity and high turbidity (Begg *et al*., 2014). **Walu** is the largest of the Spanish mackerels, growing to at least 230 cm and >60 kg, but rarely more than 45 kg in Fiji. Females attain larger sizes than males, and males above 15 kg in size are very rare. Sex ratios are dominated by females at sizes >12 kg.

Juvenile and adult Spanish mackerel are piscivorous predators, feeding mainly on pelagic clupeoid baitfish such as sardines, anchovies and pilchards, as well as squids and prawns (McPherson, 1987). Walu feed at all depths and times of day, but seem to feed most actively at dawn and dusk, and also at tide turns in inshore areas.

Lewis (1983) speculated that first maturity in both male and female walu was achieved at a size of approximately 70−80 cm FL or 2 years of age. More extensive work since then in various locations has confirmed mean length at maturity (L_{50}) for male and female walu at around 65 cm FL for males and 80 cm FL in Western Australia, with ages estimated to be about 0.8 and 1.4 years old, respectively (Mackie *et al*., 2003). These ages are likely to be higher for Fiji and Torres Strait. **Walu** have a protracted spawning season in the Torres Strait, between August−March (McPherson, 1986), but peak spawning tends to occur in October, associated with an aggregation of all size groups and equivalent sex ratios (McPherson, 1981). The season in Fiji may be more restricted, occurring during the late October-February period, with a peak in December−January (Lewis *et al*., 1983). Prior to, and after spawning, sexes may remain segregated to some extent, with males more common inshore.

Walu spawn off reef slopes and edges, often forming spawning aggregations in specific areas with some consistency from year to year. The species are asynchronous spawners, with individual fish spawning several times over the spawning season, usually in the late afternoon and early evening and during the new and full moon phases (McPherson, 1993). Larvae of Spanish mackerel are commonly associated with reef lagoonal areas (Jenkins *et al*., 1984; 1985; Thorrold, 1993), before juveniles (<10 cm) move to estuary and foreshore nursery and feeding grounds, often mangrove-associated, where they tend to remain for the first year of life (McPherson, 1981; Jenkins *et al*., 1984). In Fiji, juveniles and sub adults are commonly taken in gillnets deployed in these inshore waters. The average size of **walu** sampled in municipal markets in 2004 was 47 cm (range 17–88 cm); fish sold in non-market outlets are typically much larger adults.

Otolith studies in various locations have confirmed that walu growth is extremely rapid during the first two years of life (to 90 cm in the first 12 months in Torres Strait) before slowing considerably with the onset of maturity (McPherson, 1981). Sex-specific growth is also evident in Spanish mackerel, with females tending to live longer and grow to larger sizes (McPherson, 1992; Tobin and Mapleston, 2004). Population studies demonstrate that Fiji's **walu** stock is distinct from those in neighbouring countries and can be treated as a discrete population for regional management purposes (Lewis, 1985; Shaklee *et al*., 1990). It is however, not clear if further population differentiation exists within Fiji.

Extensive Australian studies indicate that Spanish mackerel in northern Australian waters conform to a meta-population stock structure, and show a high degree of site attachment (Buckworth *et al*., 2005). This indicates that the Fiji walu, distributed across a much smaller area, are thus likely to comprise a single population but probably with site attachment and with significant movement amongst areas associated with spawning. Extensive tagging studies on the Australia east coast showed large-scale post-spawning longshore movement but there is not the scope for this in the Fiji situation and movements are likely to be local in scale. No tagging of walu has been undertaken in Fiji to confirm this.

The key management issue, as noted previously, is that "aggregated schooling behaviour and predictable seasonal occurrence of Spanish mackerel renders the species susceptible to over-fishing" (Begg *et al*., 2014).

30.2 The Fishery

In Fiji waters, **walu** are usually taken by trolling using a variety of artificial lures, and live-bait fishing at night around lights. Smaller quantities, especially juveniles, are caught in gillnets. Seasonal spawning "runs" of this species are well known to local fishermen, who make good catches at these times. **Walu** flesh is firm and of excellent flavour. Often sold fresh or frozen as whole fish or steaks. It is the species of choice for the preparation of **kokoda**, one of the most popular Fijian seafood dishes. Local markets readily absorb all available catch. Smoked **walu** fillets have considerable potential as an export item and as a high priced local product (Lewis, 1985).

Production and Marketing: From the early to mid-1980s, the total production of **walu** from Fiji's waters was very stable, as reflected in market sales, averaging approximately 200 mt per year. However, from 1989 to 1991 the average annual sales more than doubled to 562 mt before falling to 381 mt in 1992. The most recent market survey data available suggested this had further decreased to 306 mt in 2004. Most of this decrease was in sales from non-market outlets, whereas municipal market sales increased from 7.3 mt in 1992 to 71.92 t in 2004, mostly in the Northern Division.

No more recent data are available but indications are that **walu** sales have been steadily falling during the 1990s buffered only by increased sales in Northern Division markets, and this decline has continued to the present time. An estimation of current annual landings is needed with some urgency.

Trends in prices over time may be informative in reflecting strong demand against decreasing supply. The 1992 average price for **walu** was FJD 5.52 per kg, more than twice the 1986 price, yet in 2004 was only slightly higher at FJD 5.63 per kg, despite the 30% drop in sales (381 mt to 306 mt). One possible explanation for this stability in price was the increased availability of high quality alternatives from tuna longline bycatch, notably wahoo. **Walu** prices in Suva Municipal Markets in 2017 were as high as FJD 10 per kg (S. Lee, *pers. obs.*).

Exports: Likely exported as either chilled or frozen fillets, however the generic categories used in FRCS export data make it impossible to discern if indeed this species was exported, its value, and quantity.

30.3 Stock status

Lewis (1985) interpreted the relative stability of figures for the commercial production of **walu** during the late 1980s to early 1990s as meaning that the catch may be finding its own sustainable level, at around 350 mt/ year, and that any increases in commercial production may be the result of diversion of catch from, or at the expense of, subsistence catches. He reasoned that as long as the catch of juvenile **walu** remains small, the fishery may be self-regulating, with fishing effort declining as catches decline, but did call for a scientific assessment of local **walu** stocks to be undertaken as a matter of urgency. In his opinion, it was unlikely that a large increase in the overall **walu** catch could be sustained.

No stock assessment of **walu** has been undertaken in Fiji, but detailed assessments, along with management strategy evaluation and establishing reference points, have been undertaken in adjacent areas e.g. Torres Strait (Begg *et al*., 2008), Western Australia (Mackie *et al*., 2003) and the Australian east coast (Tobin and Mapleston, 2004). These will provide a useful frame of reference for any Fiji assessment undertaken. Earlier concern over the **walu** stocks seems to have been reinforced by the continuing decline in overall sales to around 300 mt in 2004, and probably lower since then, combined with increased catches of juveniles as evidenced by increased municipal sales, and the dramatic increase in price, which needs to be confirmed. The need for an assessment of the status of the Fiji **walu** stock now seems more urgent than ever.

30.4 Management

Current Legislation and Policies Regulating Exploitation: There is no legislation covering the taking of **walu,** despite earlier proposals to institute a minimum size limit of 70 cm FL, and increase minimum net mesh size from 6.4−7.6 cm to protect juveniles (Lewis, 1985).

Management Recommendations: The recommendations proposed here are identical to those proposed by Lewis (1985). A scientific assessment of the stock of **walu** should be conducted, the results of which would be used to determine exploitation policy for this species. Large volume exports of unprocessed **walu** should be discouraged until stock assessment results are known. Foreign investment in the fishery should be discouraged as ample local expertise is available.

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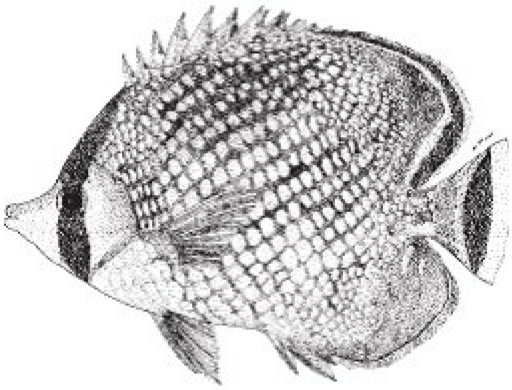
31 AQUARIUM FISH



31.1 The Resource

Species Present: Many species of fish on Fiji's coral reefs have been identified as having commercial value in the aquarium fish trade (Table 38). These include damselfish (Pomacentridae), angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), tangs (Acanthuridae), wrasses (Labridae) but a wide range of other species is available in abundance. The diversity of marine species is however less than in the central Indo-Pacific region. Fiji has very few endemic marine species that could be of special interest to collectors. Fiji's freshwater fish fauna is limited, and it is unlikely to include any species of interest to the aquarium fish trade (Lewis, 1985).

Distribution: The major areas from which wild-caught aquarium fishes are exported are the Philippines, Hawaii, Caribbean Sea, Indonesia, Mexico, Red Sea, Sri Lanka, Mauritius, Kenya, Maldives, Seychelles, Taiwan and the Pacific region. Within the South Pacific, marine aquarium fishes are presently, or have at one time been, collected and exported from Australia, Palau, Cook Islands, FSM, Guam, Kiribati, Marshall Islands, Tonga, Western Samoa, Vanuatu and Fiji (Pyle, 1993). Walt Smith International and Aquarium Fish Fiji are currently the largest companies in Fiji exporting ornamental fish their main collection area is located off the northwest coast of Viti Levu and within the Beqa lagoon, respectively (Lovell, 2010).

Table 38. Some commercially valuable aquarium fish species on Fijian reefs, and their principal collecting depths. Asterisks indicate higher value species. Source: Anon. (1987–1993), Perino (1990), Randall *et al.* (1990)

Common name	Scientific name	Collecting Depth (m)
Fiji devil or south-seas demoiselle	*Chrysiptera taupou**	2–10
oriole or bicolor angelfish	*Centropyge bicolor*	10–25
lemon-peel angelfish	*Ce. flavissmus*	< 10
coral beauty or two-spined angelfish	*Ce. bispinosus*	Outer reef dropoff >10
triangle or triangular butterflyfish	*Chaetodon baronessa*	With *Acropora* coral
dot-and-dash butterflyfish	*Ch. pelewensis*	To 30
yellow or latticed butterflyfish	*Ch. rafflesi*	
Merten's butterflyfish	*Ch. mertensii*	Outer reef slope >15
cross-hatch butterflyfish	*Ch. vagabundus*	
top-hat or scalefin anthias	*Pseudanthias squamipinnus*	
square block or squarespot anthias	*P. pleurotaenia**	Outer reef slope 30–70
pink anemonefish	*Amphiprion perideraion*	3–20
orange-fin anemonefish	*A. chrysopterus*	1–20
queen or redtooth triggerfish	*Odonus niger*	Outer reef slope
palette surgeonfish	*Paracanthurus hepatus*	Clear outer reef areas
clown coris	*Coris aygula*	
yellowtail coris	*Co. gaimard*	

Biology and Ecology: Due to their great diversity, it is difficult to make generalisations about the biology and ecology of tropical marine aquarium fishes as a whole. They are captured from near the surface to depths of 60–70 m, and may be located in a variety of habitats, depending on the species. In this respect, clownfish (*Amphiprion* spp.) are unusual, preferring to inhabit sea anemones. Feeding strategies for ornamental fishes varies from herbivore (surgeonfishes and tangs) through omnivore (wrasses) to carnivore (hawkfishes), depending on the species. They either spawn pelagic eggs or brood their larvae. Butterfly fish (Chaetodontidae) and wrasse (Labridae) are examples of indiscriminate spawners whose eggs hatch into planktonic larvae. Up to 90% 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. They may travel thousands of kilometres from their origin, before settling on a suitable reef habitat. Brooding fish lay eggs on the bottom and usually defend the eggs from predators until they hatch. The newly hatched larvae hide in the reef until they are large and fast enough to escape predation. Common spawners of this type are clown and damselfish (Family Pomacentridae) and some gobies (Family Gobiidae). After spending sufficient time drifting in sea currents, and upon reaching a suitable habitat, fish larvae settle from the water column to the reef, and shortly afterwards metamorphose into juveniles. The chances of an individual fish surviving after settling onto the reef may depend on several factors, most of which are associated with reef fish community structure (Pyle, 1993).

31.2 The Fishery

Utilisation: The major importers of marine aquarium fishes are Europe, Japan and the United States of America. Juveniles are sought after by the trade as they are often more colourful than adults and generally easier to handle and maintain in captivity. Very few of the desirable aquarium species are juveniles of commercial food fishes. They are generally not more than 6 months old and 10 cm long.

Though some aquarium fish are collected by snorkelers, they are usually collected by divers using SCUBA, small-mesh barrier nets and hand-held scoop nets. The divers work between 7−70 m and time spent in deeper water is limited because of decompression problems. Companies in the Pacific operate from 1–5 (usually only 1 or 2) medium-sized dive boats (5–8 m), with 3–5 divers on each. Boats may be in use for 2–6 days per week (Pyle, 1993). Onboard each boat has special tanks for keeping the fish alive and as unstressed as possible. Some collectors use pumps to re-circulate the sea water in the tanks.

Barrier nets typically range in length from 2−15 m. The larger nets are set where schooling fish have been seen and they are chased into the barrier net. The smaller nets are set partly around small coral rubble areas in which one or two target fish have been seen. The fish are then scooped up using the hand-held scoop nets, or if they have become enmeshed, are taken by hand. Some fish are caught solely by two scoop nets. Some aquarium fish hide between the branches of coral heads and needs to be flushed into the barrier net. Coral is sometimes broken to reduce cover and trap the fish. The method of breaking the coral is called “notching”, which is the removal of coral branches in the middle of the coral head. This is done so as to give the best chance for re-growth of the coral (Passfield and Evans, 1991).

The collected fish are placed in a small holding bucket often with a one-way gate, until the dive is finished. A hypodermic needle may be used to pierce the air bladder of each fish to reduce problems associated with decompression. Alternatively, the fish bucket is attached to a decompression line for 2−3 hours. An aquarium system at a warehouse/holding facility keeps the fish alive until shipped to the wholesaler overseas. Aquarium fish warehouse facilities in the Pacific region vary in size from about 50−200 m^2, with an average of about 100 m^2. At the first sign of any disease problems, the water is treated with antibiotics. Great care is taken with water quality with all incoming water being filtered and water and oxygen content controlled. Water is changed regularly, preferably by pumping direct from an unpolluted area of ocean (Passfield and Evans, 1991; Pyle, 1993).

Production and Marketing: A local company, Fiji Biomarine Pty. Ltd., commenced collection operations in 1976, as well as operating an aquarium in Suva. Fish were collected primarily from the Suva-Deuba coastal strip using local divers. Production by this company, which enjoyed sole export rights, gradually declined until operations ceased in 1982.

A second company, Aquarium Fish Fiji Ltd., commenced operations in August 1984, working out of Pacific Harbour, and collecting fish in the Beqa-Serua area (Lewis, 1985). At present there are five registered companies involved in the aquarium fishery trade in Fiji − Walt Smith International, Aquarium Fish Fiji, Waterlife, REL, and Seaking - (Y. Nand, *pers. comm.*), however only four were confirmed as active (U. Rabici, *pers. comm.*). Information on Waterlife and REL was limited, though it appears Waterlife also exports ornamental fish intermittently. Ornamental fish are packed individually into thick-walled polythene bags, separated by a liner of bubblewrap. The bags are inflated with pure oxygen, sealed and packed tightly in lined cardboard boxes prior to being air-freighted to overseas markets.

The number of fish exported have risen gradually from approximately 16,200 individuals in 1984, reaching nearly 150,000 in 1991, with a corresponding value of FJD 293,800 in 1984 to FJD 325,700 in 1991 (Lewis, 1985; Anon., 1984−1992). There was an unexplained drop to less than half this number in 1992. During the 2005−2008 period exports of live ornamental fish averaged approximately 113,000 kg per annum (mean value FJD 8.16 per kg), rising to an average of 171,642 kg per annum (FJD 12.67) for the period 2012−2014. The 2012−2014 values are a combination of “Freshwater ornamental fish” and “Other ornamental fish”. The existence of freshwater ornamental fish exports is suspect, according to the 2014 Fisheries Division Annual Report Fiji’s total wild-caught freshwater harvest was 4.14 mt and there is no indication in the report of any freshwater ornamental fish culture. Table 39 summarises ornamental fish exports from Fiji for the years 2005−2008 and 2012−2014.

Table 39. Quantity (kg) and value (FJD per kg) of ornamental fish exports from Fiji. Due to inconsistent product descriptions used by the Fiji Revenue and Customs Service (FRCS) and inconsistent reporting in Fisheries Division Annual Reports, the data is broken down into two sets. Source: Anon. (2005−2008), FRCS (*unpubl. data*)

	Live ornamental fish			
	Quantity (kg)	Value (FJD per kg)		
2005	125,696	(8.24)		
2006	89,734	(9.59)		
2007	116,802	(7.52)		
2008	119,304	(7.30)		
	Freshwater ornamental fish		Other ornamental fish	
	Quantity (kg)	Value (FJD per kg)	Quantity (kg)	Value (FJD per kg)
2012	89,558	(10.52)	71,444	(11.58)
2013	83,952	(10.68)	92,973	(15.08)
2014	86,205	(11.90)	90,796	(16.24)

31.3 Stock Status

Although catch numbers by species are submitted by the exporting companies each time an application for an export permit is made, recent analyses have not been conducted to determine variations in catch per unit effort for this fishery. Therefore it is not possible at present to provide a detailed assessment of the stock status of aquarium fish in Fiji. On the issue of the impact of aquarium fish collection on coral reef fishes, Perino (1990) noted that no noticeable decline in reef fish populations had occurred in Fiji despite six years of collecting activity. However, further study is required on this topic (Pyle, 1993). The reason why the number of fish exported in 1992 is approximately half of that the numbers exported in 1990 and 1991 should be investigated. It should be kept in mind that Hawaii, with a much smaller reef area than that of Fiji (<10%) and a longer history of aquarium fish collection, exports over 150,000 fish per year on a sustainable basis (Lewis, 1985).

31.4 Management

Current Legislation and Policies Regulating Exploitation: Regulation 26 of the Fisheries Regulations (Cap.158 as amended) provides, in part, that "No person shall export from Fiji live fish of any kind whatsoever", though Regulation 27 provides that an exemption may be granted by the Permanent Secretary for Agriculture and Fisheries, or any person appointed by him. In effect, this allows as much stringency in the licence conditions for aquarium fish operators as is required. Several species of reef fish involved in the ornamental fish trade are listed in Schedule 1 (Section 3) and Schedule 2 (Section 3) of the Fiji Islands Endangered And Protected Species Act 2002. This act regulates and controls the international trade, domestic trade, possession and transportation of species protected under the convention on international trade in endangered species of wild fauna and flora, and for related matters. All species of aquarium fish listed in Table 38 are listed as either 'Not Evaluated' or 'Least Concern' under CITES (IUCN, 2017). Gillett (2014) notes that no management plans or policy guidelines for aquarium fish fisheries are in place.

Management Recommendations: Teitelbaum *et al*., (2010) lists several challenges and possible solutions or actions that could be taken by the Pacific aquarium trade, these include the need for certification, risk and stock assessments, as well as improving compliance and capacity issues regarding CITES-related requirements.

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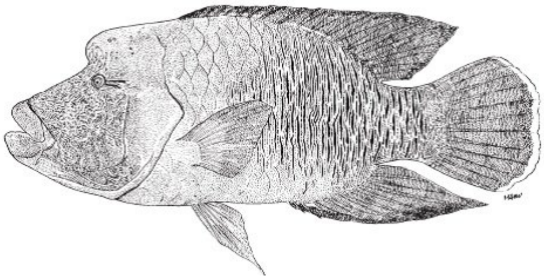
32 LIVE REEF FOOD FISH



32.1 The Resource

The live reef food fish trade (LRFFT) in Fiji appears to have been a boom-and-bust venture, initially encouraged by the Government in the late 1990s (Ovasisi, 2006). The trade increased in size from one to eight companies, before decreasing to two companies in early 2003, primarily for economical reasons (Ovasisi, 2006). This trade differs from the aquarium fish trade in three key aspects: species targeted and their size; primary markets; and the fish are ultimately consumed. Anecdotal information obtained from the Ministry of Fisheries suggests the LRFFT in Fiji has been surpassed by the chilled and frozen reef fish trade.

Biology and Ecology: Fish preferred for the LRFFT are typically carnivores at the top of their food chain. They typically have a low abundance relative to other animals in their food chain, are long lived, and mature later in life (Sadovy *et al*., 2003). Groupers and **varivoce** (*Cheilinus undulatus*) are indiscriminate spawners whose eggs hatch into planktonic larvae. A more detailed account of the biology and ecology of groupers (*Cephalopholis* spp., *Plectropomus* spp., and *Epinephelus* spp.) can be found in Profile 23 GROUPERS; therefore the biology and ecology of only the two wrasses (family: Labridae) **varivoce** and **draunikura** (*C. trilobatus*) will be briefly described below.

A detailed account of the distribution, habitat, abundance, and biology of **varivoce** can be found in Sadovy *et al.* (2003). This species is the largest living member of the family Labridae, and can grow beyond a length of 2 m and weigh over 190 kg. **Varivoce** are closely associated with coral reefs and inshore habitats throughout most of the Indo-Pacific. Juveniles are typically associated with inshore habitats with high coral cover or seagrass. As the animal grows it gradually moves towards outer and deep reef habitats and is often found along steep slopes, channels and passes. It feeds on a variety of invertebrate and small fishes. Adult **varivoce** are naturally found at low densities, rarely exceeding 20 fish per ha. This species is thought to be a protogynous hermaphrodite – initially female before changing into a hermaphrodite, with sex reversal occurring at about 15 years of age (Pogonoski *et al*., 2002; Sadovy *et al*., 2003). For reproduction, **varivoce** form spawning aggregations which can be in excess of 100 individuals. This species lives to at least 30 years, reaching sexual maturity at approximately 35–50 cm TL (<5 years of age).

Draunikura have a wide distribution, greater than that of **varivoce**. Juveniles are found on algae reefs, while adults tend to inhabit coral lagoon, coastal reef-flats, seaward reefs, and shallow reef margins with high coral cover, to depths of 20 m. **Draunikura** feed primarily on benthic, hard-shelled invertebrates such as crustaceans and molluscs, and occasionally small fishes (Carpenter and Niem, 2001; Allen *et al*., 2010). The species is oviparous, and exhibit a distinct pairing during breeding (Breder and Rosen, 1966 in Froese and Pauly, 2017)

32.2 The Fishery

Utilisation: A host of different methods are used to capture live reef fish: hook and line, trap, nets, artificial reefs, and chemicals (commonly cyanide) (Sadovy and Vincent, 2002). Traps are constructed with a steel or mangrove frame and covered in chicken wire, with a rectangular or arrowhead shape (SPC, 2001). They are placed on the bottom by divers and packed with rocks and coral in order to make it look like a natural structure. Cyanide, though an illegal and particularly destructive fishing method appears to be common. A diver squirts the cyanide solution from a squeeze bottle at the target organism; this in small doses stuns the animal, with overdoses resulting in the death of the animal (Gillett, 2010). What makes cyanide particularly damaging is that the poison kills smaller organisms including corals that come into contact with the solution, and in order to get to the stunned animal divers often break the coral structure. In Fiji, derris root appears to be the poison of choice for the capture of **varivoce**, rather than cyanide (Gillett, 2010).

Regardless of capture method, once caught the fish are held in a specially fitted dinghy (with a sea water compartment that allows free flow of water through the compartment) before they are transferred to a larger carrier vessel with similar compartments or cages anchored off reefs, until they are sold *in situ* or after transport (Gillett, 2010). Depending on size and species, live reef fish are either packed into individual polythene bags similar to aquarium fish, or into insulated and molded plastic bins (300 kg capacity). The bags and bins are inflated with pure oxygen, sealed and packed tightly in lined cardboard boxes prior to being air-freighted to overseas markets (Sadovy *et al*., 2003).

Table 40. Main species targetted by the live reef food fish trade (LRFFT) in the Pacific Islands region. Note There is currently a ban on the fishing of varivoce in Fiji. Value in the LRFFT: VH=very high, H=high, M=medium, L=low. IUCN Conservation Status: En=Endangered, NT=Near Threatened, VU=Vulnerable, LC=Least Concern. Source: Carpenter and Niem (1999b, 2001b); Sadovy (2006), SPC (2008), IUCN (2017)

Common name	Scientific name	Fijian name	Habitat and depth	Value	IUCN status
humphead wrasse	*Cheilinus undulatus*	**varivoce**	steep outer reef slopes, channel slopes and lagoon reefs. 1–60 m. Juveniles prefer *Acropora*-rich lagoon reefs.	VH	EN
tripletail wrasse	*C. trilobatus*	**draunikura**	lagoon / seaward reefs. 1–30 m	M	LC
peacock hind	*Cephalopholis argus*	**kawakawaloa, tikiloa**	tide pools and reef flats to reef slopes. 1–40 m, but commonly from 1–10 m	L	LC
leopard coral grouper	*Plectropomus leopardus*	**donu**	lagoon and mid-shelf reefs. 3–100 m. Juveniles prefer shallow rubble areas	H	NT
backsaddled coral grouper	*P. laevis*	**donuloa**	channels and outer reef shelves. 4–100 m. Juveniles prefer shallow coral rubble areas.	M	VU
squaretail coral grouper	*P. areolatus*	**batisai**	isolated coral heads in lagoons or bays but also on outer reefs. 2–150 m	M	VU
speckled blue grouper	*Epinephelus cyanopodus*	**revuya, rogoceva**	isolated coral heads in lagoons or bays and outer reefs. 2–150 m	H	LC
white spotted grouper	*E. coeruleopunctatus*	**soisoi, kasalatuiloa**	deep lagoons, channels and outer reef slopes. 2–65 m	M	LC
camouflage grouper	*E. polyphekadion*	**kawakawa, kasala**	coral-rich areas of lagoon and outer reefs. 2–60 m	M	NT
brown-marbled grouper	*E. fuscoguttatus*	**delabulewa**	lagoon pinnacles, channels and outer reef slopes. 1–60 m	M	NT
highfin grouper	*E. maculatus*		isolated coral heads in lagoons and seaward reefs	H	LC
giant grouper	*E. lanceolatus*	**kavu**	once common in shallow waters near caves	M	VU

Production and Marketing: The LRFFT in Fiji was introduced by the government in the late 1990s through the Ministry of Agriculture Fisheries and Forest Commodity Development Framework Programme. The trade began with one pilot company later increasing to eight companies, however most of these subsequently opted to move out of Fiji citing a host of reasons including high transport costs within Fiji, high international shipping costs to markets in Asia, and the inability for LRFFT operators to legally take other fish and invertebrate species (Ovasisi, 2006).

The majority of live reef fish are imported into Hong Kong, China either for local consumption or for trans-shipment to mainland China. The market's general preference is for relatively small fish (plate sized), and as a result many immature or juvenile fish are taken (Sadovy *et al*., 2003). A 3-month study of Hong Kong retail markets in 1994 and 1995, found that about 70% of **varivoce** (*C. undulatus*) and 80% of **delabulewa** (*E. fuscoguttatus*), and almost 100% of **kavu** (*E. lanceolatus*) on sale were juveniles, whereas the more commonly traded smaller species on sale, such as the orange-spotted grouper (*E. coioides*), **kasala** (*E. polyphedakion*), and **donu** (*P. leopardus*), had already attained adult size (Lee and Sadovy, 1998). It was estimated that only 10–15% of the fish entering the LRFFT wordlwide originate from full-cycle aquaculture, 50–70% are wild-caught market-size fish, and 15–40% are wild-caught, undersized and juvenile fish that are "grown out" or "ranched" in tanks or cages until they reach market size (Sadovy *et al*., 2003). In Fiji all LRFFT were wild-caught (Ovasisi, 2006).

From late 2002 until early 2003, only two companies were operating in Fiji's LRFFT: Satseas Company Ltd in Bua (Northern Division), and Atlas Ocean Products Ltd (Southern Lau). The buying prices ranged from FJD 5.50–6.00 per kg for **varivoce** and FJD 4.50–5.00 per kg for serranids or lower, depending on the fish quality. These buying prices were fixed as part of the agreement between the custodians, operators and the Fisheries Department (Ovasisi, 2006).

According to Kronen *et al*., (2006) in 2002 the LRFFT in the Lau Group, Fiji had an average catch of 345 kg per week worth FJD 966 if a mother boat was present; in the absence of a mother boat the average catch was 30 kg per week worth FJD 75. As of 2006 King Fisheries Limited was the only company operating in the LRFFT, taking over the Satseas operation in 2004. The company exported an average of 180 kg of LRFF each week, valued at FJD 1,260 (purchase value from fishers), equivalent to 9,360 kg per annum valued at FJD 65,520 (Ovasisi, 2006). CITES Trade database records indicate 41.3 kg of **varivoce** were exported in 2004. Commercial take and sale of **varivoce** was banned later that year (Gillett, 2010). It is unclear whether or not the LRFFT still operates in Fiji, anecdotal information suggests that the trade was banned shortly after 2006; however, no official government press release confirming this could be found. It has also been suggested that the LRFFT continued until no longer profitable and has since been taken over by the chilled reef fish trade, which is able to operate relatively unrestricted and unregulated compared to the LRFFT (N. Kunidrani, *pers. comm.*).

Table 41 summarises LRFFT exports from Fiji for the years 2005–2008 and 2012–2014. For the period 2012−2014 FRCS records do not specify whether or not "Trout" and "Other Salmonidae" exported were live or not. Gillett (2010) states that about four tonnes of **varivoce** were exported annually by a single LRFFT operator until a ban on the commercial take and sale of **varivoce** in 2004 resulted in the closure of the **varivoce** fishery.

Table 41. Quantity (kg) and value (FJD per kg) of live reef fish and fish commonly involved in the LRFFT exported from Fiji. Due to inconsistent product descriptions used by the FRCS and inconsistent reporting in the Fisheries Division Annual Reports, data in is broken down into two sets. Source: Anon. (2005−2008), FRCS (*unpubl. data)*

Year	Other live fish		Trout (live)[2]			
	Quantity (kg)	Value (FJD per kg)	Quantity (kg)	Value (FJD per kg)		
2005	41,724	(5.32)	15,418	(6.37)		
2006	45,503	(4.57)	5,850	(5.78)		
2007	na	na	62,163	(3.74)		
2008	81,987	(11.46)	11,502	(5.69)		
	Other live fish		Trout[1,2]		Other Salmonidae[1,2]	
	Quantity (kg)	Value (FJD per kg)	Quantity (kg)	Value (FJD per kg)	Quantity (kg)	Value (FJD per kg)
2012	694	(10.31)	470	(27.71)	6,676.5	(4.81)
2013	14,191	(9.83)	988	(9.13)	5,706	(9.22)
2014	4,557	(12.80)	25,263	(5.94)	11,067	(11.37)

[1] FIRCA records (2012–2014) do not specify whether live or not, however given the importing countries are the main markets for live reef fish (Taiwan, Hong Kong, Japan) we assume these were live fish exports.

[2] Trout and Salmonids are not found in Fiji, this is likely a mis-identification of coral trout and salmon cod (*Plectropomus* spp.).

32.3 Stock Status

The mean export quantity of LRFFT (Table 41) for the period 2012−2014 (ca. 23 mt per year) was 65% lower than that for the period 2005−2008 (66 mt per year). This decrease may be indicative of decreasing stocks, alternatively it may reflect decreased participation in the fishery (measured as number of operating companies) as noted by Ovasisi (2006). The majority of LRFFT species listed in Table 41 form large spawning aggregations. Fisher interviews collected between 2003−2005 suggest that spawning aggregations of **kasala** around Vanua Levu have declined from a CPUE[26] of roughly 80 kg per boat per day in the 1980s, to less than 20 kg for the same effort (Sadovy, 2006). Fiji's reef-fish fisheries are heavily exploited, and this has caused serious declines in at least one species of grouper, **kasala** (Sadovy, 2006) – the study did not consider other species of fish. On an individual reef basis, the yields being taken are likely to be unsustainable (Sadovy *et al*., 2003). A more detailed account on the stock status of serranids in Fiji can be found in Profile 23 GROUPERS.

Varivoce are considered uncommon and rare, even under natural (unfished) conditions; within its distribution, and even in preferred habitats densities of **varivoce** are very low for a commercial species, rarely >10 fish per 10,000 m^2 when not fished (Russell, 2004).

32.4 Management

Current Legislation and Policies Regulating Exploitation: Regulation 26 of the Fisheries Regulations (Cap.158 as amended) provides, in part, that "No person shall export from Fiji live fish of any kind whatsoever", though Regulation 27 provides that an exemption may be granted by the Permanent Secretary for Agriculture and Fisheries, or any person appointed by him. In effect, this allows as much stringency in the licence conditions for LRFF operators as required. *C. undulatus*, *E. lancelatus*, and *E. malabaricus* are

26 Catch per unit effort, Sadovy (2006) used daily landings (kg) per boa

listed in Schedule 1 (Section 3) and Schedule 2 (Section 3) of the Endangered and Protected Species Act 2002. This Act regulates and controls the international trade, domestic trade, possession and transportation of species protected under the convention on international trade in endangered species of wild fauna and flora, and for related matters.

Minimum size limits of all species of Serranids is 25 cm, and the use of any chemical or chemical compound to stupefy or kill any fish is illegal (Fisheries Act Cap. 158). Ovasisi (2006) lists management and monitoring systems currently in use, management guidelines (proposed in 2005), conservation measures, and major challenges for the LRFF trade. Since September 2004 there has been a ban on the commercial take, capture for sale, offer for sale, or possession of live or dead specimens of the humphead wrasse (Gillett, 2010).

Management Recommendations: Ovasisi (2006) lists management guidelines for the LRFF fishery. These include a ban on the taking of **varivoce**, companies must engage in the LRFF operation only, no other marine resources are to be taken by them, and licences are to be reviewed each year.

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33 DEEP SLOPE AND OFFSHORE FISH

33.1 The Resource

Fiji's exclusive economic zone (EEZ) covers roughly 1.3 million km^2. The offshore fisheries of Fiji occur around deep reef slopes, sea mounts, and in the pelagic zone within the nation's EEZ. Targeted species and fishing methods vary between these accordingly. Fisheries for deepwater bottom fish are concentrated around deep reef slopes and seamounts, often fishing at depths between 130−460 m (Stone, 2003). Deepwater bottom fish refers to a complex of groupers (Serranidae) and snappers (Lutjanidae). There are two distinct capture zones, the first of which is between 130−220 m and the second between 330–400 m. The first zone is dominated by *Pristipomoides* spp., *Aphareus rutilans*, *Paracaesio kusakarii*, *Seriola rivoliana* and *Wattsia mossambica*. The second deeper zone is characterised by *Etelis* spp., *Epinephelus* spp., and *Paracaesio stonei* (Stone, 2003). After depth, bottom features such as ridges, bottom hardness, rugosity, and slope are good predictors of species composition (Oyafuso *et al*., 2017).

Table 42 lists several groups of deepwater bottom fish commonly taken in Fiji's waters, and references to their respective profiles; ehu (*Etelis carbunculus*) has been selected as an exemplar species and is the focus of a dedicated profile. Sharks (Profile 36 SHARKS AND RAYS), tuna (Profile 37 OCEANIC TUNA) and mahi mahi (Profile 39 DOLPHINFISH/ MAHI MAHI) and other large ocean pelagics such as wahoo (*Acanthocybium solandri*) (Profile 41 WAHOO) and billfish (Families: Istiophoridae and Xiphiidae) (Profile 40 LARGE OCEAN PELAGIC FISH) are taken in the pelagic zone at varying depths; from mahi mahi (*Coryphaena hippurus*) at the surface to albacore tuna (*Thunnus alalunga*) (Profile 38 ALBACORE TUNA) around 300–400 m. Longlining is the primary fishing method of choice for commercial fisheries, artisanal and game fishers tend to use trolling with lures. Albacore (*T. alalunga*) and yellowfin (*T. albacares*) tuna are the main targets of longliners in Fiji.

Pelagics are highly mobile and very widely distributed in the western and central Pacific Ocean. None of the species listed in Table 42 are endemic to Fiji; they have wide stock ranges, some with a high degree of population structure across the Pacific and others constituting a single basin-wide genetic stock. Without any physical barriers in the open ocean, distribution and movements of stock in this three-dimensional habitat are governed by oceanic conditions such as sea temperature, current speeds, direction, location, depth, upwellings, convergences, etc. (Fromentin and Fonteneau, 2001 in Nicol *et al*., 2014). Nicol *et al.* (2014) describes and explains how changes in these oceanic conditions influence the distribution and abundance of tuna and tuna fisheries in the western and central Pacific Ocean. Table 42 lists several pelagic fish commonly taken in Fiji's waters, and references to their respective profile; **yatuloa** (Albacore tuna – *Thunnus alalunga*), **walu** (Spanish mackerel – *Scombermoris commerson*), **maimai** (Mahi mahi – *Coryphaena hippurus*) and **wau** (Wahoo – *Acanthocybium solandri*) are subjects of dedicated sub-profiles.

Biology and Ecology: Pelagic species tend to have fast growth rates, are highly mobile, have a high fecundity, and some species are relatively short lived. This is in stark contrast to the life-history of many deepwater bottom fish, which are slow growing, long lived, and tend to aggregate around submarine features such as sea mounts and deep reef slopes.

Between 1998 and 2001 the FAO published six volumes of "The Living Marine Resources of The Western Central Pacific", this series of publications proved an invaluable resource in the compilation of these profiles notably in regard to the taxonomy, and basic biology and ecology of most species listed throughout this publication. Volumes 5 and 6 cover most species of deepwater bottom fish and tunas, respectively. Moffitt (1993) in Wright and Hill (1993) discusses the biology and ecology of "Deepwater Demersal Fish", many of which are listed in Table 42. Information on various species biological parametres can be found through FishBase (Froese and Pauly, 2017).

Table 42. The common species of fish harvested from the reef slope, deep reef, offshore, and open ocean habitats of Fiji. Source: Lewis *et al.* (1983), Lewis (1984), Lewis (1985), Moffitt (1993), Stone (2003); SPC (2008), Fish Base, FAO Identification Guide Western Central Pacific.

Common name	Scientific name	Profile reference
onaga	*Etelis* spp.	34. Deepwater bottom fish
opakapaka	*Pristipomoides* spp.	34. Deepwater bottom fish
lehi	*Aphareus rutilans*	34. Deepwater bottom fish
Bedford	*Paracaesio kusakarii*	34. Deepwater bottom fish
hapu	*Epinephelus* spp.	34. Deepwater bottom fish
ehu	*Etelis carbunculus*	35. Ruby Snapper/Ehu
yellowfin tuna	*Thunnus albacares*	37. Oceanic tuna
bigeye tuna	*Thunnus obesus*	37. Oceanic tuna
albacore tuna	*Thunnus alalunga*	38. Albacore tuna
skipjack tuna	*Katsuwonus pelamis*	37. Oceanic tuna
great barracuda	*Sphyraena barracuda*	29. Large coastal pelagic fish 40. Large ocean pelagic fish
Spanish mackerel	*Scomberomorus commerson*	30. Narrow-banded Spanish mackerel
dogtooth tuna	*Gymnosarda unicolor*	29. Large coastal pelagic fish
mahi mahi	*Coryphaena hippurus*	39. Dolphinfish/Mahi mahi
opah	*Lampris guttatus*	40. Large ocean pelagic fish
escolar, oilfish	Gemphylidae	40. Large ocean pelagic fish
wahoo	*Acanthocybium solandri*	41. Wahoo
swordfish	*Xiphias gladius*	40. Large ocean pelagic fish
marlin, spearfish, sailfish	Istiophoridae	40. Large ocean pelagic fish

33.2 The Fishery

Utilisation: The majority of species listed in Table 42 are targeted by commercial fisheries. Spanish mackerel (**walu**), wahoo (**wau**), and great barracuda (**ogo**) are taken by artisanal fishers using baited line, lures, and in the case of **walu** and smaller **ogo** by spear. Ehu, **yatuloa** (albacore tuna – *Thunnus alalunga*), **yatunitoga** (yellowfin tuna – *Thunnus albacares*), and **yatulevu** (bigeye tuna – *Thunnus obesus*) are generally exported. Though taken throughout Fiji's EEZ, most of these fish are unloaded and processed in Suva.

Production and Marketing: There is considerably more information about the production and marketing of fish taken in Fiji's offshore pelagic fisheries than there is for its deep reef fisheries. The Fisheries Division Annual Report published in 2005 stated that 256.91 mt of deepwater bottom fish were sold in Fiji's municipal and non-municipal market outlets in 2004. Anecdotal information suggests much of the current deepwater bottom fish catch are sold directly to hotels, restaurants, and private buyers. Their exceptional eating quality allows these fish to fetch relatively high prices on both the local and export markets. An outlet in Pacific Harbour sold whole fresh opakapaka for FJD 18 per kg, while boneless skinless fillets go for FJD 34 per kg.

Tuna and the various pelagic species listed in Table 42 are of lower value than deepwater bottom fish, however they are caught in much larger quantities. Some of the catch from longliners ends up in municipal markets. This is more common in markets around Suva as these vessels unload their catch in Suva and the harbor/port is used as a transshipment point.

33.3 Stock Status

Deepwater bottom fish, particularly snappers, have life histories that make them prone to overfishing. However, Adams and Chapman (2004) state that the apparent collapse of the fishery in the late 1980s was not due to overfishing, rather the equilibrium catch rates were low enough to make the fishery uneconomical for most operators. It is difficult to have any sense of the state of Fiji's deepwater bottom fishery given the lack of data, which was already a problem in 2002 and has deteriorated since. Several Fisheries Division Annual Reports going back to 2002 state "the reef slopes and sea mounts [of Fiji] are populated with deep water snappers with a maximum sustainable yield of 1,800 metric tons." However, the reports give no indication of how this value was calculated, nor where it came from. Based on studies in Fiji and throughout the Pacific, Fiji's deepwater bottom fishery likely has an MSY closer to 462 mt per year (Lewis *et al.*, 1988; Dalzell and Preston, 1992; Adams and Chapman, 2004).

An assessment of **walu** stocks in Fiji has never been conducted. Continuing decline in **walu** sales and increased catches of juveniles as evident in municipal market sales raise concern over the state of Fiji's **walu** stocks. As such there is an urgent need to assess the status of the Fiji **walu** stock. The stock status of other large ocean pelagics such as opah, escolar and other large ocean pelagcis remains completely unknown. Given the highly migratory nature and wide ranges of pelagic stocks it is necessary to assess these stocks over a much wider area than a nation's EEZ alone. Table 43 below summarises the stock status of several pelagic fish in the Western and Central Pacific Ocean (WCPO). Except for albacore, Fiji catches make a very minor contribution to the overall WCPO catch based on the same stocks.

Table 43. Status of tuna in the Western and Central Pacific Ocean (WCPO). Note that the South Pacific albacore tuna catch is given rather than the WCPO catch.

Species	Overfishing	Current catch rel. to MSY	Trend	Assessment
yellowfin	No $F_{recent} / F_{MSY} = 0.75$	Below or near 668,000 mt	Increasing	Tremblay Boyer *et al.* (2017)
bigeye	Probably not $F_{current} / F_{MSY} = 1.01$	Near or over 151,380 mt	Stable	McKechnie *et al.* (2017)
skipjack	No $F_{current} / F_{MSY} = 0.62$	Above 1,532,000 mt	Stable	Rice *et al.* (2014)
South Pacific albacore		either at or less than MSY	Decreasing	Harley *et al.* (2015)
blue marlin	Not being overfished and not in an overfished state			Anon (2013)
striped marlin (SW Pacific)	Not being overfished, but approaching an overfished state			Davies *et al.* (2012)
swordfish (SW Pacific)	Not being overfished and not in an overfished state			Takeuchi *et al.* (2017)
sailfish, spearfish, black marlin	No information			No assessment available for WCPO

Species	Overfishing	Current catch rel. to MSY	Trend	Assessment
wahoo	Current fishing mortality lower than conservative target and limit reference points. Some indication that recruitment overfishing was likely to be a greater potential concern for wahoo fisheries than growth overfishing			Zischke and Griffiths (2015)

33.4 Management

Current Legislation and Policies Regulating Exploitation: Most relevant legislation/policy can be found in the Fisheries Act, the Offshore Fisheries Management Decree 2012 and its Regulations 2014. Additionally, management of Fiji's oceanic tunas is facilitated through the various Western and Central Pacific Fisheries Commission (WCPFC) Conservation and Management Measures (CMMs) and the Fiji Tuna Management Development Plan 2014−2018. The Marine Spaces Act outlines policy and the demarcation regarding Fiji's marine environment.

Management Recommendations: Current and recommended policy regarding exploitation can be found in the respective profile for each fishery (see Table 43).

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34 DEEPWATER BOTTOM FISH

The term "deepwater bottom fish" refers to a complex of snappers and groupers found beyond depths of 130 m. Not a traditional Fijian fishery, it was introduced in the late 1960s by fishers trained in Hawaii, where it was a traditional fishery with accounts dating back to at least the late 1800s (Beckley, 1883). Deepwater snapper and groupers are a popular seafood choice for hotels and restaurants due to their exceptional eating quality and most species being practically void of ciguatera toxicity.

34.1 The Resource

Species Present: Table 44 lists the 25 most common species of the deepwater bottom fish array found in Fiji waters. Though the Fijian names are provided, the common name is often used in place of the Fijian. This profile will resort to the common name where applicable otherwise the scientific name will be used. The majority of deepwater snapper species belong to the family Lutjanidae − these include *Aprion* spp., *Etelis* spp., *Paracaesio* spp., and *Pristipomoides* spp. (Carpenter and Niem, 2001). Six species listed in Table 44 belong to the family Serranidae − these are groupers of the genus *Epinephelus* spp., and *Variola* sp. A detailed profile is available for Ehu (**laulausevusevu** − *Etelis carbunculus*) (see Profile 35 RUBY SNAPPER / EHU).

Distribution: The 25 species of deepwater fishes listed for Fiji have a wide distribution throughout the central, western, and South Pacific. Species richness tends to decrease with increasing distance from the Indo-Pacific faunal center (Moffitt, 1993). Within their range these deepwater fish can be found on the continental slope, pinnacles, and seamounts at depths between roughly 130−460 m. There are two distinct capture zones in many areas, the first of which is between 130−220 m and the second between 330−400 m. The first zone is dominated by *Pristipomoides* spp., *Aphareus rutilans*, *Paracaesio kusakarii*, *Seriola rivoliana* and *Wattsia mossambica*. The second deeper zone is characterised by *Etelis* spp., *Epinephelus* spp., and *Paracaesio stonei* (Stone, 2003).

Biology and Ecology: Deepwater bottom fishes, especially snappers, tend to have slow growth with low recruitment, which results in them being highly susceptible to over-fishing. They are usually top-level carnivores, feeding on fish, squid and deepwater shrimp (Smith, 1992). Information on their biology and ecology is available in Moffit (1993).

34.2 The Fishery

Utilisation: Deepwater fishes are caught with baited tuna-circle hooks, usually 4–5 per drop, from hand-operated, electric or hydraulic reels. Hydraulic reels were once the standard but are gradually being replaced by electric, as the design and reliability of these improve. Bottom-set longlines are also used in some areas, though now illegal (see section 34.4). Baits vary, from stripped/long cut squid to tuna bellies and other fish parts. In Fiji stripped skipjack tuna is common, and a palu/chum/berley bag may be used to attract and aggregate fish, and increase catch rates (Stone, 2003). Given the habitat of these fish, the fishery is concentrated around coastal slope areas and seamounts, and lines are set between depths of 100−300 m (Adams and Chapman, 2004). Vessels targeting deepwater fishes are typically equipped with depth sounders and electronic navigational aids, to better locate productive locations and depths. In order to target deepwater snapper, lines are held a few metres above the bottom, whereas if deepwater groupers are targeted lines are often kept closer to the bottom.

The market for deepwater fishes is a fresh fish market, therefore fish are iced and fishing trips are limited to about 10 days at the most, in the case of large commercial vessels, or 3 days in the case of smaller (<10 m) vessels (Moffit, 1993). The flesh of almost all species is of excellent quality and is free of ciguatoxin - barring kahala (*Seriola*) and the yellow-edged lyretail (*Variola*) (Lewis, 1985) which are mostly distributed in shallow waters.

Table 44. List of common deepwater fishes of Fiji, and their export status. Source: Moffitt, 1993; Stone, 2003a; SPC 2008b.

Common name	Scientific name	Fijian name	Export status
ehu	*Etelis carbunculus*+	**laulausevusevu**	Dominant
onaga	*Etelis coruscans*	**reveni**	Dominant
small tooth snapper	*Etelis radiosus*	**drasesevu, batilalai**	Probably included in Ehu exports
scale mouth jobfish	*Parapristipomoides squamimaxillaris*	**ruruka, utoutoninubu**	
ornate jobfish	*Pristipomoides argyrogrammicus*	**tukula, canati**	
purple cheek opakapaka	*Pristipomoides multidens*	**pakapakaqia**	This is the most common Fiji species and is well received on the export market
yellow-finned opakapaka	*Pristipomoides flavipinnis*	**pakapakabuidromo**	An export species used in the whole deep-fried market because of its smaller size.
opakapaka	*Pristipomoides filamentosus*	**pakapakabuidamu**	
gindai	*Pristipomoides zonatus*	**yalayala**	A specialty Hawaii export species
lavender jobfish	*Pristipomoides sieboldii*	**pakapakasewa**	
red tailed opakapaka	*Pristipomoides typus*	**pakapakabatisewa**	This species is not very common.
green jobfish	*Aprion virescens*	**utouto**	
lehi	*Aphareus rutilans*	**sewidri**	Dominant
large eye bream	*Wattsia mossambica*	**sabutukula**	Local market
Bedford	*Paracaesio kusakarii*	**uluqa**	Local market
Stone's snapper	*Paracaesio stonei*	**uluqa**	Local market
scarlet snapper	*Lutjanus malabaricus* *L. timorensis*	**rosinibogi**	Occasionally exported to Hawaii
brown spotted grouper	*Epinephelus chlorostigma*	**cevanibua**	
hapu	*Epinephelus magniscuttis*	**kulinimasi**	Exported
hapu	*Epinephelus miliaris*		Exported
hapu	*Epinephelus morrhua*	**kulinidovu**	Exported
eight bar grouper	*Epinephelus octofasciatus*	**kawakawaninubu**	
hapu	*Epinephelus septemfasciatus*		Exported
kahala	*Seriola rivoliana*	**saqavotoqa**	Not exported to Hawaii as banned because of ciguatera
yellow edged lyretail	*Variola louti*	**varavaranitoga**	

+ Recently described as two separate species. The new species, the pygmy ruby snapper is yet to be given a specific epithet. It is described in SPC (2013) and Andrews *et al.*, (2016)

Production and Marketing: A detailed account of the development of Fiji's deepwater bottom fishery can be found in Stone (2003). A commercial fishery targeting deepwater bottom fish began in 1979; catches were sold locally until 1982 when a local company began exports. As this was an unexploited fishery, the initial CPUE was high, and most business plans were projected on these initial high catch rates; however, when the fishery settled down to a sustainable equilibrium, catch rates were approximately one-third of the virgin fishery. This, coupled with the development of the small-scale tuna longline fishery around the late 1980s to 1990s, and political events (which disrupted airline scheduling) eventually led to the demise of Fiji's deepwater bottom fishery in 1987 (Stone, 2003; Adams and Chapman, 2004). Lewis *et al.*, (1988) provides a detailed description of the fishery prior to 1987.

Lewis *et al.*, (1988) reported preliminary average catch rates from bottom longlining of 405 kg per set with 200 hooks and average soak times of 11 hours. If this is representative of the CPUE on the virgin stock, then the equilibrium catch rate at MSY would probably be in the region of 200 kg per set for equivalent gear and soak time. Based on the SPC data, catch rates at MSY for dropline fishing would be expected to average about 5.8 kg per line per hour. During 1987, 125 mt of fish were exported, while 35 mt were sold locally (Lewis *et al.*, 1988). In 1985, local prices ranged up to FJD 3 per kg whole weight, whereas Honolulu auction prices averaged USD 6−9 per kg. In 1989, there were at least 22 larger vessels locally involved in the fishery. As mentioned, some of the commercial fishing areas began to show declines in CPUE during the late 1980s and this and other economic factors prompted alternative investment by fishermen in longline gear for sashimi tunas and other pelagic species.

During the first six months of 1990, only 43.7 mt of deepwater snappers were exported from Fiji and were not expected to exceed 100 mt for the entire year. In 1994 there were two large commercial vessels actively involved in the deepwater snapper fishery, but several 8.6 m vessels supplied deepwater bottom fish to hotels and other markets. Prices paid for these fish averaged between FJD 3−4 per kg.

In 1998, 25.9 mt of deepwater bottom fish were exported by Fiji companies, this gradually increased to 52.20 mt in 2002 (Stone, 2003). The 2002 export composition shown in Table 45 had an average value of USD 7.92 per kg, of which **onaga** commanded the highest price − USD 9.44 per kg. The Fisheries Division Annual Report record a total export value of FJD 530,000 for deepwater bottom fish in 2002 (Anon., 2003). A 2016 survey of Central Division municipal markets found that **pakapaka** had a mean price of FJD 7.74 per kg, and **utouto** FJD 6.40 per kg (Ministry of Fisheries, *unpubl. data*).

From 2001–2003 an average of 11 deepwater snapper fishing licences were issued per year. This decreased to an average of about 6 licences per year for the period 2005−2011 (Fisheries Division Annual Report, 2011; Stone, 2003). However, Stone (2003) points out there are a number of fishers fishing and exporting through a pack-house who do not have a licence. As far back as 2002, deepwater snapper licences were not strictly monitored, nor were catch data logsheets submitted. Hence judging the state of the fishery is largely guess work. Stone (2003) suggests Fiji's total deepwater bottom fishery production is likely twice the export volume as "the Zone 1 (70–120 fathoms, or 130–220 m) fishery for deepwater snappers, apart from *Aphareus* spp., are almost all marketed locally while the Zone 2 caught fish are exported." Anecdotal information from local fishing companies suggests there are few (about 5) commercially licenced deepwater snapper fishing vessels, none of those licenced are semi-industrial vessels. Therefore the subsistence and artisanal fishery likely contribute the majority of total landings. A local company based out of Pacific Harbour sold boneless deepwater snapper fillets for FJD 19.30−37.50 per kg, whole onaga (gilled and gutted) and ehu sold for approximately FJD 18 per kg in 2017.

Table 45. Production volume (mt) of several species of deepwater bottom fish, values for municipal and non-municipal markets were combined. na: not available. Source: Fiji Fisheries Division Annual Reports (Anon., 2002–2004), + Stone (2003)

Common name	Scientific name	Fijian name	2002 (exports, mt)+	2002	2003	2004
opakapaka	*Pristipomoides* spp.	**opakapaka**	1.13	38.90	70.12	105.52
Timor snapper, scarlet snapper	*Lutjanus timorensis, L. malabaricus*	**rosinibogi**	na	10.81	38.22	90.11
large eye bream	*Wattsia mossambicus*	**sabutukula**	na	0.44	19.18	0.08
hapu	*Epinephelus* spp.		2.35	na	na	na
ehu	*Etelis carbunculus*	**laulausevusevu**	22.27	na	na	na
onaga	*E. coruscans*	**reveni**	18.62	na	na	na
lehi	*Aphareus rutilans*	**sewidri**	7.84	1.29	5.06	6.62
Bedford	*P. kusakarii*	**uluqa***	na	28.47	7.02	24.24
green jobfish	*Aprion virescens*	**utouto****	na	51.74	4.55	30.34
Total			**52**	**131.65**	**144.15**	**256.91**

* Fisheries Division Annual Reports list bedford and **uluqa** as separate species in market surveys, however the reports also state that they are the same species. Volumes for "**uluqa**" and "bedford" were therefore combined to produce this table.
** The 2002 Fisheries Division Annual Report grouped this species within the deepwater snapper category, hence its inclusion here.

34.3 Stock Status

Lewis *et al.* (1988) gave estimates of MSY for Fijian deep slope stocks ranging between 550–1,600 mt per year, based on comparative data from elsewhere in the Pacific or based on an estimate of 4,900 mt taken from results of a Japanese survey (Anon., 1987). Subsequent to that, an analysis by Nath and Sesewa (1990) of commercial catch data from four seamounts and three coastal areas showed that in all instances, the initial catch rates fell to a level where fishing became uneconomic. The potential yield range at MSY for the entire Fiji group has been estimated at between 409 and 1,230 mt per year (Dalzell and Preston, 1992).

Several Fisheries Division Annual reports going back to 2002 state that "The reef slopes and sea mounts [of Fiji] are populated with deep water snappers with a maximum sustainable yield of 1,800 metric tons." However, the reports give no indication of how this value was calculated, nor where it came from. The closest value can be found in Lewis *et al*. (1988), which was an estimated initial yield of 1,400 mt per year. Throughout the South Pacific once initial catch-rates (yield) for deepwater bottom fish settled down to a "sustainable equilibirum", these were around one-third of the virgin fishery (Adams and Chapman, 2004). Therefore, the claim of a "maximum sustainable yield of 1,800 metric tons" by the Fisheries Division seems to be a significant over-estimation. Assuming the findings from Adams and Chapman (2004) are applicable to Fiji, and working from an initial yield of 1,400 mt (Lewis *et al*., 1988), Fiji's deepwater bottom fishery has a MSY of 462 mt per year – a value closer to the lower range estimated by both Lewis *et al.* (1988) and Dalzell and Preston (1992).

Deepwater bottom fish, particularly snappers, have life histories that make them prone to overfishing. However, the apparent collapse of the fishery in the late 1980s was not likely due to overfishing; rather the equilibrium catch rates were low enough to make the fishery uneconomical or unprofitable for most operators (Adams and Chapman, 2004). It is difficult to have any sense of the state of Fiji's deepwater bottom fishery given the lack of data, which was already a problem in 2002 and has deteriorated since.

34.4 Management

Legislation and Policies Regulating Exploitation: The Offshore Fisheries Management Regulations 2014 of the Offshore Fisheries Management Decree 2012, lists the following policy laws and regulations that are relevant to deepwater bottom fisheries:

Part 4 - Licences and Authorisations

15. (1) A Fiji fishing vessel shall not be used for fishing or related activity within Fiji fisheries waters except with a licence to fish issued by the Permanent Secretary pursuant to section 32 of the Decree.
(2) The owner or operator of a Fiji fishing vessel applying for a licence to fish within Fiji fisheries waters may apply to be licensed to fish for the following fish species in the application form set out in Schedule 6A… (c) Deepwater Snapper, unless the Fiji fishing is 100 percent owned by Fiji nationals"

SCHEDULE 1 (Regulation 3) - Prohibited and Restricted Areas.
The restriction on fishing vessels within 3 nautical miles radius of reef systems within Fiji fisheries waters does not apply to vessels using the drop line method targeting deep water snapper.

SCHEDULE 2C (Regulation 6) - Prohibited Fishing Gear and Methods
"7. Longline targeting DWS or any bottom dwelling fish species."

Detailed information on further legislation/policy regarding exploitation can be found in Stone (2003), this includes guidelines imposed by the Fisheries Division Ministry in 1987, Legal Notice 25 of 1990, which superseded the 1989 Guidelines, and the Fisheries Management Bill 2002.

Epinephelus malabaricus is listed in Schedule 1 (Section 3) of the Endangered and Protected Species Act 2002.

Management Recommendations: Compared to the heyday of this fishery roughly 15–20 years ago, the number of commercial fishers appears to have decreased substantially. Although a few boats are licenced, there are no semi-industrial fishing boats targetting these fish. Therefore the key management requirement is that the Ministry of Fisheries strictly monitor and enforce licensing, and licensing requirements for the fishery. Without this basic information it is difficult to make recommendations for the fishery. Given the susceptibility of these fish to overfishing, a precautionary approach to management is recommended and it is strongly suggested that the Ministry of Fisheries develop a management plan for this fishery.

The Fiji Revenue and Customs Service (FRCS) should clearly and accurately categorise export products, in the case of most fisheries products the information provided is of little use due to very general categories used and obvious mis-identifications/mis-reporting. A possible solution is to attach fisheries officers with the relevant FRCS departments, provided the fisheries officers are capable of accurately identifying various marine products.

Hill *et al.* (2016) discusses types of stock assessments for resource-limited deepwater snapper fisheries − these harvest strategies involve a monitoring program, formal assessment, and decision rules. Each fishery is tested using data from the Pacific region (Tonga and New Caledonia), and their results and limitations discussed.

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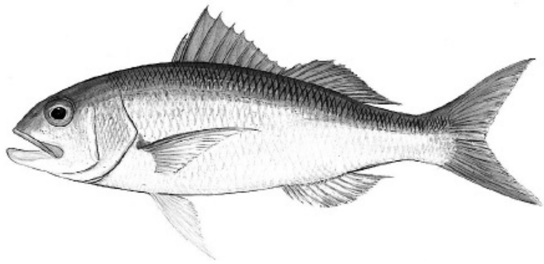
35 RUBY SNAPPER / EHU



35.1 The Resource

Species status: Ehu (*Etelis carbunculus*), also known as ruby snapper, is one of several species of deepwater bottom fish to occur in Fiji. Recently this species has been divided into two, the new species known by the common name "pygmy ruby snapper" (*Etelis* sp.) but is yet to be given a specific epithet (Andrews *et al*., 2016; SPC, 2013). The new species is almost identical in appearance to ehu except for a black marking on the top of the caudal fin in the ruby snapper, which is absent in the pygmy ruby snapper, and a much sharper spine on the operculum of the pygmy ruby snapper (SPC, 2013).

The pygmy ruby snapper (*Etelis* sp.) dominates catches off the west coast of Australia, however this dominance reduces as one goes towards the eastern Pacific, where *E. carbunculus* dominates ehu catches (Andrews *et al*., 2016) - this is discussed in more detail further on under biology and ecology. With this in mind, any information or data cited regarding ruby snapper/ehu/*E. carbunculus* prior to Andrews *et al*., (2016) likely refers to a mix of both species the ruby snapper (*E. carbunculus*) and the pygmy rugby snapper (*Etelis* sp.).

Distribution: Ruby snappers are widely distributed in the tropical Indo-Pacific Ocean from the Hawaiian Islands to East Africa, and Australia northward to southern Japan; also reported off northern New Zealand (Allen, 1985; Carpenter and Niem, 2001). The species inhabits rocky bottoms at depths between about 90–400 m. In Fiji waters ehu is commonly taken between 330–400 m (Stone, 2003).

Biology and Ecology: Ehu shares many of its life-history traits with other species of deepwater snapper i.e. long lived, slow growth rates, late maturity, low fecundity, and low rates of natural mortality, the combination of which indicate a very low production potential (Koslow *et al*., 2000). Ehu feed on fishes and larger invertebrate such as shrimp, crabs, and squids, as well as planktonic organisms including pelagic urochordates (Allen, 1985).

Spawning occurs throughout most of the year in Vanuatu, with peak activity during November (Allen, 1985). L_{50} (length at which 50% are sexually mature) for ehu in Hawaii was estimated at 27.9 cm FL (DeMartini and Lau, 1999). Little is known about the juvenile stages of ehu, or most deepwater bottom fish for that matter. From Moffitt (2003) and Moffitt and Parrish (1996) it can be presumed that juvenile ehu inhabit relatively featureless habitats such as sand and mudflats at depths of 60–100 m. These fish remain in this habitat until they have reached a length of approximately 20 cm, before moving out to the high-relief slope habitats more typical of adults.

Ehu grow to a maximum standard length of at least 80 cm, though are commonly found around 50 cm (Carpenter and Niem, 2001). Based on increment counts from otoliths the maximum age of ehu is 21 years, and total mortality (*Z*) - from the Hoenig regression - is 0.21 per year (Williams *et al*., 2013). Kalish *et al.* (2002) estimates a maximum age of at least 30 years for ehu; this likely applies to both *E. carbunculus* and *Etelis* sp. as they had not been Recognised as separate at this time. Von Bertanlanffy growth parametres are provided below in Table 46. Carolt (1988) suggests that the K value obtained in his study and that of Sua (1990) − both of which used the ELEFAN[27] method − may be biased upward as the growth performance values calculated were much higher than those obtained by Brouard and Grandperrin (1984) in Vanuatu. Ehu appear to be restricted to maximum depths of about 400 m. These fish aggregate along features such as seamounts, and move along deep reef slopes (Koslow *et al*., 2000).

27 Electronic Length-Frequency Analysis

As previously mentioned ehu actually comprise two separate species, which look almost identical – the ruby snapper (*E. carbunculus*) and the pygmy rugby snapper (*Etelis* sp.). As noted, the latter is yet to be given a specific epithet. Work by Andrews *et al*., (2016) show two trends in stock structure; in the southern hemisphere, a dominance of *Etelis* sp. that increases and largely replaces *E. carbunculus* from the east to west Pacific, and a possible decreasing dominance of *Etelis* sp. from the south to north Pacific. The pygmy ruby snapper appears to make up approximately half the population of ehu in Fiji as reflected in catch composition, 75% in Wallis and Futuna, 85% in New Caledonia, and 100% in northwest, western, and southwest Australia, whereas the ruby snapper (*E. carbunculus*) comprise 100% of the catches in Guam, Hawaii, and roughly 85% of ehu catches in Tonga (Andrews *et al*., 2016).

Etelis sp *and E. carbunculus* and have high levels of genetic diversity throughout the South Pacific suggesting widespread mixing and connectivity. Local patchiness was observed, however this may also be correlated with a low sample size (Goldstien *et al*., 2015).

Table 46. Von Bertanlanffy growth estimates for ehu (*Etelis carbunculus*) populations throughout the Pacific. FL = fork length.

Area	*L_∞ (cm)	K	t_0	Method	Reference
New Caledonia	89.6 (FL)	0.28	0.51	Otoliths	Williams *et al.* (2013)
Hawaii	71.8 (FL)	0.19	4.03	Otoliths	Smith and Kostian (1991)
Vanuatu	127.0 (FL)	0.14	1.62	Otoliths	Smith and Kostian (1991)
French Polynesia	68.0 (FL)	0.15	3.05	Otoliths	Smith and Kostian 1991)
Vanuatu	132.4*	0.22		ELEFAN	Carolt (1990)
Tonga	136.0*	0.31		ELEFAN	Sua (1990)
Vanuatu	94.0*	0.07		Otoliths	Brouard and Grandperrin (1984)

* Author(s) did not specify which length was used

35.2 The Fishery

Utlisation: Caught in the same manner as other deepwater bottom fish mentioned above. Lines set for ehu tend to be held a few metres above the bottom.

Production and Marketing: Though ehu do not show up in local market data (Table 45), anecdotal reports suggest the vast majority if not used for subsistence is sold directly to restaurants and hotels - the report by Raravula (2013) does show this to some extent, though it should be noted that for the local market "**pakapaka**" and "**opakapaka**" are often used as generic names for *Pristipomoides* spp. and *Etelis* spp. a company based out of Pacific Harbour, sold whole ehu (gilled and gutted) for FJD 18 per kg, boneless fillets retailed for about FJD 38 per kg in 2017.

Exports: Ehu are the dominant species in the deepwater bottom fish export market. The market has traditionally been Hawaii; however, for a host of reasons outlined in Stone (2003), the market has had to change to include Japan and the US mainland. 22.27 mt of ehu was exported in 2002, valued at USD 7.11 per kg (Stone, 2003), neither Fisheries Division Annual Reports nor Fiji Revenue and Customs Service (FRCS) specify species of deepwater bottom fish in export records.

35.3 Stock Status

Recent Fiji-specific information or data are sparse. Therefore, assessing the stock status of ehu is largely guess work. Ehu made up 36% of deepwater bottom fish caught during a survey of Fiji's waters during the 1980s (Ellway, 1990). Assuming Fiji's deepwater bottom fishery has a MSY of 462 mt per year (see earlier stock status of deepwater bottom fish). Assuming ehu make up 36% of this, it can be assumed ehu in Fiji has a MSY of about 166 mt per year. McCoy (2010) notes a trend of decreases in fishing activity and/or landings in Fiji, however given the paucity of information it is difficult to say whether this is due to a drop in catch, reduced or stagnant prices, increased operation costs, or a combination of these factors. On a positive note, several studies including Gomez *et al*., (2014) and McCoy (2010) state that Fiji's waters have sufficient habitat to support considerable stocks of deepwater bottom fish.

35.4 Management

Current Legislation and Policies Regulating Exploitation: There is no specific management, legislation or policy regarding ehu. Any management or policy that pertains to deepwater snapper or deepwater bottom fish pertains to this species. These are described in general in the previous section, and in more detail in Stone (2003).

Management Recommendations: Williams *et al.* (2013) recommend maintaining a fishing mortality <0.1 for ehu, in order to maintain a reasonable spawner biomass-per-recruit. This is a "cautious approach to management, given the uncertainty in estimates of natural mortality and mixed fishery considerations." Goldstien *et al.* (2015) advocated for maintaining the full level of genetic diversity throughout the various ehu populations in the Pacific. In order to do so stocks must not be overfished as mixing is more likely to occur in large populations.

Hill *et al*. (2016) discussed types of stock assessments for resource-limited deepwater snapper fisheries − these harvest strategies are biomass dynamic models, length-based indicators, and catch-curve analysis. Each involves a monitoring program, formal assessment, and decision rules. These are tested using data from the Pacific region (Tonga and New Caledonia), their results and limitations discussed.

At the moment the most pressing issue is the near complete lack of data collected and published by the Ministry of Fisheries, the absence of which make assessing the state of the fishery and determining future actions very difficult.

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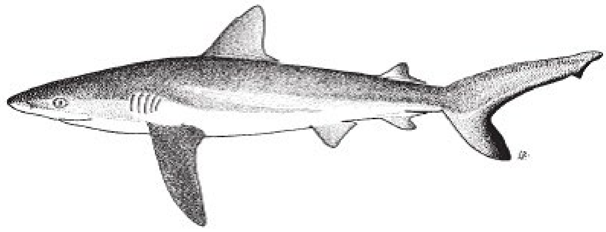
36 SHARKS AND RAYS



36.1 The Resource

Species Present: Though rays are not targeted for their fins in the same manner that sharks are, the two groups are closely related, sharing similar biological characteristics. Some species of pelagic shark and ray are also taken by the same fisheries. Therefore, both groups are included in this profile. The most common species group of shark in Fiji waters is the requiem or whaler sharks (Dalzell and Preston, 1992). In offshore waters, sharks such as silky (*Carcharhinus falciformis*) and oceanic whitetip sharks (*C. longimanus*) are commonly seen and captured around Fish Aggregation Devices (FADs). Deepwater sharks such as dogfish sharks (*Squalus* spp., *Centroscyllium* spp.), and six and seven gilled sharks (*Hexanchus* spp., *Heptranchus* spp.) are a bycatch of the deepwater snapper fishery (Lewis, 1985). A representative list of shark and ray species commonly encountered in Fiji waters is provided in Table 47.

Table 47. Species of shark and ray taken in Fiji waters. Species taken in artisanal and subsistence fisheries are likely under-represented/omitted from the list due to lack of reports, this is particularly true of rays. Source: Lewis (1985), Carpenter and Niem (1998b), Swamy (1999), GFSC (2012), Glaus *et al.* (2015), Piovano and Gilman (2016), IUCN (2017). The list is likely biased towards pelagic species.

Species name	Common name	CPUE*	IUCN category+
Sharks (superorder: Selachimorpha)			
Alopias pelagicus	pelagic thresher	0.0022	VU
Alopias superciliosus	bigeye thresher	0.0081	VU
Alopias vulpinus	thresher shark	0.0003	VU
Carcharhinus albimarginatus	silvertip shark	0.0022	NT
Carcharhinus amblyrhynchos	grey reef shark	0.0013	NT
Carcharhinus brachyurus	bronze whaler	0.0100	NT
Carcharhinus cautus	nervous shark		DD
Carcharhinus falciformis	silky shark	0.0430	NT
Carcharhinus galapagensis	Galapagos shark	0.0003	NT
Carcharhinus leucas	bull shark		NT
Carcharhinus limbatus	blacktip shark	0.0027	NT
Carcharhinus longimanus	oceanic whitetip shark	0.0174	VU
Carcharhinus melanopterus	blacktip reef shark	0.0003	NT
Carcharhinus obscurus	dusky shark		VU
Carcharhinus plumbeus	sandbar shark	0.0016	VU
Carcharhinus sorrah	spot tail shark		NT
Carcarodon carcharias	great white shark	0.0002	VU
Centrophorus moluccensis	smallfin gulper shark		DD
Centroscyllium nigrum	Pacific black dogfish		DD
Cephaloscyllium isabellum	draughtboard shark		LC
Dalatias licha	kitefin shark	0.0002	NT
Echinorhinus brucus	bramble shark		DD

Species name	Common name	CPUE*	IUCN category+
Echinorhinus cookei	prickly shark		NT
Etmopterus brachyurus	short tail lantern shark		DD
Euprotomicrus bispinatus	pygmy shark		LC
Galeocerdo cuvier	tiger shark	0.0014	NT
Galeorhinus galeus	whiskery shark	0.0005	VU
Hemitriakis japanica	Japanese tope shark		LC
Heptranchias perlo	sevengill shark		NT
Hexanchus griseus	bluntnose sixgill shark		NT
Hexanchus nakamurai	bigeye sixgill shark		DD
Isistius brasiliensis	cookie cutter shark	0.0014	LC
Isurus oxyrinchus	shortfin mako	0.0670	VU
Isurus paucus	longfin mako shark	0.0144	VU
Mustelus manazo	star spotted smooth-hound		DD
Nebrius ferrugineus	tawny nurse shark		VU
Negaprion acutidens	sicklefin lemon shark		VU
Negaprion brevirostris	lemon shark		NT
Pseudocarcharias kamoharai	crocodile shark		NT
Prionace glauca	blue shark	0.1932	NT
Rhincodon typus	whale shark		EN
Sphyrna lewini	scalloped hammerhead	0.0030	EN
Sphyrna mokarran	great hammerhead	0.0019	EN
Sphyrna zygaena	smooth hammerhead	0.0024	EN
Squalus japonicus	short spine spurdog		DD
Squalus megalops	shortnose spurdog		DD
Stegostoma fasciatum	leopard shark		EN
Triaenodon obesus	whitetip reef shark	0.0005	NT
Zameus squamulosus	velvet dogfish	0.0003	DD
Rays (superorder: Batoidea)			
Aetobatus narinari	spotted eagle ray		NT
Manta birostris	giant manta ray	0.0021	VU
Manta alfredi	Alfred manta		VU
Mobula mobular	devil fish		EN
Pteroplatytrygon violacea	pelagic stingray	0.2252	LC
Rhynchobatus australiae	bottlenose wedgefish		VU
Taeniura lymma	bluespotted ribbontail ray		NT

+IUCN category (DD=Data Deficient, LC=Least Concern, NT=Near Threatened, VU=Vulnerable, EN=Endangered). (Source: IUCN, 2017)
*Shark captures per 1000 hooks, Fiji pelagic longline fishery (Piovano and Gilman, 2016)

Distribution: The majority of sharks and rays listed in Table 47 have a wide distribution throughout Fiji, occurring in a range of habitats. Bull sharks and hammerhead sharks tend to be coastal and semi-pelagic. Bull sharks and scalloped hammerhead sharks are known to use several rivers and estuaries throughout Fiji as nursery or pupping grounds, namely Navua, Rewa, and Ba (Brown *et al*., 2016; Cardenosa *et al*., 2016; Vierus, *unpubl. data*). Other species of shark such as the sevengill, bluntnose sixgill, big eye sixgill, short spine spurdog, shortnose spurdog, and velvet dogfish are mostly found at depths between 300–600 m, with some species known to occur beyond this depth.

Biology and Ecology: Nichols (1993) and Carpenter and Niem (1998) provide a brief overview of the biology of sharks and rays. Sharks and rays belong to the subclass Elasmobranchii − members of this taxon are characterised by having five to seven pairs of gill clefts opening to the exterior, and small placoid scales; they generally lack a swim bladder, and have a cartilaginous skeleton (Carpenter and Niem, 1998). In general, sharks and rays are difficult to age, but have a relatively slow growth rate (except when very young), and females tend to reach greater maximum lengths than males. The majority of commercially important shark and ray species in the Western Central Pacific region are ovoviviparous or viviparous, have a long gestation period and low fecundity. Shark and ray species usually display sex and size segregation and females of some species may move inshore to give birth in selected nursery or pupping areas.

The characteristics of low fecundity, long gestation, slow growth, and often localised movements result in many shark and ray populations being very vulnerable to recruitment over-fishing. This fact is becoming very apparent in almost all commercial shark fisheries, especially off the Atlantic and Pacific coasts of the US, and in the Australian and New Zealand shark fisheries. Along the Atlantic Coast overfishing of large predatory sharks such as the bull, great white, dusky, and hammerhead has led to a population explosion of rays, skates (Family: Rajidae) and small shark prey species in that area (University of Miami, 2007).

36.2 The Fishery

Utilisation: Demand for the gills of manta (*Manta* spp.) and devil (*Mobula* spp.) rays have risen dramatically since the early 2000s. The gill rakers of these rays are now used in traditional Chinese medicine though they were not historically used for this purpose (Platt, 2012). Other species of stingray such as *T. lymma* are caught and sometimes consumed at the subsistence level.

While shark meat is well regarded in many countries (e.g. Australia) and supports sizeable fisheries, it is not eaten in many areas of Fiji because of traditional taboos on its use (Glaus *et al*., 2015). The exceptions to this case are the Rotuma and Rabi communities where shark is readily accepted. A small quantity of longline-caught shark, mainly mako shark, is exported to Japan. Because of the high urea content of the flesh, which breaks down to produce ammonia, sharks and rays intended for use as meat need to be bled and dressed soon after capture (Lewis, 1985) and are often stored separately onboard from the target tuna species.

Shark fins have been a traditional element of Chinese haute cuisine. It is often used in a soup or stewed and served at special occasions such as weddings or banquets. The fin rays (needles and nets) provide texture, while the flavour comes from the other soup ingredients. Demand for shark fins increased following the opening of the mainland China economy in the later 1980s, and Hong Kong as the entrepôt has long been the world's largest shark fin trading center (Clarke *et al*., 2007). For this trade, fins need to be removed by curved rather than straight cuts, and not all the fins are used. The sharkfin and bêche-de-mer trade in Fiji are closely linked, often utilising the same trade chains and being instigated by Chinese traders (Glaus *et al*., 2015). The skin of many species has been used to produce quality leather, and the teeth of tiger and mako sharks, in particular, are used for jewellery while the jaws are cured and dried as curios. Sharks such as thresher, mako and great white shark are also the target of gamefishermen, because of their fighting qualities and size.

Since at least the early 1980s, interest has grown world-wide in the liver of deepwater sharks as a source of squalene, a fine oil used for medicinal and cosmetic purposes. Between 1985 and 1987, experimental fishing for squalene-rich deepwater sharks was conducted in Fiji waters, under the direction of Fiji Fisheries Division. The trials were suspended principally because of a decline in the squalene price during 1987 (T. Adams, *pers. comm.*). From 1987 until 1992 in Solomon Islands, and from 1991−1994 in Papua New Guinea, commercial fishing ventures targeted deepwater gulper sharks, mainly *Centrophorus* spp., using bottom-set deepwater longlines. The cessation of the Solomon Islands shark fishing venture has been attributed to a weakening in the price of squalene (Richards *et al*., 1994). Shark cartilage is also utilised in the extraction of chondroitin, which is used in conjunction with glucosamine to treat arthritic conditions as a supplement (Sim *et al*., 2007).

Production and Marketing: Sharks are caught by gill nets, set lines, ocean longlines and various other techniques. In Fiji, most are taken as a bycatch of the pelagic longline fishery. Fiji's longline fishery has a nominal catch rate of 0.610 elasmobranchs per 1000 hooks; sharks and rays made up of 2.4 and 1.4%, respectively, of the total longline fish catch for the period 2011–2014 (Piovano and Gilman, 2016). Of this total, blue sharks (*P. glauca*) and the pelagic stingray (*P. violacea*) accounted for 51 and 99% of caught sharks and rays, respectively. Of the captured elasmobranchs, 34.6% were finned and the carcass discarded, 10.9% had the entire carcass retained, and 45.8% were released alive, and 8.7% were discarded dead (Piovano and Gilman, 2016). Manta rays form a small portion of the elasmobranchs captured in Fiji's pelagic longline fishery. Piovano and Gilman (2016) report only 13 manta rays captured from 2011–2014; of this, 5 were finned and 4 retained, the remainder (4) discarded either dead or released alive.

The percentage of sharks caught in Fiji's longline industry that are retained varies greatly between species. The grey reef (88%), shortfin mako (53%), longfin mako (50%), and oceanic whitetip (31%) sharks are the species most retained (Swamy, 1999). Judging from observer data the species most retained are often the ones commonly captured dead. However, it can be presumed that the numbers of shark taken in Fiji's longline fishery has declined from what was reported in Swamy (1999); as a result of the CMMs introduced by the WCPFC in 2011, and Marine Stewardship Council (MSC) certification of Fiji's albacore tuna longline fishery in 2012. The CMMs include "no take" provisions, and the MSC certification included action plans, which "required evidence of effective management measures to ensure the fishery does not hinder the recovery and stock rebuilding of the blue, short-finned mako, silky and oceanic whitetip sharks."

Glaus *et al*., (2015) report that there is a small artisanal and subsistence shark fishery in Fiji. 82% of fishers reported that sharks were caught as bycatch whereas the remaining fishers (18%) targeted sharks. Catch numbers ranged from 2–3 animals per week as bycatch, and 3–6 animals per week per person as a targeted fishery, and largely comprised of blacktip reef sharks (*C. melanopterus*), whitetip reef sharks (*T. obesus*), various hammerhead shark species (*Sphyrna* spp.), bull sharks (*C. leucas*) and tiger sharks (*G. cuvier)* (Glaus *et al*., 2015).

Fiji has been a significant exporter to south east Asian markets of dried shark fins, one of the most expensive seafood items (Hindmarsh, 2007). The fins are handled locally by Chinese traders (Richards *et al*., 1994). Fisheries Division Annual Reports and Fiji Revenue and Custom Authority data (FRCS, *unpubl. data*) indicate an average of 45 mt of dried shark fins worth about FJD 195,500 were exported annually for the period 1980–1982. This declined to a mean of 16 mt per year from 1983−1990 (Anon.,1987–1991, Richards *et al.* 1994). In 1992, exports increased dramatically to 69 mt and 65.6 mt in 1993 (Anon., 1993). It is likely that this phenomenon was directly related to the resurgence of the local longline fishery at that time (Richards *et al*., 1994). From 2001 until 2011 there was no mention of shark fin exports in Fisheries Division Annual Reports, despite there being roughly 930 permits issued for the export of "Shark Meat/Fin" for each of the years 2006, 2010, and 2011 (Anon., 2001–2012). Furthermore, Fisheries Division Annual Reports record sharks being landed, with up to six companies involved in the export of sharks and shark fin, several exclusively i.e. no other products exported (Anon., 2007,2011,2012). Therefore, it can be assumed shark fins were still being exported, possibly mis-declared or mislabelled under generic categories such as "seafood" or "dried marine products", a practice known to occur (Knott, 2017).

Prices of dried shark fin rose substantially from approximately FJD 8 per kg prior to 1994, to about FJD 115 per kg in 2012 (Anon., 1995, 2013). Export volume and total value of dogfish and other sharks, and shark fins are available for the years 2005–2008 and 2012–2014 (Table 48). Prices have continued to increase since that time.

A review of shark fin-weight ratios can be found in Hindmarsh (2007). Ratios vary according to species and fishery (which determines how fins are cut) but generally shark fins comprise 1–22% of the weight of a dressed shark i.e. gilled, headed, gutted, and all fins removed. Hong Kong Census and Statistics Department data showed total imports of shark fins into Hong Kong dropped by 42% between 2010 and 2015 − from almost 11,000 mt to about 6,300 mt (Knott, 2017). Decreases in shark fin exports since 2010 may be attributed to shipping companies and airlines banning the transport of shark fin. In 2010, Maersk implemented a worldwide ban on shark fin carriage followed by China Ocean Shipping Company (Cosco Shipping) in July 2016 (Knott, 2017). In 2012 Cathay Pacific banned shark fin air cargo, and the following year Qantas implemented a total ban on all shark fin products (Parry, 2013a; 2013b).

The decrease in shark fin exports from 33 mt in 2012 to 11 mt in 2013, and apparently no exports in 2014 may be the result of Air Pacific (Fiji Airways) ceasing the transport of “all but sustainable shark products” in June 2013. Prior to this, airfreight through the company grew from 45 mt in 2009 to almost 1,000 mt in 2012. Seafood products namely bêche-de-mer (see Profile 1 SEA CUCUMBERS) and dried shark fin were suspected to make up the bulk of cargo. Not all the cargo shipped originated from Fiji, as the country is used as a transport hub for the surrounding Pacific Islands. The increase in Air Pacific’s airfreight was likely caused by competing airlines (Cathay Pacific in particular) coming under increased pressure to cease transporting sharkfins − it is estimated up to 650 mt of shark fins were flown by Cathay Pacific in 2011 (Parry, 2013a).

Table 48. Volume (kg) of sharks and sharkfins exported from Fiji, value (FJD) provided in brackets below quantity. Source: Anon. (2006−2009); FRCS (*unpubl. data*)

Product Description	2005	2006	2007	2008	2012	2013	2014
dogfish and other sharks	35,207	11,100	183,011	25,000	20,000	na	na
	(848,392)	(583,740)	(339,829)	(19,587)	(19,876)		
sharkfins	na	na	na	na	33,496	10,591	na
					(4,166,581)	(1,122,992)	

36.3 Stock Status

Despite a lack of comprehensive global data on the decline in stocks of shark and ray species, and an even greater lack of Fiji-specific data there is a general consensus among scientists that globally shark stocks have undergone dramatic reductions. As a result of their low fecundity and relatively slow growth, shark and ray stocks are vulnerable to over-fishing (see above), coupled with mounting fishing pressure since the 1950s in response to growing demand for, and increasing value of, shark fins (Juncker *et al*., 2006).

36.4 Management

Current Legislation and Policies Regulating Exploitation: Fiji does not have a national management plan or National Plan of Action for sharks at present. Recognising the regional nature of pelagic shark stocks, a Regional Plan of Action for Sharks was however launched in 2008, the first in the world (https://www.ffa.int/node/286). A generic shark WCPFC CMMs had been introduced in 2007 (CMMs 2007−2010), and was revised in 2014 (CMMs 2014−2005). The first single species WCPFC CMMs for sharks (oceanic white-tip) in 2011 (CMMs 2011–07), followed by silky shark in 2013 (CMMs 2013−2008). It is anticipated that other shark species (e.g. threshers, hammerheads and possibly manta and devil rays) CMMs will follow in due course. As Fiji is a member of the WCPFC, without its own management plan for shark fisheries, management measures default to the WCPFC's CMMs. The shark CMMs provide for non-retention of dead sharks, release of live sharks unharmed, introduction of mitigation measures, and annual reporting of sharks numbers caught by national fleets in annual reports to the Commission. MSC certification of Fiji's albacore tuna longline fishery required action plans for improvement, which had to be met within five years of the initial certification in December 2012. These action plans required evidence of effective management measures to ensure the fishery does not hinder the recovery and stock rebuilding of the blue, shortfin mako, silky and oceanic whitetip sharks (MSC, 2017).

According to Mangubai *et al.* (*in press)*:

> " The Fiji Government plans to sign the Shark Memorandum of Understanding under the CMS[28], and is developing fisheries regulations for the conservation of shark and ray species across its territorial waters, which will include a ban on the commercial harvesting, possession, trade and shipment of all species of sharks and rays from its coastal waters (A. Batibasaga, *pers. comm.*). The only harvesting that will be allowed is: (i) traditional harvesting of sharks and rays by communities for food (subject to a daily bag limit); and (ii) commercial harvesting of three species of pelagic sharks (blue (*P. glauca*), shortfin mako (*I. oxyrinchus*) and longfin mako (*I. paucus*)), as bycatch by the domestic and distant water tuna fleets with sharks needing to be landed whole with their fins intact."

Several species of sharks and sawfish are listed in Schedule 1, Section 3 of the Endangered and Protected Species Act. Several species are listed as near threatened, vulnerable, and endangered by CITES (Table 47), and the shortfin mako (*I. oxyrinchus*) is listed on Appendix II of the CMS.

The Offshore Fisheries Management Regulations 2014 state that "Shark lines – trace wire, baited shark lines attached to floats (Hook 99)" are prohibited.

Given the lack of management measures for sharks at the national level, artisanal and subsistence shark fisheries in Fiji for inshore/coastal species are controlled at the local community level under the traditional marine tenure system in place in Fiji.

28 Convention on the Conservation of Migratory Species of Wild Animals

Management Recommendations: The general consensus is that more biological, ecological, and fisheries data are required for the management of shark and ray fisheries/stocks. In view of the scarcity of these data and given susceptibility of sharks to overfishing, a precautionary approach is strongly urged. Fiji needs to implement a national management plan for sharks. If so, it would need to be compatible with regional measures (e.g. WCPFC CMMs).

Several studies (Brown *et al*., 2016; Cardenosa *et al*., 2016; Vierus *et al*., *unpubl. data*) suggest fishing gear restrictions, namely banning the use of gill-nets within the Rewa and Ba River estuaries particularly during possible peak parturition times. Based on observations of umbilical scars and anecdotal reports from fishers in this period is likely November−February. The Rewa and Ba river estuaries were identified as important aggregation and potential parturition grounds for several species of shark. Gillnets are associated with high incidence of shark bycatch and higher mortality of captured sharks.

The use of J-hooks, shark lines[29], and wire trace may be banned in pelagic longline fisheries as these increase the chances of capturing sharks and rays (Piovano and Gilman, 2016; Bromhead *et al*., 2013) as is required under the Offshore Fisheries Management Regulations (2014) Increased observer presence onboard commercial fishing vessels, and more stringent reporting is advised.

A common management measure in EU and US fisheries is a fin weight to carcass weight ratio. The US National Marine Fisheries Service adopted the 5% fin to carcass weight ratio in the early 1990s. The ratio states that the total weight of fins onboard not exceed 5% of the dressed weight (headed, gutted, and finned) of the carcass (or 2% of the whole weight of the shark). However, as Hindmarsh (2007) and Biery and Pauly (2012) point out there are several issues with this management measure regarding the practicality of it – the ratio varies by shark species, fishery, and fin cut – and weakening of the legislation for example applying the 5% ratio to the whole weight rather than dressed weight, and increasing the ratio. An increase to 6% of whole weight would allow two or more sharks to be finned and discarded for every shark retained. Both studies suggest sharks should be landed with fins attached to avoid these issues and improve monitoring.

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29 A description of shark lines can be found in WCPFC (2014)

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37 OCEANIC TUNA

37.1 The Resource

Species present: As the common English name of oceanic tuna is more widely used throughout Fiji, rather than the Fijian or scientific name, the common English name will be used throughout this profile. The main oceanic tuna species occurring in Fijian waters are the deep swimming adults of **yatunitoga** (yellowfin − *Thunnus albacares*), **yatulevu** (bigeye − *T. obesus*) and **yatuloa** (albacore − *T. alalunga*), and the surface-schooling **yatusewa** (skipjack − *Katsuwonus pelamis*).

Other tunas occurring less commonly are **yatuyatu** (mackerel tuna - *Euthynnus affinis*) and dogtooth tuna[30] (*Gymnosarda unicolor*) – both are included in the large coastal pelagics profile because of their neritic/inshore distribution – and frigate tuna (*Auxis thazard*), taken mostly offshore as a minor surface fishery bycatch. Pacific bluefin tuna (*Thunnus orientalis*) occasionally occur in Fiji waters as large post-spawning adults from the northern hemisphere, whereas temperate water southern bluefin tuna (*Thunnus maccoyii*) are not known from Fiji.

Distribution: Yellowfin and bigeye occur throughout the tropical and sub-tropical waters of the Pacific Ocean (40ºN to 40ºS) (Collette, 2001). In Fiji, they occur mostly as deep-swimming adults captured by longline gear, but may be found as juveniles in surface schools with skipjack tuna in summer, and large yellowfin may be taken at the surface when actively feeding. Both species are currently managed as western and eastern Pacific populations by the respective Regional Fisheries Management Organisations (RFMOs) (i.e. WCPFC and Inter American Tropical Tuna Commission).

Albacore tuna also occur as deep swimming adults in Fiji waters, they are the main target of the longline fishery, and are featured in Profile 38 ALBACORE TUNA. Juveniles occur at the surface in temperate waters further south of Fiji. Albacore are managed as southern and northern stocks across the Pacific basin, with limited mixing between the two stocks across the Equator. Skipjack are highly mobile and wide ranging, but occur mainly in Fiji waters during the summer months. In earlier years, they supported an active seasonal pole-and-line fishery, but never a long-term purse-seine fishery other than occasional short-term exploratory visits and some Fish Aggregation Device (FAD)-based fishing in the 1980s by NZ vessels. Frigate tuna are taken as a minor bycatch in pole-and-line and purse seine fisheries throughout the Western and Central Pacific Ocean (WCPO).

Biology and Ecology: Yellowfin and bigeye grow to at least 200 kg, whereas albacore rarely exceed 50 kg in weigh, and skipjack 20 kg. All species maintain core body temperatures several degrees above the surrounding sea temperature. Yellowfin occur at the surface as juveniles, often with juvenile bigeye and skipjack, but spend increasing time at depth as they grow and develop a swim bladder. Bigeye tuna prefer lower temperatures than yellowfin and are usually found around or below the thermocline in the daytime, rising toward the surface at night following diurnal prey movements. They also have higher tolerance of lower dissolved oxygen levels. Albacore prefer lower temperatures (often 17°–21ºC) and are rarely seen at the surface outside temperate waters, living near or around the thermocline in most sub-tropical and tropical areas. Skipjack are inhabitants of the mixed layer at all stages of their life, and lack a swim bladder; larger fish may need to make descents to cooler water to avoid over-heating.

30 Actually a bonito rather than a tuna

Oceanic tuna species feed largely on epipelagic fishes, squids and crustaceans. Yellowfin as adults feed throughout the surface layer on epipelagic species but also near the thermocline on occasions, whereas adult bigeye tends to feed more at depth on mesopelagic species, as do albacore. Skipjack feed almost exclusively in the surface layers, on a range of epipelagic species. Productivity in the open ocean in the WCPO is generated largely by the nutrient-rich equatorial upwelling, with prey organisms concentrated near the boundaries of the Western Pacific Warm Pool; these productive zones move with El Niño Southern Oscillation (ENSO) events, giving rise to large shifts in biomass distributions of surface species in particular.

Yellowfin spawn year-round throughout the equatorial areas and during summer months in sub-tropical areas in waters above 26ºC. Maturity is attained at around 100 cm at approximately 20 kg, at the end of the second year of life. They are opportunistic serial spawners, spawning every few days when favourable conditions are encountered. Spawning occurs over a wide area of the WCPO and larvae are accordingly widely distributed throughout the WCPO. Bigeye spawning also occurs over a wide area of the WCPO where water temperatures are above 24ºC, though with evidence of some concentration of spawning activity in the central Pacific. Maturity (L_{50}) in most areas is attained at around 105 cm FL at the end of the third year of life (Farley *et al*., 2014). There is some indication of greater age at maturity but similar size of Eastern Pacific Ocean bigeye. Skipjack maturity is reached at the end of the first year of life, at around 40–45 cm FL (1.5–2.0 kg); opportunistic spawning occurs over a wide area of the WCPO. All of the tunas are highly fecund, releasing millions of eggs per spawning, but with generally with very low survival to adulthood. As noted, spawning of tropical tunas is essentially opportunistic, with no evidence of coordinated spawning activity, spawning aggregations or specific spawning areas.

Tuna age and growth estimates have generally been based on reading daily and annual rings in otoliths, corroborated where available with tagging data, length frequency progression data and other data sources. Recent estimates of bigeye age and growth suggest growth is faster than previously estimated, with implications for the productivity of the stock (Farley *et al*., 2017). Most tuna species grow at equivalent rates for the first year of life, to around 40–45 cm FL, and then diverge rapidly thereafter, related in part to the development of a swim bladder in some species, and resulting less demanding energy budgets. Yellowfin are relatively fast growing, with a maximum size of around 180 cm FL but with few fish surviving beyond 6 years. Bigeye tuna with a maximum size of 180 cm FL, are now believed to have similar rapid growth rates but slightly slower than yellowfin, and slower for Eastern Pacific Ocean bigeye than the WCPO. Skipjack rarely survive beyond 4–5 years of life, with very rapid turnover in populations

Tuna movements have been well studied in the WCPO via several large-scale tagging programmes carried out by the Pacific Community (SPC) since the late 1970s. Although individual tunas are demonstrably capable of long distance movements − thousands of nautical miles in some cases - fish movement throughout the life history at the population level is generally more limited, and tropical tunas are best regarded as highly mobile rather than highly migratory.

As noted, all three tropical tuna species are managed on the basis of separate western and eastern stocks with limited mixing as indicated by tagging data. Recent genetic studies for yellowfin in particular have suggested finer scale genetic structuring may be present (Tremblay-Boyer *et al*., 2017), but the implications of this for management are as yet unclear.

37.2 The Fishery

Utilisation: The oceanic tunas are monitored and managed at the regional level by RFMOs, according to the mandate provided by the United Nations Fish Stocks Agreement. At the national level they are monitored and managed by Ministry of Fisheries, with a requirement for compatibility of measures with RFMO measures applying thoughout the stock's range. The WCPO catch of yellowfin, bigeye, skipjack and albacore in 2016, broken down by gear, is shown below, with the 2016 Fiji catch by species provided for comparison. Note that the South Pacific albacore catch is given, rather than the WCPO catch. Except for albacore, Fiji catches make a very minor contribution to the overall WCPO catch based on the same stocks. Artisanal fishers using various gears, notably trolling and vertical handlining, around floating objects and anchored FADs, which serve to aggregate pelagic and midwater species, take some skipjack and yellowfin, but negligible bigeye and albacore in Fiji waters in the surface layers.

Gamefishing is an important component of tourist/recreational activity, targetting billfish and other large pelagics, with yellowfin an important target species.

Table 49. Catch composition by gear type in the western and central Pacific. For gears, p/s = purse seine, p/l = pole-and-line, and l/l = longline. The domestic fisheries of Indonesia (ID) and Philippines (PH) employ several other methods and are indicated in the table. Source: WCPFC Tuna Fishery Yearbook31.

Common name	Total catch (mt) – all gears	Catch by gear (% total)	Trend	Fiji catch (2016) provisional
yellowfin	650,491	p/s 61%, p/l 4%, l/l 14% others 22% PH/ID	Increasing	3,928 mt (<1% of WCPO catch)
bigeye	152,806	l/l 42%, p/s 41%, p/l 2%, others 14% PH/ID	Stable	1,190 mt (<1%)
skipjack	1,816,650	p/s 78%, p/l 8%, l/l 1%, others 12% PH/ID	Stable	Negligible
South Pacific albacore	68,601	l/l 95%, troll 4%, other < 1%	Decreasing	7,269 mt (10.4%)

Production: The Fiji pole-and-line fishery was developed in the mid-1970s to supply the PAFCO cannery at Levuka, and operated until 1997, with catches peaking at close to 6,000 mt in 1982 and 1990 (Smith, 1999). One private vessel continued to operate until 2001, but no vessels are currently operating. It seems unlikely that pole-and-line fishing might resume in Fiji, given the marginal economics of the seasonal fishery, the increasingly reduced access to traditional baiting grounds by custodians, and anecdotal information that the seasonal influx of fish to Fiji waters has been reduced by greatly increased catches over time in equatorial waters. No purse seine fishing has occured in Fiji waters for several decades.

The Fiji longline fleet developed during the 1980s, although a distant water longline fleet had been unloading primarily albacore tuna to the Pacific Fishing Company (PAFCO) cannery in Levuka for some years prior to that. The Fiji-based longline fleet has grown and also fluctuated considerably since that time. In 2016, it comprised 89 vessels, of which 80 were Fiji-flagged and the remainder chartered foreign vessels. Fifty of these vessels operated in Fiji waters, within an imposed cap of 60 vessels, whereas 39 vessels were licensed and authorised to fish on the high seas.

Table 50 below shows annual landings for the three main oceanic species for the past 5 years. Catches have been relatively stable during this time, although yellowfin catches seem to have increased somewhat in recent years. Nearly 90% of catch by all vessels were reported as taken in the Fiji EEZ (Anon., 2017). The catch is mostly landed in Suva, with some sold locally and some exported in unknown relative quantities. Of the 14,527 mt landed in 2016, 9,621 mt was reported processed and exported, with albacore making up 48% of exports, and yellowfin (32%), bigeye (11%) and tuna-like species making up the remainder (9%). The balance, around 4,900 mt, was utilised locally (Anon., 2017).

31 https://www.wcpfc.int/statistical-bulletins, accessed: August 2017

Fiji enjoys both EU duty-free status through an Interim Economic Partnership Agreement, and MSC certification for the longline fishery (since 2012), but it is not clear to what extent these concessions are accessed. The main sashimi markets (for mainly yellowfin and bigeye) are Japan, the USA and the EU, whereas Thailand, USA, Taiwan and Vietnam are the main cannery markets, for whole frozen round and cooked loins, in the latter case mostly from PAFCO albacore landed by foreign fleets.

Table 50. Total annual catch estimate for the Fiji national longline fleet from 2012−2016 (mt). The term 'provisional' for the 2016 suggest this might not be the final figures. Source: Anon (2017)

Species	2012	2013	2014	2015	2016 (provisional)
Albacore	7,958	6,202	6,703	7,793	7,269
Yellowfin	2,081	1,328	3,594	3,609	3,928
Bigeye	1,019	685	1,586	1,169	1,190

37.3 Stock Status

Stock assessments are undertaken at regional level, by the relevant RFMO, in this case the WCPFC. A summary of the current stock status for albacore, yellowfin and bigeyethe three species is provided in Table 51. Albacore is discussed in detail in Profile 38 ALBACORE TUNA. None of the three species is currently clearly subject to overfishing or in overfished state, although the outcomes of the recent bigeye assessment (August 2017) are still under discussion. As a result of changes in the spatial structure of the assessment model, and the inclusion of revised age and growth estimates (faster growth, and hence increased stock productivity), the WCPO bigeye stock has gone from overfished to the current greatly improved situation. The positive changes for bigeye tuna stock status in the 2017 assessment are primarily due to three factors: the inclusion of the new growth curve information, the inclusion of the new regional assessment structure, and the estimated increases in recruitment in recent years.

Table 51. Summary of the current stock status of western and central Pacific Ocean tuna.

Species	Overfishing	Overfished state	Current catch rel. to MSY	Assessment
yellowfin	No $F_{recent} / F_{MSY} = 0.75$	No $SB_{latest} / SB_{F=0} = 0.33$	Below or near 668,000 mt	Tremblay Boyer *et al.* (2017)
bigeye	Probably not $F_{current} / F_{MSY} = 1.01$	Probably not $SB_{latest} / SB_{F=0} = 0.28$	Near or over 151,380 mt	McKechnie *et al.* (2017)
skipjack	No $F_{current} / F_{MSY} = 0.62$	No $SB_{curr} / SB_{F=0} = 0.52$	Above 1,532,00 mt	Rice *et al.* (2014)

37.4 Management

Management of Fiji's oceanic tunas is facilitated through the various WCPFC CMMs, the Offshore Fisheries Management Decree 2012 and its Regulations 2014 in addition to the Fiji Tuna Management Development Plan 2014–2018. The relevant CMMs for the three tropical species is CMMs 2016−2001, the tropical tuna CMMs for bigeye, yellowfin and skipjack in the WCPO. The CMMs is due to expire at the end of 2017, and work has been proceeding on a bridging measure to allow WCPFC to develop a new CMM in 2018.

Many CMMs relate to the purse seine fishery and thus do not impact Fiji.

The longline fishery measures however include the following provisions:

1. bigeye catch limits − Each member that caught less than 2,000 tonnes of bigeye in 2004 shall ensure that their catch does not exceed 2,000 tonnes in each of the next 4 years from 2014−2017). [no issue for Fiji – catches barely exceed 1,0000 mt];
2. yellowfin measures − Members, Cooperating Non-members and Participating Territories (CCMs) of the WCPFC agree to take measures not to increase catches by their longline vessels of yellowfin tuna [Fiji catches did increase slightly in recent years but may have been absolved by revised 2016 limits]; and
3. Exemptions are provided to Small Island Developing States on several measures.

At national level, the Ministry of Fisheries has adopted the Tuna Management and Development Plan (TMDP) 2014−2018. It has imposed a cap of 60 vessels on the national longline fleet, and as a flag state, provides authorisations for Fiji flag vessels to fish in the high seas (Anon., 2017). Under an increased commitment to monitoring and surveillance, observer and e-logsheet programmes are in place, and e-monitoring trials are in progress. Bio-economic analyses are being undertaken, and will further inform the TMDP.

Current Legislation and Policies Regulating Exploitation: Legal Notice 25 of 1990 (LN 25/90) inserted three new regulations and three new schedules into the Fisheries Act Subsidiary Legislation (Cap.158 as amended), to require a special licence for Fiji fishing vessels catching tuna or deepwater snapper in Fiji waters, and to apply several compliance conditions. These conditions include catch reporting requirements and a requirement to accommodate observers onboard licensed vessels.

Relevant legislation includes the Offshore Fisheries Management Decree 2012 and its Regulations 2014.

Management Recommendations: No additions or changes to current policy are recommended, in view of the fact that management occurs at regional RFMO level. In addition, the Ministry of Fisheries Division exerts additional control via the Fiji Tuna Management and Development Plan and other instruments as below:

Offshore Fisheries Management Decree 2012 (Decree No. 78 of 2012)

- The Director shall publish the Fisheries Management Plan by way of Regulations.
- A Fiji fishing vessel or fishing vessel used for sport or recreational fishing shall not be used in the internal waters, archipelagic waters, territorial sea or exclusive economic zone of Fiji unless under the authority of a valid licence
- Every licence or authorisation issued by the Permanent Secretary shall, unless earlier cancelled or suspended, be valid for a period not exceeding 36 months from the date of issue
- Observers shall be permitted to board any vessel issued with a valid licence

Offshore Fisheries Management Regulations 2014

- A fishing vessel shall not be used for fishing or related activity within Fiji fisheries waters except with a licence to fish issued by the Permanent Secretary.
- The operator of a licensed or authorised fishing vessel shall duly complete in the English language, daily records or reports of all catch; and by-catch by species.
- The operator of a fishing vessel licensed or authorised under this Decree shall install, maintain and operate a registered Mobile Transceiver Unit at all times and in accordance with the manufacturer's specifications and operating instructions and standards approved by the Director.

Fiji Tuna Management and Development Plan 2014–2018

- The scope of the Plan focuses on Fiji longline fishery and includes all "Fiji fishing vessels" active both in Fiji's EEZ and those authorised to fish in the high seas. The Plan also extends to Fiji fishing vessels licensed through charters, joint ventures and licensed to fish in other EEZs. The Fiji purse seine fishery is managed under the Multilateral Treaty between the US and Certain Pacific Island States. The pole-and-line fishery is managed under Fiji-Japan Bilateral Agreement. The Plan does not extend its scope to sport, recreational, test and exploratory fishing. Area of application of this plan is covered in the Offshore Fisheries Management Decree
- Fiji currently has two management tools with regard to the longline fishery in its national waters, a total allowable catch (TAC) for all tuna species and a restriction on the number of vessels it licences to fish in its national waters.
- In 2014 there was (i) a fishing licence limit of 60 vessels out of which a limit of 12 vessels applies to the Archipelagic waters and Territorial seas; and (ii) a national TAC of 12,000 metric tonnes across all target tuna species excluding skipjack; and (iii) a provisional SP albacore TAC of 7,294 mt.

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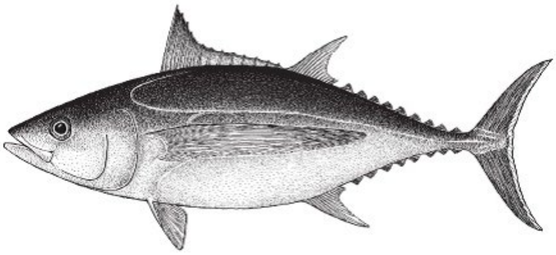
38 ALBACORE TUNA



38.1 The Resource

Species status: Albacore (**yatuloa** - *Thunnus alalunga)* are the most abundant of the deep-swimming tunas in Fiji waters, and are the main target species of the Fiji national longline fishery. Like most oceanic tunas, they are wide ranging in most oceans between at least 40ºN and 40ºS (Collette, 2001). Their long pectoral fins are distinctive, as is the species' white meat, highly prized for canning. Albacore is the only tuna classified and allowed to be sold as white meat tuna in most jurisdictions.

Distribution: Albacore are distributed throughout the Pacific, but are believed to comprise north and south Pacific populations, with limited mixing across the Equator (Murray, 1994). In Fiji, they are not caught at the surface and most fish taken by longline are adults (>80 cm FL). Abundance can vary greatly seasonally and inter-annually as fish undertake latitudinal and longitudinal movements in response to oceanographic conditions (Langley, 2004). They are not a schooling species but may aggregate in small groups for feeding, expecially in temperate waters where they may be the target of surface troll fisheries e.g. New Zealand coastal waters, and along the Sub-Tropical Convergence Zone.

Biology and Ecology: Albacore have been well studied due to their commercial importance, and a series of increasingly refined stock assessments for the South Pacific stock have been available since 1998. Their biology is well understood, and extensive tagging experiments have been undertaken, though not as extensively as with tropical tunas in view of their more limited schooling behaviour.

Albacore grow to at least 120 cm FL and possibly 60 kg maximum weight (Collette, 2001). They occur as juveniles in southern waters, in the vicinity of the Sub-Tropical Convergence Zone (40ºS) and the coastal waters of New Zealand and Australia, then gradually move north into sub-tropical waters as they grow, and may move back and forth on a seasonal basis. In Fiji waters, they are not seen at the surface, occurring at depth at their preferred temperatures of 13º–25ºC, or lower for short periods, often around the thermocline but occasionally ranging down to 600 m (Collette, 2001; FishBase[32]).

Albacore are sub-surface feeders as adults, taking a variety of mesopelagic fish, squid and crustaceans. They may move closer to the surface at night in pursuit of vertically migrating prey. As juveniles and sub-adults, they can be caught trolling and by pole-and-line at the surface, using both live and dead bait. Spawning occurs in sub-tropical and tropical waters (10º–25ºS) in the southern summer months. Length and age at maturity (L_{50}) were determined by Farley *et al.* (2014) as 87 cm FL and 4.5 years respectively. Albacore are highly fecund like most tunas. Eggs and larvae are pelagic, and occur widely in tropical and subtropical areas, indicative of the broad band across the South Pacific Ocean where spawning occurs.

As noted, juveniles occur in southern waters around 40ºS, at the surface in small schools, often associated with skipjack and other tunas, where they are fished by troll and pole-and-line gear. Juveniles are generally not found in Fiji waters. Albacore grow rapidly in their first year, to 45–50 cm FL, after which growth slows, to around 10 cm per year until age 4, when growth slows even more (Harley *et al*., 2016). Maximum age reached is at least 9 years, at around 120 cm FL. Males predominate at larger sizes, and growth rates begin to diverge after maturity is reached. Growth rates and size at age of albacore increase eastwards across the southern WCPO, reaching a maximum size at around 160ºW (Williams *et al*., 2012).

32 http://www.fishbase.se/summary/Thunnus-alalunga.html, accessed: August, 2017

Tagging data for south Pacific albacore are quite limited relative to those available for the tropical tunas, but have served to demonstrate the discrete nature of the south Pacific population, and the seasonal latitudinal movements undertaken between temperate and subtropical/topical waters (Williams *et al*., 2010). Langley (2004) examined the oceanographic conditions that may result in temporarily lower catch rates in domestic albacore fisheries, as biomass shifts occur across the south Pacific.

38.2 The Fishery

Utilisation: The South Pacific albacore total catch in 2016 was 68,601 mt, and has been declining for several years. 95% of the catch was taken by longline fleets of various nations, 4% by the southern troll fishery, and less than 1% by other gears (Williams *et al*., 2017). It should be noted that the longline fisheries mostly take mature-aged larger fish with relatively little of the younger immature age classes caught. The total WCPO albacore catch, including troll, pole-and-line and longline fisheries north and south of the Equator but west of 150ºW, was larger with the inclusions of these northern fisheries, at 97,822 mt.

In Fiji waters, albacore are taken only by the national longline fleets, but are also landed at Pacific Fishing Company (PAFCO) by an international fleet fishing in other EEZs and on the high seas. Albacore are the main component of the sub-tropical longline catch and are either processed for export, mostly as frozen cooked loins, or exported as whole round or fresh fish. Fiji national fleet albacore landings comprise a significant proportion of the South Pacific catch (10%). Albacore do not appear in municipal markets, but may be purchased from wholesale/retail outlets for domestic consumption in hotels, and restaurants.

Production and Marketing

Landings from the Fiji longline fleet has been described in the previous Profile 37 OCEANIC TUNA. Table 52 below shows annual landings for albacore for the past 5 years. Catches have been relatively stable during this time, and since 2015, have been compiled from landings rather than logsheets. In contrast, the South Pacific albacore total catch has been declining for several years, as noted above. Nearly 90% of the albacore catch by all Fiji national vessels were reported as taken in the Fiji EEZ (Anon., 2017). The catch is mostly landed in Suva, with some sold locally and some exported (see below). Domestic sales of albacore are made though wholesale outlets and longline landing sites.

Table 52. Annual albacore catch estimate for the Fiji national longline fleet, 2012−2016 (mt). Source: Anon (2017)

2012	2013	2014	2015	2016 (provisional)
7,958	6,202	6,703	7,793	7,269

Exports

In 2016, albacore made up 48% of the exports of tuna and tuna-like species, 9,621 mt in total, from the longline fishery. A total of 4,900 mt of longline catch was sold locally but it is unknown how much of this was albacore. Exports comprise fresh tuna, whole frozen round tuna and frozen cooked loins, the latter mainly from PAFCO and not included in these export data. The main sashimi/fresh markets are Japan, the USA and the EU (mostly for yellowfin and bigeye), whereas Thailand, USA, Taiwan and Vietnam are the main cannery markets for frozen cooked loins and whole frozen round. Fiji enjoys both EU duty-free status under an Interim Economic Partnership Agreement, and MSC certification for the longline fishery (2012), but it is not clear to what extent these concessions are accessed.

38.3 Stock Status

As with all WCPO tunas, the assessment are conducted throughout the range of the stock, in this case South Pacific albacore in the southern region of the WCPO, to 150ºW. The most recent stock assessment for albacore was conducted in 2016, with catch data to the end of 2013 (Harley *et al.*, 2016). South Pacific albacore continue to be assessed as not subject to overfishing (F_{curr}/F_{MSY}= 0.39) and not in an overfished state ($SB_{latest}/SB_{F=0}$ = 0.4) and the current catch is rated as at the level of, or above the MSY of 76,800 mt.

Although stocks are considered healthy, CMMs of the Western and Central Pacific Fishery Commission (CMM 2015−02) notes that, given the age-specific mortality of the fish caught by the longline fleets [the longline catch comprises mostly spawning adults], any significant increase in effort would reduce CPUE to low levels with only moderate increases in yields. CPUE reductions may be more severe in areas of locally concentrated fishing effort". Economic concerns rather just biological concerns need to be taken into account with this fishery, with the selective harvest of larger fish and potentially lower yields.

38.4 Management

Management of South Pacific albacore throughout the range of the stock is the responsibility of the RFMO, in this case the WCPFC, through the application of Conservation and Management Measures (CMMs) and other prescriptions. The CMMs applying to South Pacific albacore (CMM 2015−02), given the lack of immediate biological concerns, are mostly concerned with maintaining economically viable catch rates, and proposes no direct management intervention other than requiring that the number of vessels targetting south Pacific albacore be kept at 2005 or recent historical (2000–2004) levels. It additionally calls for improved reporting and cooperation in research and data collection to reduce any uncertainty in assessment and management advice.

At the same time FFA members have developed the Tokelau Arrangement (Anon., 2014) which provides a framework for the development of cooperative zone-based management of South Pacific albacore tuna fisheries, including potentially wider implementation of the Harvest Strategy for the south Pacific albacore fishery that was agreed between members of the FFC Sub-Committee on South Pacific Tuna and Billfish Fisheries in 2013. The final text of the Tokelau Arrangement was agreed at the 91st meeting of the Forum Fisheries Committee in October 2014. The Arrangement currently does not include allocation of high seas catches, and not all potential members have signed. The current status of implementation of the Arrangement is unclear. Fiji is believed to be a signatory to the Arrangement.

At national level, the Ministry of Fisheries has adopted the Tuna Management and Development Plan (TMDP) 2014–2018. It has imposed a cap of 60 vessels on the national longline fleet, and as a flag state, provides authorisations for Fiji-flag vessels to fish in the high seas (Anon., 2017). Under an increased commitment to monitoring, observer and e-logsheet programmes are in place, and e-monitoring trials are in progress. Bio-economic analyses are being undertaken, and will further inform the Tuna Management and Development Plan (TMDP).

Current Legislation and Policies Regulating Exploitation: Relevant legislation incudes the Offshore Fisheries Management Decree 2012 and its Regulations 2014 − see the description of the Fiji Tuna Management and Development Plan 2014−2018 in the management section above. In summary, in 2014 there was a:

1. Fishing licence limit of 60 vessels out of which a limit of 12 vessels applies to the Archipelagic waters and Territorial seas;
2. National TAC of 12,000 metric tonnes across all target tuna species excluding skipjack;
3. Provisional SP albacore TAC of 7,294 metric tonnes.

Management Recommendations: No additions or changes to current policy are recommended, in view of the fact that regional management occurs at regional RFMO level.

The Fiji Tuna Management and Development Plan 2014−2018 appears consistent with the regional management and appropriately addresses Fiji's needs.

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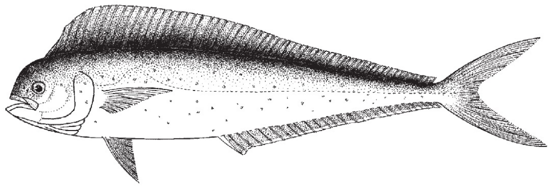
39 DOLPHIN FISH / MAHI MAHI



39.1 The Resource

Species Present: Two species of dolphin fish (**maimai**) exist in the world's oceans, including Fiji waters – the common dolphin fish (*Coryphaena hippurus)* and the pompano dolphin (*C. equiselis*). The latter is much smaller and is of considerably less importance to fisheries (Collette *et al*., 2011a.) The information in this profile will therefore tend to focus on *C. hippurus. C. equiselis* are frequently misidentified as juvenile or female *C. hippurus*, and are not usually separated in available statistics.

Distribution: These two species have a widespread distribution throughout tropical and temperate waters. **Maimai** occur throughout the Atlantic, Indian, Pacific Oceans and the Mediterranean Sea, and throughout their range are most common in waters between 21º–30°C SST (Collette *et al*., 2011a, 2011b). *C. equiselis* has been found to depths of 119 m (Nobrega *et al*., 2009), whereas *C. hippurus* are known to a depth of 85 m (Collette *et al*., 2011b).

Biology and Ecology: A comprehensive account of the biology of **maimai** can be found in Palko *et al.* (1982). **Maimai** are open ocean pelagic species but occasionally approach the coast. They feed on flying fishes, small fish, squids and crustaceans. **Maimai** typically concentrate beneath floating debris such as logs and *Sargassum* weed, and are known to follow ships (Collette, 1999).

In tropical regions with water temperatures greater than 21ºC, spawning for both species is likely year-round. Eggs are pelagic - the eggs of common dolphinfish off Taiwan range from 1.0−1.6 mm and have one oil globule present. They hatch at about 3 mm, and exhibit flexion at 7.5−9.0 mm standard length (Collette, 2010). **Maimai** exhibit rapid growth; the first year growth rate of common dolphinfish ranges from 1.43−4.71 mm per day, which is equivalent to 52−172 cm and a weight of about 10 kg in the first year (Anon., 2010; Collette, 2010). Table 53 lists the Von Bertalanffy Growth Equation growth parametres, as well as length-weight equations for **maimai** in different areas. Common dolphinfish grow to a length of 2.1 m TL, but commonly to 1 m. The International Game Fishing Association (IGFA) all-tackle record for common dolphinfish is 39.46 kg. Pompano dolphinfish are known to grow up to 75 cm but commonly to 50 cm (Collette, 1999), the IGFA all-tackle record is 3.86 kg (Collette, 2010).

Dolphinfish are gonochorists (sex ratio of about 1:1), and exhibit sexual dimorphism - male **maimai,** known as 'bulls', develop a prominent bony crest on the front of their head when they reach a standard length of around 35 cm (pompano dolphinfish) or a forklength of about 40 cm (common dolphinfish). Females retain their more slender, streamlined shape. At smaller sizes males and females are externally indistinguishable (Palko *et al*., 1982). During spawning **maimai** will pair off (Nakamura, 1971 in Palko *et al*., 1982). **Maimai** can live up to four years, but usually less than two (Collette, 2010).

Maimai exhibit seasonal movements, as the fish try to stay in areas roughly associated with the 23ºC isotherm. (Kraul, 1999). Though **maimai** are taken all year around, January−April are considered the best months for catching **maimai** in Fiji[33]; this coincides with the summer season.

33 http://www.fijifishingcharters.com/blog/posts/best-season-for-fiji-fishing, accessed: October 2017

39.2 The Fishery

Utilisation: Maimai are a highly prized food and gamefish wherever they occur. They are caught by trolling, longline, nets and harpooning. The “kannizzati” and “shiira-zuke” fishery of Malta and Japan, respectively, use attracting devices such as floating bundles of bamboo reefs or cork planks to accumulate **maimai** before nets are set (Palko *et al*., 1982). Fishers tend to look for any floating debris in the water or current lines and fish around and along these, taking advantage of the **maimai**’s affinity for schooling under these.

In French Polynesia **maimai** are also taken by harpooning the fish from a specially designed fishing boat known as the “poti marara”. These boats feature a centre console closer to the bow than a typical aft centre console boat, but the real distinguishing feature is a large “joy stick” rather than a wheel for steering - this allows the skipper to keep one hand free to handle the harpoon, which is fixed to the boat by a line. **Maimai** are spotted as they swim along the surface and as the boat approaches the fish at speed, the skipper uses their free hand to spear the fish. This fishing method requires considerable skill and concentration, there are reportedly few current experts in this unique fishing style (Borel, 1990).

In Fiji **maimai** are primarily taken by trolling and longline, in the latter case often as bycatch. **Maimai** are prolific hunters and will strike almost any type of lure. Longline fisheries for **maimai** differ from those of tuna (see Profile 37 OCEANIC TUNA) in that hooks are fished closer to the surface, with few hooks between floats.

Table 53. Growth and mortality estimates for **maimai** for various locations. A review of global growth parametres for *C. hippurus* can be found in Chang *et al.* (2013). * L_∞ refers to asymptotic length (measured as fork length, FL), (M) = male, (F) = female, if no gender is provided assume this value is a mean of both. Source: Uchiyama *et al.* (1986)[8], Patterson and Martínez (1991)[7], Uchiyama and Boggs (2006)[6], Benjamin and Madhusoodana (2012)[5], Furukawa *et al.* (2012)[4], Chang *et al.* (2013)[3], Guzman *et al.* (2014)[2], Solano-Fernández *et al*. (2015)[1]

Scientific	Source	Location	L_∞ (cm)*	K	M	Length-weight relationship
C. hippurus	1	Central Mexican Pacific	231.65	0.87		$W=2.446 \times 10^{-5}*FL^{2.750}$
	2	Pacific Panama	171.5	0.36	0.52	$W=6.73 \times 10^{-5}FL^{3.44}$
	3	Taiwan	149.4	0.72		
	4	East China Sea	104.9 (M)	0.84		
	4	East China Sea	93.8 (F)	1.03		
	5	Indian Ocean	194.30	0.40	0.60	
	6	Central North Pacific	(F)			$W=1.0693 \times 10^{-5}*FL^{2.9337}$
	6	Central North Pacific	(M)			$W=8.0856 \times 10^{-5}*FL^{3.0157}$
	7	Ecuador	195	0.41	0.55	
	8	Hawaii	189.93 (M)	1.19		
	8	Hawaii	153.27 (F)	1.41		
C. equiselis	8	Hawaii	61.39	2.17		

Production and Marketing: Maimai in Fiji are taken at all fishery levels − subsistence, artisanal, and commercial. Commercially **maimai** are taken by shallow longlines − one sector of the Fiji longline fishery now targets **maimai** rather than albacore, although this fishery is reportedly seasonal to be able to compete in the international export market with the large volume of fish from the Ecuador/Peru fishery. **Maimai** are seldom seen in municipal markets as Table 54 below shows. The majority of **maimai** in the local market are sold through non-municipal market outlets, often directly to resorts and restaurants as shown by Raravula (2013). Annual estimated catches by the Fiji flagged long-line fleet are shown in Table 55. It is unclear what caused the substantial increase in catches caught in 2010.

Table 54. Volume (mt) and value (FJD per kg) of **maimai** sold in municipal and non-municipal market outlets. Value provided in brackets below volume. The last published Fishery Division Market Survey with species details was in 2004, hence the inconsistency below. Source: Anon. (2003−2005); Raravula (2013), Ministry of Fisheries (*unpubl. data)*

Year	Municipal market	Non-municipal market outlet	Total (local market)
2016	na (6.59)	na (na)	na
2012*	na (na)	37.65 (5.50–12.00)	na
2004	0.11 (na)	9.52 (4.91)	9.63
2003	1.2 (na)	9.66 (na)	10.86
2002	0.38 (na)	14.64 (na)	15.02

*Based on values taken from Raravula (2013) which only considered sales to four large resorts in the Western Division. The study reported that these resorts collectively purchased 1,568 kg of maimai fillets, and 13 kg whole fish per month. A fillet : whole weight ratio of 1:2 was assumed. FJD 5.50 per kg is the whole fish value, whereas FJD 12 is the fillet value.

Table 55. Annual estimated catches (mt) of **maimai** for the Fiji Flagged Longline Fleet. Source: WCPFC (2009, 2011−2016)

2007	2008	2010	2011	2012	2013	2014	2015
141	294	1830	79	198.5	313.3	386	305

39.3 Stock Status

No Fiji-specific information on **maimai** stock(s) could be found. Both species are listed as of Least Concern by the IUCN Red List (Collette *et al*., 2011a; 2011b). Given their fast growth, early maturity, and short lifespan **maimai** should be robust to exploitation.

39.4 Management

Legislation and Policies Regulating Exploitation: Relevant policy regarding **maimai** exploitation can be found in Schedule 1 (Regulation 3) and Schedule 2C (Regulation 6) of the Offshore Fisheries Management Decree 2012 − Offshore Fisheries Management Regulations 2014. The policy listed below is not an exhaustive account.

Part 4 - Licences and Authorisations

> A Fiji fishing vessel shall not be used for fishing or related activity within Fiji fisheries waters except with a licence to fish issued by the Permanent Secretary pursuant to section 32 of the Decree. The owner or operator of a Fiji fishing vessel applying for a licence to fish within Fiji fisheries waters may apply to be licensed to fish for Mahimahi. If the Fiji fishing vessel is 100 percent owned by Fiji nationals, this application is not required.

Schedule 1 (Regulation 3)

Prohibited and Restricted Areas
All areas within 3 nautical mile radius of reef systems within Fiji fisheries waters are prohibited, as well as all internal waters within Fiji fisheries waters.

Restricted Areas (Applicable to Specific Categories of Fishing Vessels)
Archipelagic waters and Territorial sea are restricted to both foreign fishing vessels, locally-based foreign fishing vessels, and Fiji fishing vessels with a fish hold capacity equal to or greater than 40 cubic metres. This restriction does not apply to Fiji longline vessels with a fish hold capacity less than 40 cubic metres targeting tuna and tuna like species and that utilise no more than 2500 hooks per set.

The coordinates of the archipelagic waters and territorial sea of Fiji are described in the Marine Spaces Act (Cap. 158A) and delineated in official charts.

Schedule 2C (Regulation 6)

Prohibited Fishing Gear and Methods
Any driftnet fishing gear.
Use of dynamite, gelignite or other explosive substance.
Use of any chemical or chemical compound including—

(a) any substance containing derris;

(b) any substance containing rotenone.

Shark lines – trace wire, baited shark lines attached to floats (Hook 99).
Hook types – any hook types declared by the Minister by notice in the Gazette as a prohibited hook type.

Management Recommendations: None required at present, the species has life history traits that make it quite resilient to fishing pressure. More stringent monitoring and reporting is required as the **maimai** fishery is fast growing with the demand for local and export markets; a number of tuna operators switch to **maimai** at different times of the year.

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40 LARGE OCEANIC PELAGIC FISH

40.1 The Resource

Species present: Fiji does not have traditional fisheries for large ocean pelagics, and therefore the common English name is often used in place of the Fijian name. Therefore, the common English name will be used throughout this profile. The species considered in this profile, drawn from the large number of widely distributed species which inhabit the vast ocean realm, are primarily midwater species taken by the Fiji longline fishery. They are landed as by-catch incidental to the target catch of oceanic tunas covered in Profile 37 OCEANIC TUNA. The long list of finfish species taken in the WCPO longline (and purse seine) fisheries is given by Bailey *et al.* (1996). Most species are uncommon and not considered here, for example sunfishes and other limited mobility species, a range of gempylid species (snake mackerels), lancet fishes and bramids (pomfrets). Sharks and rays are covered in Profile 36 SHARKS AND RAYS.

There is also a suite of large oceanic pelagic fishes occurring in Fiji waters and/or captured incidentally around floating objects (e.g. Fish Aggregation Devices (FADs) and logs) typically by purse seine gear but also on a smaller scale by artisanal fishers − these are mostly surface predators which also occur in coastal areas, like for example the neritic tunas (kawakawa and frigate/bullet mackerels), barracudas, tripletails, rainbow runners and jacks, as well as smaller species such as scads (*Decapterus* spp.) and triggerfish. Whilst Fiji has no purse seine fishery, some of these species may be unloaded during transhipment by foreign purse seine vessels and appear in market records, along with small FAD-associated artisanal catches, but are generally not considered here.

The species included in the profile, primarily those landed as longline bycatch by the Fiji longline fleet and marketed mostly in the Central Division, are listed below in Table 56. The wahoo (**walunitoga, wau**), asterisked in the Table, has been selected as the exemplar species for more detailed consideration in Profile 41 WAHOO, whereas mahi mahi (Profile 39 DOLPHIN FISH/MAHI MAHI) and oceanic tunas (Profile 37 OCEANIC TUNA) are the subject of separate profiles in their own right. The great barracuda (**ogo**) has been included here, as well as in Profile 29 LARGE COASTAL PELAGIC FISH and Profile 40 LARGE OCEAN PELAGIC FISH, as it is common component of landings. Many oceanic pelagic species grow to very large sizes, notably the billfishes, as shown below, with several species reaching over 750 kg in weight. Many lack traditional Fijian names as they were not taken in traditional fisheries.

Table 56. List of large ocean pelagic fishes in Fiji. Source: Lewis *et al.* (1983); Lewis (1984, 1985), Fish Base[34], Carpenter and Niem (1999, 2001).

Common name	Scientific name	Fijian name	Max. length (cm)
Coryphaenidae			
dolphin fish, mahi mahi	*Coryphaena hippurus*	**maimai**	210
Lamprididae			
opah	*Lampris guttatus*		180
Sphyraenidae			
great barracuda	*Sphyraena barracuda*	**ogo**	200
Gempylidae			
escolar	*Lepidocybium flavobrunneum*		150
oilfish	*Ruvettus pretiosus*		200
Scombridae			
wahoo	*Acanthocybium solandri*	**walunitoga, wau**	210
Xiphiidae			
swordfish	*Xiphias gladius*	**sakuvorowaqa**	450
Istiophoridae			
blue marlin	*Makaira mazara*	**sakuvorowaqa**	500
black marlin	*Makaira indica*	**sakuloa**	450
striped marlin	*Tetrapturus audax*	**sakusisi**	350
shortbill spearfish	*Tetrapturus angustirostris*	**sakuvorowaqa**	450
sailfish	*Istiophorus platypterus*	**sakuvorowaqa**	200

Distribution: Virtually all the species included are very widely distributed in the western and central Pacific Ocean (Carpenter and Niem, 1999; 2001), and in many cases are global circum-tropical species. They are mostly highly mobile species with wide stock ranges where those are known, but usually having some degree of population structure across the Pacific basin. Billfish – swordfish and marlins – typically might have several sub-populations, whereas wahoo may constitute a single basin-wide genetic stock. As a corollary, none of the species listed are endemic to Fiji and all are widely distributed throughout the Fiji EEZ.

Some of the species included also regularly occur in coastal or even riverine waters, notably the great barracuda (**ogo**); others also occur in contiguous reef slope waters e.g. sailfish, wahoo and mahi mahi, but most are true open ocean inhabitants. Within the three-dimensional habitat of the open ocean, the various species occupy differing depths within the vertical profile. Deep-swimming species often undergo diurnal migrations toward the surface at night along with similar movements of prey, or in accordance with lunar cycles.

Some species, such as wahoo, mahi mahi and sailfish, rarely leave the mixed surface layer (the top 100 m of the ocean) and may be caught by both surface and sub-surface gear, whereas most longline species may normally be caught at considerable depths (e.g. opah, escolar, swordfish). Some billfishes may spend considerable time at the surface whilst also diving to great depths (1000 m) when feeding or thermoregulating (e.g. swordfish). Most large ocean pelagics are capable of long distance movement for feeding, spawning or polewards seasonally in the hemispheric summers following preferred warmer

34 http://www.fishbase.org

temperature waters. Some large ocean pelagics tend to be seasonal visitors to Fiji waters, or show strong seasonality in local abundance e.g. tropical tunas in summer, wahoo in winter months. Little tagging has been done with ocean pelagics, other than the main commercial tuna species, to demonstrate the nature and extent of their movements throughout the life history.

Biology and Ecology: Apart from mahi mahi and wahoo, the most prominent components of the catch are the *billfishes*, of which blue marlin are the most commonly taken tropical open ocean billfish species. These are followed by swordfish, the smaller spearfish, sailfish and striped marlin, with black marlin, a continental rather than island species, not commonly taken. Swordfish are rarely seen at the surface in Fiji waters, and are the deepest swimming of the billfishes. Spearfish which grow to around 60 kg are often associated with high islands. Sailfish often occur closer inshore and striped marlins are normally inhabitants of sub-tropical waters. Striped marlin along with swordfish are the most valued of the billfish as food fish. In Fiji, because of their surface predatory behaviour and readiness to take lures and baits, the billfishes are also important target species for gamefishing operation. Opah or moonfish, with their striking colouration, and orange flesh, are highly sought-after food fish, inhabiting deeper water; they are also endothermic with the heart temperature maintained above that of the surrounding water.

The popularity of escolar and oilfish, white fleshed fish often used as illegal substitutes in some countries for other high value species, is somewhat compromised by the purgative qualities of the flesh at times. **Ogo**, specifically the great barracuda, are caught in significant quantities often far offshore, as well as in inshore waters. Most large ocean pelagics are opportunistic predators, feeding at various depths on fish and squid; the prey may show nocturnal movements towards the surface, with the large pelagics following them. The billfishes may use their bills or swords to stun prey, and may also cooperate in small groups to herd baitfish for consumption (e.g. sailfish).

The large billfish (blue, black, striped marlin) grow rapidly, as do swordfish, attaining maturity within 4−5 years at large size; sexual dimorphism in growth is common, with females attaining much larger sizes. Spawning can occur over wide areas, and be year-round in tropical species, and seasonal in others, especially at higher latitudes. Most species have preferred temperature ranges for spawning, mostly above 24ºC; fertilisation is external with planktonic larvae growing rapidly and quickly becoming predatory. Growth of the large billfish species can be very rapid, as noted, attaining maturity within 4−5 years at weights of several hundred kilos. Little information is available on opah or escolar age and growth in Fiji waters.

As noted, relatively little tagging work has been done with large ocean pelagic species, with some anecdotal movement information available from gamefish tagging programmes, and many seasonal movements are well known anecdotally. Most stock discrimination work has been done with genetic markers. The existence of several stocks across the Pacific has been demonstrated for some billfish species e.g. striped marlin, swordfish, black marlin, sailfish, whereas blue marlin may constitute a single Pacific-wide stock. Little is known of the stock structure of other large ocean pelagics such as opah and escolar, but any population units can be assumed to be extensive in area.

40.2 The Fishery

Utilisation: The large coastal pelagic species included in this profile are restricted to those commonly taken by longline gear. The Fiji longline fleet developed during the 1980s, although a distant water longline fleet had been unloading primarily albacore tuna to the PAFCO cannery in Levuka for some years prior to that, with some bycatch species traded locally to limited extent (e.g. wahoo, opah, and escolar).

The Fiji-based longline fleet has grown and also fluctuated considerably since the 1980s. In 2016 it comprised 89 vessels, of which 80 were Fiji-flagged and the remainder chartered foreign vessels. 50 of these vessels operated in Fiji waters, within an imposed cap of 60 vessels, whereas 39 vessels were licensed and authorised to fish on the high seas. Nearly 90% of catch by all vessels was reported as taken in the Fiji EEZ (Anon., 2017). The catch is mostly landed in Suva, with some sold locally and some exported. No consistent data are available on the disposal of the landings, and few data are available on the extent of bycatch discards.

Artisanal fishers using various gears, notably trolling and vertical handlining, around floating objects and anchored FADs, which serve to aggregate pelagic and midwater species, take a variety of species in small quantities. Gamefishing is an important component of tourist activity, targetting billfish and other large pelagics (e.g. wahoo, mahi mahi, barracuda, etc.).

Production and Marketing: Landings data are collected on marketable species, with all longline catches required to be reported under Fiji law, and compliance with relevant WCPFC Conservation and Management Measures (CMMs) (Anon., 2017). In 2016 and most recent years, total landed catch for the Fiji national fleet has been around 14,000 mt, with target tunas (albacore, yellowfin and bigeye) making up around 85% of the landings, and non-target species around 15% of the landings. The extent of discards is unknown but will include species with little or no commercial value e.g. lancet fishes, and snake mackerels.

Table 57 below lists the landings of non-tuna target species for the most recent years (2015, 2016). Other less desirable components may be discarded and not recorded, whereas as some species (e.g. designated key shark species) are required to be released alive or discarded even if dead. The increase in landings for 2016 over 2015 is attributed to the use of actual landings rather than logsheet data (Anon, 2017).

Table 57. Estimated landings (mt) of non-target tuna-like species for the Fiji longline fleet from 2015–2016. Source: Anon (2016, 2017)

Species group	2015	2016
blue marlin	155	180
swordfish	122	118
spearfish	79	75
sailfish	na	43
striped marlin	36	30
black marlin	2	4
marlin (unspecified)	n/a	22
Total billfish	**394**	**472**
mahimahi	305	397
opah	269	306
wahoo	237	280
barracudas	n/a	48
escolars	50	42
other species / unspecified	345	595
Total finfish	**1,545**	**1,668**

The landings of non-target species are dominated by mahi mahi, opah and wahoo, reflecting their market value and the established demand for them. Lower value species might be generally discarded as noted. The data currently do not distinguish between mahi mahi taken in a recently developed seasonal surface fishery for mahi mahi, and mahi mahi taken by conventional deep tuna longlining. This will be discussed in Profile 39 DOLPHIN FISH/MAHI MAHI. The billfishes make up about 20–25% of the "tuna-like" landings, with blue marlin and swordfish making up more than 50% of the billfish catch.

The "other species" category in Table 57 is believed to be mostly blue shark, the landing and sale of which is allowed, unlike the other key shark species (P. Williams, *pers. comm*). The most recent reliable market survey data (i.e. 2004), are summarised for the large pelagics included in the survey categories and are shown in Table 58. Most sales are in non-market outlets where they are presumably purchased from landings sites and later traded. Sales were dominated by the high value and much sought-after wahoo, which make up nearly half the total, and may serve as a ready substitute for **walu,** catches of which may be declining whilst demand for this iconic species remains strong (see Profile 29 LARGE COASTAL PELAGIC FISH and Profile 30 NARROW-BANDED SPANISH MACKEREL).

The great majority of supplies are likely to be from longline landings. The tunas, including the neritic mackerel tuna, and rainbow runners, make up just under 70 mt, and may be supplied in part by artisanal fishers. The situation since 2004 is unknown, in the absence of reliable market survey data, but wahoo landings are now over 250 mt in recent years, and much of this is consumed locally. It is not clear why opah did not show up in the 2004 market survey, but possibly much is exported, as is mahi mahi, at least seasonally. Some exports of large oceanic pelagics (e.g. opah and wahoo) are known to occur but no reliable data are available on these exports.

Table 58. The volume (mt) of large oceanic pelagic species in 2004, as recorded in market surveys. Source: Anon (2005), Fisheries Division, *unpubl. data*)

Common name	Municipal markets	Non-municipal market outlets	Total
Tuna			
skipjack	0.19	12.13	12.32
yellowfin	4.43	19.84	24.27
mackerel tuna	14.13	16.27	30.40
Non-tuna			
wahoo	6.71	65.12	71.83
mahimahi	0.11	9.53	9.64
marlin	0	10.29	10.29
sailfish	0	1.12	1.12
rainbow runner	1.03	3.96	4.99
Total	**26.6**	**138.26**	**164.86**

40.3 Stock Status

Stock assessments are available for several WCPO billfishes and are summarised in Table 59.

Table 59. Species of large oceanic pelagics, stock assessments and their outcome.

Species	Outcome	Assessment
blue marlin	Not being overfished and not in an overfished state	Anon. (2013)
striped marlin (SW Pacific)	Not being overfished, but approaching an overfished state	Davies *et al.* (2013)
swordfish (SW Pacific)	Not being overfished and not in an overfished state	Takeuchi *et al.* (2017)
sailfish, spearfish, black marlin	No information	No assessment available for WCPO

Reference points (Limit Reference Point, Target Reference Point)[35] and Harvest Control Rules have yet to be developed for most billfishes. The three species for which assessments have been carried out have not given rise to serious concerns at this time. The stock status of other large ocean pelagics such as opah, escolar and other large ocean pelagcis remains completely unknown.

40.4 Management

Current Legislation and Policy Regulating Exploitation: Management of the highly mobile large coastal pelagics, notably the billfishes, is by the Offshore Fisheries Management Decree 2012 and its Regulations 2014, and the Tuna Management Development Plan 2014−2018. The responsibility for management throughout the range of the stocks in the WCPO rests with the responsible RFMO, the WCPFC, via series of CMMs.

There are CMMs currently applying, *inter alia*, to the following large coastal pelagic species, in addition to those applying to tunas, sharks, turtles and seabirds, and some operational aspects of fishing e.g. transhipment. These CMMs are listed below:

- CMM 2005–03 North Pacific albacore [5.88mt caught by 8 Fiji vessels]
- CMM 2006–04 Southwest Pacific striped marlin [22.74 mt caught by 69 vessels]
- CMM 2009–03 Swordfish [45.3 mt caught by 55 vessels]
- CMM 2010–11 North Pacific albacore [5.88 mt caught by 8 vessels]

The catches of these species covered by CMMs are reported annually to the WCPFC, as well as operational details, and necessary actions taken. For mahi mahi see Profile 39 DOLPHINFISH/MAHI MAHI

Management Recommendations: No additional policy or legislation is required at this time, as no management interventions have been prescribed for any of the large coastal pelagic species.

35 Further information on these Reference Points can be found in Caddy (1998), and https://www.wcpfc.int/harvest-strategy.

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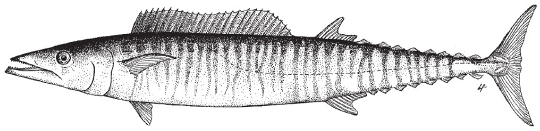
41 WAHOO



41.1 The Resource

Species Status: Wahoo (**wau** - *Acanthocybium solandri)* are the only species in this highly specialised genus. Their large size, impressive streamlined appearance and superior eating qualities make them a highly sought-after species, and based on their fighting qualities, are a mainstay of the local gamefishing scene. They are believed to comprise a single genetic population world-wide (Thiesen *et al*., 2008), but most likely a single western Pacific stock for management purposes, based on morphometric measurements and parasite fauna (Zischke *et al*., 2013a), and assumed mixing rates.

Distribution: Wahoo are widely distributed throughout Fiji offshore waters, as part of their global distribution throughout tropical and sub-tropical waters. They are mostly restricted to upper surface layers (epipelagic) and tend to concentrate around oceanic features and discontinuities, such as current lines, temperature fronts, seamounts and around floating objects and debris. They are usually solitary as adults or at times in small feeding aggregations. This absence of schooling behaviour means that there are no large commercial fisheries for them, as is the case for most scombrids.

Biology and Ecology: Considerable new information on wahoo biology and ecology has become available in recent years as result of studies in the Coral Sea and eastern Australia (Zischke, 2012), as well as unpublished work in Fiji (Tuwai, 1999). Wahoo grow to at least 210 cm FL and in excess of 90 kg (Thiesen *et al*., 2008) although fish larger than 45 kg are apparently relatively uncommon in the Coral Sea (Collette, 2001; Zischke *et al*., 2013b), and in Fiji longline catches (Tuwai,1999). Sex ratios are usually biased in favour of females, and may be of the order of 3:1 in some situations, for reasons which are not clear. Maximum sizes attained by males and females are however similar, as are growth rates and the length-weight relationship. Juveniles (fish less than 70 cm FL) are rarely encountered, presumably related to the selectivity of most capture methods targeting large fish.

Wahoo are top level predators of the open ocean, and are one of the fastest fish in the sea in short bursts, often spectacularly leaping out of the water when chasing actively swimming prey. Favoured food items are flying fish, tunas and squid (Zischke, 2012). As indicated by the absence of gillrakers, fish are ingested whole or in the case of larger prey, initially slashed to immobilise then swallowed. Digestion is extremely rapid.

Wahoo spawn in their first year of life, with 50% of Coral Sea females attaining maturity at 104 cm FL whereas Tuwai (1999) in Fiji records size at first maturity for females and males at around 70 cm. This may be a function of the more tropical environment in Fiji or a feature of productive local populations, or just apply to a proportion of individuals. The lengthy spawning season in Fiji coincides with the austral summer, from December to April. In eastern Australian waters, Zischke *et al*. (2013b) report females spawning from October to March. Wahoo are batch spawners, with repeated spawning possibly every 2−3 days during the peak spawning period. Batch fecundity is high and correlated with fish size, with between 0.6 and 5 million oocytes released per spawning event. Spawning aggregations have not been observed and spawning is assumed to occur by external fertilisation in the open ocean as with most scombrids, possibly in small groups of individuals taking advantage of favourable environmental conditions for the subsequent survival and growth of larvae and post-larvae.

Larvae and juveniles of wahoo are widely distributed thought the oceans, in both neritic and oceanic waters, down to depths of 200 m. Buoyant eggs and mobile larvae enable wide dispersal potential in their habitat, through transport by ocean currents. Recent studies based on daily growth increment readings in otoliths have shown wahoo growth to be extremely rapid, particularly in the first year of life with fish typically reaching over 100 cm (and 20 kg) in that time (Tuwai, 1999; Zischke *et al*., 2013b). The species is relatively short lived with maximum age of the largest fish typically around 7 years but most fish caught less than 3 years old. The growth performance index for wahoo in the Coral Sea is one of the highest of all pelagic fish, with their growth and maximum size most similar to dolphinfish/mahi mahi, with whom wahoo share similar habitats and several behavioural traits (Zischke *et al*., 2013b). There is no evidence of sexual dimorphism in growth, or differences in maximum size attained by males and females.

Little conventional tagging has been carried out with wahoo, but electronic tagging has shown both the capacity to undertake rapid long-range movement (Theisen, 2007), as well as site fidelity (Sepulveda *et al*., 2011) to oceanographic features such as seamounts. Thiesen *et al*. (2008) report a wahoo tagged in Hawai'i being recovered nearly 2,800 km from the point of release 198 days later.

41.2 The Fishery

Utilisation: In Fiji waters, wahoo are taken as significant bycatch in the longline fishery, by artisanal fishers around FADs and floating objects and as a primary target of gamefishing activity, mostly by trolling lures and baits at relatively high speed. The longline catch that is landed in Fiji is mostly used for local consumption, but an unknown portion of the catch is exported to international markets. No additional processing occurs, although wahoo are canned in one Pacific location (Pago Pago in American Samoa) to produce a high demand local product. In domestic markets, wahoo has become an important alternative to the iconic **walu** when supplies are seasonally limited or even as a response to possible long-term resource depletion.

Production and Marketing: As noted above (Anon., 2107), wahoo are a significant component of the landings of the Fiji longline fleet, totalling 237 mt and 280 mt in 2015 and 2016, respectively. There is some evidence that this may have decreased relative to catches in the 2000s. The 2008 Fisheries Division Annual Report (Anon., 2009) shows wahoo catches close to 600 mt in 2006, and between 350−588 mt in the period 2004−2008, but it is unclear what factors may have influenced this e.g. changes in fleet fishing strategy, different data sources, or real decease in resource abundance.

There are no readily available data on gamefish catches of wahoo, but wahoo may dominate tournament catches in some locations e.g. Pacific Harbour (Tuwai, 1999). Most wahoo consumption by recreational fishers is assumed to be personal. Few wahoo are traded in municipal markets, with most sales though non-market outlets. The most recent reliable market survey data, those for 2004, show a total of 72 mt was marketed in that year, with 90% through non-market outlets. No more recent data are available, nor do export data show that much wahoo is sent to overseas markets. Prices in 2004 in outlets were in the range FJD 3.80−4.00, whereas in 2016, this was much increased, in the range FJD 10−13, in line with similar increases in similar finfish commodities during that interval.

Exports: Some exports of wahoo are known to occur but no reliable data are available on these exports.

41.3 Stock Status

Zischke and Griffiths (2015) undertook a per-recruit stock assessment of wahoo in the south west Pacific Ocean, utilising commercial and recreational fisheries data, and found the current fishing mortality to be lower than conservative target and limit refence points, although with some indication that recruitment overfishing was likely to be a greater potential concern for wahoo fisheries than growth overfishing, with current fishing mortality possibly exceeding the target reference point of F_{SSB40}[36]. There is currently no concern regarding the status of the south west Pacific wahoo stock, and stock is likely to be quite resilient, given the rapid growth rates and high turnover in populations.

36 fishing mortality at which the spawning stock biomass per recruit [SSB/R] is 40% of the SSB/R at F=0. (F=fishing mortality)

41.4 Management

There is currently no need for management of wahoo, which would need to occur on a regional scale by the RFMO (WCPFC in this case). No examples of wahoo management intervention are known from other areas, although on a local scale, gamefish daily bag limits have been imposed in some countries, presumably on a precautionary basis rather than response to local depletion.

Current Legislation and Policies Regulating Exploitation: There is no legislation covering the taking of wahoo, other than that catches in the longline fishery be reported.

Management Recommendations: None applicable or recommended

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42 RIVERS AND ESTUARY FISH

Fiji's freshwater wetlands comprise mangroves, peat swamps, rivers, lakes, and reservoirs. Collectively, these wetlands equate to approximately 0.3% of Fiji's land surface. The country's largest islands have mountainous interiors typical of high volcanic islands. This relief creates a distinct rain shadow on the western side of Viti Levu, and a partial one towards the north-west of Vanua Levu. Rainfall trends in Fiji exhibit high inter-annual variability, with the ENSO significantly influencing rainfall patterns especially on the 'dry' side of the larger islands (Kumar *et al*., 2014).

Viti Levu and Vanua Levu have many permanent rivers and streams however, only Viti Levu has rivers and catchments of considerable size. The Rewa, Navua, and Sigatoka rivers drain over 70% of Viti Levu, with the Rewa River and its tributaries being the largest, with a catchment area covering nearly a third of the island. These rivers go on to create Fiji's largest estuaries, which in turn are highly productive fishing grounds. The Ba and Nadi rivers are considered Fiji's most economically important, possibly a result of the mangrove stands associated with their estuaries. The Ba and Nadi rivers have a combined catchment area of only 15% of Viti Levu and both these rivers are located in the Western Division − Fiji's dry zone. Vanua Levu's longest river, the Dreketi River is 55 km long − others on the island are considerably shorter (Gray, 1993). At least 166 freshwater fish species are known to inhabit Fiji's rivers, 13 of which are endemic (Copeland *et al*., 2016).

Fiji's total mangrove area is approximately 425 km^2 making it the third largest in the Pacific. The largest of these areas are found at the mouths of the Ba, Rewa, and Nadi rivers on Viti Levu, and the Labasa River on Vanua Levu. Collectively they make up 28% of Fiji's mangrove forests (Ellison, 2009; Tuiwawa *et al*., 2014). There are eight mangrove species (*Bruguiera gymnorrhiza, Rhizophora stylosa, R. samoensis, Heritiera littoralis, Lumnitzera littorea, Excoecaria agallocha, Xylocarpus granatum)* including one hybrid (*R. x selala*) in Fiji. Of these species, *B. gymnorhiza, R. stylosa, R. samoensis* and *R. x selala* (a cross between *R. stylosa* and *R. samoensis*) dominate (Ellison, 2009 in Mangubhai *et al*., 2019; Tuiwawa *et al*., 2014).

42.1 The Resource

Species Present: As previously mentioned, rivers in Fiji hold a high diversity of fish species. There are 166 known freshwater fish species, 13 of which are endemic (Copeland *et al*., 2016). Table 60 lists 60 species of freshwater and estuarine fish species known to Fiji. It should be noted that Table 60 is not exhaustive, and includes only conspicuous species - a more comprehensive list can be found in Boseto and Jenkins (2006) and Ryan (1980).

Table 60. Freshwater and estuarine fish species of Fiji. Life history taken from Copeland (2016) and Jenkins *et al*., (2010), based on descriptions from Elliott *et al*., (2007): FR - freshwater resident; FS - freshwater straggler; EM - estuarine migrant, MM - marine migrant; A - amphidromy; COB - obligate catadromy; FC - facultative catadromy. * Endemic, ** Introduced. Source: Beumer (1985)[3], Carpenter and Niem (1999a)[4], Boseto and Jenkins (2006)[5], Jenkins (2010)[6], Copeland *et al.* (2016)[1], FishBase (2017)[2]

Common name	Scientific name	Fijian name	Life history[6]	Ref.
banded-tail glassy perchlet	*Ambassis urotaenia*			1
Australian short-finned eel	*Anguilla australis*	**duna (generic.)**		2,3,4
giant mottled eel	*Anguilla marmorata*	**diria**	C	1,2,3,4
Polynesian long-finned eel	*Anguilla megastoma*	**tautaubale , balebalekoro**	C	1,2,3,4
Pacific short-finned eel	*Anguilla obscura*	**badamu, malavo**		2,3,4
amboina cardinalfish	*Apogon amboinensis*		EM	1
	Awaous guamensis	**vodina**	A	2
large snout goby	*Awaous melanocephalus*	**vodina**		2
	Awaous ocellaris	**vodina**	A	2
Java barb	*Barbonymus gonionotus* **			1
throat-spine gudgeon	*Belobranchus belobranchus*		A	1,2
duckbill sleeper	*Butis butis*		A	2
bull shark	*Carcharhinus leucas*	**qio (generic.)**	MM	2
sharp-nose river mullet	*Cestraeus oxyrhyncus*			2
lobed river mullet	*Cestraeus plicatilis*			2
milkfish	*Chanos chanos*	**yawa**		2
grass carp	*Ctenopharyngodon idella* **	**ikasusu**		2
common carp	*Cyprinus carpio* **			2
dusky sleeper	*Eleotris fusca*	**bukovu**	A	2
broadhead sleeper	*Eleotris melanosoma*	**voloa**	C	2
mosquitofish	*Gambusia affinis* **		FS	2
toothed ponyfish	*Gazza minuta*	**kaikai**	EM	5
strongspine silver-biddy	*Gerres longirostris*	**matu**	EM	5
Celebes goby	*Glossogobius celebius*			2
freshwater moray	*Gymnothorax polyuranodon*	**daradarakai**	COB	2
freshwater pipefish	*Hippichthys albomaculosus*	**ika saisai**		5
silver carp	*Hypophthalmichthys molitrix* **			2
	Hypseleotris guentheri		FS	2
dark-margined flagtail	*Kuhlia marginata*	**sakelo, drava**	COB	1,2
silver flagtail	*Kuhlia munda*	**mataba**	IS	2
rock flagtail	*Kuhlia rupestris*	**ikadroka**	COB	1,2
freshwater snake-eel	*Lamnostoma kampeni*		EM	1

Common name	Scientific name	Fijian name	Life history[6]	Ref.
striped ponyfish	*Leiognathus fasciatus*		EM	1
otomebora mullet	*Liza melinoptera*	**molisa**	FC	2
mangrove red snapper	*Lutjanus argentimaculatus*	**damu**	FC	1
orange-spotted therapon	*Mesopristes kneri* *	**reve**	COB	2
flat-nosed pipefish	*Microphis argulus*		FS	2
short-tailed pipefish	*Microphis brachyurus*		FS	2
stream pipefish	*Microphis brevidorsalis*		FS	2
bar head pipefish	*Microhis leiaspis*		FS	2
ragged-tail pipefish	*Microphis retzii*		FS	2
largemouth bass	*Micropterus salmoides* **			2
flathead mullet	*Mugil cephalus*	**koto, uralo**	FC	2
freshwater mangrove goby	*Mugilogobius notospilus*			2
swollengut worm eel	*Neoconger tuberculatus*	**dunaduna saidra**		5
snakehead gudgeon	*Ophieleotris aporos*	**ika bau**		2
Mozambique tilapia	*Oreochromis mossambicus* **	**maleya (generic.)**	FS	2
Nile tilapia	*Oreochromis niloticus* **	**maleya (generic.)**	FS	2
Wami tilapia	*Oreochromis urolepis* **	**maleya (generic.)**		2
Wami tilapia	*Oreochromis hornorum* **	**maleya (generic.)**		2
shortfin molly	*Poecilia mexicana* **			2
guppy	*Poecilia reticulata* **			2
stone moroko	*Pseudorasbora parva* **			2
speckled goby	*Redigobius bikolanus*		A	2
lekutu red goby	*Redigobius leveri* *	**vovo se damu**	FR	1
Roemer's goby	*Redigobius roemeri*		FS	2
rosy bitterling	*Rhodeus ocellatus* **			2
Fiji goby	*Schismatogobius vitiensis* *	**vovo drili**	A	1,2
red-tailed goby	*Sicyopterus lagocephalus*	**vo (generic.)**	A	1
	Sicyopus zosterophorum		A	1
	Stenogobius sp.		A	1
Mele's stiphodon	*Stiphodon mele*		A	1
	Stiphodon pelewensis		A	1
	Upeneus sulfereus		MM	1
green swordtail	*Xiphophorus hellerii* **		FS	2
	Yirrkala gjellerupi		EM	1

Several groups of fish listed in Table 60 and important freshwater invertebrate are the subject of dedicated profiles. Table 61 below lists these.

Table 61. Fresh water and estuarine species covered in other profiles, and their respective profile reference.

Common name	Fijian name	Profile reference
Australian short-finned eel	**duna (generic.)**	43. Freshwater eels
Pacific short-finned eel		
giant mottled eel		
Polynesian long-finned eel		
bull shark	**qio (generic.)**	36. Sharks and rays
sharpnosed river mullet	**kanace (generic.)**	20. Mullet
otomebora mullet		
flathead mullet		
Mozambique tilapia	**maleya (generic.)**	44. Tilapia
Nile tilapia		
wami tilapia		
blue tilapia		
freshwater clam	**kai (generic.)**	13. Freshwater clam
freshwater crustaceans		8. Freshwater crustaceans

Distribution: Species of fish listed in Table 60 are found in a wide variety of freshwater and brackish water habitats throughout Fiji. Freshwater fish species richness is dependent on physical habitat factors, including vegetation cover, river flow, water temperature, pH and oxygen levels (Jenkins and Jupiter, 2011), and presence of invasive species (Jenkins *et al*., 2010). In pristine catchments of the Kubulau District, higher species abundance and diversity were observed in the wet season and were associated with significantly greater flow, pH, and dissolved oxygen; the opposite pattern for fish diversity and abundance was associated with degraded catchments of Macuata Province (Jenkins and Jupiter, 2011). The presence of **maleya** (tilapia - *Oreochromis* spp.) in Fiji's rivers is strongly associated with a lower fish diversity (Jenkins *et al*., 2010).

Biology and Ecology: The many species listed in this category have very divergent life histories and biological parametres. Copeland (2016) and Jenkins *et al*., (2010) categorise Fiji's freshwater and estuarine fish species based on life history, feeding guild, status category (indigenous, endemic, and introduced), and presence in mid-reach and low-reach sites. Definitions and examples of these categories can be found in Elliott *et al*., (2007). Information on specific species biological parametres can also be found through FishBase (Froese and Pauly, 2017).

42.2 The Fishery

Utilisation: Freshwater fish species are predominantly harvested by communities living in the interior of Fiji, and estuarine species by coastal communities. Of the finfish, the freshwater eel **duna** (*Anguilla* spp.) and the introduced tilapia **maleya** (*Oreochromis* spp.) are the most abundant and widely consumed freshwater species. Apart from **duna** the most important species of native fish are the flagtails (**sakelo**, **mataba**, and **ikadroka** - *Kuhlia* spp.) and several species of goby (Family: Gobiidae and Eleotridae) (Thaman, 1990). Of these **duna** and **maleya** can occasionally be found on sale in municipal markets, though the vast majority of **maleya** sold are cultured. These two are the subject of dedicated profiles – 43 FRESHWATER EELS, and 44 TILAPIA. For the most part freshwater finfish are harvested for subsistence use. This is in contrast to the freshwater invertebrate **kai** *Batissa* spp. (Profile 13 FRESHWATER CLAM) and freshwater crustaceans (Profile 8 FRESHWATER CRUSTACEANS), which form the basis of major artisanal fisheries.

Freshwater finfish are taken by a variety of gear such as spear, nets, weirs, hook and line, and poisons. In contrast to marine, freshwater fishing gear is typically very small-scale. The use of poisons, natural or synthetic, is illegal as mentioned in section 42.4 Management. Dakuidreketi and Vuki (2014) describe several traditional fishing methods in detail as well as the gender roles of men and women in freshwater subsistence fisheries. These are briefly described as follows:

- **Qolua** uses hollow bamboo stalks as a fish trap - this mainly targets eels;
- **Nimanima** is often used in creeks where there are large depressions in the rocks - it involves removing water from these depressions in order to trap the fish;
- **Duva** (*Derris* sp.) roots are pounded and the toxins released are used to stupefy fish;
- **Burbura** involves thrusting spears into shallow bodies of water such as muddy or swampy ground ; and
- **Cina** is essentially capturing fish at night with the aid of artificial light.

Production and Marketing: Production statistics for Fiji's wild-capture freshwater and estuarine finfish production are difficult to come by as fish and invertebrate data are often combined into a single category. The life history of the many species listed in Table 60 also make teasing freshwater and estuarine catches, from coastal catches difficult as the same species can occur throughout these habitats, which may overlap anyway. Nevertheless, Gillett (2016) estimated Fiji's total (finfish and invertebrate) harvest in 2014 at 3,731 mt valued at FJD 7,408,000. Gillett (2009) estimated a volume of 4,146 mt worth FJD 6,860,000 was harvested in 2007. The author notes that these are crude approximations − the 2014 estimate was calculated from 2007 values by "decreasing that volume by 10% for degradation of freshwater systems, and increasing the value by 20% to account for price increases". Production of freshwater finfish is primarily restricted to the susbsistence level.

Duna are the most valuable freshwater finfish. The production and marketing of **duna** as well as that of freshwater invertebrates are covered in more detail in their respective profiles. Table 61 provides a reference to these. Table 62 lists the production volume and value of freshwater and estuarine species of finfish. The last detailed market survey published by the Ministry of Fisheries was in 2004, and the 2016 data provided by the Ministry of Fisheries only covers the Central Division.

In 2004, 66% of **damu** (mangrove jack**)** were sold in non-municipal market outlets - the majority of this in the Western Division. Generally non-municipal market outlet sales of species in Table 62 were greater than in municipal market outlets. Apart from **mataba** the majority of sales both municipal and non-municipal market outlets occurred in the Northern Division. As Fiji's largest rivers are all located in the Central and Western Division, it is curious that the majority of sales occur in the Northern Division. This difference may be due to habitat conditions or health and/or reflect differences in employment and market preference, as the Northern Division is the least developed out of the three Divisions surveyed. **Damu** catches may come from lagoons and reefs rather than brackish environments - fishing pressure on **damu** throughout Fiji is largely dependent on the occurrence of ciguatera within the stock. If a stock is known to be susceptible to ciguatera toxicity it is generally avoided.

Table 62. Sale volume (mt) of freshwater and estuarine finfish at municipal (MM) and non-municipal market (NM) outlets. Mean municipal market value (FJD per kg) provided in brackets below sale volume. Source: Anon. (2003–2004), Ministry of Fisheries (*unpubl. data*)

Species	2003		2004		2016
	MM	NM	MM	NM	MM
damu*	33.07	74.93	52.77	102.41	
	(4.82)		(4.81)		(7.28)
ikadroka	8.98	8.98	6.46	9.39	
	(na)		(2.88)		(na)
mataba*	na	0	1.27	0.2	
	(na)		(na)		(na)
reve	7.83	7.83	9.65	11.18	
	(4.00)		(3.43)		(na)
yawa*	0.86	0.37	8.51	11.22	
	(3.01)		(2.71)		(5.38)

***damu** (*L. argentimaculatus*), **mataba** (*K. munda*), and **yawa** (*C. chanos*) are also caught in marine environments. **Yawa** are captured wild and also cultured in the north of Viti Levu (Billings and Pickering, 2010).

42.3 Stock Status

The few studies that have surveyed Fiji's freshwater finfish communities appear to come to similar conclusions, i.e. productivity of Fiji's native freshwater finfish is low and the majority of current production comes from introduced species such as **maleya** (*Oreochromis* spp.) and various species of carp. Pristine catchments have a higher diversity and abundance of freshwater fish than do degraded catchments (Jenkins and Jupiter, 2011). Furthermore, the presence of **maleya** is strongly associated with a lower fish diversity (Jenkins *et al*., 2010). As such, the intrusion of invasive and introduced species further into Fiji's freshwater ways is likely reducing an already low finfish productivity.

According to Mangubhai *et al*., (2019), "threats to wetlands, lakes, rivers and catchments include alternation in flows for water supply or hydropower generation, gravel extraction, reduction in forest cover and water quality from poor land use practices, loss of riparian vegetation, introduction of invasive species (e.g. water hyacinth *Eichhornia crassipes*, cichlid (*O. mossambica*)), pollution and overexploitation. Dams and weirs impact the life-cycles of amphidromous species that migrate between freshwater and saltwater habitats (Lin *et al*., *in press*). The result of these threats, and an ever-increasing population putting further pressure on fish stocks and the environment, is that the status of Fiji's freshwater and estuarine finfish is poor and continues to be degraded.

42.4 Management

Current Legislation and Policies Regulating Exploitation: Fiji is a signatory to the Ramsar Convention[37], however there is no policy to protect wetlands in general, or those of national significance (Mangubhai *et al*., 2019. Policy and legislation regarding developments that could affect wetlands can be found in the Environment Management Act 2005. Policies implied by the Act indicate that development proposals, which could impact wetland habitats for example construction of a dam or reclamation of mangrove areas must be approved by an Environmental Impact Assessment (EIA) administrator. However, a review by Turnbull (2003) stated that:

> "the Fijian state is not serious about using EIA to control environmental quality. Factors other than technical shortcomings are shaping the way the state constrains EIA practice. Unless these factors change, the comprehensive EIA proposed in Sustainable Development legislation will not prevent environmental degradation."

Most provisions in the Fisheries Act pertaining to freshwater and estuarine fish are given below:

Use of nets in estuaries

7. No net other than hand nets, wading nets and cast nets shall be permitted for the purpose of taking fish in the estuary of any river or stream or in the sea within 100m [l00 yards] of the mouth of a river or stream. *(Amended by 87 of 1979)*

Use of poison

8. No person shall take, stupefy or kill any fish in any lake, pool, pond, river, stream or in the sea by the use of any of the- following substances or plants:-
   (a) any chemical or chemical compound;
   (b) any substance containing derris;
   (c) any substance containing the active principal of derris, namely, rotenone; and
   (d) any plant or extract of or derivative from any plant, belonging to the genera *Barringtonia, Derris, Euphorbia, Pittosporum or Tephrosia,* or place any of such substances or plants in any water for the purpose of taking, stupefying or killing any fish.

Fishing in fresh water

10. No person shall kill or take fish of any kind (excluding shellfish) in fresh water in any manner other than by means of a hand net, portable fish trap, spear, line and hook.

Stretched measurement for nets

For the purposes of these Regulations, stretched mesh shall be measured by taking two diagonally opposing knots of the mesh of the net and drawing them apart until the remaining two knots of the mesh just touch each other.

Mesh of hand nets

13. The mesh of a hand net may be of any size.

Mesh of cast nets

14. The mesh of cast nets shall not be less than 30 mm [1.25 inches], wet and stretched. *(Amended by 87. of 1979)*

37 ramsar.org

Nets for sardines and whitebait[38]

15. Nets for taking sardines and whitebait may have a mesh size of not less than 30 mm [1.25 inches], wet and stretched, but their overall dimensions shall not exceed 10.5 m [35 feet] measured along the cork line and 1.5 m [5 feet] from the cork line to the ground rope. It is prohibited to join two such nets together. Such nets may not be used to take fish other than sardines or whitebait. *(Amended by 87 of 1979)*

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Several species of fresh and brackish water finfish have minimum size limits, and/or are included in the Endangered and Protected Species Act − these are listed in Table 63 along with their respective reference in the Endangered and Protected Species Act. This Act outlines laws, legislation, and permitting regarding species listed under CITES and several indigenous species not listed in CITES.

Apart from the national legislation and policy listed above, freshwater and estuarine/brackish fisheries are also governed by traditional fisheries management measures. Dakuidreketi and Vuki (2014) note that very few traditional fisheries management measures are in place, and those that are used include restrictions (tabu) on certain areas and fishing methods. The measures put in place are entirely dependent on the communities. Awareness programs, education, and experience has had some influence on these management measures, as Dauidreketi and Vuki (2014) note "recently, Tonia villagers have realised that destructive fishing methods such as the use of duva (*Derris* spp.) is not good. Now, a ban on the use of duva is in place and the village chief can impose penalties if a fisher is caught using it. In addition, the use of chemicals and dynamite are now prohibited."

Table 63. Minimum size limits (Fisheries Act) and reference within the Endangered and Protected Species Act of freshwater and estuarine finfish in Fiji. na=not applicable

Scientific name	Fijian name	Minimum size limit (mm)	EPS Act reference
Chanos chanos	**yawa**	300	na
Gerres longirostris	**matu**	100	na
Gazza spp.	**kaikai**	100	na
Hippichthys albomaculosus	**ika saisai**	na	Schedule 1 (Section 3)
Kuhlia rupestris	**ika droka**	150	na
Lutjanus argentimaculatus	**damu**	300	na
Mesopristes kneri	**reve**	na	Schedule 1 (Section 3)
Mugil spp.	**kanace**	200	na
Naso tuberculatus	**dunaduna saidra**	na	Schedule 1 (Section 3)
Redigobius leveri	**vovo se damu**	na	Schedule 1 (Section 3)
Redigobius spp.		na	Schedule 2 (Section 3)
Schismatogobius vitiensis	**vovo drili**	na	Schedule 1 (Section 3)

38 Whitebait (**cigana**) is a collective term for the immature fry of fish (usually 2.5–5 cm long). During May and June **cigana** can be found making their way up many of Fiji's rivers (Parkinson, 1999).

Management Recommendations: Given the close link between the health of freshwater fauna and the quality of freshwater, it is essential that policy and action be taken to improve catchment health and reduce pollution entering rivers and streams. As such the following are recommended:

- Strongly enforce ban on the use of poisons for stupefying fish;
- Improve land management practices that impact the quality of freshwater, which should include restrictions on gravel extraction, forest management, and protection of riparian vegetation. Lessons could be learnt from land and catchment management practices adopted by farmers in Queensland, Australia as the state has large sugarcane farms and a tropical climate similar to that of Fiji;
- Introduce policy to protect wetlands, monitor, and enforce said policy;
- Education and awareness programs for communities that are dependent on freshwater and or brackish water species for their livelihood.

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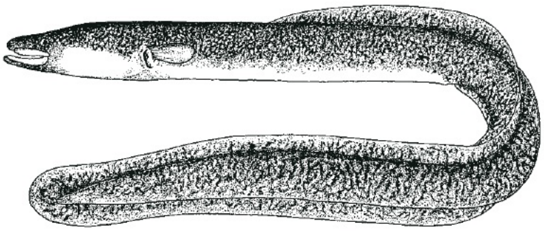
43 FRESHWATER EEL



43.1 The Resource

Species Present: Duna is the generic Fijian name for all freshwater eels (Pickering and Sasal, 2017). Six species of the genus *Anguilla* are present in the south-west Pacific region - four long-finned species and two short-finned species. Three of these species are recorded from Fiji; **badamu** or **malavo** (Pacific short-finned eel − *Anguilla obscura*), **diria** (giant mottled eel − *A. marmorata*), and **tautaubale** (Polynesian long-finned eel − *A. megastoma*) (Beumer, 1985; Carpenter and Niem, 1999a). The freshwater moray (*Gymnothorax polyuranodon*) is also found in Fiji, but are not as dominant as of *Anguilla* spp.. (Tsukamoto et al., 2014)

Distribution: *A. obscura* is widespread in the South Pacific region from Papua New Guinea to the Society Islands and Rapa (Allen, 1991). According to Lewis (1985), only *A. obscura* and *A. marmorata* are common in Fiji, where they are found in all rivers. Distribution records of **duna** from Fiji are as follows: **tautaubale** - *A. megastoma* (Viti Levu), **diria -** *A. marmorata* (Suva, Ovalau, Narokorokoyawa, Kadavu, Nairai and Rewa River, Viti Levu); **badamu** - *A. obscura* (Suva, Kanacea, Rewa River) (Beumer, 1985). The Sovi Basin protected forest is a reported 'hot spot' for **duna** (Pickering and Sasal, 2017).

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 (Beumer, 1985). The breeding location(s) of South Pacific eels are not well known, but based on a study of the genetic relationships within adult **diria** the species may have up to four spawning locations within the South Pacific, presumably in the vicitiny of Fiji and Vanuatu (Minegishi *et al*., 2008; Pickering and Sasal, 2017). Peak recruitment periods have been recorded for three eel species in a small river at Namelimeli (2 km east of Navua Town) in Fiji: **badamu** occurs from February to April, **diria** in April and from September to October, and **tautaubale** in April and October (Hewavitharane *et al*., 2018). There is some evidence of recruitment occurring year round in **badamu** and **diria**. Hewavitharane *et al*. (2018) also found that peak recruitment occurred during seasons of heavy rain, from September to October and from February to April commencing 1 hour after sunset on the day following a new moon.

The leaf-like larvae (*leptocephalus*) drift in regular ocean currents, changing to a more eel-like shape as they approach land. Then known as *glass eels*, they actively migrate with tides into estuaries, gradually becoming pigmented brown *elvers* which migrate upstream into fresh water. There they live and grow for many years and are known as *yellow eels*. The cycle continues with their maturation and migration downstream as *silver eels* (Lewis, 1985).

In Fiji, **badamu** prefer still-water, and marshy habitats, while **diria** and **tautaubale** prefer fast flowing waters. Sampling by Beumer (1985) at several locations on Viti Levu produced **diria** specimens varying in length from 277−620 mm and in weight from 35−600 g. This species is known to attain a weight of at least 5 kg in Fiji, and can reach a maximum length of about 2 m. Specimens of **badamu** varied in length from 225−775 mm and in weight from 20−1,150 g. In other parts of its range, **badamu** is known to occur in small creeks as well as swamps and lakes, with males growing to a maximum length of approximately 80 cm (Carpenter and Niem, 1999a); females of up to 165 cm and 9kg have been recorded (C. Hewavitharane, *pers. comm.*). **Tautaubale** grow to a maximum length of about 1 m (Carpenter and Niem, 1999a), and the species is typically associated with headwaters of rivers and can be found at higher altitudes (Jacoby and Gollock, 2014), hence its Tahitian name puhi-mauá (eel of the mountains).

43.2 The Fishery

Utilisation: World-wide, eels in various stages of their life-histories are fished commercially. As the upstream migrations of elvers are often predictable and involve large numbers of individuals, elvers and glass eels are caught in special nets 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 of silver eels means that they are in strong demand for smoking. Eels may also be exported live (Lewis, 1985). Freshwater eels outside the South Pacific are generally well researched and heavily fished. The farm gate price of eel in Japan is FJD 60 per kg, which retails in restaurants for approximately FJD 300 per kg. Farming eels relies on capture-based culture or ranching as breeding eels in captivity is not yet commercially feasible (Pickering and Sasal, 2017).

There is no organised fishery for **duna** in Fiji. They are caught with baited lines, spears, a variety of traditional woven traps, hollow poles and cane knives, and harvested predominantly by women. A recent study found 45% of women interviewed harvested eels, and caught between one to twelve eels per trip for subsistence purposes (Thomas *et al.*, 2020). Very few sold eels for income. **Duna** are appreciated for their good eating qualities by *iTaukei* Fijians, and they also hold a strong value in Fijian culture - some communities regard **duna** as a totem (Pickering and Sasal, 2017).

It is uncertain whether or not the major eel markets (Japan, Korea, and China) would accept Fijian eels due to differences in the culinary quality of the eels. A detailed discussion on the private sector perspective of Fijian **duna** can be found in Pickering and Sasal (2017). At the moment there is only one aquaculture operation in Fiji, rather **duna** are occasionally found as incidental catch when harvesting ponds of other freshwater species such as prawn or tilapia. Pacific Ocean Culture is harvesting yellow eels from their drains, fattening them up, filleting processing and selling them. They are also trying to catch elvers from their drains on peak recruitment seasons for grow out but they do not have the technical expertise as yet.

Production and Marketing: In 2007 the global harvest of eels from fisheries was 230,000 mt, 70% of which was consumed in Japan. China is now the world's largest eel consumer (Pickering and Sasal, 2017). Preference in international markets is for the short-finned eels with their uniform body colouration. **Badamu** would probably be acceptable. There is a limited market in southeast Asia for large (>1.5 kg) eels - the other local species would have some potential there. Negligible quantities of freshwater eels are marketed locally and no separate statistics are kept. Most local consumption is for subsistence purposes (Lewis, 1985). As such it is uncommon for **duna** to be sold in municipal markets. Anecdotal information suggests large **duna** sold in Suva municipal market fetch prices of FJD 50–80 per eel (Pickering and Sasal, 2017), while smaller ones (i.e. about 60 cm) would be sold for FJD 30 each (Thomas *et al*., 2020).

Although Fiji generally lacks the marshy areas which support large eel populations, there are areas such as the Navua flats, which should carry reasonable quantities of eels, in addition to the more dispersed populations inhabiting major rivers. It appears that Fiji may have some potential for the intensive farming of eels.

43.3 Stock Status

Pickering and Sasal (2017) note that freshwater eels outside the South Pacific region are threatened to the point where they are now highly endangered, and state "the South Pacific region is a 'last frontier' for freshwater eels". There is concern that given the scarcity of freshwater eels in other regions of the world, their high value and vulnerability to depletion places freshwater eels in danger of becoming the next 'sea cucumber'. It is assumed that stocks of freshwater eels in the South Pacific are in relatively good condition but modest in size, however given the scarcity of research and stock assessments little is actually known about local **duna** stocks. Threats such as habitat degradation or barriers to migration (such as dams) are likely to negatively affect stocks of **duna**.

Diria appears to be the most abundant species in Fiji, whereas **tautaubale** are rarely seen (and have low recruitment abundance); however **diria** habitats are easily accessible relative to **tataubale'** habitats. As such their apparent abundance may be due to bias during surveys (Pickering and Sasal, 2017). Of the one year's catch of glass eels in 2015–2016, 55% consisted of **badamu**, 41% **diria**, and the remaining 4% **tautaubale** (Pickering and Sasal, 2017).

43.4 Management

Current Legislation and Policies Regulating Exploitation: There is currently no legislation specifically relating to eels. However, the following legislation may be applicable to the fishery, particularly the fishing of glass and yellow eels:

Use of nets in estuaries

7. No net other than hand nets, wading nets and cast nets shall be permitted for the purpose of taking fish in the estuary of any river or stream or in the sea within 100m [l00 yards] of the mouth of a river or stream. *(Amended by 87 of 1979)*

Use of poison

8. No person shall take, stupefy or kill any fish in any lake, pool, pond, river, stream or in the sea by the use of any of the- following substances or plants:-
   (a) any chemical or chemical compound;
   (b) any substance containing derris;
   (c) any substance containing the active principal of derris, namely, rotenone;
   (d) any plant or extract of or derivative from any plant, belonging to the genera *Barringtonia, Derris, Euphorbia, Pittosporum or Tephrosia,* or place any of such substances or plants in any water for the purpose of taking, stupefying or killing any fish.

Mesh of hand nets

13. The mesh of a hand net may be of any size.

Meshes of other nets

16. The meshes of wading nets and of all other nets not specifically mentioned in these Regulations shall be in no part less than 50 mm [2 inches], wet and stretched. *(Amended by 87 of 1979)*

Management Recommendations: None required at present. Lewis (1985) recommended that if a local fishery for adult eels develops, some restrictions on numbers of fishermen and nets in each production area may be required. Regulations should be placed in order to protect **duna** habitats and limit obstacles to migration or provide means for **duna** to get around them. As with all freshwater fisheries emphasis needs to be placed on improving water and catchment health.

Overfishing does not appear to be a problem yet, however research should be conducted to determine whether this is the case or not. Management of a glass and yellow eel fishery should be considered as a pre-emptive measure given the concern that **duna** may become over exploited as freshwater eel fisheries in other regions, particularly Asia, are already heavily overfished/exploited.

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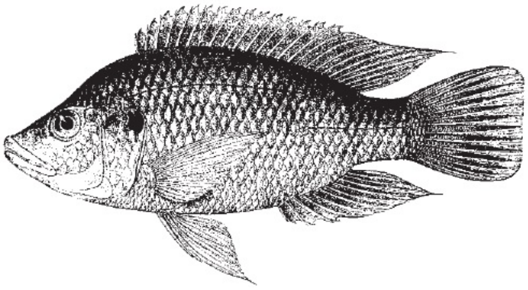
44 TILAPIA



44.1 The Resource

Species Present: The Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*O. niloticus*), "Chitrilada strain" Nile tilapia (*O. niloticus*), "Israeli strain" Nile tilapia (*O. niloticus*), *O. hornorum*, *O. aureus* and a hybrid red tilapia (possibly from an *O. mossambicus* and *O. niloticus* cross) have all been introduced to Fiji, where no tilapia naturally occur, mostly during the 1970s and 1980s, with the exception of the Mozambique which was introduced several times much earlier. Genetically Improved Farmed Tilapia (GIFT), a strain of *O. niloticus* established through selective breeding, was introduced most recently in 1998. **Maleya** is the generic Fijian name for members of the genus *Oreochromis*.

Distribution: The natural distribution of **maleya** is limited to Africa and the near east. Introductions to Fiji of the various species and strains were made from different countries at various times as noted above. A summary of these introductions is given in Table 64.

Table 64. Details of introductions of **maleya** to Fiji from the late 1940s−1988. Source: McKinna *et al.* (2010), Anon. (1991), Gulick (1990)

Common name	Scientific name	Country of origin	Year
Mozambique tilapia	*Oreochromis mossambicus*	Not available	Late 1940s
	O. mossambicus	Malaysia	Mid-1950s
Nile tilapia	*O. niloticus* (Israeli strain)	Malaysia	Late 1960s and 1970s
Wami tilapia	*O. hornorum*	Taiwan	Early and mid-1980s
Wami tilapia	*O. aureus*	Taiwan	Early and mid-1980s
Nile tilapia	*O. niloticus*	Israel	1979
Nile tilapia	*O. niloticus* (Chitrilada strain)	Thailand	1988
GIFT tilapia	*O. niloticus* (GIFT strain)	Phillipines	1998

In the late 1950s and early 1960s, *O. mossambicus* were deliberately released into the Sigatoka, Rewa and Navua Rivers because existing stocks of native freshwater fishes were perceived as having little nutritional value. This species was also released into waterways on Vanua Levu. All of the introductions since 1960 have been made with aquaculture of tilapia as the ulimate motivation, although most species have readily established in the wild.

Biology and Ecology: Maleya are members of the family Cichlidae, comprising over 100 species according to some authorities. All tilapia species were considered as belonging to the genus *Tilapia*, but in recent years, mouth-brooding species have been classified into *Oreochromis* or *Sarotherodon* (Shokita *et al.*, 1991). Just before the breeding season, an *O. niloticus* male forms a territory and makes a conical shaped breeding site or nest. Subsequently, the male lures a female into the nest to mate. After oviposition, the male releases sperm to fertilise the eggs and the female holds the fertilised eggs in her mouth, where they develop. Five to seven days after spawning, hatchlings of 8–9 mm in TL hatch out, but remain in the mother's mouth. About 2 weeks after spawning, juveniles become independent of the mother (Shokita *et al.*, 1991).

44.2 The Fishery

Utilisation: Because of the relatively long time *O. mossambica* have been in Fiji, people have become accustomed to their appearance and taste. This has hastened the acceptance of other species of **maleya** introduced for pond culture, and no doubt greatly contributed to the acceptance of other species of **maleya** introduced for pond culture, and contributed to the large number of farms supported by the Rural Aquaculture Programme. Trials at the Nausori and Suva markets with live fish have shown high acceptance. Fish were purchased by all races, with Indo-Fijian and Chinese customers preferring plate-sized fish (250–300 g) while no particular size preference was shown by indigenous Fijians (Anon., 1991).

Production and Marketing: Maleya sells in local markets for approximately FJD 5 per kg, and has a farm gate value of approximately FJD 3.50 per kg (Gillett, 2016). Using these figures, the 2014 yield had a market value of FJD 752,500. Prior to 1989, sales of **maleya** in municipal markets had not exceeded 6 mt per year, though much of the catch may have been used for subsistence purposes. Since then, the weight of **maleya** sold in municipal markets has increased rapidly from 20 mt in 1990 to 72 mt in 1992. There was a slight decline to 63 mt in 1993 (Fiji Fisheries Division, *unpubl data*). In 2000 farm-gate production of **maleya** peaked at approximately 1 million FJD, dropping off to about 125 000 FJD in 2004 (Anon., 2009). Gillett (2016), citing the head of the Aquaculture Division of the Fisheries Department indicated a production of 150.5 mt in 2014, with an estimated farm gate value of FJD 526,750. No data are available for recent years.

44.3 Stock Status

Maleya are an introduced species for Fiji for which there is little information about whether or not they have impacts on native fish species, so a precautionary approach should be taken by avoiding their introduction into any watersheds where they are not present. Information suggests **maleya** populations in Fiji's waterways are robust and continue to invade further upstream and into new waterways (Jenkins *et al.*, 2010).

44.4 Management

Current Legislation and Policies Regulating Exploitation: None at present

Management Recommendations: Efforts should be made to prevent **maleya** invading waterways in order to conserve native freshwater fish biodiversity.

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