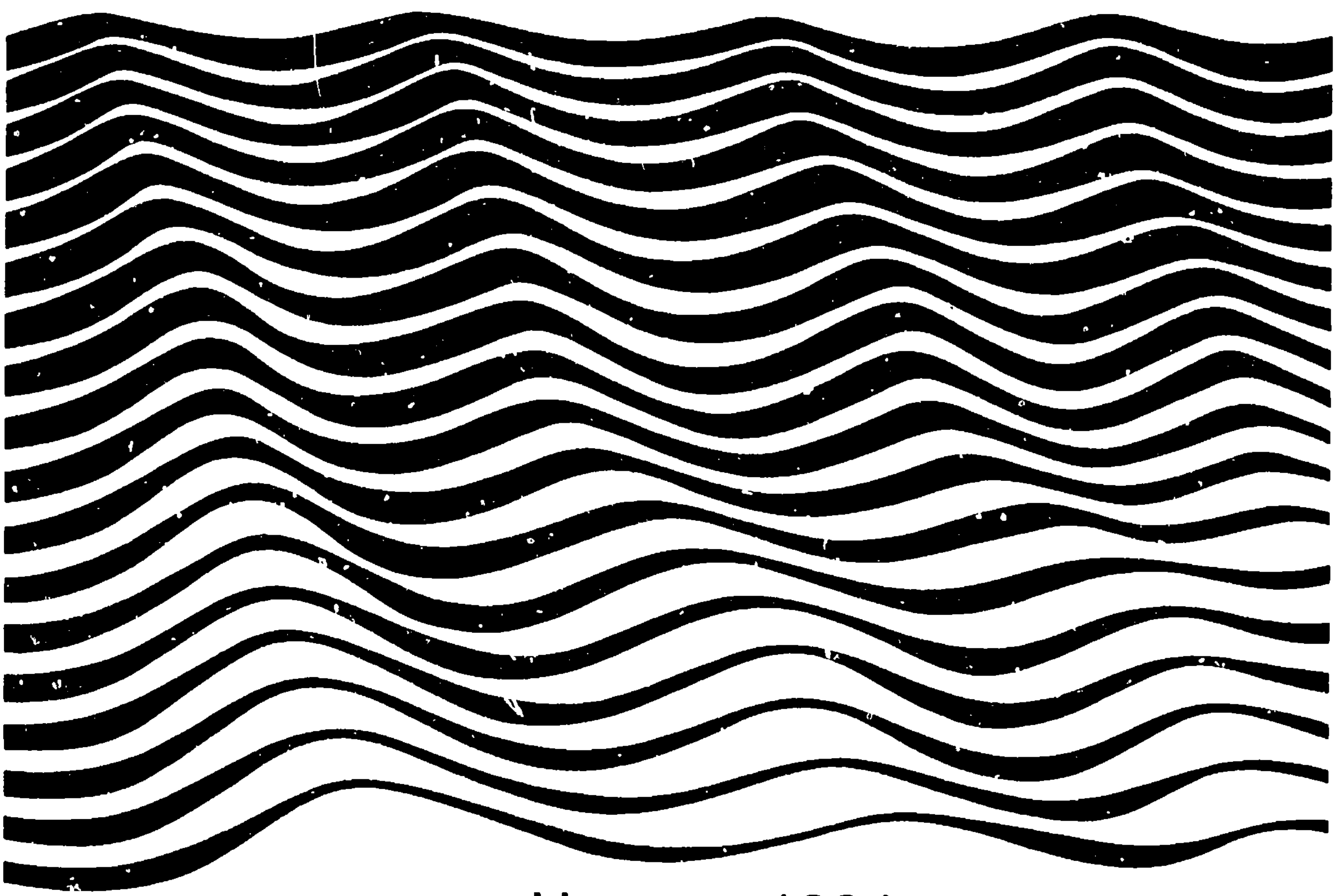
Unesco reports
in marine science 27

Productivity and processes in island marine ecosystems

Recommendations and scientific papers
of the Unesco/IOC sessions
on marine science co-operation in the Pacific,
at the XVth Pacific Science Congress,

Dunedin, New Zealand, February 1983



Unesco, 1984

UNESCO REPORTS IN MARINE SCIENCE

No.		Year
1	Marine ecosystem modelling in the Eastern Mediterranean Report of a Unesco workshop held in Alexandria, Egypt, December 1974 English only	1977
2	Marine ecosystem modelling in the Mediterranean Report of the Second Unesco Workshop on Marine Ecosystem Modelling English only	1977
4	Syllabus for training marine technicians Report of an IOC/Unesco workshop held in Miami, Florida, 22-26 May 1978 Available in English, French, Russian and Spanish	1979
5	Marine science syllabus for secondary schools Report of an IOC workshop held at United World College of the Atlantic, United Kingdom, 5-9 June 1978 Available in Arabic, English, French, Russian and Spanish	1979
6	Organization of marine biological reference collections in the Mediterranean Arab countries Expert meeting held in Tunis, 20-23 September 1978 Available in Arabic, English and French	1979
7	Coastal ecosystems of the southern Mediterranean: lagoons, deltas and salt marshes Report of a meeting of experts, Tunis, 25-27 September 1978 Available in Arabic, English and French	1979
8	The mangrove ecosystem: Human uses and management implications Report of a Unesco regional seminar held in Dacca, Bangladesh, December 1978 English only	1979
9	The mangrove ecosystem: scientific aspects and human impact Report of the seminar organized by Unesco at Cali, Colombia, 27 November-1 December 1978 Available in English and Spanish	1979
10	Development of marine science and technology in Africa Working Group of Experts sponsored by ECA and Unesco, Addis Ababa, 5-9 May 1980 Available in English and French	1980
11	Programa de Plancton para el Pacífico Oriental Informe final del Seminario-Taller realizado en el Instituto del Mar del Perú, El Callao, Perú, 8-11 de septiembre de 1980 Spanish only	1981
12	Geología y geoquímica del margen continental del Atlántico Sudoccidental, Informe final del Taller de Trabajo organizado por la Unesco en Montevideo, Uruguay, 2-4 de diciembre de 1980 Spanish only	1981
14	Marine science and technology in Africa: present state and future development Synthesis of Unesco/ECA survey missions to African coastal states, 1980 Available in English and French	1981
15	Fishery science teaching at the university level Report of a Unesco/FAO workshop on university curricula in fishery science, Paris, May 1980 Available in Arabic, English, French, Russian and Spanish	1981
16	Marine and coastal processes in the Pacific: ecological aspects of coastal zone management Report of a Unesco seminar held at Motupore Island Research Centre, University of Papua New Guinea, 14-17 July 1980 English only	1981
17	The coastal ecosystems of West Africa: coastal lagoons, estuaries and mangroves A workshop report, Dakar, 11-15 June 1979 Available in English and French	1981
18	Coral reef management in Asia and the Pacific: some research and training priorities Report of a Unesco workshop held in Manila, Philippines 21-22 May 1981 English only	1982
19	Mareas rojas en el Plancton del Pacífico Oriental Informe del Segundo Taller del Programa de Plancton del Pacífico Oriental, Instituto del Mar, Callao, Perú 19-20 de noviembre de 1981 Spanish only	1982
20	Quantitative analysis and simulation of Mediterranean coastal ecosystems: The Gulf of Naples, a case study Report of a workshop on ecosystem modelling Ischia, Naples, Italy, 28 March to 10 April 1981 Organized by the United Nations, Educational, Scientific and Cultural Organization (Unesco) and the Stazione Zoologica, Naples English only	1983
21	Comparing coral reef survey methods A regional Unesco/UNEP workshop, Phuket Marine Biological Centre, Thailand, December 1982 English only	1983
22	Guidelines for marine biological reference collections Prepared in response to a recommendation by a meeting of experts from the Mediterranean Arab countries Available in English, French and Arabic	1983
23	Coral reefs, seagrass beds and mangroves: their interaction in the coastal zones of the Caribbean Report of a workshop held at West Indies Laboratory, St. Croix, U.S. Virgin Islands, May, 1982 English only	1983
24	Coastal ecosystems of Latin America and the Caribbean The objectives, priorities and activities of Unesco's COMAR project for the Latin America and Caribbean region Caracas, Venezuela, 15-19 November 1982 Available in English and Spanish	1983
25	Ocean engineering teaching at the university level Recommended guidelines from the Unesco/IOC/ECOR workshop on advanced university curricula in ocean engineering and related fields, Paris, October 1982 Available in English, French, Spanish, Russian, Arabic and Chinese	1983
26	Global survey and analysis of post-graduate curricula in ocean engineering English only	1984
27	Productivity and processes in island marine ecosystems. Recommendations and scientific papers from the Unesco/IOC sessions on marine science co-operation in the Pacific, at the XVth Pacific Science Congress, Dunedin, New Zealand, February 1983 English only	1984

Unesco reports
in marine science 27

Productivity and processes in island marine ecosystems

Recommendations and scientific papers
of the Unesco/IOC sessions
on marine science co-operation in the Pacific,
at the XVth Pacific Science Congress,

Dunedin, New Zealand, February 1983

Unesco, 1984

PREFACE

Unesco Reports in Marine Science are designed to serve specific programme needs and to report on developments in projects conducted by the Unesco Division of Marine Sciences, including those involving collaboration between the Division and the Intergovernmental Oceanographic Commission, particularly in the field of training, education, and mutual assistance in the marine sciences.

Designed to serve as a complement to the *Unesco Technical Papers in Marine Science*, the *Reports* are distributed automatically to various institutions and governmental authorities. Individuals may, at their request, receive copies of specific titles, but cannot be included on the automatic distribution list. Both the *Reports* and the *Technical Papers* series are free of charge.

Requests for copies of specific titles or for additions of institutions or authorities to the mailing list should be addressed, on letterhead stationery if possible, to:

Marine Information Centre
Division of Marine Sciences
Unesco
Place de Fontenoy
75700 Paris
France.

CONTENTS

ABSTRACT

This volume of the Unesco Reports in Marine Science primarily describes the Special Sessions that were organized by Unesco/IOC at the XVth Pacific Science Congress (Dunedin, New Zealand, 1-11 February 1983). These sessions dealt with resource management and conservation, primary and secondary productivity, nutrition, growth and physiology of marine organisms, remote sensing and oceanography and future marine science cooperation in the Pacific. Research projects were proposed for joint implementation by different Unesco/IOC member states in the Pacific on primary, consequent and related productivity of mangrove sites; effects of atolls and seamounts on productivity of ocean waters; assessment of black coral resources; and environmental risks from shoreline development. Projects involving exchange of scientists and information were proposed, together with components involving training and education in marine sciences. Papers were invited and presented on island mass effects, remote sensing, coral reef and mangrove productivity.

RESUME

Le présent numéro des Rapports de l'Unesco sur les sciences de la mer est essentiellement consacré aux sessions spéciales organisées par l'Unesco/COI durant le vingt-cinquième Congrès scientifique du Pacifique (Dunedin, Nouvelle-Zélande, 1er-11 février 1983). Ces sessions portaient sur les sujets suivants : gestion et conservation des ressources, productivité primaire et secondaire, nutrition, croissance et physiologie des organismes marins, télédétection et océanographie, et avenir de la coopération en matière de sciences de la mer dans le Pacifique. Il a été proposé, afin qu'ils soient menés conjointement par différents Etats du Pacifique membres de l'Unesco/COI, des projets de recherche portant sur la productivité des mangroves à l'échelon primaire et aux autres échelons ; l'influence des atolls et des monts sous-marins sur la productivité des eaux océaniques ; l'évaluation des ressources en corail noir ; et les dangers de l'aménagement du littoral pour l'environnement. Il a été également proposé des projets comportant des échanges de scientifiques et d'informations, ainsi que des éléments formation et éducation dans le domaine des sciences de la mer. Les participants ont été invités à présenter des communications sur les effets de masse des îles, la télédétection, les récifs de corail et la productivité des mangroves.

RESUMEN ANALITICO

En este documento de la serie "Informes de la Unesco sobre ciencias del mar" se da cuenta de las reuniones especiales que la COI organizó durante el XV Congreso de Ciencias del Pacífico (Dunedin, Nueva Zelandia, 1º a 11 de febrero de 1983). En dichas reuniones se examinaron la gestión y conservación de los recursos, la productividad primaria y secundaria, la nutrición, crecimiento y fisiología de los organismos marinos, la teledetección y la oceanigrafía y la futura colaboración en materia de ciencias del mar en el Pacífico. Para su ejecución conjunta por varios Estados del Pacífico miembros de la COI, se propusieron proyectos de investigación sobre la productividad primaria, consecuente y afín con los manglares, las repercusiones de los atolones y crestas marinas en la productividad de las aguas oceánicas, la evaluación de los recursos de coral, negro y los riesgos que representa para el medio ambiente el desarrollo incontrolado de las costas y bordes de las playas. Se formularon proyectos relativos al intercambio de científicos y de informaciones, además de otros elementos relativos a la capacitación y educación en materia de ciencias del mar. Se invitó a que se sometieran documentos sobre los efectos de las masas insulares, la teledetección, los arrecifes de coral y la productividad de los manglares, y así se hizo.

РЕЗЮМЕ

Настоящий том Докладов по морским наукам ЮНЕСКО содержит главным образом информацию о специальных заседаниях, организованных ЮНЕСКО/МОК на XV Тихоокеанском научном конгрессе (Данедин, Новая Зеландия, 1-11 февраля 1983 г.). Эти заседания были посвящены вопросам рационального использования и сохранения ресурсов, первичной и вторичной продуктивности, питания, развития и физиологии морских организмов, дистанционного зондирования и океанографии, а также будущего сотрудничества в области морских наук в Тихом океане. Ряд государств-членов ЮНЕСКО/МОК предложили совместно осуществить в Тихом океане научно-исследовательские проекты, посвященные первичной, консеквентной и смежной продуктивности мангровых участков; влиянию атоллов и банок на продуктивность вод океана; оценке ресурсов черных кораллов; возможным опасным последствиям разработки береговой линии для окружающей среды. Были предложены проекты, связанные с обменом учеными и информацией, а также компоненты, связанные с подготовкой и образованием в области морских наук. Были представлены подготовленные по запросам доклады о воздействии островных масс, дистанционном зондировании, коралловых рифах и продуктивности мангровов.

ملخص

يتضمن هذا العدد من سلسلة تقارير اليونسكو لعلوم البحار في معظمه عرضا للدورات الخاصة التي نظمتها اليونسكو وكوي في المؤتمر الخامس عشر لعلوم المحيط الهادي (دندين ، نيوزيلندا ١٠ – ١١ فبراير/شباط ١٩٨٣) . وتناولت هذه الدورات ادارة الموارد وصونها ، والانتاجية الأولية والثانوية ، والتغذية ، ونمو الكائنات العضوية البحرية وفسيولوجيتها ، والاستشعار عن بعد والاقيانوغرافيا ، والتعاون في مجال علوم البحار في المحيط الهادي في المستقبل . واقترحت مشروعات للبحوث تشترك مختلف الدول الأعضاء في اليونسكو وكوي في تنفيذها في المحيط الهادي فيما يتعلق بالانتاجية الأولية والانتاجية التي تترتب عليها وتتصل بها لمواقع المنغروف ، وتأثير الجزر المرجانية الحلقية والجبال البحرية على انتاجية مياه المحيطات ، وتقييم موارد المرجان الأسود ، والأخطار البيئية الناجمة عن تنمية الخط الساحلي . واقترحت مشروعات تقتضي تبادل العلماء والمعلومات ، وذلك بالاضافة الى عناصر للتدريب والتعليم في علوم البحار . وطلبت وقدمت دراسات عن تأثير الكتل الجزرية والاستشعار عن بعد والشعب المرجانية وانتاجية المنغروف .

摘　　要

本卷《教科文组织海洋科学报告》主要叙述教科文组织／政府间海洋学委员会在第十五届太平洋科学大会（新西兰，达尼丁，1983年2月1－11日）期间组织的特别会议的情况。这些会议讨论了太平洋地区的资源管理和保护，海洋生物的初级和第二级生产能力、营养、生长及生理学，遥感与海洋学以及今后的海洋科学合作等问题。会议建议教科文组织／政府间海洋学委员会太平洋地区的会员国就下述方面联合实施研究项目：红树林区的初级和随后的有关生产能力；环礁和海山对海洋生产力的影响；黑珊瑚资源估价；岸线开发对环境的危害。会议还提出了有关交换科学家和情报的项目，同时提出了有关海洋科学培训和教育的活动。会议还征集收到了有关岛屿质量效应、遥感、珊瑚礁和红树林生产能力等方面的论文。

SUMMARY

A number of ideas relating to possible regional cooperation amongst Pacific member states were generated during the Unesco/IOC Sessions held in conjunction with the XVth Pacific Science Congress (Dunedin, New Zealand, 1-11 February 1983).

Although a number of studies have been made on the productivity of mangrove areas, no definitive in-depth investigation has yet taken place quantifying the causal relationships between mangrove productivity, enhancement of nutrient availability and the production of higher animals. A study was recommended by a participant from Fiji to determine the productivity and nutrient input from mangrove species, together with an examination of mechanisms of transfer to animals. Special attention would be given to exploitable species. Effects on lower plant production were also cited as worthy of study.

It was recognized that the island mass effect can have significant effects on productivity of surrounding seas. Little attention has been paid to determining if similar effects arise from low atolls or even seamounts. A project was, therefore, proposed to study the characteristics of surface waters, upstream and downstream of atolls, in terms of nutrient content and productivity.

At the initiative of a participant from Tonga, a project proposal was formulated to determine black coral resources of Pacific islands and to establish appropriate management techniques for this highly-valued resource, which is already being used for jewelry-making in different areas of the Pacific.

Several participants expressed their concern about the rapid degradation of shoreline areas, due to the development of the tourist industry. It was recommended that an independent group of referees be set up to review proposals for development.

Discussion took place on the need for exchange of information and of scientists between established research centers and laboratories in developing Pacific countries. It was recommended that information exchange be supported through appropriate publications and that exchange visits between scientific institutions be encouraged.

Participants recognized a lack of training, directed particularly toward the need of Pacific island nations in the management of their coastal zones, shorelines and nearshore resources. Support was, therefore, recommended to enable Pacific island inhabitants to take advantage of long- and short-term courses offered and planned in countries such as Fiji and Australia.

ACKNOWLEDGEMENT

This report is based on a 1983 document entitled "Report on Organization of Special Unesco/IOC (WESTPAC) Sessions at XVth Pacific Science Congress, Dunedin, New Zealand, 31 January to 11 February 1983, which was produced and edited by J.W. Brodie, 1 Fettes Crescent, Wellington, New Zealand.

Dr. J.W. Brodie also ably undertook the organization of the Unesco/IOC special session on "Productivity of Marine Island Ecosystems". He chaired this, as well as the further discussions on "Future Cooperation in Pacific Marine Science Studies". Special thanks are given to Dr. Brodie for his work in making the meeting possible.

Throughout the organization of the special sessions, there was close cooperation with the Congress organizers: Professor C.F.W. Higham, Secretary General; Dr. George Broad, Executive Secretary; Professor D. Campbell, Program Organizer; and with the convenors of Section F (Coral Reefs), Mr. E.W. Dawson, and Section E (Marine Sciences), Dr. J.B. Jillett.

---

1. INTRODUCTION

1.1 Background

This document is primarily a report of the proceedings of the Unesco/IOC (WESTPAC) sessions convened by the Unesco Division of Marine Sciences and Intergovernmental Oceanographic Commission at the XVth Pacific Science Congress (Dunedin, New Zealand, 31 January - 11 February 1983).

Unesco's programs in relation to the ocean and its resources have been drawn up in response to the growing importance of human activities involving the resources of the ocean. The purposes of the programs are to contribute to the advancement of knowledge of the ocean and of those studies which are essential to the use and rational management of its living and non-living resources; to strengthen national and regional capacities in research and training; to contribute to the development of international cooperation in marine research and the dissemination of oceanographic data and information.

The Unesco Division of Marine Sciences executes a major Interregional Project on Research and Training Leading to the Integrated Management of Coastal Systems (COMAR). COMAR's prime objective is to contribute to the establishment of a scientific basis for understanding the characteristics and functioning of the coastal zone. By means of appropriate training and use of information associated with research activities, Unesco works to reinforce the capacity of its member states to optimally use, manage, and protect the coastal zone. This program emphasizes the necessary establishment of a scientific basis for such activity. It also recognizes the need to integrate science with management and training and to get the right information to the decision-makers and to the public.

The Intergovernmental Oceanographic Commission of Unesco, through the different task teams of its Program Group for the Western Pacific (WESTPAC), plans and helps execute programs in the fields of: coastal and continental shelf oceanography; ocean dynamics; ocean science in relation to living resources; marine pollution research and monitoring; marine geology, and geophysics and non-living resources. It also operates with WMO, the Integrated Global Ocean Services System (IGOSS), and itself operates the International Oceanographic Data Exchange (IODE) system.

1.2 Unesco/IOC Sessions during the XVth Pacific Science Congress

The wide range of interest and profound knowledge of the participants at the XVth Pacific Science Congress enabled the organization of special sessions for the identification of marine science program activities in the Pacific. Those sessions led to the identification of a number of specific research projects of concern to Pacific island areas on which Unesco/IOC resources, amongst others, might be brought to bear.

The theme of "productivity in marine island ecosystems" was chosen as the result of a survey on the principal concerns and problems associated with Pacific island nations. Generally speaking, many Pacific island states look toward the marine environment to provide significant resources to sustain the development of their societies. The theme of marine productivity, in relation to current patterns of exploitation and development, was therefore chosen as a focus for the Unesco/IOC special session. Particular attention was devoted to an attempt to understand the basic principles of the natural systems of greatest ecological importance.

1.3 Structure of the Report

Section 2 contains an account of the Unesco/IOC sessions that were organized during the XVth PSC (Dunedin, New Zealand, 11 February 1983). These sessions took place on 2, 3, and 4 February as joint sessions with Section F (Coral Reefs) of the XVth Pacific Science Congress. On 5 and 10 February, special discussion sessions were organized on future cooperation in marine science in the Pacific region. The discussion sessions produced recommendations concerning a number of projects suitable for implementation.

Section 3 presents the different proposals formulated by the participants to the Unesco/IOC special sessions for marine research in the Pacific. Section 4 contains the papers presented by special request of Unesco and its IOC. The names of those people who attended the Unesco/IOC sessions are presented in Annex I.

2. SESSION REPORTS

2.1 Coral Reef Resources Management and Conservation

The session was held jointly with Section F (Coral Reefs) of the XVth Pacific Science Congress. After an opening address by the Chairman (Dr. E. Gomez, Philippines) on the perspectives of coral reef research and management in the Philippines, the following papers were presented:

(1) Perspectives on coral reef research and management of coral reef ecosystems (E. Gomez);

(2) The challenge of conserving and managing coral reef ecosystems (A.L. Dahl);

(3) The problems and efforts of protecting the coral reef in Bali, Indonesia (A. Soegiarto);

(4) The status of the world's coral reefs: a multi-variate approach to policy development (R.H. Bradbury and R.E. Riechelt);

(5) A review of the Indian coral resource management and conservation (M.D.K. Kuthalingham and V.K. Venkataramani).

2.2 Primary Productivity, Nutrition, Growth and Physiology

This session was held jointly with Section F of the XVth Pacific Science Congress. After an introductory address on the topic by the Chairman (B.V. Preobrazhenky), the following papers were delivered:

(1) Seasonal changes in the kinetics of primary production by reef-building corals at Davies Reef, Great Barrier Reef, Australia (B.E. Chalker and W.C. Dunlap);

(2) Primary productivity of atolls and high island lagoons of the southern Pacific Ocean: a comparison of their functioning (M. Richard and F. Rougerie);

(3) In situ monitoring of coral reef primary production and calcification with electrodes (D.J. Barnes);

(4) Sediment microphytobenthos productivity in the coral zone, Vietnam, and some South China Sea islands nearshore waters (L.L. Kuznetsov);

(5) Nutrient pools in lagoonal sediments of coral reefs (L.S. Hammond).

2.3 Coral Reef Resource Management and Conservation

This session was chaired by A.L. Dahl and was held jointly with Section F of the XVth Pacific Science Congress. The following papers were presented:

(1) Resource and management planning for northern Great Barrier Reef islands: fisheries, tourism and conservation (R. Buckley);

(2) Economic management of lagoons (A.M. Rapson);

(3) The selection and management of coral reef preserves (G.J. Bakus);

(4) Scientific value of northern Great Barrier Reef Islands (R. Buckley);

(5) Man and atolls: traditional utilization and conservation of marine resources and recent changes in Tuvalu and Kiribati (L.P.Zann);

(6) Soviet studies of Pacific islands ecosystems (Y.P. Bagenkov).

The above papers will be presented in separate publications. Further information on this point can be obtained from Mr. E.W. Dawson, New Zealand Oceanographic Institute, Wellington, New Zealand.

2.4 Productivity of Marine Island Ecosystems

This session was held jointly with Section E and was chaired by Dr. J.W. Brodie. Worthwhile discussion followed the papers and helped to focus analysis at the subsequent special sessions to identify research projects and to discuss potential cooperative activities in the region. An average of 35 people attended each of the discussion sessions (see Annex I, attendance list).

The papers solicited by Unesco and its IOC are reproduced in Section 4 of this report and include the following:

(1) Influence of topography of nearby land masses in combination with local water movement patterns on the nature of nearshore marine communities (C. Birkeland);

(2) The island mass effect on the sea surface chlorophyll concentration in the Southwestern Tropical Pacific: statistical evidence (Y. Dandonneau);

(3) Future possible use of remote sensing products as evaluated by sensing of the ocean eddy system in central New Zealand (E.J. Barnes);

(4) Coral reef fisheries: a review of issues and prospects (G. Russ);

(5) Abundances of herbivorous fishes and measures of food availability across the continental shelf in the Central Great Barrier Reef region (G. Russ);

(6) Mangrove fishes in Wairiki Creek and their implications on the management of resources in Fiji (P. Lal, K. Swamy, P. Singh);

(7) Bait fisheries and their possible impact on coastal fisheries in island states (A. Lewis).

2.5 Future Marine Science Cooperation in the Pacific

Two special discussion sessions were held on this topic. The first was held on the morning of February 5 as a preliminary statement of interests. The second was a subsequent definitive session held on the afternoon of February 10, where the nature of selected projects, together with potential inputs, was discussed.

2.5.1 Preliminary session

Speakers invited to the preceding sessions, together with invited participants, the chairmen and convenors of Sections E (J.E. Jillett) and F (E.W. Dawson) and a large number of observers, took part in these preliminary discussions.

Research topics discussed during the preceding sessions, as well as possible extensions and additions to these, formed an introductory basis for a wide-ranging discussion. The Chairman (Dr. J.W. Brodie) explained Unesco/IOC's interest in the identification of research projects that could be part of a program of significant collaborative studies in the Pacific region.

The potential sources of financial support for possible projects were outlined by the representative from Unesco/IOC.

Those were: Regular Program Budget of Unesco and its IOC; Unesco Funds in Trust; United Nations Development Program funds, particularly for inter-regional activities; and bilateral arrangements which could include funds from donor countries and institutions. The projects should be designed to include aspects of training, as well as field science.

2.5.1.1 Mangroves

A participant from Fiji stressed the need for a detailed study of the productivity of mangroves in relation to fisheries. The following were some of the comments fielded: there is a diverse range of mangrove types, with probable highly different environmental responses, which should be taken into account; Australia is organizing a Workshop on Mangrove Productivity at the Australian Institute of Marine Science in 1985; the work of the Unesco/UNDP Regional Training Pilot Program on Mangrove Ecosystems of Asia and Oceania was noted and commended.

Other speakers pointed out a variety of additional points: mangroves could have a role in neutralizing urban wastes and preventing pollution of lagoons; forestry aspects were considered important in Papua New Guinea; conversion of mangrove areas to aquaculture is planned for Sabah, a process not found to be generally advantageous in Thailand; a substantial interest on the part of Australia in mangrove problems was mentioned.

2.5.1.2 Effects of islands on ocean productivity

The contribution of high islands to productivity of island coastal waters results in the so-called "island mass effect". This parallels productivity contributions of low atolls by lagoonal effects, upwelling and other physical processes generated by the underwater profile (see paper by C. Birkeland, Section 4.1). Specific studies of productivity effects induced by atolls and seamounts were suggested and a general program of such studies was supported. The applicability of remote sensing techniques in furthering such studies was noted.

2.5.1.3 Developments on island coastlines

The immediate need for study and advice on the problems likely to be generated by tourist development on island shorelines was pointed out. A coastal erosion project in Kiribati was noted and it was indicated that the University of South Pacific can undertake environmental assessment of such situations.

2.5.1.4 Shoreline and nearshore resource assessment

The need for development of capabilities in resource assessment, data collection, conservation of reef resources, and management of associated coral reef fisheries, was strongly expressed by speakers from Kiribati, Papua New Guinea, Australia, and Hawaii. The desirability of developing a system of indicators of fisheries productivity potential for reefs was put forward. The existence of a coastal resources assessment, use, and management survey by Chile at Easter Island was noted.

2.5.1.5 Black coral resource assessment and management

The need for a survey of the shallow water black coral (*Antipathes*) resource and its management and utilization in Tonga and Kiribati was stressed.

2.5.1.6 Physical environment of coral reefs

Several speakers outlined the need for a proper understanding of the physical processes in the coral reef environment. Aspects such as nearshore circulation, tidal effects, residence time of lagoon waters, local upwelling and seasonal variability require study in parallel with research into natural reef productivity or the restoration of productivity after over-exploitation.

2.5.1.7 Cooperative facilities

A number of study, training, and support possibilities were outlined:

(1) University of South Pacific, Fiji, is planning courses leading to B.Sc. or M.Sc. in Marine Sciences;

(2) Pacific country representatives would be welcome to attend the Khabarovsk Institute of Economic Studies, U.S.S.R. and assistance could be offered for such studies;

(3) South Pacific Regional Environment Program can offer assistance in appropriate projects;

(4) University of South Pacific has staff and facilities that are available on a consultant basis;

(5) U.S.S.R. offers possibilities of collaboration with Far East scientific workers and ships on island problems;

(6) Australia offers courses on tropical coastal management and has models for marine park development through examples on the Great Barrier Reef; and

(7) Australia makes available the results of experiments with equipment modified for coral reef studies.

2.5.2 Planning session

Invited participants, as well as a number of observers, took part in discussions which followed the preliminary session of 5 February. Specific projects for consideration were presented at this definitive session and a number of prepared statements and proposals, relating to various concerns, were presented (see Section 3).

2.5.2.1 Major project proposals

Discussion highlighted six main projects that were recommended to Unesco/IOC for support and implementation. These were:

(1) Determination of primary, consequent and related productivity at a mangrove site;

(2) A study of the effect of atolls and seamounts on the productivity of ocean waters in the Pacific;

(3) Development of a mechanism to assess environmental risks from shoreline development in Pacific islands;

(4) Exchange of scientists and information on Pacific coral reef studies; and

(5) Support for training and education in marine sciences.

2.5.2.2 Other proposals

A number of other topics were identified and the meeting took note of the following:

(1) Biological study of deep-water shrimps related to possible use as an economic resource (participant from Fiji);

(2) Definitive studies of the coral reef reserves for marine parks in Papua New Guinea;

(3) A study of regeneration of mangroves in the Mekong Delta (participant from U.S.S.R.);

(4) Application of remote sensing to problems in Pacific surface waters (participants from New Zealand and Australia);

(5) River-bank erosion and harbor siltation at Apia, Western Samoa, study of remedial procedures;

(6) Collaborative multi-disciplinary ship borne expeditions in the Pacific (participant from U.S.S.R.);

(7) Evaluation of the yield and potential of coral-reef fisheries (participant from Australia);

(8) Preservation of pre-historic stone fishing weirs on the Great Barrier Reef; and

(9) Identification of productivity indicators for coral reefs (participant from Guam).

2.6 Future Cooperation in Marine Science in the Pacific

The preliminary session on 5 February fulfilled the anticipated need for the recognition of a spectrum of projects and topics of concern to both the Pacific countries and research scientists over a range of disciplines.

The Unesco/IOC session brought to light concerns about a number of Pacific island problems. While some of these are specific, most are applicable to many islands. The six projects identified by the definitive session on 10 February are appropriate for Unesco support and are of immediate or eventual administrative significance to island governments. Possible inputs from cooperating countries were also identified.

3. PROPOSED PROJECTS

This section contains a formal account of the major projects proposed by the meeting.

3.1 Determination of Primary, Consequent and Related Productivity of a Mangrove Site

3.1.1 Justification

A number of studies of the productivity of mangroves have been made, but there has not been an intensive study of the possible causal relationships between mangrove productivity, the enhancement of nutrient status and the production of higher animals including those exploitable by man as food. Results could provide a base for substantive advice to management agencies and governments on the best use of mangrove resources.

It was recommended that support be sought for a medium term (3-5 year) multi-faceted study at a selected mangrove site to determine productivity and the nutrient input from the mangrove species, effects on lower plant production and the mechanisms of energy nutrient and material transfer to animals, particularly covering the exploitable species.

The project was suggested by a participant from Fiji. Initial surveys are needed to select a geographically appropriate mangrove situation that approaches most nearly the ideal of an estuarine system having simple land drainage input, shallow depth and outer boundaries that can be readily monitored. The selection should take into account already existing information.

3.1.2 Project outline and proposed implementation

Preliminary examination of available data could be made by a steering group, consisting of representatives of the concerned Fijian and Australian agencies. Some New Zealand agencies (NZ Oceanographic Institute and Cawthron Institute) would be willing to assist at the initial assessment stage. The name of Dr. John Bunt, Director of AIMS, Townsville, was suggested as convener. Following preliminary assessment, a work plan and budget could be developed and a start made, perhaps within the Unesco/UNDP Mangrove Project for Asia and the Pacific.

The project should be located in Fiji and would involve the participation of many specialists on the physical regime, chemistry, microbiology of water and substrate, and the botanical and zoological aspects of the contained biosystems. The project should also involve training of local personnel to enhance indigenous research capabilities.

This project could well be included in the present Unesco/UNDP Mangrove Project in Asia and the Pacific. Of itself, the project would put into practical effect some of the general characteristics proposed in previous mangrove study programs.

3.1.3 Sources of support

(1) Fiji, through its Ministry of Agriculture and Fisheries, is already concerned with definitive studies of the fauna of mangrove areas;

(2) The James Cook University, Townsville, would like to be involved and Australian agencies might be approached to provide the equivalent of one man-year to such a project. This could involve, for example, a number of scientists in field study periods of four to six weeks. The Australian Institute of Marine Sciences, Townsville, has a substantial concern with mangrove studies and would be likely to be involved in such a project;

(3) Travel and per diem for field work at a $10,000 p.a. level would be significant. A sum of $6,000 towards participation in Steering Group meetings and a similar sum for a participants symposium in 1985 would be appropriate. If this last were held in Fiji, then additional funds would be needed.

Funding for travel and field expenses would need to be provided, in part at least, from Unesco or similar sources.

3.2 Effects of atolls and seamounts on the productivity of ocean waters in the Pacific

3.2.1 Justification

The project has been put forward by New Zealand (NZ Oceanographic Institute, Wellington, The Cawthron Institute, Nelson) and by a participant from France (ORSTOM, Nouméa, New Caledonia), to study the productivity effects generated by low atolls and seamounts. It is thought that such effects may lead to important increases in biomass production. Investigation of individual atolls and comparative studies are needed in order to confirm generality of the relationship and to quantify principal characteristics. However, before any action is taken, it will be necessary to discuss specific projects with the Island Governments concerned, so that a proposal can be put forward with appropriate support.

3.2.2 Project outline and implementation

(1) The NZ Oceanographic Institute is interested in providing one man-month per year, for up to three years, for work on physical and biological aspects. This would include work on primary productivity and nutrients and on the use of remote sensing methods.

(2) The Cawthron Institute, Nelson, NZ, can provide two man-months per year, for up to three years, for studies of microbially-mediated nutrient cycling processes in lagoons and ocean surface waters. New Zealand could make use of the research vessel Tangaroa for aspects of this investigation that paralleled other projects in the selected area of study.

(3) ORSTOM, Nouméa, has indicated an interest in collaborating on this project.

(4) The concerned Island Governments might be able to make local vessels available.

(5) Funding would be sought from sources within Unesco or elsewhere for travel costs and per diem and fares.

3.3 Shallow Water Black Coral Survey

An assessment of shallow water black coral (*Antipathes*) resources in Tonga is required to provide a secure basis for the development of the industry. The components of such a survey were suggested to be:

(1) Resource assessment study in three islands (Tongatapu, Vava'u, and Ha'apai) to determine a management and development program.

(2) Assessment of product utilization and provision of training to develop artisan capabilities. The Tongan Government could provide a vessel for two weeks to be used by an experienced consultant or consulting team.

3.4 Mechanism to Assess Environmental Risks from Shoreline Developments in Pacific Islands

3.4.1 Justification

The development of tourist facilities in a number of Pacific islands has led to the degradation of shorelines. The unwanted effects resulting from this development include interference with natural sediment movements, which leads to coastal erosion. Two development proposals currently require examination in Tonga.

It was recommended that an independent group of technical experts be set up. This group would be composed of competent people, experienced in the environmental impact field. Island Governments, in order to obtain a professional opinion on projects, could refer development proposals to such a group. The function of the group would also be to recommend both an appropriate investigation and the mechanism to carry it out.

The need for such a service has been brought forward by the participant from Tonga. The lack of local expertise to advise Island Governments is a problem common to a number of island nations.

3.4.2 Implementation

In each instance the costs involved would be transport of the selected consultant to and from the site, maintenance on the job and an average two week's consulting fee. An approximate sum of $7,000 would cover one project.

3.5 Exchange of Scientists and Information on Pacific Coral Reef Studies

An exchange program involving scientists and information concerned with coral reefs was proposed by participants from the Philippines, Guam, and Papua New Guinea.

3.5.1 Justification

Considerable discussion took place underlining the need for scientist exchange schemes, involving both established research centers and laboratories in developing Pacific countries. It was recommended that:

(1) Support be given to efforts to develop an information exchange among coral-reef scientists, involving Quarterly Reports on Work in Progress, a Directory of Research and Research Workers at intervals of three years, and the exchange of bibliographic data;

(2) Support be given to a regular and on-going program of short-term exchange between established research centers and those of developing countries.

3.5.2 Implementation

It was recognized that substantial data sources exist, for example, in the Hawaii Institute of Marine Biology and the Great Barrier Reef Marine Park Authority. There are also some retrieval systems in operation. The proposal, however, would involve all Pacific coral-reef scientists, including those from developing nations. The University of Guam Marine Laboratory has offered to coordinate activities initially.

3.5.3 Support required

The following components of support are suggested:

(1) Meetings of an information interchange group could be convened at the time of either the Pacific Science Congresses or of the International Symposium on Coral Reefs. Some travel funds would be needed. ($5,000 per meeting);

(2) Operational funding of information interchange activities would not necessarily involve substantial costs. These would include costs of production and distribution of a quarterly newsletter and triennial directory. The exact costs could be determined at a later date;

(3) The scientist exchange program, as detailed in the proposal put forward by the participant from the Philippines, would involve travel and subsistence expenditures of $10,000 per year from an external source, such as Unesco. These funds would be matched by acceptance of similar costs by established institutions whose members participated in exchange visits.

There was wide support in the meeting for this proposal. Statements of interest came from the Hawaii Institute of Marine Biology, the Institute of Marine Resources, Suva, New Zealand and Australia, and the South Pacific Regional Environment Program.

3.6 Support for Training and Education in Marine Sciences

3.6.1 Justification

Presently, the Pacific island nations are faced with a lack of training in the management of their coastal zones, shoreline and nearshore resources. It was recommended, therefore, that support be extended to enable Pacific island personnel to take advantage of long- and short-term courses offered and planned in Fiji and Australia.

3.6.2 Implementation

It is anticipated that the following courses may be available:

(1) Fisheries and Marine Science. The University

of South Pacific at Suva already offers courses toward the Diploma of Tropical Fisheries, a practical course oriented toward management. Courses are planned leading to a B. Sc. in Fisheries and Marine Sciences and to the M.Sc. degree.

(2) Tropical Coastal Zone Management. Australian Institute of Marine Sciences, Townsville, plans a workshop on Tropical Coastal Zone Management, to which Pacific countries would be welcome to send participants. The cost per individual could be around $2,000. Agencies such as the Queensland Coastal Zone Management Group, the Bureau of Mineral Resources and James Cook University are also interested in workshops and courses on coastal zone management.

3.6.3 Support required

The cost of sending a student to Suva may well be found in already-existing funding opportunities. These could be investigated by Unesco. The travel and subsistence costs of attending a Coastal Zone Management Workshop could be sought within Unesco regular program activities or through bilateral arrangements.

3.6.4 Other training possibilities

The meeting noted with appreciation the generous offer by participants from the USSR. of study opportunities at the Khabarovsk Institute of Economic Studies and of shipboard and field collaboration with Far East scientific workers.

4. PAPERS PRESENTED AT THE UNESCO/IOC (WESTPAC) SESSION

4.1 Influence of Topography of Nearby Land Masses in Combination with Local Water Movement Patterns on the Nature of Nearshore Marine Communities

by

Charles Birkeland*

ABSTRACT

Tropical nearshore marine communities (seagrass beds, coral reefs, and algal flats) are generally recognized as being the most productive natural communities. The limiting factors in productivity are not sources of energy, which are often superabundant. Rather, they are essential nutrient materials which appear to be in short supply and are recycled at the physiological level in symbioses, at the community level in detrital food webs, and at the regional level by current patterns. The enhanced marine productivity in the vicinity of islands, the "island mass effect", results from the input or retention of chemical nutrients in shallow nearshore communities by terrestrial runoff, groundwater seepage, nitrogen fixation by benthic organisms, benthic nutrient regeneration, secondary production of mucus, internal waves, upwelling, eddying, and increased residence time of water. All nine of these mechanisms operate around high islands, but terrestrial runoff and the detritus-based food chain are not as important at atolls. From information presently available, the average primary productivity does not differ significantly between high islands and atolls; major differences between these systems appear to result from occasional intense pulses of nutrients into waters around high islands. The importance of nutrient recycling in tropical ecosystems suggests that we should prune and recycle, rather than crop the resources and that dynamiting of reefs for fishes is likely to have substantially greater long-term effects on tropical oceanic nearshore communities than on temperate nearshore communities.

---

*University of Guam
Marine Laboratory
UOG Station
Mangilao
GUAM 96913

1. INTRODUCTION

It is generally recognized that shallow tropical benthic marine communities (seagrass beds, coral reefs, algal flats) are among the most productive ecosystems in the world, marine or terrestrial (Table 1). It is also recognized that this production often comes about in areas surrounded by oligotrophic ocean (Sargent and Austin, 1949; Odum and Odum, 1955; Khon and Helfrich, 1957; Stoddart, 1969; Sournia and Ricard, 1976a). It is clear that energy is not the limiting factor for primary production because there is about as much sunshine a mile out to sea as there is on the reef flat. Essential nutrient materials, not energy, must be limiting.

Table 1 Estimates of primary production ($g\ C\ m^{-2}\ yr^{-1}$) in various ecosystems made by different authors (Crisp 1975, Lewis 1977)

Tropical seagrass beds	4650
Coral reefs	4200
Tropical algal communities	3836
Peru current	3650
Sugar cane fields	3450
Sewage treatment ponds	1800
Kelp bed	1750
Spartina marsh	1600
Estuarine benthos	1320
Temperate algal communities	920
Coniferous woodland	800
Deciduous woodland	785
Field grass	500
Long Island Sound plankton	470
Eutrophic lakes plankton	75-250
English Channel plankton	135
Sargasso Sea plankton	134
North Sea plankton	100
Open ocean near coral reefs	
Barbados	50
Rongelap	28
Hawaii	21-37
Oligotrophic lakes plankton	7-25

The importance to the coral reef ecosystem of input nutrients, even on a minute scale, was illustrated when

Meyer et al. (1893) found that excretion of ammonium, nitrogen, and phosphorus by schools of junvenile haemulid fishes, returning to the coral reef after foraging for prey on seagrass beds, was enough of an additional input of nutrients that corals beside the resting fish schools grew faster than did other corals. This study was also the first tangible documentation of the effects of nutrient flow between tropical coastal ecosystems.

Essential nutrients, rather than energy, are evidently also in short supply for fishes. Fishes that specialize in browsing on coral polyps or mucus appear to need a few small worms, crustaceans, or fish eggs in their diet on occasion to obtain certain essential amino acids (Birkeland and Newdecker, 1981). The main staple, coral appears to be in superabundant supply. At least 45 species of fishes on coral reefs eat fish feces in addition to other foods (Robertson, 1982).

The availability of essential nutrients is influenced on a large scale by the movements of water. Vagaries in the patterns of water movements, which distribute nutrients, are causal factors in fluctuations in abundances of populations of tropical marine organisms. This year, 17 million seabirds of 18 species virtually disappeared from Christmas Island (Schreiber and Schreiber, 1983) and hundreds of dead juvenile seabirds were observed on Guguan (Marianas Islands). These populations may have been devastated by decreases in food availability brought about by lowered productivity when the shifts in current patterns called "el Nino" caused decreases in available nutrients. Conversely, population explosions of crown-of-thorns seastars (Acanthaster planci) came about when there was a sudden input of a substantial amount of additional nutrients into the coastal waters of high islands, brought by heavy rains following extensive droughts. Populations of tropical marine organisms were once expected to be relatively stable, in comparison with populations of temperate marine organisms. This expectation grew out of the observations that temperatures fluctuate less annually in the tropics. However, as evidence accumulated from field work, it became apparent that tropical marine populations fluctuate as much as do temperate marine populations and changes in nutrient availability brought about by vagaries in water movements are responsible for a part of these drastic fluctuations in tropical marine populations.

The productivity of ocean waters is substantially increased near land masses (Doty and Oguri, 1956; Jones, 1962; Sorokin, 1973; Gilmartin and Revelante, 1974). This "island mass effect" must result ultimately from an input or prolonged retention of nutrients. There are at least nine mechanisms by which the presence of a land mass could produce an increase in input or retention of nutrients: terrestrial runoff, groundwater seepage, nitrogen fixation by benthic organisms, benthic nutrient regeneration, secondary productivity, internal waves, upwelling, eddying, and increased residence time of water.

2. TERRESTRIAL INPUTS

The importance of input of nutrients by runoff or seepage from terrestrial sources on productivity of nearshore marine ecosystems is beyond doubt. Within two years after the Aswan Dam reduced the discharge of silt from the Nile, the fisheries production of the eastern Mediterranean dropped to 3.7% of its previous levels (Aleem, 1972). Sutcliffe (1972, 1973) was able to predict the future catches of marine bivalves, lobsters, and fishes on the basis of land drainage or river discharge records. Chidambaram and Menon (1945) and Murty and Edelman (1966) found strong correlations between sardine catches and the amounts of rainfall or the monsoon intensity on the east coast of India.

Phytoplankton blooms occur mostly around high islands, particularly in bays with large watersheds. Red tides also occur mainly in bays in continental areas or on large islands. Phytoplankton blooms have been recorded in Tumon Bay, Guam, in historical records as far back as the earliest Spanish occupation (Marsh, 1977). Field studies off Guam led Marsh (1977:334) to conclude that phytoplankton blooms "... are usually associated with the beginning of the rainy season. It is probable that heavy rains coming after an extended dry season wash a pulse of nutrients, especially phosphorus, off the watershed and stimulate a bloom. Eventually, as the most easily available nutrients wash off the land, the runoff water becomes more dilute and the plankton bloom in the bay dies out. With the onset of the dry season, accumulation of easily leachable nutrients begins again on the watershed and the seasonal cycle is repeated." Marsh also noted that no phytoplankton blooms have been observed in Pago Bay, which has a generally smaller watershed and a lower input of groundwater than Tumon Bay.

Blooms of the benthic alga *Entermorpha clathrata* have been shown by field studies and laboratory experimentation to be a result of groundwater seepage of nitrates (FitzGerald, 1978).

The input of nutrients from terrestrial sources through water transport can come about by either runoff or seepage. Guam is a particularly interesting island on which to observe these phenomena because the northern half of Guam is limestone of raised reef origin and the southern half is basalt of volcanic origin. Therefore, most of the input of nutrients comes from seepage in the north and by runoff in the south of Guam. There are no rivers in the northern half because the water filters down through the limestone into a freshwater lens which "floats" on salt water several feet above sea level. The nitrates are introduced to the shorelines by springs and outflows of groundwater percolations. Nitrates appear in these seepage areas in concentrations up to 13.2 times greater than is usual for reef flat water and a positive correlation exists between high nitrogen levels and the distribution of *Enteromorpha* (FitzGerald, 1978). The ultimate origin of the fixed nitrogen may be tangen-tangen (a legume, *Lucaena leucocephala*), a blue-green alga (*Nostoc muscorum*), and soil bacteria, all of which are common in the northern limestone plateau over the freshwater lens on Guam. Phosphates do not show a significant input by seepage.

In contrast, there are 40 streams or rivers in the southern half of Guam. There is a significant input of reactive phosphates into nearshore environments at the river mouths, but the input of nitrates is negligible.

3. LAGOONAL PRODUCTIVITY

One would not expect terrestrial runoff or groundwater seepage to be as important on atolls as on high islands. Indeed, there are biological indications that there is more terrestrial input on high islands. For example, *Sargassum*, *Gracilaria*, and *Eucheuma* are generally found on high islands and rarely on atolls (Tsuda, 1976, 1982). Algal blooms and red tides occur around high islands but rarely around atolls. Because of the dependence for survival of the planktotrophic larvae of *Acanthaster* on dense concentrations of phytoplankton for adequate food supply, outbreaks of *Acanthaster planci* occur only around high islands (Table 2). Suspension-feeders, such as sponges, are more abundant on high islands and boring of coral skeletons by bivalves and sponges are both more frequent and intense on high islands (Highsmith, 1980).

Table 2 The frequency of outbreaks of *Acanthaster planci* on high islands and atolls in Westinghouse surveys (1969-1972) from results compiled by Marsh and Tsuda, 1973.

	High Islands	Low Islands (Atolls)	
Conditions 1 and 2 (normal)	4	20	24
Conditions 3 to 5 (abundant *Acanthaster*)	19	2	21
	23	22	45
	$X^2_{adj[1]} = 21.5$ ($p << .001$)		

The prevalence of recycled materials in the diets of coral reef animals is greater than might be presumed, at least at high islands. In a comparison of decapod crustaceans associated with colonies of *Pocillopora verrucosa* between high islands and atolls, Kropp and Birkeland (1982) found there were no significant differences between the obligate associates which fed directly on coral mucus. Nonobligate associates, however, especially xanthid crabs, which fed mainly on detritus, were significantly more abundant and diverse in the lagoons of high islands (Table 3).

Table 3 Proportion of obligate and nonobligate *Pocillopora* coral associates in collections of decapod crustaceans taken from coral heads in French Polynesia

	Takapoto (Atoll)	Mooréa (High Island)	
Obligates	258	286	544
Nonobligates	68	252	320
	326	538	864
	$X^2_1 = 58.8$***		

The lagoons of high islands are rather low in phytoplankton productivity but have more plant decomposition products and ten times the particle content of the waters immediately offshore (Sournia and Ricard, 1976b). Johannes (1967), Johannes and Gerber (1974), Sournia and Ricard (1976b), and Sournia (1977) all concluded that in coral reef ecosystems, phytoplankton may have lost its "usual" role and decomposition products of benthic plants may be of greater importance in the food webs of coral reefs. Scott and Jitts (1977) concluded that the photosynthetic production by zooxanthellae within corals occupying only 25% of the substratum was about three times greater than the primary production by phytoplankton. Lewis (1982) calculated that in an area with only 39% coral cover, the secondary production by corals was about 1000 kcal m^{-2} y^{-1}. Johannes (1967) calculated that mucus was released as detrital material into lagoonal waters in amounts equivalent to 40% of coral respiration. A major source of food for coral reef animals has indeed been found to be detrital materials, including algal fragments and coral-produced mucus. Fish, crabs, and copepods will all eat coral mucus (Benson and Muscatine, 1974). Gerber and Marshall (1974a, b) showed that the guts of zooplankton rarely contained phytoplankton, but contained detritus instead. In field observations at Palau, Ross Robertson (1982) followed the fates of 5,975 feces produced by 88 species of fishes. At least 45 species of fishes ate fish feces in addition to other foods. Field observations have also been made on corals eating fish feces (McCloskey and Chesher, 1971).

4. COMPARISONS BETWEEN HIGH ISLANDS AND ATOLLS

While it is clear that terrestrial runoff and groundwater seepage must be more influential on high islands than on atolls, while it is known that the detrital food chain is of greater magnitude on high islands, and while phytoplankton blooms, red tides, *Sargassum*, *Gracilaria*, *Eucheuma*, burrowing bivalves and sponges, and outbreaks of *Acanthaster* are all more frequent on high islands, there is no evidence that the primary production on atolls is any less than on high islands (Table 4). A problem with comparisons in Table 4 is that most of the data were obtained by different investigators and so much of the variance could be a result of differences between individual techniques. We need paired comparisons. However, by all indications, primary production still does not ordinarily differ between atolls and high islands. Phytoplankton blooms, red tides, and outbreaks of *Acanthaster* do not result from usual conditions; they result from intense pulses of nutrients from runoff caused by extra heavy rains (Birkeland, 1982). Evidence of these pulses has been found only for high islands.

Table 4 Comparison of primary production at high islands, atolls, and open ocean sites near coral reefs from estimates made by different authors

Gross primary production (g c m^{-2} yr^{-1})
(from Lewis, 1977)

HIGH ISLANDS		ATOLLS		OPEN OCEAN NEAR REEFS	
Coral Reefs			**Reef Flats**		
Hawaii-Coconut Island	7300	5329	Enewetak algal flat	Barbados	50
Puerto Rico - El Mario reefs	4450	4715	Laccadives-Kavaratti lagoon	Hawaii	21-37
Guam-Oiti reef flat	2600	4234	Enewetak algal flat	Rongelap	28
India-Manauli reef	2500	4200	Enewetak coral-algal flat		
Hawaii-North Kapaa	2427	3285	Enewetak windward reef flat		
Andaman Islands - Port Blair	1200	3000	Laccadives-Minicoy reef		
		2250	Laccadives-Kavaratti reef		
Seagrass Beds		2190	Enewetak coral-algal flat		
		1250	Rongelap		
Florida - Long Key	3880				
Puerto Rico - Island Magueyes	1350				
Puerto Rico - West La Gata reef	980				

While influential groundwater seepage and extra heavy terrestrial runoff may occur only at high islands, nitrogen fixation by blue-green algae is operational at both high islands and atolls.

5. WATER MOVEMENTS

Internal waves, eddying, upwelling, and increased residence time of water are all influences on productivity that are brought about by alterations of patterns of water movement which result from land masses obstructing uniform current flow. These alterations are caused by both high islands and atolls. Finn Sander (1973, 1981) showed that at Barbados, internal waves were far more influential to phytoplankton productivity than were terrestrial runoff or benthic-pelagic coupling of nutrient regeneration. Eddies that form in the wake of land masses or in the lee of points of land can aggregate plankton into concentrations 40 times greater than in adjacent water (Alldredge and Hamner, 1980), can facilitate local recruitment of littoral animals with long pelagic larval stages (Boden, 1952; Emery, 1972), and can maintain offshore populations of coastal planktonic organisms (Emery, 1972). This concentration of larval organisms may be particularly influential in attracting pelagic billfishes and tunas to land masses, a process which increases the pelagic fisheries production in the vicinity of land masses.

Upwelling is generally brought about by currents turning offshore or by winds blowing offshore of continental land masses or by currents being shifted upward over a sill. These happenings do not usually occur at oceanic high islands or atolls. So, upwelling is not as prevalent a phenomenon at mid-Pacific islands as internal waves might be.

The final mechanism by which land masses enhance the productivity of a region is by enclosing water or causing water to eddy and thereby increasing the cohesion and the residence time of the planktonic community. The incubator effect of cohesion of water masses or relatively long residence time of water may explain some otherwise confusing anomalies in tropical marine systems. For example, an upwelling of nutrients occurs off southeast Taiwan in the Kuroshio current, yet the fisheries are rich off Okinawa to the north. This may be because, although the productivity of phytoplankton is high off southeast Taiwan, the standing crop of phytoplankton is still too low to support a fishery. The water mass remains fairly cohesive as the Kuroshio current flows north. By the time the water mass reaches Okinawa, the phytoplankton cells have divided enough times to build up a standing crop large enough to support a fishery.

This same process may explain why Acanthaster planci outbreaks have been a chronic problem on Ponape but have apparently not occurred on Kosrae. While Kosrae and Ponape are the two high islands which have the greatest potential for phytoplankton blooms of all the Carolines (Cowan and Clayshulte, 1980), the waters around Ponape are contained in a lagoon surrounded by a barrier reef. The waters around Kosrae, which is surrounded by a fringing reef, are carried away and dispersed by longshore currents. At Ponape, the lagoon may act as an incubator, with water in the lagoon having a long enough residence time to allow phytoplankton to build up a standing crop large enough to support larvae of A. planci. Although the waters off Kosrae contain enough nutrients to allow phytoplankton blooms, the waters move away from the island before the phytoplankton have undergone enough cell divisions to build up a standing crop sufficient enough to support larvae of A. planci. The dispersion of water could also thin out the concentration of A. planci larvae, as well as the food supply of the larvae. Studies of fish larvae indicate that upwelling of nutrient-rich water leads to phytoplankton blooms, but the movement of the upwelling waters disperse food organisms, so that the food particles are too low in concentration to support larval anchovy growth (Smith and Lasker, 1978).

The Acanthaster outbreaks on Guam originated at the northern ends of both Tumon and Agana bays in 1968 and 1979, but not at other bays. At the northern ends of these two bays, the water has a relatively long residence time, but the sediment plume is apparently carried directly out of the other bays and dispersed into the open sea.

To test "productivity" or rates of biomass accumulation at these various sites, fouling panels were set out in groups of four in the open and in groups of four in fish-exclusion cages at each of the sites. Four sites were in slow-current areas and four were in closely-matched fast-current areas. In all cases, both inside and outside the cages, slow-current areas showed greater rates of biomass accumulation than did fast-current areas (Table 5). Furthermore, in the two areas in which outbreaks of A. planci originated in the past, each showed twice the rate of benthic biomass accumulation of any of the other areas (Table 5). This again indicates that the A. planci may have survived better in areas with higher productivity, perhaps from terrestrial nutrient runoff and relatively long residence time of water.

6. NUTRIENT CYCLES

Like the tropical rainforests, coral reef ecosystems may be able to withstand pruning and recycling, but not harvesting and exporting, since most of the nutrients are recycled and not imported. The removal of living materials from a coral reef community on a large scale might cause depletion at a rate at which the system would be unable to replenish and maintain itself. (see Birkeland, 1984, for further discussion of this point).

Fouling panels have been set out under similar conditions near offshore islands, as well as on the continental coast of the Caribbean. They were also placed on the side of an island with upwelling in the eastern tropical Pacific coast of Panama and on the opposite side of that island, in fast-current areas and closely-paired slow-current areas around Guam (Table 6). These data indicate that rates of biomass accumulation on panels and the nature of the biota at the site are more clearly predictable by reference to the surrounding land masses and the local residence time of the water than by differences between oceans.

Table 6 Dry weight of fouling communities which grew on plexiglass plates during 77 day periods at a depth of 9 m

CARIBBEAN	
San Blas Islands	
Ocubsui -- 6.5 km off coast	27.3 ± 3.7 (8)
Ogogpuquid -- 13.5 km off coast	24.4 ± 3.5 (8)
Panama Coast	
Drake's Island, Portobelo	51.9 ± 2.3 (8)
Punta Galeta	53.5 ± 3.8 (8)
WESTERN PACIFIC	
Guam	
Tumon and Agana Bays - slow current	117 ± 13.8 (8)
Uruno and Facpi Points - slow current	49.8 ± 3.0 (8)
Uruno, Tumon, Facpi Points - fast current	28.7 ± 18.2 (12)
EASTERN PACIFIC	
Isla Taboquilla	
north - opposite side from upwelling	40.9 ± 4.2 (8)
south - exposed to upwelling	
wet season	188 ± 33.0 (8)
dry season	306 ± 156 (4)

Table 5 Dry weight of fouling communities which grew on plexiglass plates during 77 day periods at a depth of 9 m. Each sample set consisted of 4 plates. Dry weights are given in $\bar{Y} + S_{\bar{y}}$ (gms m^{-2}).

EXPOSED TO FISH GRAZING			IN FISH-EXCLUSION CAGES		
	Slow-Current Area	Fast-Current Area		Slow-Current Area	Fast-Current Area
Uruno Point	48.5 ± 0.91	42.3 ± 3.35	Tumon Bay	37.3 ± 2.19	31.4 ± 3.21
Tumon Bay	123 ± 7.98	38.9 ± 1.81			
Agana Bay	111 ± 4.81				
Facpi Point	51.0 ± 1.85				

7. CONCLUSION

I believe that a knowledge of the effects of land masses of various forms, terrestrial runoff of nutrients into nearshore waters, and residence time of water on the productivity of marine communities and on the reproductive patterns of the populations is essential if we expect to obtain a workable understanding of the fisheries potential and dynamics of the tropical marine communities.

REFERENCES

Aleem, A.A. 1972. Effect of river outflow management on marine life. Mar. Biol. 15:200-208.

Alldredge, A.L. and W.M. Hamner. 1980. Recurring aggregation of zooplankton by a tidal current. Estuarine and Coastal Marine Science 10:31-37.

Benson, A.A. and L. Muscatine. 1974. Wax in coral mucus: energy transfer from corals to reef fishes. Limnol. and Oceanogr. 19:810-814.

Birkeland, C. 1984. Sources and destinations of nutrients in coral reef ecosystems. In Comparing Coral Reef Survey Methods. Unesco Reports in Marine Science 21: 4-5.

Birkeland, C. 1982. Terrestrial runoff as a cause of outbreaks of *Acanthaster planci* (Echinodermata: Asteroidea).

Birkeland, C. and S. Neudecker. 1981. Foraging behavior of two Caribbean chaetodontids: *Chaetodon capistratus* and *C. aculeatus*. Copeia 1981 (1): 169-178.

Boden, B.P. 1952. Natural conservation of insular plankton. Nature 169 (4304):697-699.

Chidambaram, K. and M.D. Menon. 1945. The correlation of the west coast (Malabar and South Kanara) fisheries with plankton and certain oceanographic factors. Proc. Indian Acad. Sci. 22(B):355-367.

Cowan, P.A. and R.N. Clayshulte. 1980. Marine baseline water quality of the Trust Territory of the Pacific Islands. Univ. Guam WERI Tech. Rept. 14. 98 p.

Crisp, D.J. 1975. Secondary productivity in the sea. Pages 71-89. In D. E. Reichle, J.E. Franklin and D.W. Goodall (eds.), Proceedings of a Symposium on Productivity of World Ecosystems. National Academy of Sciences, Washington, D.C.

Doty, M.S. and M. Oguri. 1956. The island mass effect. J. Cons. perm. int. Explor. Mer. 22(1):121-128.

Emery, A.R. 1972. Eddy formation from an oceanic island: ecological effects. Carib. J. Sci. 12(3-4):121-128.

FitzGerald, W.J., Jr. 1978. Environmental parameters influencing the growth of Enteromorpha clathrata (Roth) J. Ag. in the intertidal zone on Guam. Botanica Marina 21:207-220.

Gerber, R.P. and N. Marshall. 1974a. Ingestion of detritus by the lagoon pelagic community at Eniwetok Atoll. Limnol. and Oceanogr. 19:815-824.

Gerber, R.P. and N. Marshall. 1974b. Reef pseudoplankton in lagoon trophic systems. Proceedings, Second International Coral Reef Symposium, Brisbane. 1. Biology: 105-107.

Gilmartin, M. and N. Revelante. 1974. The "island mass effect" on the phytoplankton and primary production of the Hawaiian islands. J. Exp. Mar. Biol. Ecol. 16(2):181-204.

Highsmith, R.C. 1980. Geographic patterns of coral bioerosion: a productivity hypothesis. J. Exp. Mar. Biol. Ecol. 46(2-3):177-196.

Johannes, R.E. 1967. Ecology of organic aggregates in the vicinity of a coral reef. Limnol. and Oceanogr. 12(2):189-195.

Johannes, R.E. and R. Gerber. 1974. Import and export of net plankton by an Eniwetok Coral Reef Community. Proceedings, Second International Coral Reef Symposium, Brisbane 1:97-107.

Jones, E.C. 1962. Evidence of an island effect upon the standing crop of zooplankton near the Marquesas Islands, central Pacific. J. Cons. perm. int. Explor. Mer. 27(3):223-231.

Kohn, A.J. and P. Helfrich. 1957. Primary organic productivity of a Hawaiian coral reef. Limnol. and Oceanogr. 2:241-251.

Kropp, R.K. and C. Birkeland. 1982. Comparison of crustacean associates of Pocillopora verrucosa from a high island and an atoll. Proceedings, Fourth International Coral Reef Symposium, Manila 2:627-632.

Lewis, J.B. 1977. Processes of organic production on coral reefs. Biol. Rev. 52:305-347.

Lewis, J.B. 1982. Estimates of secondary production of reef corals. Proceedings, Fourth International Coral Reef Symposium, Manila 2:369-374.

Marsh, J.A., Jr. 1977. Terrestrial inputs of nitrogen and phosphorus on fringing reefs of Guam. Proceedings, Third International Coral Reef Symposium, Miami 1. Biology:331-336.

Marsh, J.S., Jr. and R.T. Tsuda. 1973. Population levels of Acanthaster planci in the Mariana and Caroline Islands 1969-1972. Atoll Res. Bull. 170:1-16.

McCloskey, L.R. and R.H. Chesher. 1971. Effects of man-made pollution on the dynamics of coral reefs. Pages 229-238. In J.W. Miller, J.G. Van DerWalker and R.A. Wallen (eds.), Scientists-in-the-Sea. TEKTITE II. U.S. Dept. Interior, Washington, D.C. 620 p.

Meyer, J.L., E.T. Schultz, and G.S. Helfman. 1983. Fish schools: an asset to corals. Science 220: 1047-1049.

Murty, A.V.S. and M.S. Edelman. 1966. On the relation between the intensity of the south-west monsoon and the oil-sardine fishery of India. Indian J. Fish. 13(1-2): 142-149.

Odum, H.T. and E.P. Odum. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecol. Monogr. 25:295-320.

Robertson, D.R. 1982. Fish feces as fish food on a Pacific coral reef. Mar. Ecol.-Progr. Series 7:253-265.

Sander, F. 1973. Internal waves as causative mechanisms of island mass effects. Carib. J. Sci. 13(3-4):179-182.

Sander, F. 1981. A preliminary assessment of the main causative mechanisms of the "island mass" effect of Barbados. Mar. Biol. 64:199-205.

Sargent, M.C. and T.S. Austin. 1949. Organic productivity of an atoll. Am. Geophys. Un. 30:245-249.

Scott, B.D. and H.R. Jitts. 1977. Photosynthesis of phytoplankton and zoonxanthellae on a coral reef. Mar. Biol. 41:307-315.

Schreiber, R.W. and E.A. Schreiber. 1983. Reproductive failure of marine birds on Christmas Islands, Fall 1982. Trop Ocean Atmosphere Newsletter, February 1983: 10-12.

Smith, D.F., N.C. Bulleid, R. Campbell, H.W. Higgins, F. Rowe, D.J. Transfer, an- H. Tranter. 1979. Marine food-web analysis: an experimental study of demersal zooplankton using isotopically labelled prey species. Mar. Biol. 54:49-59.

Smith, P.E. and R. Lasker. 1978. Position of larval fish in an ecosystem. Rapp. P.-V. Reun. Cons. Inst. Explor. Mer 173:77-84.

Sorokin, Y.I. 1973. Microbiological aspects of the productivity of coral reefs. Pages 17-45. In O.A. Jones and R. Endean (eds.), Biology and Geology of Coral Reefs II. Biology (1). Academic Press, New York.

Sournia, A. 1977. Analyse et bilan de la production primaire dans les récifs coralliens. Ann. Inst. océanogr., (Paris) 53(1):47-74.

Sournia, A. and M. Ricard. 1976a. Données sur l'hydrologie et la productivité du lagon d'un atoll fermé (Takapoto, Isles Tuamotu). Vie Milieu 26(2), ser. B:243-279.

Sournia, A. 1976b. Phytoplankton and its contribution to primary productivity in two coral reef areas of French Polynesia. J. Exp. Mar. Biol. Ecol. 21:129-140.

Stoddart, D.R. 1969. Ecology and morphology of recent coral reefs. Biol. Rev. 44:433-498.

Sutcliffe, W.H., Jr. 1972. Some relations of land drainage, nutrients, particulate material, and fish catch in two eastern Canadian bays. J. Fish. Res. Bd. Canada 29:357-362.

Sutcliffe, W.H., Jr. 1973. Correlations between seasonal river discharge and local landings of American lobster (Homarus americanus) and Atlantic halibut (Hippoglossus hippoglossus) in the Gulf of St. Lawrence. J. Fish. Res. Bd. Canada 30(6):856-859.

Tsuda, R.T. 1976. Occurrence of the genus Sargassum (Phaeophyta) on two Pacific atolls. Micronesica 12(2):279-282.

Tsuda, R.T. 1982. Seasonality in Micronesian seaweed population and their biogeography as affecting wild crop potential. Pages 27-31. In R.T. Tsuda and Y.-M. Chiang (eds.), Proceedings of Republic of China-United States Cooperative Science Seminar on Cultivation and Utilization of Economic Algae. Univ. Guam Marine Laboratory, Mangilao. 122 p.

4.2 The Island Mass Effect on the Sea Surface Chlorophyll Concentration in the Southwestern Tropical Pacific: Statistical Evidence (1)

by

Yves Dandonneau

(Centre ORSTOM, B.P. A5, Nouméa, New Caledonia)

ABSTRACT

The island mass effect is tested on 4845 sea surface chlorophyll concentrations, determined on samples taken randomly by merchant ships in the southwestern tropical Pacific. For each datum, the distance to the nearest island or bank has been estimated and the chlorophyll concentrations have been examined in relation to that distance. In the equatorial region, the chlorophyll content increases with the distance, due to sampling and to the dominant effect of the equatorial upwelling. The island mass effect is obvious in the other regions. It can be characterized by the negative slope (b) of the chlorophyll-distance relation. Thus, it appears that the island mass effect is weak around the Fiji islands (b= -.00006); it increases slightly between 8°S and 14°S (b = -.00009), and is stronger around New Caledonia and Vanuatu (b = -.00030).

The vertical mixing is generally considered one of the main causes of the island mass effect. This can be partly tested using 952 XBT profiles. The results seem to indicate that the islands and banks around New Caledonia and Vanuatu tend to temper the vertical structure of the 50 to 200m layer, thus favoring the vertical diffusion of the nutrients. By contrast, vertical structure is emphasized in the Fiji islands. These islands seem to trap water masses, although the main stream seems to flow around the archipelago. This hypothesis has to be confirmed by more data or more innovative experiments.

---

(1) This work is a provisional part of a larger study undertaken in collaboration with Loic Charpy, from the Centre ORSTOM de Papeete. The study will encompass the Central South Tropical Pacific. The author would appreciate being consulted before referring to this paper.

1. INTRODUCTION

The island mass effect on primary production has been observed by Doty and Oguri (1956). They noted a significant increase in the carbon fixation from offshore to inshore stations. Bennett and Schaefer (1960) and Jones (1962) confirmed the existence of this relation, but also described some transects where no enrichment clearly appeared when islands were approached. More intense field work led to a statistical demonstration by Gilmartin and Revelante (1974). However, the mechanisms of the observed enrichment remain obscure or, at least, their relative importance and quantitative effects have not yet been assessed.

On the other hand, the fact that tunas tend to congregate in schools around islands has long been reported. Certainly, it is a daily reality for fishermen. Blackburn (1965) and Sund et al.(1981) have pointed out the role of the islands, banks, and seamounts in concentrating these schools. They observed that an increase in the amount of food is not always the reason for this concentration. Sander (1981) examines the possible causes of the enrichment:

(1) the land drainage may be important if the island is large enough, or close to human concentrations or areas of intensive agriculture;

(2) a benthos-ocean interaction may release large amounts of nutrients into the ocean water, from excretion or remineralization;

(3) the thermocline can be affected and nutrients diffuse into the mixed layer if the island perturbs the current field and the internal wave propagation.

The island mass effect is examined here using measurements of chlorophyll concentration at the sea surface, from samples randomly taken by merchant ships (Programme SURTROPAC, Centre ORSTOM de Nouméa). The selected area is limited by 0°, 24°S and 160°E, 170°E, where many islands and archipelagos are present, and where the sampling density is high enough.

2. MATERIAL AND METHODS

2.1 Chlorophyll measurements

The filtrations (20 cm^3 of sea water on Millipore HA filters, 13 mm in diameter) are handled by the crews of merchant ships which cooperate in this program. After the filters are stored in a dark and dry place, the chlorophyll concentration is estimated according to the method of Dandonneau (1982): the filters are stuck on a glass plate and automatically scanned, using a thin layer chromatography door adapter to a Turner model 111 fluorometer. A calibration coefficient allows an estimation of the chlorophyll concentration in the water from the fluorescence of the filters' surface.

2.2 Determination of the distance to the closest island or bank

The southwestern tropical Pacific is especially rich in islands and banks (Figure 1). Since no complete computerized shoreline and banks positions are available (at least to our knowledge), the chart of the studied area has been summarized: a grid has been adopted, 12' x 12' in latitude and longitude, covering the whole area. The resulting matrix is 120 x 150, corresponding to 24°S - 0° and 160°E - 170°W. The matrix was first set to zero, and then all the grid elements, including a part of an island or a bank, were set to a distinct value.

The position of each chlorophyll datum corresponds to one element of the grid; if this element has a non-null value (i.e. an island or a bank), the distance of the closest island is null. Otherwise, the neighboring elements are tested in such a succession that the tested zone spreads as a stain, centered at the position of the data. When a non-null element is found, the process is stopped, and if Δi and Δj are the differences of the indices of the data position and the closest island position in the matrix, the distance in miles is $d \times \sqrt{\Delta i^2 + \Delta j^2} \times 12$.

This procedure gives rough results, especially for the short distances, since the positions of the islands and of the data are defined with a precision of about 12 miles. However, the island mass effects are carried by the currents, at speeds which may exceed the time scales of the effects. Our ignorance of the current field makes it illusory to examine the results with more precise distances. The distance computed here is only an index. The probability of observing an island mass effect increases when this index decreases.

3. RESULTS

Our main data set is composed of 4845 sea surface chlorophyll concentrations, measured in the area mapped on Figure 1. The position, date, and distance to the closest island on each one is indicated. On Figures 3 to 7, the abscissa axis has been divided according to distance categories which follow a logarithmic progression: less than

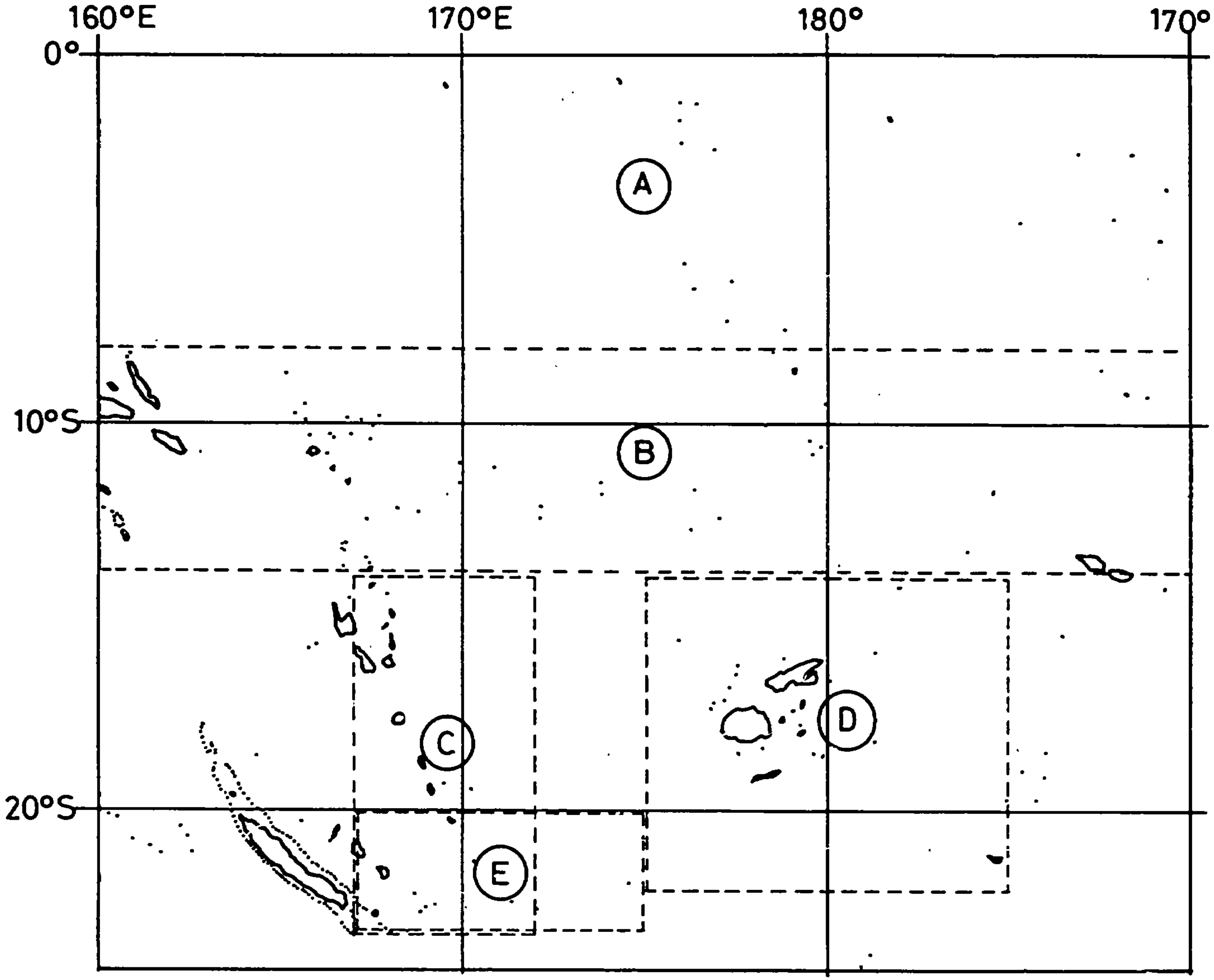


Figure 1 : Studied area and sub-areas

10 nautical miles, 10 to 20 miles, 20 to 41, 40 to 87, 87 to 182 and more than 182 miles. The mean chlorophyll concentrations (or mean vertical temperature gradient on Figures 6 and 7) for each distance category have been computed and plotted. The sea surface chlorophyll concentrations have a log-normal distribution (Figure 2). Most of the values are low in these tropical regions of the Pacific. Higher mean values generally mean more frequent occurrences of unusually high concentrations.

The risk of introducing a bias has been kept clearly in mind. Figure 3 (top) shows the mean chlorophyll concentrations for the different distance categories for the whole data set. These mean values decrease slightly with increasing distances up to 182 nautical miles. The mean value, however, for the observations made farther than 182 miles from any island or bank is surprisingly high. The data from the equatorial zone (8°S - 0°) exhibit high chlorophyll concentrations directly related to the distance to the nearest island (thus suggesting an "inverse island mass effect"!). More likely, the equatorial area is well known as an upwelling one. Since the effect of upwellings dominates that of islands, most of the variance here is due to the upwelling.

Another enrichment area has been shown in the very southern part,where the winter conditions favor the vertical mixing and induce higher chlorophyll concentrations at the sea surface (Dandonneau and Gohin, in preparation). Figure 5 shows the relation between the distance and the chlorophyll concentrations in zones C (New Caledonia - Vanuatu) and E (New Caledonia - Hunter island) in winter and in summer. The island mass effect is obvious at both seasons, thus confirming the overall impression given by Figure 4. The winter enrichment in the south does not seem to induce a bias in the results, and Figure 3, which accounts for winter and summer data, can be interpreted in terms of island mass effect.

Between 8°S and 14°S (zone B), the cholorophyll concentrations are low, and the effect of the distance is weak. Around Fiji, the concentrations are also low, but at less than 10 miles from islands or banks, the concentrations increase noticeably. Zones C and E look similar and the mean chlorophyll concentrations increase regularly when approaching the islands.

The 952 bathythermograms available in the same area allow a look at the thermocline and vertical stability. The mean temperature vertical gradient increases with the distance to islands or banks both in summer and in winter conditions. It is higher in summer, between 14°S and 23°S and 163°E and 172°W (Figure 6). The maximum temperature gradient does not vary markedly, but both in summer and winter, it increases close to the islands. Around Fiji (Figure 7), these relations are reversed: the mean temperature gradient varies over a wider range and is higher close to islands, while the maximum temperature gradient increases with the distance.

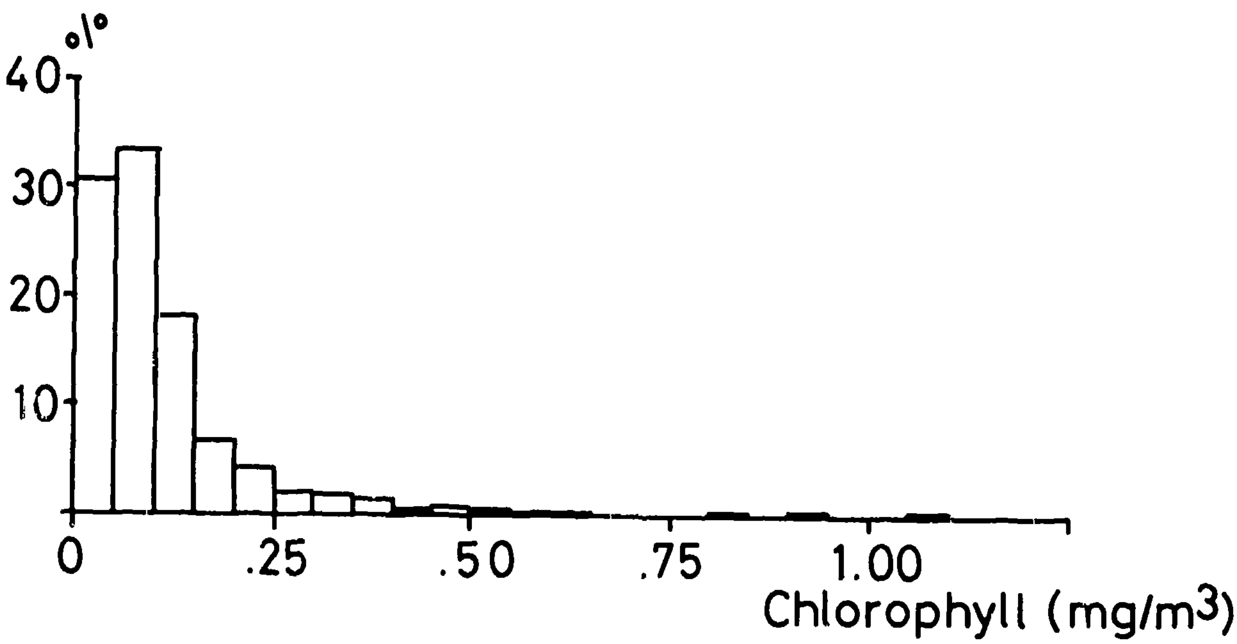
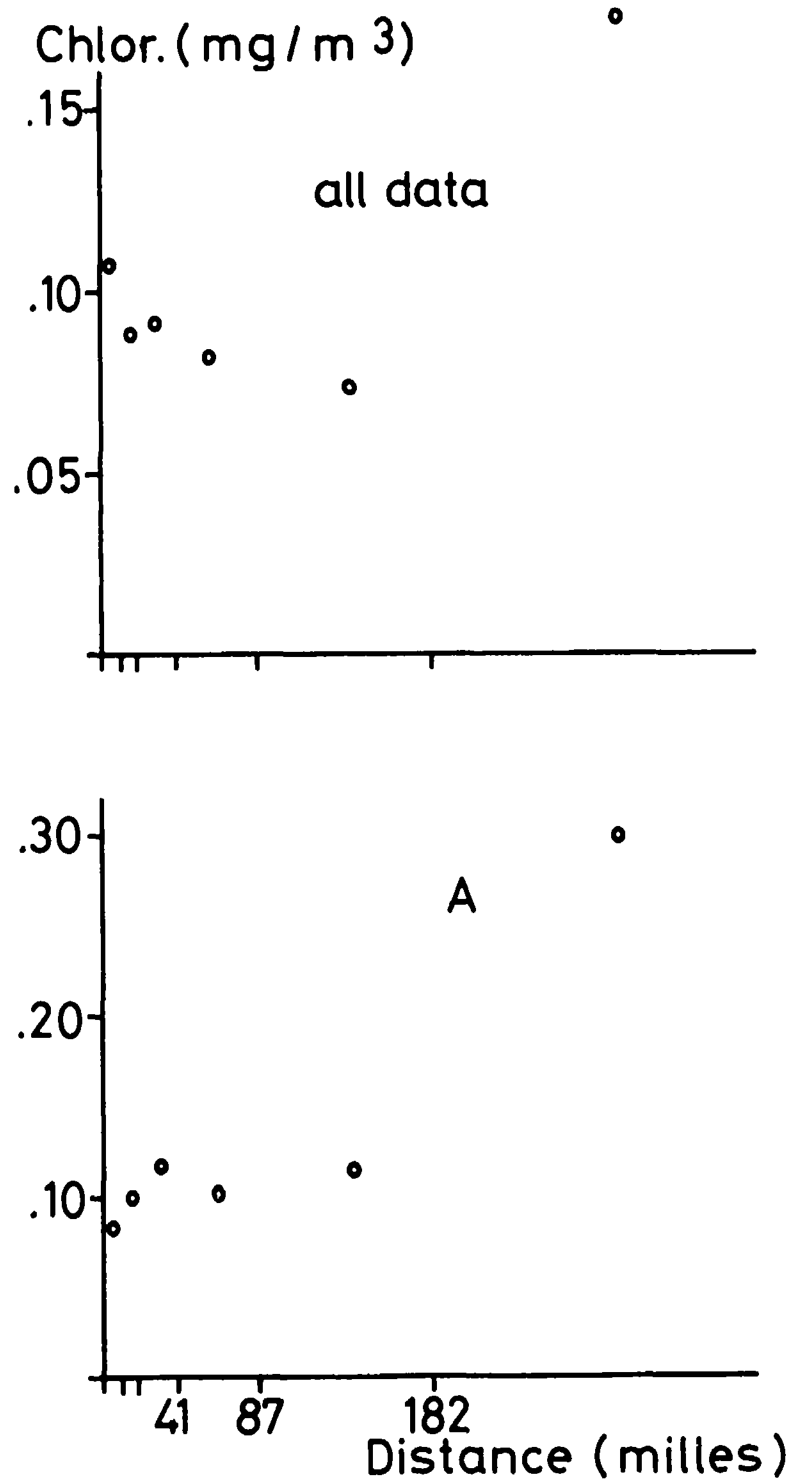


Figure 2: Distribution of the chlorophyll concentrations in zone B (New Caledonia - Vanuatu).

Figure 3: Mean sea surface chlorophyll concentrations at increasing distances, from the nearest island or bank. Top: all data (0° - 24°S, 160°E - 170°W); bottom: zone A (0° - 8°S, 160°E - 170°W).



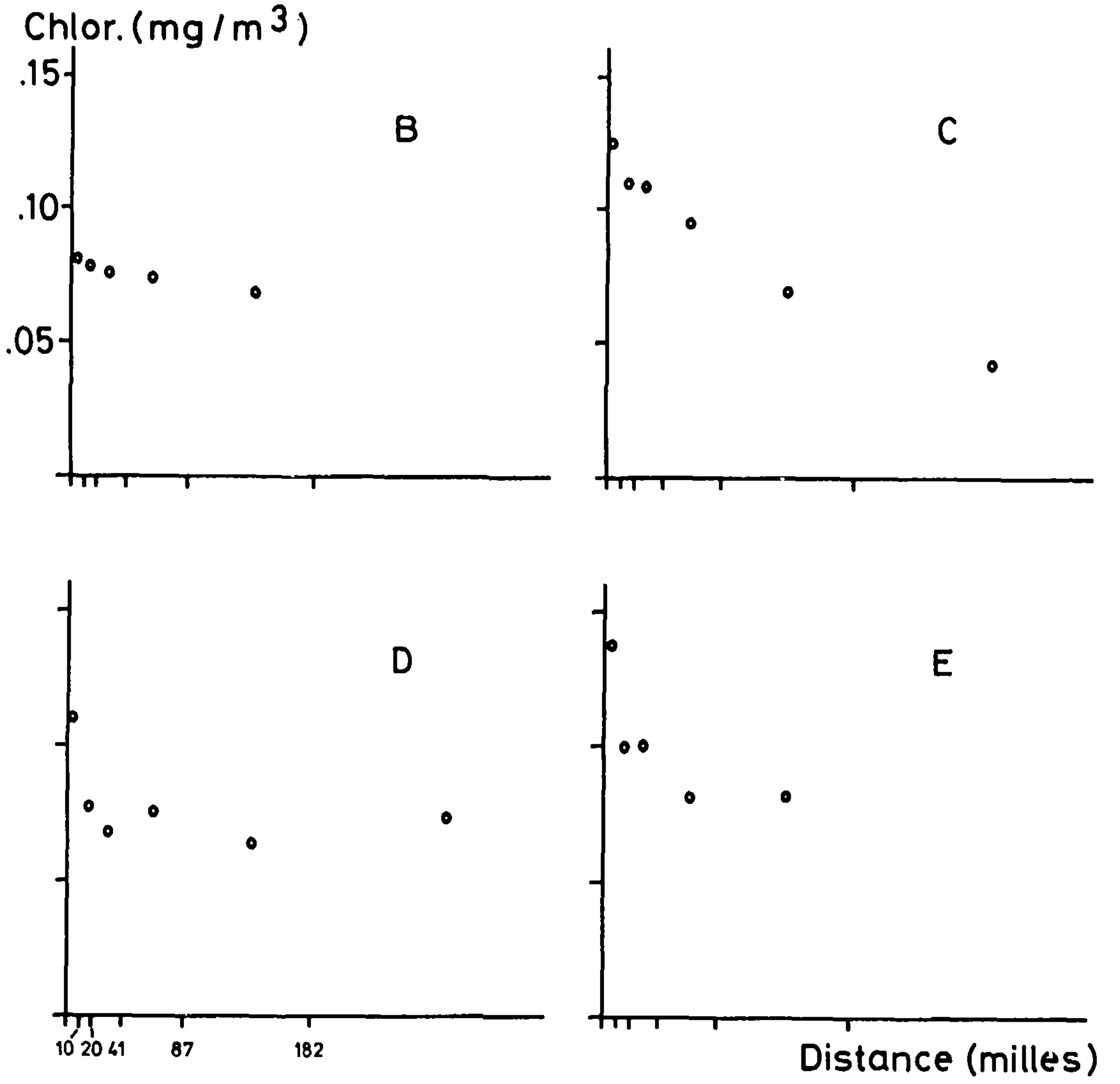


Figure 4 : Mean sea surface chlorophyll concentrations at increasing distances from the nearest island or bank.
Zone B : Y = .0787 - .00009 x (r = .96)
Zone C : Y = .1188 - .00030 x (r = .95)
Zone D : Y = .0829 - .00006 x (r = .39)
Zone E : Y = .1155 - .00032 x (r = .73)
(see figure 1 for the delimitation of the different zones).

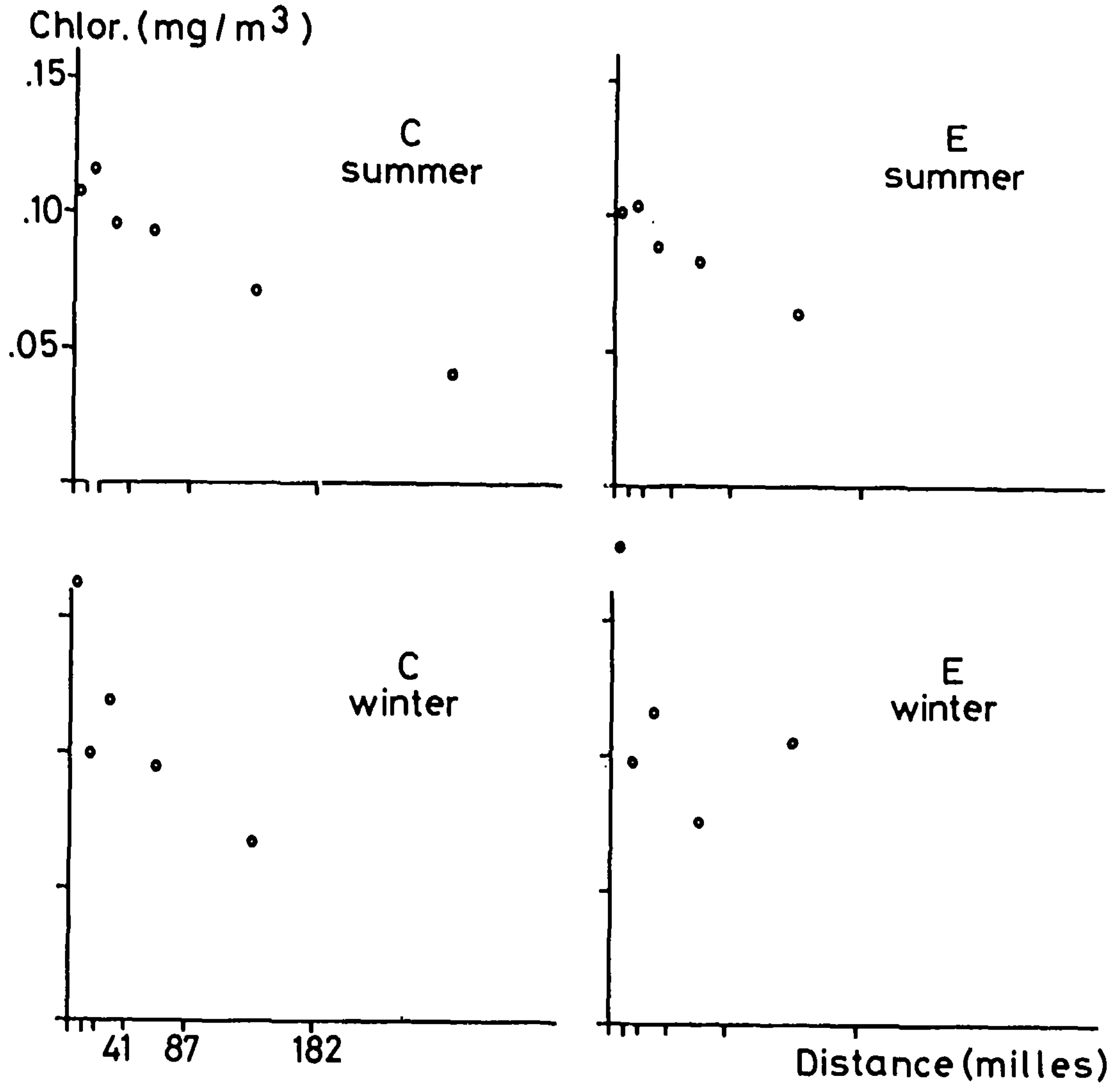
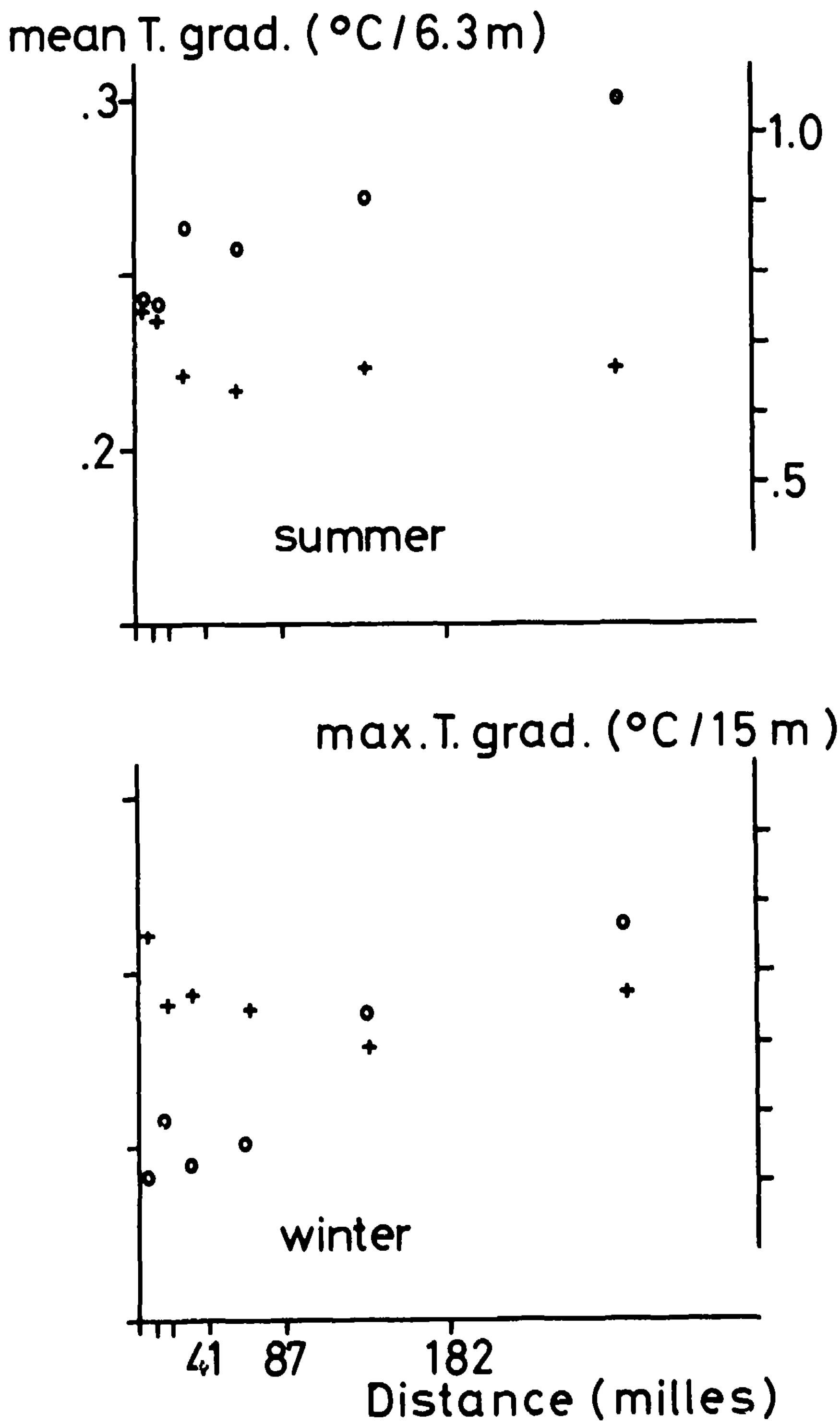


Figure 5 : Mean sea surface chlorophyll concentrations at increasing distances from the nearest island or bank. Winter (May to October) and summer (November to April) conditions in zones C and E (see figure 1).

Zone C (winter) : Y = .1354 - .00055 x (r = .81)
(summer) : Y = .1104 - .00026 x (r = .98)
Zone E (winter) : Y = .1296 - .00032 x (r = .44)
(summer) : Y = .1022 - .00030 x (r = .97)
(see figure 1 for the delimitation of zones C and E).

Figure 6: Vertical gradient of temperature at increasing distances from the nearest island or bank (o ; mean gradient between 50 and 200 m depth; + : maximum gradient over 15 m in the same layer). Data from the New Caledonia and Vanuatu area: 14° - 23°S, 163 - 172°E.



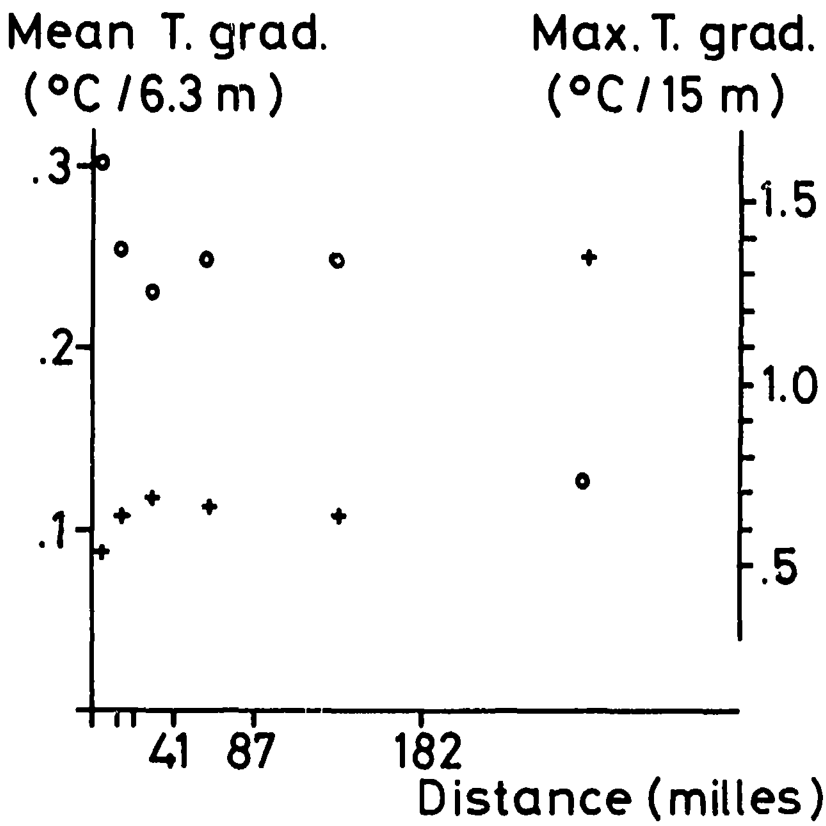


Figure 7: Vertical gradient of temperature at increasing distance from the nearest island or bank.
(o : mean gradient between 50 and 200 m depth;
+ : maximum gradient over 15 m in the same layer).
Data from the Fiji islands area : 14° - 22°S, 175°E - 175°W).

4. DISCUSSION AND CONCLUSION

The island mass effect is observed in all areas, except in the equatorial zone south to 80°S. There, the upwelling is responsible for most of the variations and completely hides other possible sources of enrichment. Chlorophyll concentrations at the sea surface alone are not enough to quantify the island mass effect, since they are only an aspect of the productivity of the whole euphotic layer. The relationships between the sea surface chlorophyll concentration and various other parameters (Dandonneau and Gohin, in preparation) are too vague for this purpose. However, it is interesting to note that the island mass effect is more obvious around New Caledonia and Vanuatu (Zones C and E) than around Fiji (Zone D), and than further north, between 8°S and 14°S (Zone B).

The available bathythermograms allow some hypothesis. The mean temperature gradient between 50 and 200 m depth decreases when approaching the islands around New Caledonia and Vanuatu (Figure 6). This leads to an argument for exchanges between the nutrient-rich deep waters and the homogenous surface layer. The mean temperature gradients around Fiji follow an opposite pattern, increasing when approaching the islands. Here, the islands possibly trap the water and restrain the currents, so that the turbulent mixing and the subsequent new production are reduced. By contrast, New Caledonia, Vanuatu, Santa Cruz and Solomon islands make up a more or less continuous archipelago through which the water masses must pass. Since the Fiji islands are isolated, they could be bypassed by the currents.

The physical processes called for heretofore can partly explain the observed island mass effect. We have no data to account for the other possible causes of the island mass effects (reviewed by Sanders, 1981). The land drainage may be a partial explanation of the higher chlorophyll concentrations very close to the Fiji islands, New Caledonia and Vanuatu (Figure 4). The ocean-benthos interactions cannot be considered ineffective. An interesting, but perhaps fortuitous, detail of this point is the slight decrease of the sea surface chlorophyll concentration at less than 10 miles from islands in summer (Figure 5): the cause could be an intense grazing by the reef benthos and associated populations.

In such a study, care must be taken to avoid all possible biases. The islands are not randomly distributed and the data have been sampled along the sea routes. Thus, biases might be introduced, in the form of a hidden relationship between the distance to the nearest island, and the latitude, for instance, so that our island mass effect would be nothing but a latitude effect. The partition into homogenous areas (Figure 1) was adopted for this reason. But a consequence of this is that the number of data is lowered in each zone. Therefore, the results tend to be less significant. However, it seems that the island mass effect is substantiated by this data set and is more efficient around New Caledonia and Vanuata than elsewhere in the region. These results must be confirmed by more data and more precise investigations into the difficult problem of vertical mixing. This study might also be improved by replacing the crude distance between the nearest island and the observation by an "index of insularity", taking into account more than one island. This is due to the fact that a group of islands may have a greater effect than one isolated island in an otherwise deserted oceanic area.

Acknowledgements

This work was possible thanks to the kind cooperation of the crews of 30 merchant ships who have regularly picked samples from the sea surface. I am also grateful to Jean-René Donguy, who was the initiator of the SURTROPAC program, and to Henri Walico, who insures the processing of the filters and the chlorophyll determinations.

REFERENCES

Bennet, E.B., M.B. Schaefer. 1960. Studies of physical, chemical, and biological oceanography in the vicinity of the Revilla Gigedo Islands during the "Island current survey" of 1957. Inter-Ameri. Trop. Tuna Comm., Bull., 4(5): 219-317.

Blackburn, N. 1965. Oceanography and the ecology of tunas. Oceanogr. Mar. Biol. Ann. Rev., 3: 299-322.

Dandonneau, Y. 1982. A method for the rapid determination of chlorophyll plus phaeopigments in samples collected by ships. Deep sea res., 29(5): 647-654.

Dandonneau, Y., F. Gohin. in preparation. An objective analysis of the latitude and time variations of the sea surface chlorophyll concentration around New Caledonia.

Doty, M.S., M. Oguri. 1956. The island mass effect. J. Cons. Int. Explor. Mer, 22(1): 33-37.

Gilmartin, M., N. Revelante. 1974. The "island mass" effect on the phytoplankton and primary production of the Hawaiian islands, J. exp. mar. biol. ecol., 16: 181-204.

Jones, E.C. 1962. Evidence of an Island effect upon the standing crop of zooplankton near the Marquesas Islands, Central Pacific. J. Cons. Int. Explor. Mer. 27(3): 223-231.

Sander, F. 1981. A preliminary assessment of the main causative mechanisms of the "Island mass effect" of Barbados. Mar. Biol. 64(2): 199-205.

Sund, P.N., M. Blackburn, F. Williams. 1981. Tunas and their environment in the Pacific ocean: a review. Oceanogr. Mar. Biol. Ann. Rev. 19: 443-512.

4.3 Remote Sensing of Oceanographic Parameters in the New Zealand Region

by

E.J. Barnes*

ABSTRACT

Current work involving the assessment of conditions adjacent to New Zealand by both oceanographic remote sensing methods and ground truth techniques are described. Patches of ocean having a large thermal contrast have been monitored by the use of the thermal infrared data from satellites and the results have been compared with circulation deduced by classical oceanographic methods.

Suggestions regarding the applicability of remote sensing methodologies to the determination of productivity patterns in the Pacific are made.

* New Zealand Institute of Oceanography
P.O. Box 12-346
Wellington North
NEW ZEALAND

1. INTRODUCTION

It is widely acknowledged that data from remote sensing sources have the potential to greatly improve our understanding of oceanographic processes, particularly the variability with time. The range of data products potentially available includes sea surface temperature from infrared sensors, ocean color from the Coastal Zone Color Scanner, sea surface elevation from radio altimeters and radar imagery, amongst others. Although we have not yet used remote sensing products to help assess productivity around Pacific islands, it has the considerable potential value of increasing understanding of a variety of relevant processes.

We would like to describe some on-going work in the New Zealand region before coming back to some of the types of data that could be collected in the future as part of an island productivity study. There have been tantalizing glimpses of the potential of oceanographic remote sensing around New Zealand(Fig.1). Landsat images give clues to the flow of the southland current along the Canterbury coast. However, the only information available to us on a regular basis, in the near term, is data from meteorological satellites.

Sea surface temperature pattern changes have been shown to be strongly correlated with changes in the surface current field by overseas workers, and our studies confirm this. Our philosophy in entering this field has been to monitor, via the remote sensing products, a patch of the ocean within which we know there is a large thermal contrast and where we have, or think we have, a reasonable understanding of the circulation based on classical methods. We have been specifically monitoring the variability in the temperature field off the east coast of New Zealand, by the use of thermal infrared data from satellites.

2. GROUND TRUTH

Circulation of surface water associated with the East Cape Current and the cooler Southland Current is of interest (Fig.2). The East Cape Current is that part of the East Auckland Current which does not turn north near East Cape. The Southland Current is the combined flow of subtropical water moving eastward around the south of the South Island and then north up to the East Coast, together with the subantarctic water flowing northeast on the continental slope. The temperature gradient across the boundary of these two water masses forms the subtropical convergence, the boundary of which is often very distinct in cloud cover imagery (Figure 3).

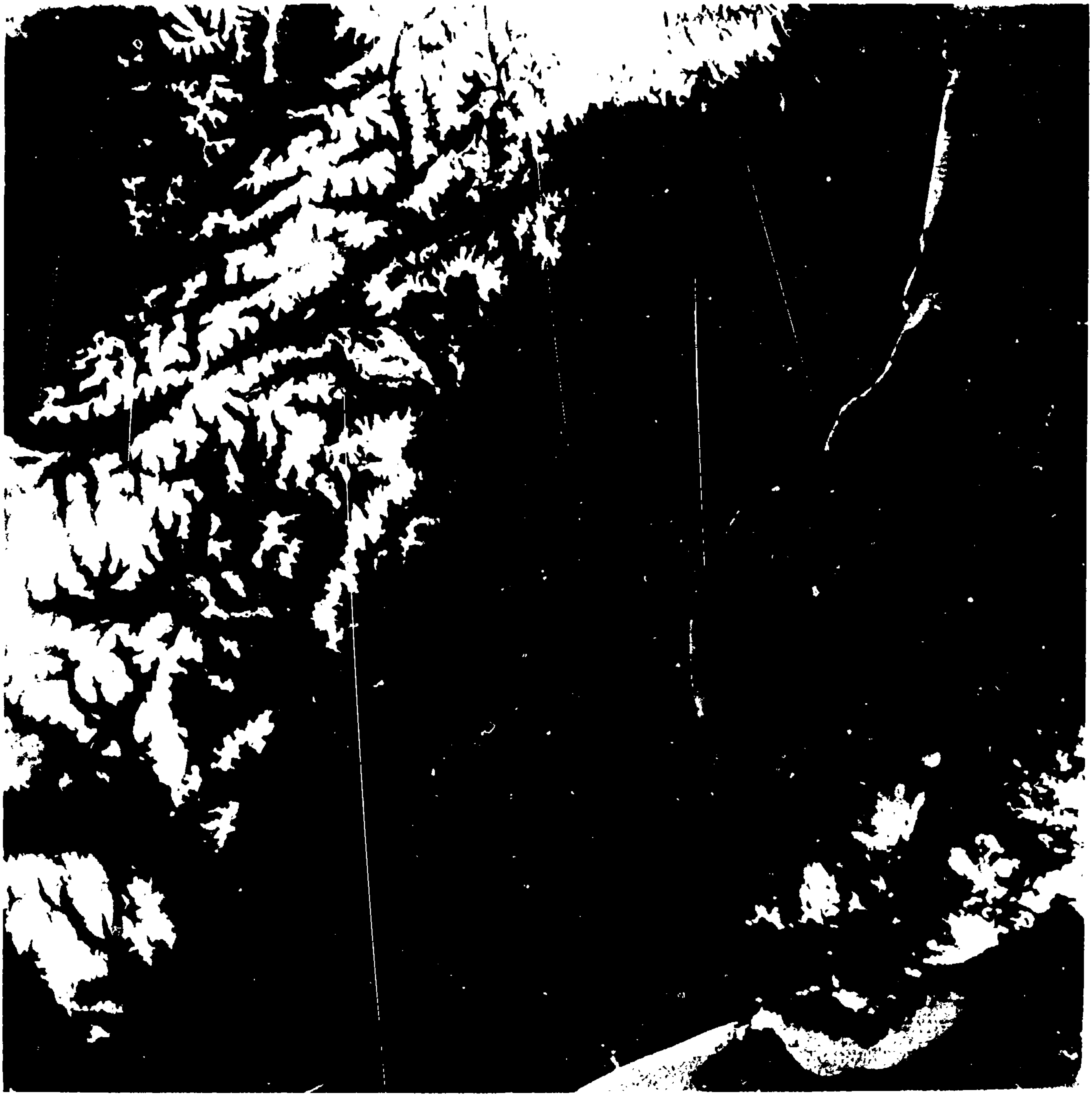


Figure 1 : Landsat image showing river outflow, East Coast, South Island.

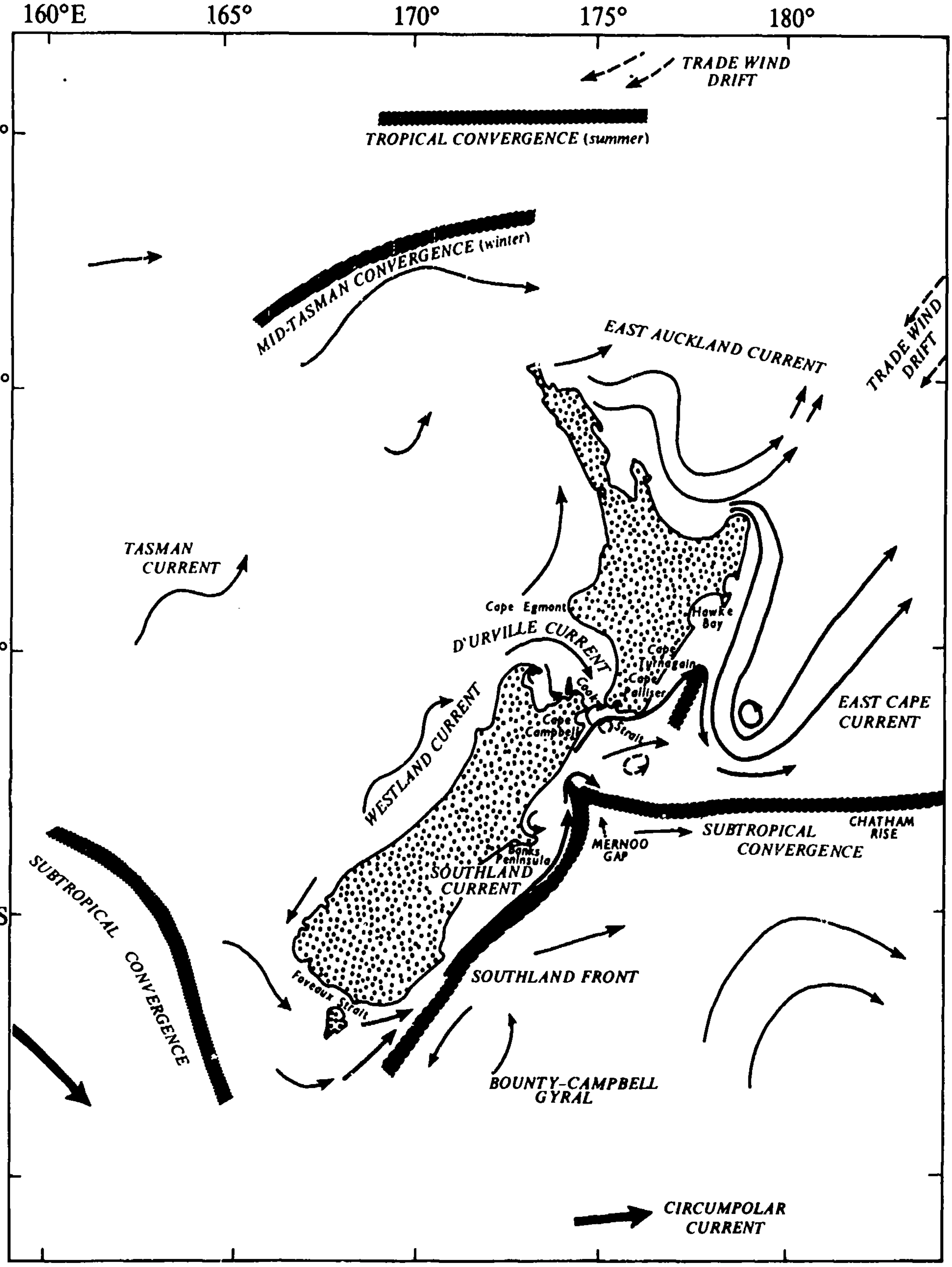


Figure 2 : Ocean currents around New Zealand as shown by Heath (1973).

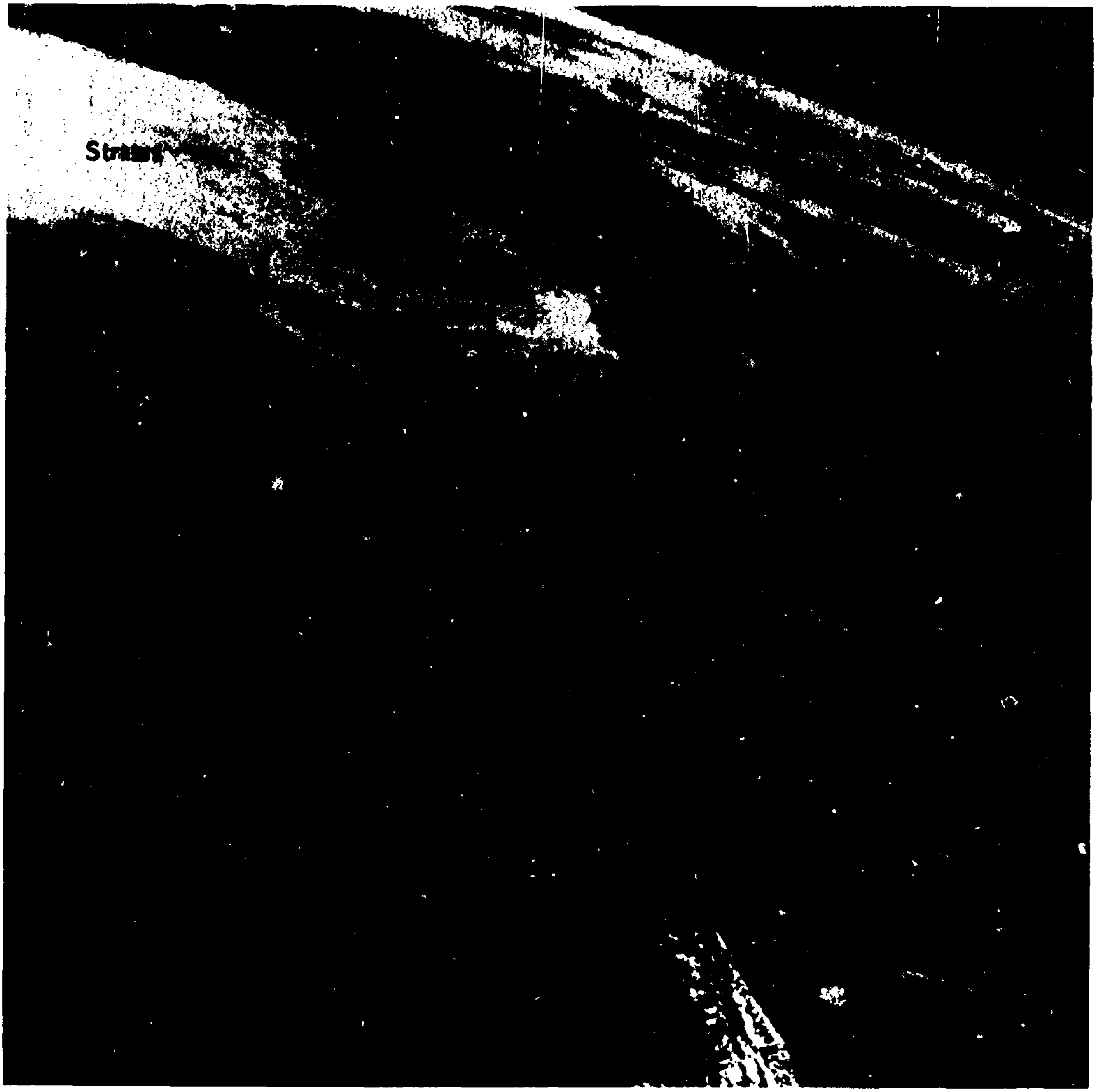


Figure 3 : New Zealand region cloud cover
showing demarcation of convergence.

The Southland Current branches near Kaikoura. One component meanders toward the east, while the other component travels northward on the Continental Shelf and slope, sweeping across the southern end of Cook Strait. Warmer water of the D'Urville Current flowing through Cook Strait combines with Southland Current water, along with some of the East Cape Current water off Cape Paliser. The combined water can loop as far as Cape Turnagain, before being caught up in a permanent eddy system that exists off the Wairarapa Coast and subsequently moving off the Northeast.

3. SATELLITE SEA SURFACE TEMPERATURE DATA

Sea surface temperature has been measured traditionally from surface ships of opportunity or from oceanographic cruises dedicated to physical oceanography. Surface temperature variability in thermograph profiles down the east coast of New Zealand is shown in Figure 4.

With the advent of satellite radiometers with good sea surface temperature resolution, such as NOAA 6 and 7, much improved spatial and temporal coverage is available. These satellites carry a scanning radiometer that has five bands, two of which are sensitive at a wavelength of eleven and twelve micrometers in the thermal infrared. The spatial resolution per pixel is 1.1 km at the sub satellite point and the thermal resolution is 0.1 degree C. However, the standard product available from meterologic sources is an image of New Zealand at a scale of 1 : 4,000,000 approximately, which has the temperature scale rounded to 1 degree C steps. Thus, the resolution has been degraded both spatially and thermally where much data of oceanographic value has been lost. If the full resolution is used, imagery which apparently accurately indicates surface current flow can be obtained. Examples of standard and enhanced products are listed in Table 1 and shown in Fig. 5, 6, 7, and 8.

4. COMPARISON OF SATELLITE IMAGES WITH PUBLISHED CIRCULATION DATA

Heath (1975) concluded that there was a large anti-cyclonic eddy at the head of the Hikurangi Trench at 41 degrees south, 179 degrees east, with a secondary eddy at 42 degrees, 30 minutes, 175 degrees, 30 minutes east, based on geotrophic flow. A salinity plot along the axis of the East Cape Current System indicates these two features (Fig. 9). These data were collected in March 1969. However, the dominant feature of the sea surface temperature imagery collected between March 1982 and January 1983 is an eddy centered at 42 degrees south, k76 degrees east. This appears to be a permanent feature, bathymetrically trapped and is apparently Heath's secondary feature. His main eddy does not appear in any sample.

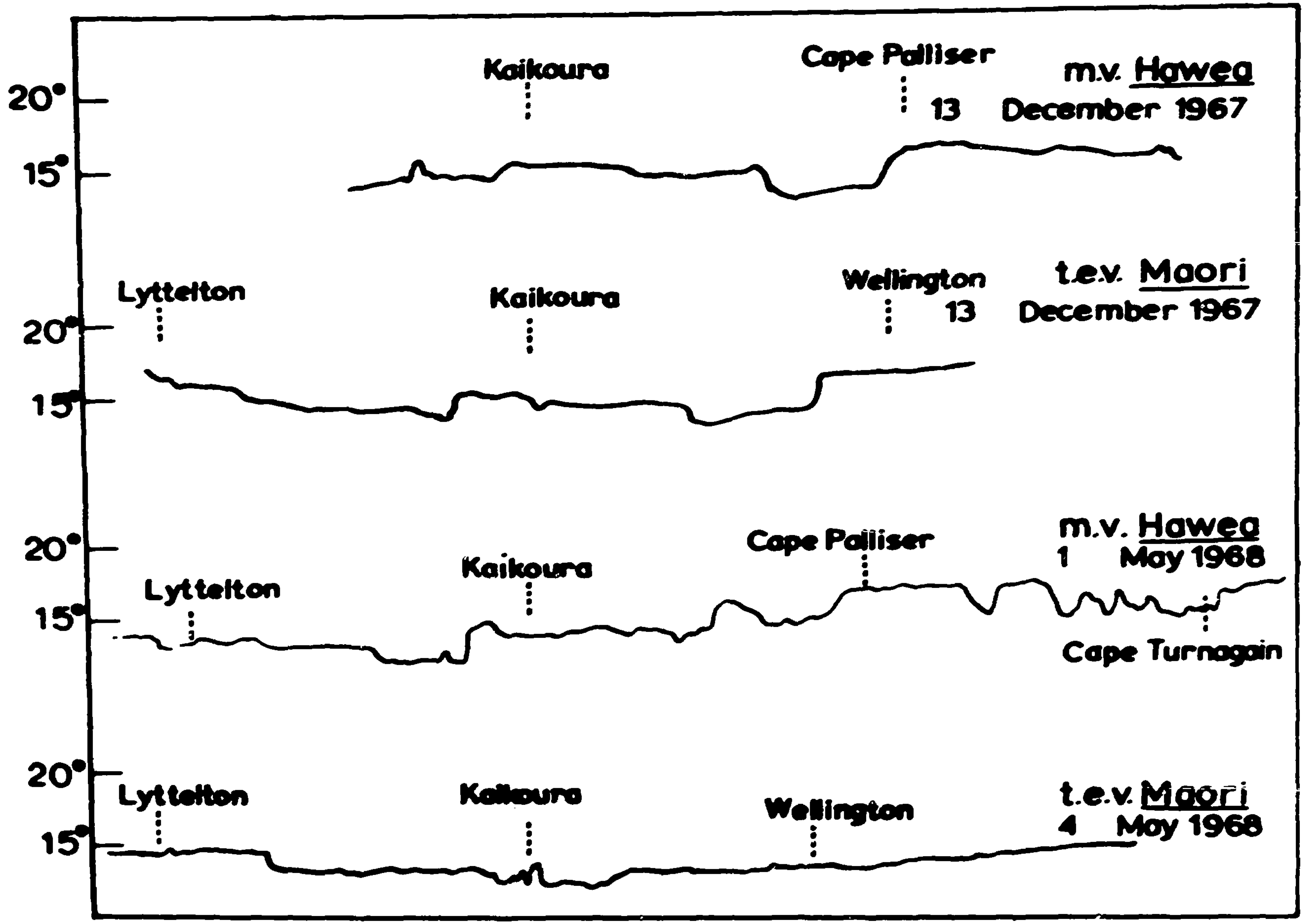


Figure 4 : Thermograph recording down east coast, N.Z.

Table 1

REMOTE SENSING COVERAGE OF SEA SURFACE TEMPERATURE IN NEW ZEALAND REGION

Data Source: NOAA Satellites	11 μm band, AVHRR sensor
Data Collection Agency:	N.Z. Meteorological Service, Wellington
Standard Products:	(1) Daily SST image NZMS area 733 1°C resolution
	(2) 5 Day composite 8 x 8 pixel, 1°C resolution. Area 733 (see fig. 5)
	(3) Weekly SST analysis Area 733
Special Products: by arrangement with NZMS	(1) Raw data on computer compilible tape
	(2) Selected areas of New Zealand region
Special Products by arrangement with D.S.I.R.	(1) Various enhancements of the raw data
	(2) Color coded products

Figure 5 : Sea Surface Temperature, Weekly mosaic.

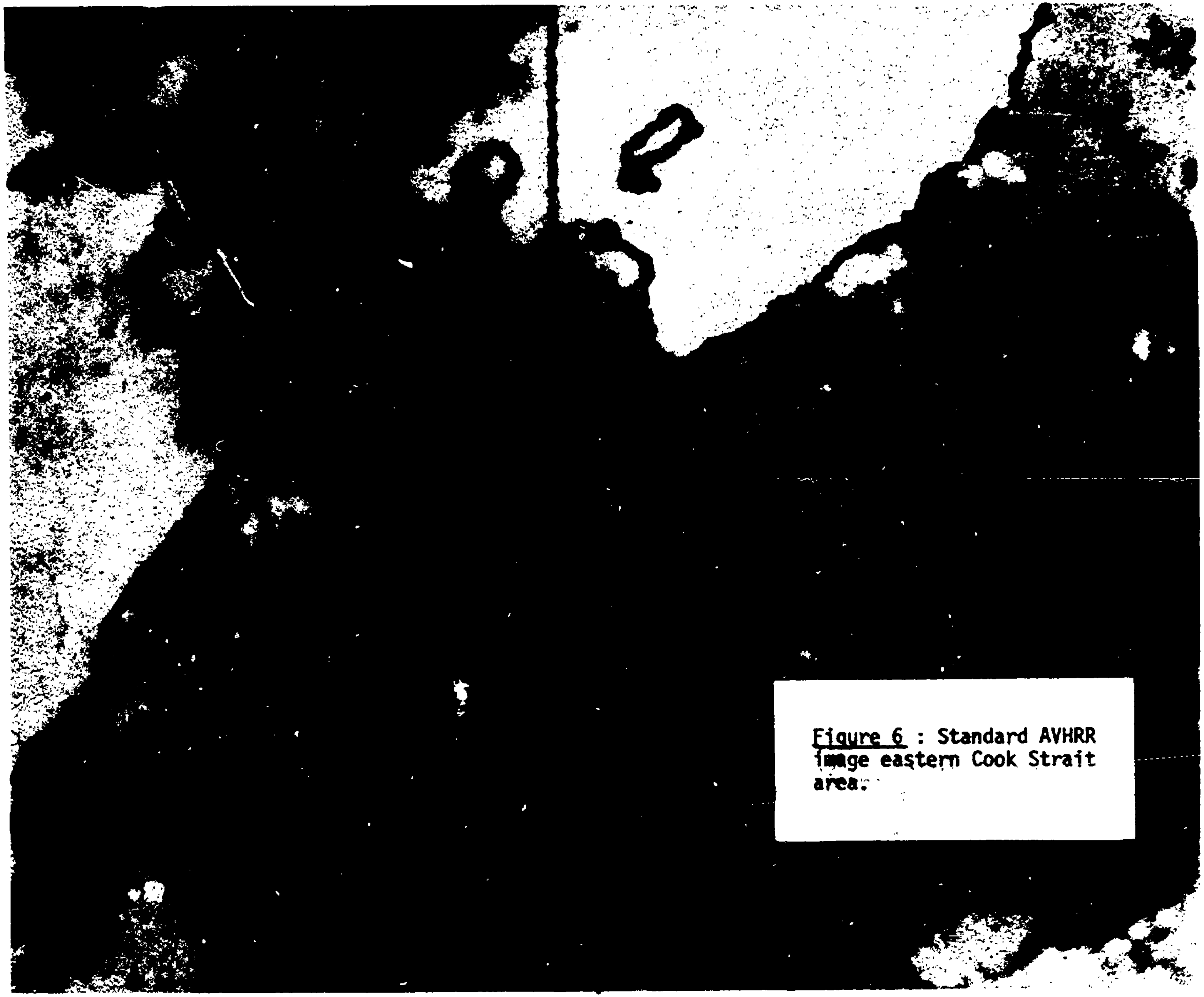


Figure 6 : Standard AVHRR image eastern Cook Strait area.

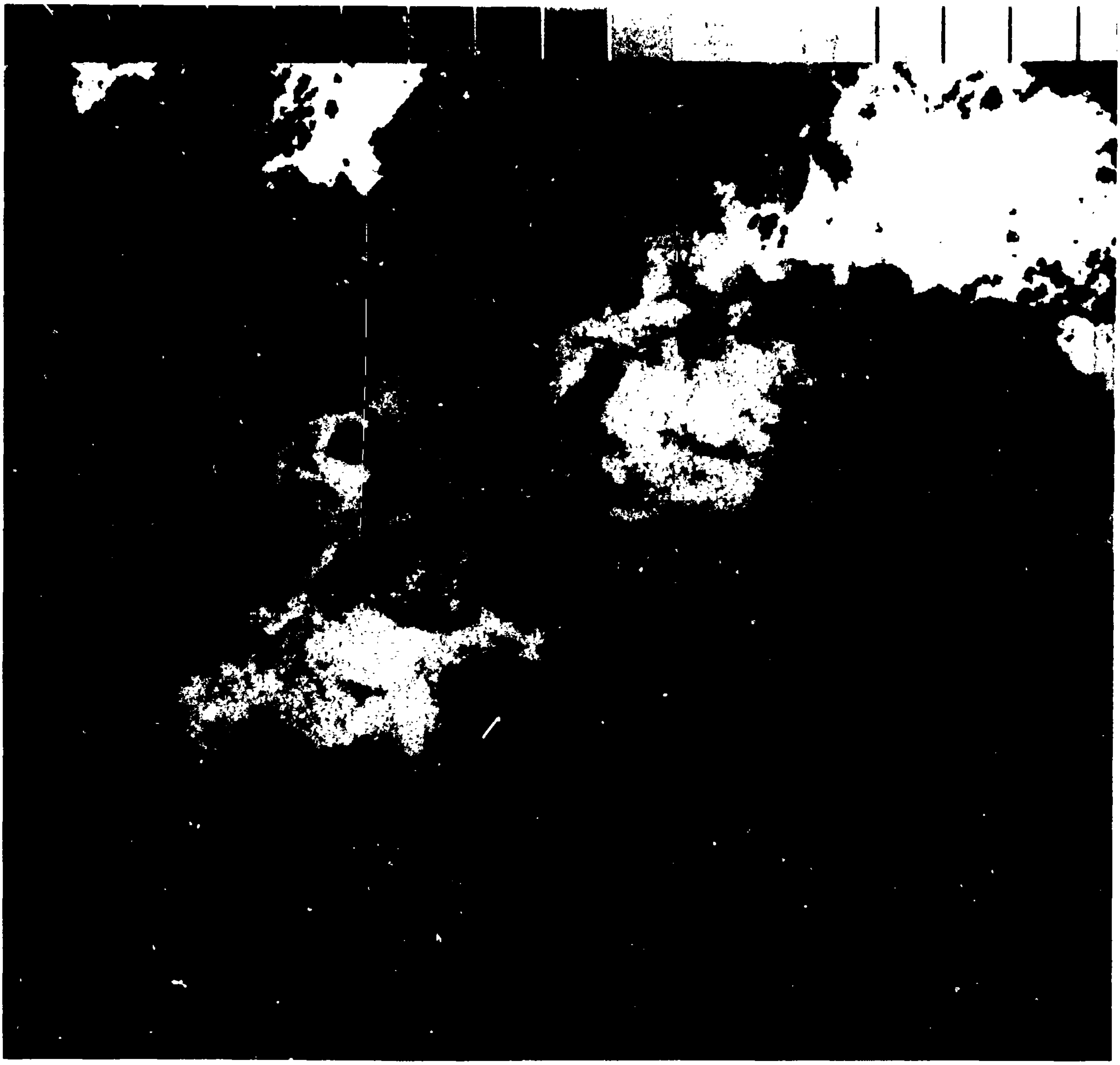


Figure 7 : Enhanced AVHRR image eastern Cook Strait area.

Figure 8 : Enhanced and color coded Cook Strait area.

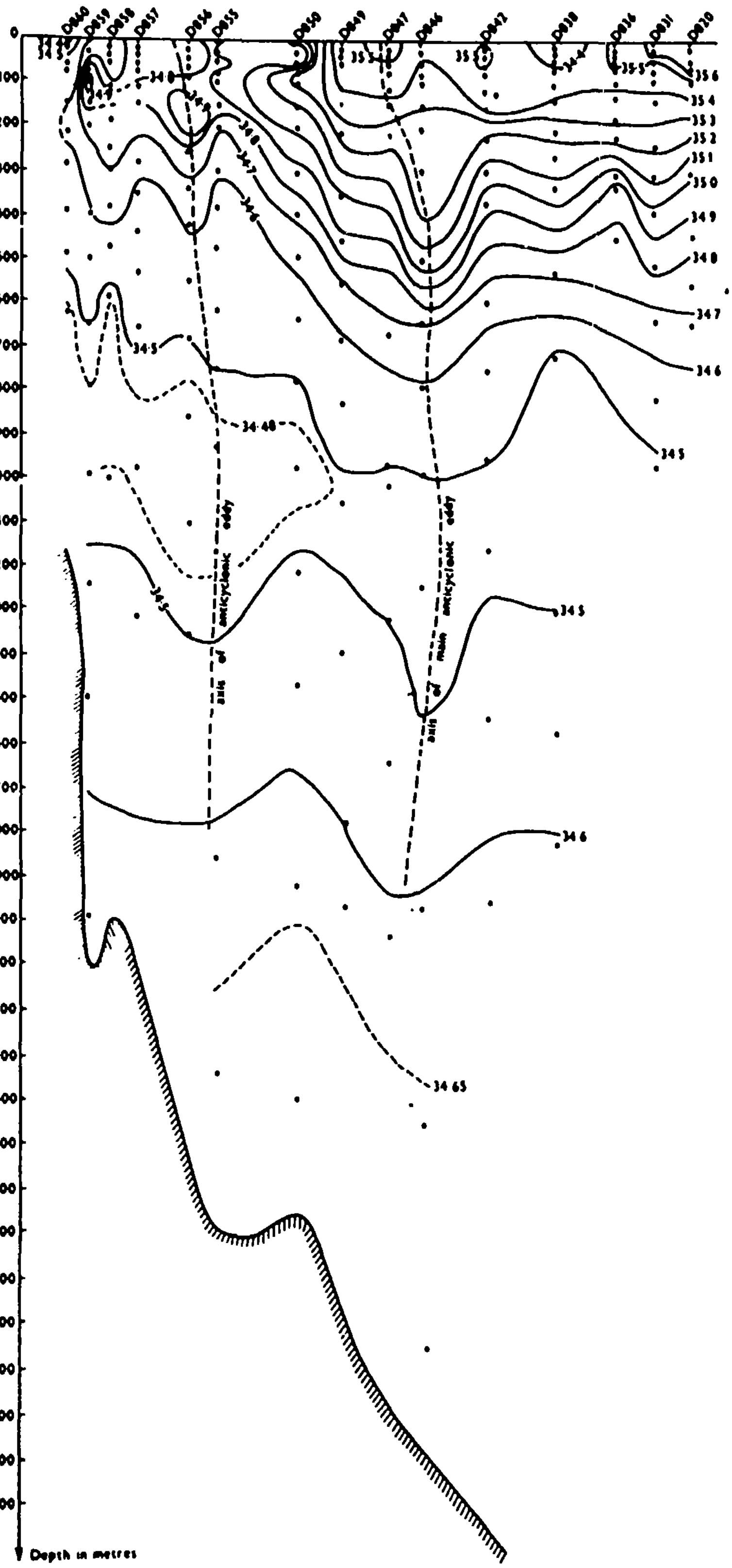


Figure 9 : Salinity profile, East Cape Current System

as an obvious feature in the 1982 imagery. The warm tongue of East Cape Current water, however, is generally plainly visible.

On the basis of the satellite pictures we have to date, the 42 degrees, south eddy is quite stable in position. From April 1981 to the present, the center has stayed within 40 km of 42 degrees. 10 minutes, 175 degrees, 50 minutes. It is normally the largest signal present, with up to 2 degrees C temperature change across its boundary at times, over a distance of approximately 20 km. An average value from the diameter of the Central 1 degree C disc is 70 km. By contrast, Heath's main eddy has never been an obvious feature on any of the low resolution data. It is probable, however, that it does exist as a stable feature. When high resolution data is available further to the north, it will become more apparent.

The temperature contrasts within the Southern Loop of the East Cape Current are much less than the eastern Cook Strait region. To the southwest of the 42 degree eddy of the Kaikoura Coast, a clockwise flow is apparent. Some surface water is circulated rather than rejoining the easterly flow. Along this boundary, the instability produced by opposing current flows is readily apparent in the high resolution imagery. Repeated daily sampling of a kilometer and 1 degree C by remote sensing is an effective way to study dynamic boundary effects.

By reference to the satellite images, it is readily understandable how the variability of surface temperature reported by various workers off the Kaikoura coast could occur. Heath attributed the reported 50 to 55 day temperature modulation observed in this area (which is stronger in winter than in summer) to the seasonable position change of the tongue of the East Cape Current water and its effects on shed eddys, which are guided more or less actively to the southwest.

The presence, however, of a potentially stable well-defined eddy at 42 degrees south suggests the situation is somewhat more complicated. The amount of recirculation of Southland Current water and the degree of pickup of East Cape Current water is quite variable. It is, no doubt, influenced by atmospheric forcing and tidal modulation in Cook Strait as well. Further work with satellite track buoys and imagery should elucidate the situation. It should also provide some insight into how well the surface temperature expresses the subsurface flow.

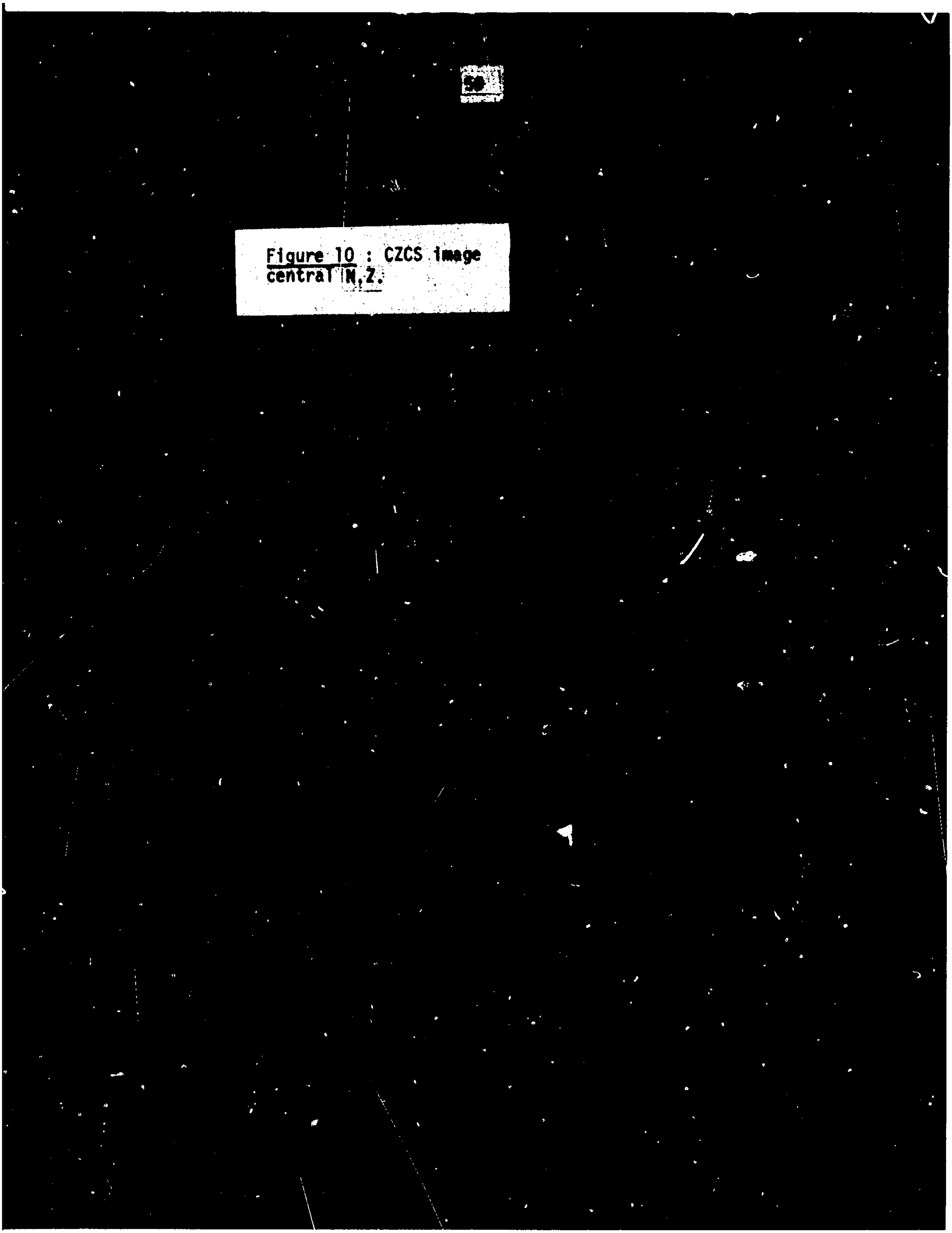


Figure 10 : CZCS image central N.Z.

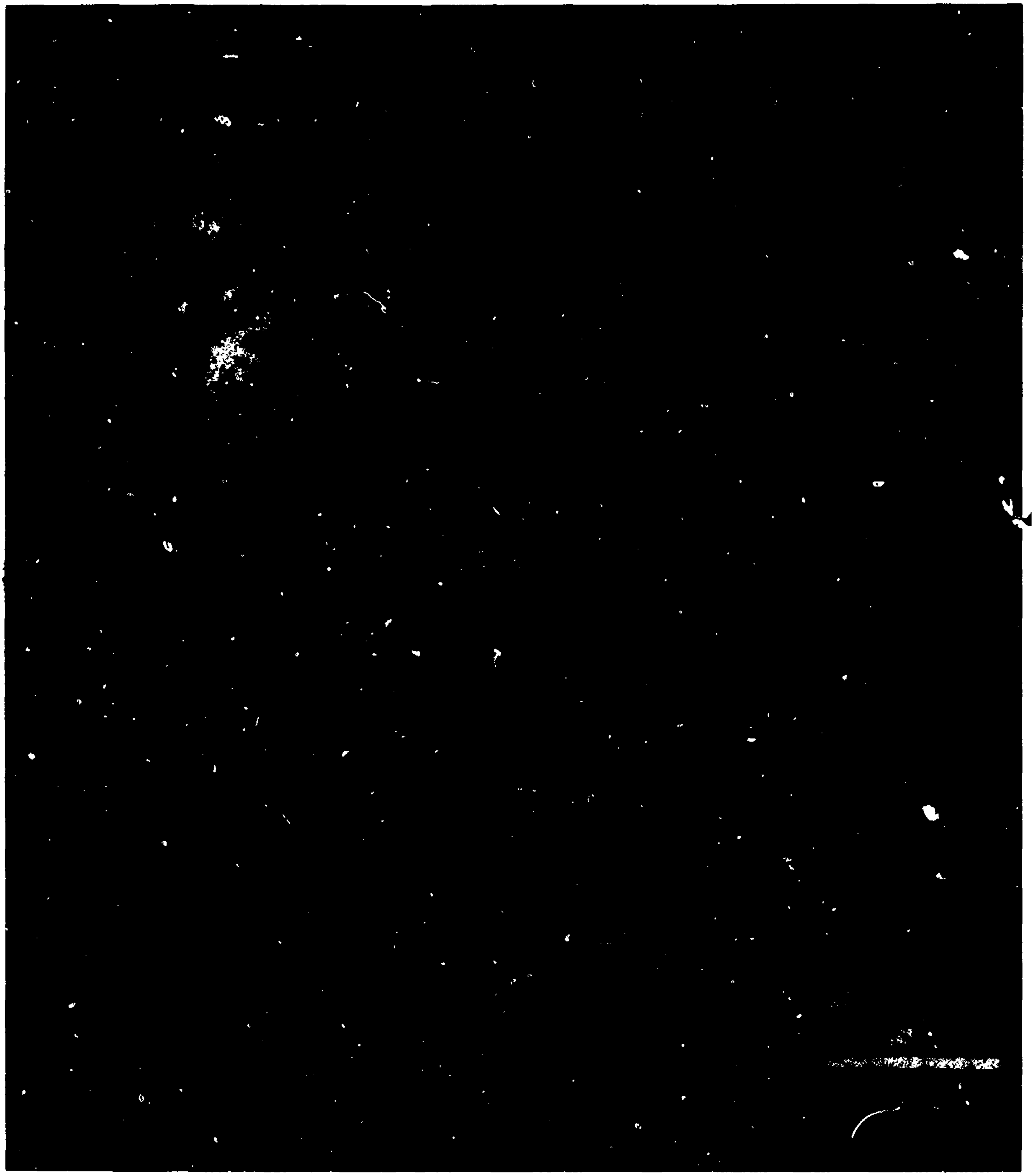


Figure 11 : Lau Group Landsat image.

5. CONCLUSION

It is becoming apparent to us that fine-scale sea surface temperature imagery is a useful tool in understanding surface current circulation. Also available at times are scenes from the Coastal Zone Color Scanner. This sensor has the potential to measure chlorophyll-a in surface waters to an accuracy of 30 percent, by measuring differentially absorption of a number of narrow visible wave lengths.

Observation of the Cook Strait region, carried out in July 1979, showed that the eddy at 42 south was, on this occasion, as far to the west as it has been observed (Figure 10). This observation would suggest that this eddy can pull streamers of chlorophyll-rich water around its western boundary. The sea surface temperature data from the image obtained at this time concur with later NOAA imagery. Because no ground truth is available for this area, it is difficult to interpret Chlorophyll-a values.

Pacific islands that have large lagoons would be an ideal target for remote sensing imagery of the Coastal Zone Color Scanner type. The contrast in chlorophyll-a levels between the lagoons and the open ocean should be readily measured as it would be over seamounts in the region. We are actively pursuing the problems of atmospheric correction for CZCS at the present time. We expect to have data coincident with a cruise off the northwest of the South Island, which will be measuring Chlorophyll-a distribution in April 1983.

The thermal infrared sea surface temperature could be used in the same way as described to observe current flows both in large lagoons and around islands. Another available product is imagery suitable for the mapping of coral reefs. Part of the Lau Group from a Landsat scene is shown in Figure 11. Although little use of remote sensing imagery seems to have been made of the Pacific islands, we feel we are close to the stage where we will be able to utilize any data we can obtain.

REFERENCE

Heath, R. (1975) Oceanographic circulation off the East Coast of New Zealand. Memoir of the New Zealand Oceanographic Institute 55E

Bibliography

Caroll, W. 1982. The NOAA satellite series. Applications of Environmental Satellites. CSIRO.

Heath, R.A. 1972. "Wind Derived Water Motions off the East Coast of N.Z." N.Z. Journal of Marine and Fresh Water Research, Vol. 6, No. 3.

Horis, W.A., et al. 1980. Nimbus-7 Coastal Zone Color Scanner: System Description and Initial Imagery. Science, Vol. 210, No. 3.

Garner, D.M. 1959. "The Subtropical Convergence in N.Z. Surface Waters". N.Z. J. Geol. Geophys. 2: 315-337.

Garner, D.M. 1961. "Hydrology of N.Z. Coastal Waters, 1955". N.Z.O.I. Memoir No. 8.

McDonnell, M.J. and D. Pairman. 1982. "PEL Image Processing Capability - Sea Demonstration" Physics and Engineering Laboratory Report No. 817.

4.4 Abundances of Herbivorous Fishes and Measures of Food Availability Across the Continental Shelf in the Central Great Barrier Reef Region.

by

G. Russ*

ABSTRACT

There are significantly higher abundances of herbivorous grazing fishes on coral reefs on the mid-and outer continental shelf (respectively 50 and 100 km from the coast) than on reefs inshore (10 km from the coast) in the central region of the Great Barrier Reef. Field experiments designed to measure standing crop and productivity of turf algae, together with yield to grazing fishes on an inshore, a midshelf and an outershelf reef are described and preliminary results presented. The data indicate a broad correlation between the availability of turf algae and the abundance of herbivorous fishes. It is suggested that the availability of food may be an ultimate factor influencing the cross-shelf distribution of herbivorous fishes.

* Australian Institute of Marine Science
PMB No. 3
Townsville M.S.O.
Qld 4810
AUSTRALIA

1. INTRODUCTION

Survey work carried out at the Australian Institute of Marine Science (AIMS) has established that a very distinctive pattern of distribution and abundance of coral reef fishes exists across the continental shelf in the central region of the Great Barrier Reef (Williams, 1982; Williams and Hatcher, 1983; Russ, unpublished data). This pattern includes distinctive changes in species composition, species diversity and trophic structure across the shelf. The next phase of this work involves monitoring programs and field experiments designed to determine what causes or, at least, maintains the pattern observed. The two main areas of investigation are studies of recruitment of fishes and food availability to fishes.

One of the major cross-shelf trends in the abundance of trophic categories is a significant increase in the outer-shelf reefs (Williams and Hatcher, 1983; Russ, unpublished data). This paper provides information on the cross-shelf patterns of abundance of herbivorous fishes and some preliminary results of experiments designed to measure food availability in the form of standing crop and productivity of turf algae) to these fishes, together with yield of algae to grazing fishes, across the Continental Shelf.

2. STUDY SITES AND METHODS

The study was carried out in the central region of the Great Barrier Reef, off Townsville, Queensland (Figure 1). Data on abundances of herbivorous fishes are taken from collections made by Williams and Hatcher (1983), using explosives on the windward reef slopes of the inshore reef, approximately 10 km from the coast (Pandora), one mid-shelf reef, approximately 50 km from the coast (Rib) and one outershelf reef, approximately 100 km from the coast (Myrmidon) (see Figure 1). This information is supplemented by a visual census survey of the three major families of large, herbivorous grazing fishes (Acanthuridaed, Scaridae, Siganidae) on two inshore reefs (Pandora, Phillips), and in each of 5 zones of 3 mid-shelf reefs (Rib, John Brewer and Lodestone) and 3 outershelf reefs (Myrmidon, Dip, Bowl) which will be detailed elsewhere. The gross morphology and environment of these study reefs has been summarized by Done (1982). In general, the inshore reefs are small, relative to mid- and outershelf reefs, and are characterized by high turbidity and relatively low exposure to wave action.

Figure 1 Location of Pandora (inshore), Rib (mid-shelf) and Myrmidon (outershelf) reefs in the central region of the Great Barrier Reef off Townsville, Queensland, Australia.

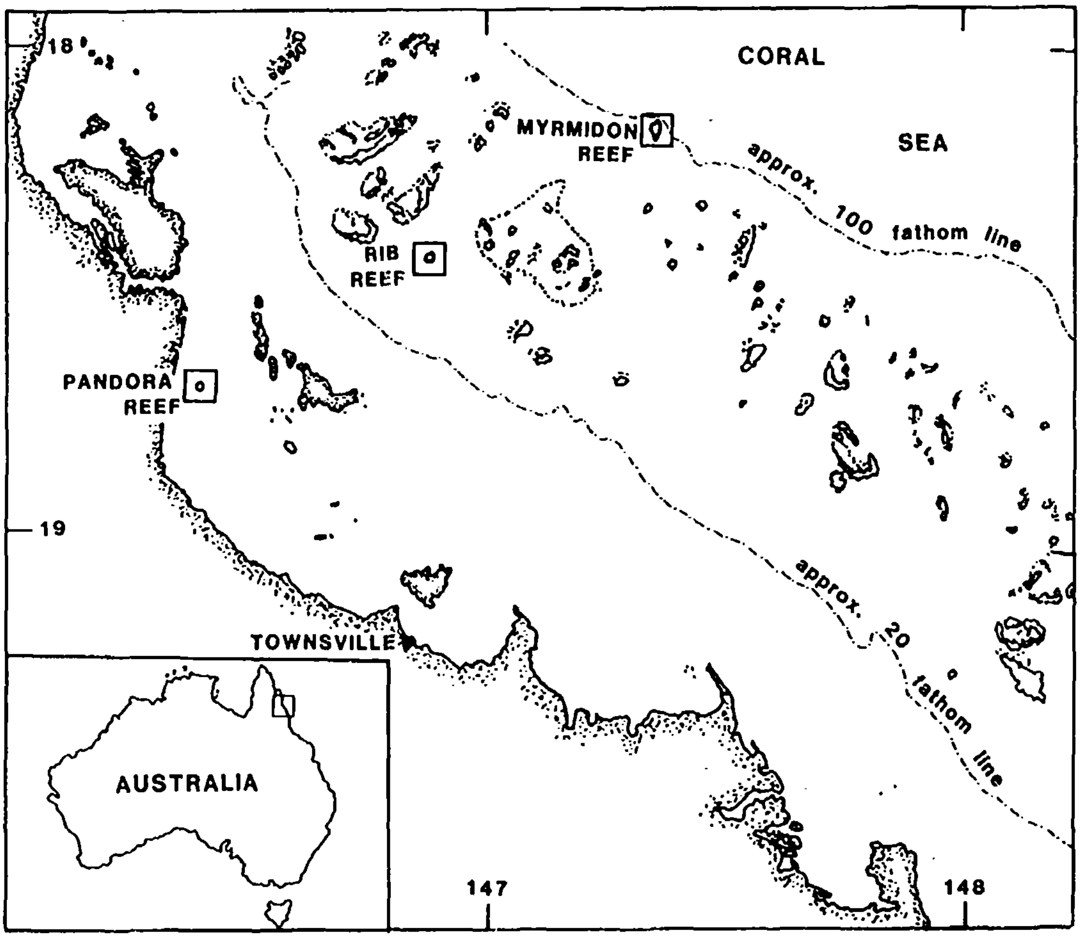
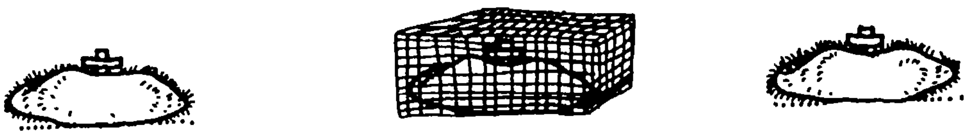


Figure 2 Summary of experimental design to measure standing crop and productivity of turf algae and yield of algae to herbivorous grazing fishes. Dead *Porites* (approximately 15 cm in diameter) were immersed as settlement surfaces for algae.

TREATMENT A — TREATMENT B — TREATMENT C



4 MONTHS UNCAGED — 4 MONTHS UNCAGED, 1 MONTH CAGED — 5 MONTHS UNCAGED

1. TURF ALGAE SCRAPED FROM BLOCKS.
2. ASH FREE DRY WT.
3. CHNP ANALYSIS (NUTRITIONAL VALUE)

B - A = PRODUCTIVITY

B - C = YIELD

Figure 3 Estimated mean (n = 4) standing crop of large, herbivorous fishes (grams fresh weight per m^2) for various zones on inshore, mid-shelf and outer-shelf reefs. Ph = Phillips Reef, Pan = Pandora Reef, Rib = Rib Reef, J.B = John Brewer Reef, Lod. = Lodestone Reef, Myr.= Myrmidon Reef, Dip.= Dip Reef, Bowl = Bowl Reef.

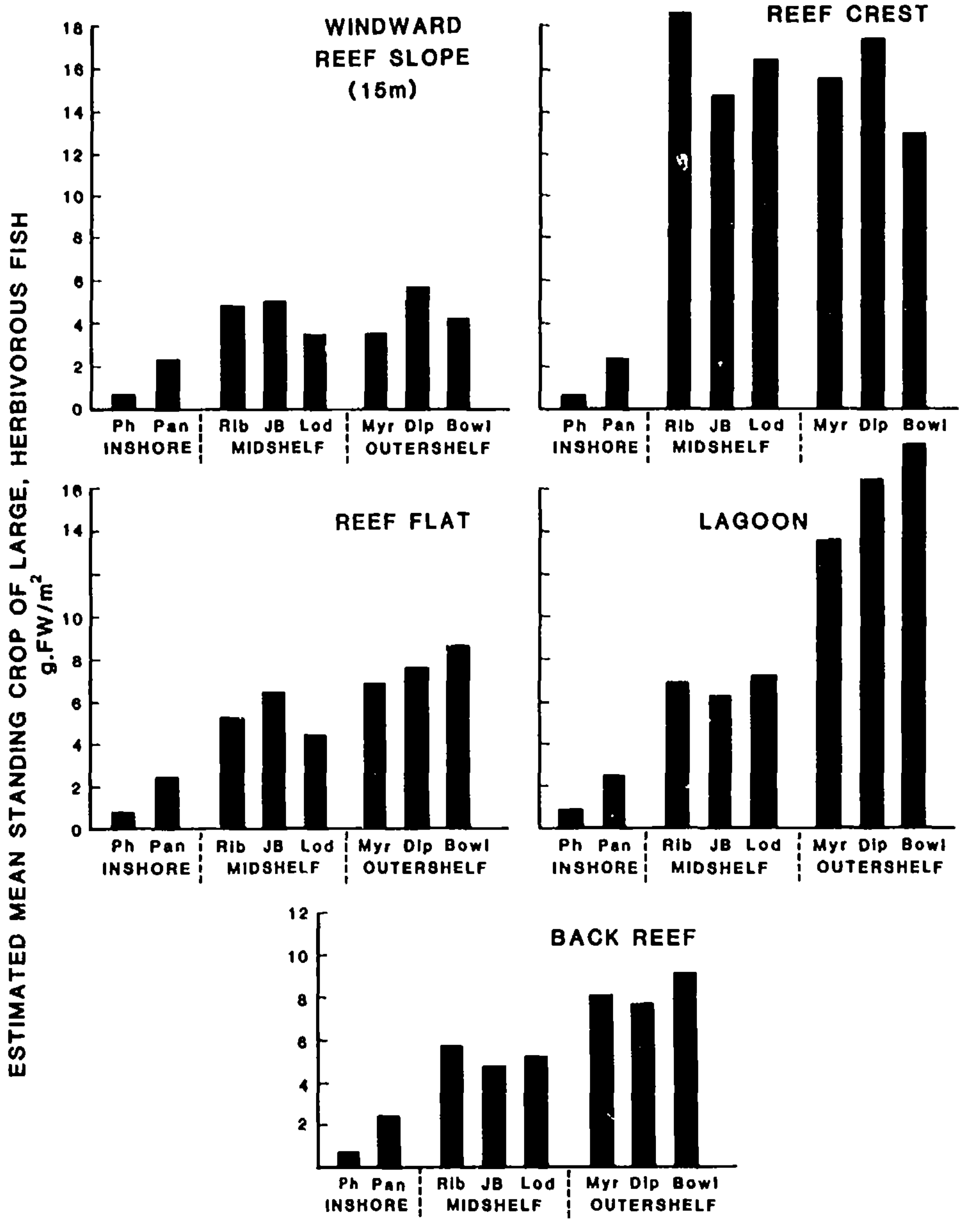


Figure 4a Porités head immersed uncaged for 5 months (June to October 1982) at Myrmidon Reef. Note low standing crop of turf algae and scrape marks made by grazing scarids.

The fishes surveyed feed primarily on turf algae (small filamentous brown, green and red algae). Experiments designed to measure standing crop and productivity of turf algae, together with yield of turf algae to grazing fishes, were carried out at a depth of 3-4 m on the windward reef slopes of one inshore reef (Pandora), one mid-shelf reef (Rib) and one outershelf reef (Myrmidon). Dead *Porites* coral heads (approximately 15 cm in diameter) were immersed as settlement surfaces for turf algae. The experimental design is similar to that of Hatcher (1981) and is outlined in Figure 2. Upon removal from the water, the algae were scraped from the surface of each *Porites* head. The algae were thus treated as an homogenate. The surface area of each *Porites* head was estimated. Standing crop of turf algae at each site was estimated from scrapings from *Porites* heads, together with estimates of percentage cover of turf algae on the natural substratum (obtained from chain transects). The algal biomass per unit area of Treatment B minus Treatment A (see Figure 2) was used as an estimate of productivity (for the one month period under study) and that for Treatment B minus Treatment C an estimate of yield to grazing fishes.

Figure 4b *Porites* head immersed uncaged for 4 months and then caged for an additional month (October 1982) at Myrmidon Reef. Note the relatively high standing crop of turf algae.

3. RESULTS

Estimates made by Williams and Hatcher (1983) of standing crop of algal grazing fishes (croppers and scrapers only-see Hatcher, in press) on the windward reef slopes of reefs across the continental shelf in the central region of the Great Barrier Reef indicate an increase in the abundance of herbivorous fishes from inshore to mid-and outershelf reefs (Table 1).

Table 1

INSHORE	MID-SHELF	OUTERSHELF
8.53	22.8	27.07

Standing crop (grams fresh weight per m^2) of algal grazing fishes (croppers and suckers) across the continental shelf in the central region of the Great Barrier Reef. The figures are means of ten quantitative explosive collections of approximately 150 m^2 each on the windward reef slopes of Pandora (inshore), Rib (mid-shelf) and Myrmidon (outershelf) reefs (from Williams and Hatcher, 1983).

This result is supported by visual census data collected by this author which provide estimates from various reef zones (Table 1, Figure 3).

A general summary of some preliminary results of the productivity/yield experiments carried out in October 1982 and January 1983 is given in Table 2. Note that all figures in the table are ratios of cross-shelf differences. The main points derived from Table 2 are :

Table 2

Estimated ratios of various parameters across the continental shelf in the central region of the Great Barrier Reef.

	INSHORE	MID-SHELF	OUTERSHELF
STANDING CROP : FISHES	1	2.67	3.17
STANDING CROP : TURF ALGAE	2.5	1	1.25
PRODUCTIVITY : TURF ALGAE	1	10-15	10-15
FOOD AVAILABILITY	1	4-6	5-7.5
YIELD TO FISHES	?	HIGH	HIGH

1. Standing crop of herbivorous fishes is higher on mid-and outershelf reefs than on reefs inshore.

2. There is a higher standing crop of turf algae inshore, relative to mid-and outershelf reefs.

3. There is a much higher standing productivity of turf algae on mid-and outershelf, relative to inshore.

4. There is a greater availability of food on mid-and outershelf reefs than on inshore reefs, which is due essentially to a higher productivity of turf algae.

5. Yield of turf algae to herbivorous fishes seems to account for a fairly high proportion of the production on mid-and outershelf reefs.

An example of one replicate from the experiment performed on the outershelf reef (Myrmidon) in October 1982 is shown in Figure 4. Figure 4a shows a *Porites* head which was immersed uncaged for 5 months (=*Treatment C*). Note the very low standing crop of turf algae and the scrape marks made by grazing scarids. Figure 4b shows a *Porites* head which was immersed for 4 months uncaged and *then caged* for an additional month. Note the relatively high standing crop of turf algae, indicative of a very high productivity and yield to grazing fishes on this outershelf reef.

4. DISCUSSION

The preliminary results presented here suggest that there is a greater availability of food on the mid-and outershelf reefs, relative to inshore, due essentially to a higher productivity of turf algae. Thus, there is a positive correlation between food availability and standing crop of large, herbivorous fishes. These observations are consistent with a causal relationship between the availability of algae as food and the abundance of herbivorous fishes. Direct testing of this causal relationship will require large scale field experiments in which the abundance of fishes is monitored. Indirect tests could come from studies of the relationship between the availability of algae and the abundance of herbivorous fishes along across-shelf transects at different latitudes, where the patterns in the availability of food or abundance of fishes differ from those in the central region (Williams, pers. comm.)

The likely proximal factors causing or maintaining differences in community structure of coral reef fishes across the continental shelf in the central Great Barrier Reef region have been summarized by Williams and Hatcher (1983). They suggest that the patterns of distribution and abundance could result from :

(1) Differential availability of larvae across the shelf.

(2) Pattern of settlement and habitat selection by post larvae (e.g. in response to food availability, physical factors, etc.)

(3) Differential survivorship after settlement.

Differences in the availability of algae may be a proximal factor influencing habitat selection by post-larvae or differential survivorship after settlement. It is unlikely, however, that post larvae can judge the potential productivity of turfs in a given area and it seems likely that the cross-shelf patterns are determined prior to, or at the time of recruitment (Williams, pers. com.). The availability of algae is more likely to be an ultimate factor determining the distribution and abundance of herbivores. Differences in the availability of food maintained over (evolutionarily) long periods of time may have led to the selection of mechanisms related either to habitat selection or limited dispersal, which ensure maximum recruitment of herbivores to mid-and outershelf area.

ACKNOWLEDGEMENT

Comments by Dave Williams improved the ideas expressed in this manuscript.

REFERENCES

Done, T.J. 1982 . Pattern in the distribution of coral communities across the central Great Barrier Reef. Coral Reefs 1 : 95-107

Hatcher, B.G. 1981 . The interaction between algae and grazers on a coral reef. Ph.D. Thesis Univ. of Sydney.

Hatcher, B.G. (in press). Grazing in coral reef ecosystems. In D.J. Barnes (ed.) Perspectives on Coral Reefs. Australian Institute of Marine Science.

Williams, D. McB. 1982 . Patterns in the distribution of fish communities across the central Great Barrier Reef. Coral Reefs 1 : 35-43.

Williams, D.McB. and A.I. Hatcher. 1983 . Structure of fish communities on outer slopes of inshore,mid-shelf and outershelf reefs of the Great Barrier Reef. Mar. Ecol. Prog. Ser. 10 : 239 - 250.

4.5 A Review of Coral Reef Fisheries

by

Garry Russ *

ABSTRACT

A review of fisheries production from coral reefs is presented and some characteristics of coral reefs, of life histories of coral reef fishes, and of resident coral reef fish communities are examined. Some recent technical and scientific advances of significance to the development of coral reef fisheries are reviewed and an examination is made of aspects of coral reef fisheries management.

---

* Australian Institute of Marine Science
P.M.B. No.3, Townsville M.C.
Queensland
AUSTRALIA, 4810

1. INTRODUCTION

The fisheries resources of coral reefs appear to be substantial. Smith (1978) estimated the fisheries potential of tropical reef and adjacent shallow water habitats at about 9% of the then present annual commercial ocean fish landings. The estimated contributions of coral reef fishes to the total catch in two regions of the Indo-Pacific are 8-20% in the Philippines (Alcala, 1981) and 18-25% in West Sabah, Malaysia (Mathias and Langham, 1978). Fishes are a major source of protein throughout many Indo-Pacific countries, and many islands, reefs and atolls have been exploited for hundreds, if not thousands, of years. Despite this, coral reefs have generally been neglected in fisheries management throughout the Indo-Pacific region for a variety of reasons. Socio-economic conditons in many of the countries which utilize extensively the fisheries resources of coral reefs preclude allocation of sufficient funds for management of these resources. Most management to date has been organized by foreign aid programs in which scientists tend to think in terms of large-scale commercial operations (Carpenter, 1977). Furthermore, coral reefs cannot be fished readily with large-scale gear, particularly trawls. They are generally accessible to small-scale fisheries only (Marshall, 1980). Thus, despite their fisheries potential, coral reefs have received a disproportionally small amount of attention from fisheries managers.

This paper examines some characteristics of coral reefs, of life histories of coral reef fishes, and of communities of coral reef fishes, which pertain to reef fisheries. It then examines some consequences of these characteristics to potential fishery yields and reviews available yield data. Some recent technical and scientific advances of significance to the development of coral reef fisheries are reviewed. Finally, an examination is made of aspects of management of coral reef fisheries. Throughout the paper, an attempt is made to identify and make recommendations for future research needs.

2. SOME CHARACTERISTICS OF CORAL REEFS PERTINENT TO FISHERIES POTENTIAL

Relatively little of the space within the geographic range of warm-water reefs is actually occupied by reef communities, i.e. reefs are rare (Huntsman, 1980). Reefs are also discontinuous, often small (e.g. a few hectares) and separated from other reefs by relatively large distances (e.g. many kilometers).

Reefs tend to develop in clear, relatively nutrient-poor waters, although such conditions are not essential for reef development. The amount of nutrient input to reefs can vary greatly. For example, Andrews and Gentien (1982) have suggested that the reefs on the central Great Barrier Reef are influenced by periodic nutrient upwelling.

Coral reefs concentrate nutrients by constant entrapment of plankton from oceanic waters. The fact that coral reefs have some of the highest recorded levels of primary productivity of any natural ecosystem is due to the retention and recycling of nutrients. Finally, reefs provide shelter for a great variety of organisms. There is a positive correlation between the structural complexity of the substratum (provided by corals) and the standing crop of fishes (e.g. Talbot, 1965).

3. LIFE HISTORY CHARACTERISTICS OF REEF FISHES

The vast majority of coral reef fishes are site-attached, having fairly well defined territories or home ranges. They have a great range of maximum sizes (e.g. L_∞ = 10-280 cm) growth rates (e.g. K = 0.11-1.13), longevities (e.g. 3 - 26 years), and natural adult mortalities (e.g. M = 0.2-1.85) (examples of asymptotic length L_∞ and coefficients of growth K taken from Munro, in press; examples of coefficients of natural mortality M and longevity taken from Huntsman, 1980 and Pauly, 1980).

Coral reef fishes tend to have very high fecundity and almost invariably have a planktonic larval phase. Length of larval life varies from species to species and ranges from 1 to 10 weeks (Randall, 1963). Depending upon the prevailing currents, larvae may disperse over large distances (at least tens to hundreds of kilometers). There is an extremely high mortality rate in this planktonic phase of the life cycle, with only a small percentage of larvae settling on a suitable substratum (i.e. a reef) and metamorphosing into adults. A further aspect of reproduction of coral reef fishes which is relevant to fisheries management is that many species are sequential hermaphrodites. Many species of serranids and scarids are protogynous, starting life as females and becoming males in mid-life.

There is very little experimental evidence and no general consensus of opinion on what limits the size of populations of coral reef fishes. Many studies appear to have been carried out under the implicit assumption that availability of resources plays a major role in limiting population size (see review by Sale, 1980). Space and food are the resources most often assumed to be limiting; however, recent studies have questioned this assumption of resource limitation (e.g. Williams, 1980; Doherty, 1982). Doherty (1982), on the basis of his own experiments on coral reef fishes, and drawing attention to the frequently observed strong and weak year classes in many commercially exploited fishes, has suggested that a closer examination of the question "how often are coral reef fishes limited by resources and how often by recruitment?" is required. Predation is known to be a major source of mortality in coral reef fishes but there are few experimental studies on the role of this factor in limiting population size. More research must be directed toward the question "what limits the population sizes of coral reef fishes?".

4. CHARACTERISTICS OF COMMUNITIES OF CORAL REEF FISHES

Communities of coral reef fishes are characterized by large numbers of species, low numbers of individuals per species, many species consisting of small individuals and high trophic complexity (see review by Sale, 1980). As stated above, there is a positive correlation between substratum complexity and the standing crop of fishes. Coral reefs support some of the highest known standing crops of fishes, consisting mostly of planktivores, small herbivores and primary carnivores. Standing crops are 30-40 times higher than those recorded for representative (demersal) fishing grounds in South East Asia, the Mediterranean and other temperate areas (see Stevenson and Marshall, 1974; Carpenter, 1977 and Table 1).

4.1 Some consequenses of the characteristics of reefs and reef fishes to potential fishery yields

The following factors seem important:

(1) In such diverse communities, large production of a single species is unlikely (Huntsman, 1980). An exception to this may be the massive schools of planktivorous fishes (e.g. caesionid) which frequent the reef slopes, together with certain species of siganids, acanthurids and also *Balistes vetula* from Pedro Bank in the Caribbean (Munro pers.comm.).

(2) Initially, man tries to harvest the relatively rare high-order carnivores (e.g. serranids). Serranids are usually in very low abundance on heavily-fished reefs. Even on the relatively lightly-fished reefs of the central Great Barrier Reef, catches close to centers of population are poor compared with those on reefs located large distances from such centers. For example, the average weight of individuals of *Plectropomus leopardus* (coral trout) taken from near Townsville has been reduced by 1 kg over the past 15 years (Craik, 1979). These higher-order carnivores have low rates of natural mortality. Growth and maximum harvest can be attained only with low rates of fishing mortality and high ages of recruitment to the stock (Huntsman, 1980).

Table 1

STANDING CROPS OF CORAL REEF FISHES

(METRIC TONS/KM^2)

LOCATION	STANDING CROP	REFERENCE
Offshore reef, GBR	209	Golman & Talbot (1976)
Inshore reef, GBR	93	Williams & Hatcher (1983)
Mid-shelf reef, GBR	239	Williams & Hatcher (1983)
Outershelf reef, GBR	156	Williams & Hatcher (1983)
Fringing reef, Hawaii	62	Brock (1954)
Fringing reef, Hawaii	132	Mc Cain & Peck (1973)
Kaneohe Bay, Hawaii	125	Wass (1967)
Reef flat, Eniwetok atoll	9	Odum & Odum (1955)
Fringing reef, Virgin Is.	160	Randall (1963)
Fringing reef, Virgin Is.	38	Damman *et al.*(1969)
Fringing reef, Red Sea	35	Clark *et al.*(1968)
Fringing reef, Mauritius	8	Cushing (1971)
Fringing reef, Mauritius	21	Cushing (1971)
Patch reef, Bermuda	49	Bardach (1959)

S.E. Asian Fishing Grounds (Representative Environments) (Carpenter, 1977)	$\bar{x}$ = 2.9	S.E. = 0.5
Temperate and Mediterranean Fishing Grounds (Carpenter, 1977)	$\bar{x}$ = 2.5	S.E. = 1.0

(3) It may be far more prudent to concentrate fishing effort on those species in lower trophic levels with higher turnover rates (e.g. caesionids) or at least direct efforts at many trophic levels.

(4) Because reef fishes move very little, they are prone to over-exploitation, and recovery of depleted stocks may be slow.

(5) Protogyny affects the choice of a management strategy: at least a few fish must survive to the age at which they become males (Huntsman, 1980).

(6) A high diversity of species results in problems of modeling, predicting trends in and managing fisheries, together with problems of marketing the fishes.

(7) Despite the high primary productivity and high standing crops of fishes, the nutrient cycling properties of reefs and the high diversity of fishes suggests that the harvestable component of reef fish stocks is extremely limited and may be exhausted rapidly by any intensive exploitation (Huntsman, 1980). Munro (1976) referred to this view as "the popular misconception ...." and Stevenson and Marshall (1974) stated that "Such pessimism overlooks the possible synergism of associated shallow habitats and fails to recognize that proportionally small releases from recycling systems may be appreciable when production is extremely high. Pessimism also overlooks the food chain reapportionments that may occur without upsetting a system where consumer populations are harvested". Marshall (1980) made rough estimates of production and demand for four estuaries in southern New England and obtained demand figures that required all the estimated production. Marshall noted that these estuaries are harvested intensively and continue to sustain good yields. He concluded that "a system must be harvested if one is to make an appraisal of its yield potential". Furthermore, those who suggest that fisheries activities on reefs can be expanded might argue that cases of depletion essentially reflect our inability to manage a reef fishery, rather than a gradual depletion of nutrients and energy from a "closed system".

5. YIELDS OF FISHES FROM CORAL REEFS

This subject has been reviewed by Stevenson and Marshall (1974), Carpenter (1977), Marshall (1980), Munro (in press) and Marten and Polovina (in press). A summary of these reviews is provided in Table 2. These yields are, of course, the combined yields of all species, but the figures are not directly comparable for several reasons. First, the total area fished

Table 2
Yields of fishes from coral reefs
(Metric Tons/Km^2/Year)

LOCATION	AREA(Km2)	YEAR	YIELD	FISHING EFFORT	REFERENCE
Jamaica	11,760	1945	2.0	High	Munro (1969)
Jamaica		1962	4.0	High	Munro (1973)
Jamaica (Sth)	3,420	1968	4.1[b]	Medium	Munro (1977)
Jamaica		1971	2.2	High	Munro (1973)
Caribbean		?	4.0	?	Gulland (1971)
Bahamas		?	2.5[a]	?	Gulland (1971)
Cuba	55,000	1962	0.5	Low	Buesa Mas (1964)
Puerto Rico	2,300	1971	0.8[c]	High	Juhl & Suarez-Caabro (1972)
Bermuda	1,035	1956	0.4	Low	Bardach & Menzel (1975)
Mauritius	350	1945	4.7[a]	High	Wheeler & Ommanney (1953)
Mauritius		1977	3.5	High	FAO (1979)
Kenya (Nth)	20,000	1977	4.9	?	FAO (1979)
Kenya (Sth)		1977	5.6	?	FAO (1979)
Tanzania (Nth)	17,000	1977	4.7	High	FAO (1979)
Tanzania (Sth)		1977	4.8	?	FAO (1979)
Mahe (East)		1977	1.4	Low	FAO (1979)
Mahe (West)		1977	3.1	Low	FAO (1979)
Fijian Atolls		Recent	4.4[a]	?	Bayliss-Smith (in press)
Lamotrek Atoll		1964	0.4	Low	Alkire (1965)
American Samoa		Recent	8.0[c]	High	Hill (1978)
American Samoa	3	Recent	18.0[c]	High	Wass (1980)
Philippines(Sumilon)	0.5	1976	9.7[c]	High	Alcala (1981)
Philippines(Sumilon)	0.5	1977	14.0[c]	High	Alcala (1981)
Philippines(Sumilon)	0.5	1978	15.0c	High	Alcala (1981)
Philippines(Sumilon)	0.5	1979	23.7c	High	Alcala (1981)
Philippines(Sumilon)	0.5	1980	19.9c	High	Alcala (1981)
Philippines(Apo)	0.75	1980	12.8[c]	High	Alcala & Luchavez (1982)

Yield of representative fishing grounds $\ddot{x}$ = 2.53 S.E. = 0.56
(Including North Sea and Western Greenland) (Moissev, 1969)

a MSY based on catch-effort data over a series of years.
b MSY based on modified exponential surplus-yield model.
c Probably near MSY due to high fishing effort.

varies considerably, ranging from 0.5 to thousands of square kilometers. Second, the type of substratum and the maximum depth of fishing varies. For convenience, the yield figures can be divided into those from large areas, with fishing to depths of up to 30-40 m. Third, fishing methods and target species vary, e.g. the Caribbean trap fishery takes mostly serranids, carangids, lutjanids, pomadasyids, mullids and the larger scarids and acanthurids, whilst the Philippine fishery includes gill nets and handlines in addition to traps and takes high proportions of caesionids and giant herrings (Elopidae) in addition to pomacentrids, siganids, acanthurids and carangids, with only a small proportion of the catch consisting of serranids and lutjanids. Nevertheless, Table 2 indicates the following points:

(1) Yields of fishes from most coral reefs (and coralline shelves in many cases) compare very favorably with harvest data of many temperate demersal stocks (e.g. North Sea, Western Greenland, English Channel).

(2) Stevenson and Marshall (1974), Carpenter (1977) and Marshall (1980) all conclude that a potential yield of between 0.5 and 5.0 metric tons/km^2/year can be expected from coral reefs. These figures are based mainly on yields from what Marshall (1980) has termed the "superecosystem" of reef and adjacent habitats such as lagoons, mangroves, seagrasses, and nearby coralline shelves, e.g. most of the figures for the tropical western Atlantic (various authors) and the western Indian Ocean (FAO, 1979). The "predicted" figure of 0.5 to 5.0 metric tons/km^2/year contrasts with the values reported from relatively pure coral reef islands and atolls in American Samoa and the central Philippines (8.0 - 23.7 metric tons/km^2/year). Various arguments regarding the validity and representative nature of these results have been made by Marshall (1980) and Alcala (1981). It is suggested here that these differences may be based largely upon the comparison of results from studies which include large areas of coralline shelf, where the target species are often large, long-lived predators with studies which restrict themselves to small areas of "true" coral reefs, where a wide range of species is taken. Two final points can be made here. Firstly, from the tables of standing crops and yields, one can arrive at an estimate of an "average" annual yield of all species combined of 5% of the standing crop. On this basis, two relatively unexploited reefs of the central Great Barrier Reef (Rib and Myrmidon reefs) may have potential yields of 12 and 8 metric tons/km^2/year, respectively. Secondly, Alcala (1981) has replicated his results over time (5 year period) and space (Sumilon, Apo reefs, see Table 2). It is suggested that further investigations into the nature of reefs giving such high yields is warranted.

(3) Obviously, yield values should correlate well with

fishing effort and this seems to be the case.

(4) Many of the values in the table are actual yields, as opposed to potential yields. Stevenson and Marshall (1974) made estimates of fishing effort and harvests for isolated human populations living on atolls. This was done to gain an insight into the potential of reef area fisheries to meet protein needs and to examine people's reliance upon such food sources (see their Table V). Munro (1977) used catch data for 1968 and a modified exponential surplus yield model to calculate a potential maximum yield of 4.1 metric tons/km^2/year for the coralline island shelf of South Jamaica under the prevailing harvesting system (see Figs. 1a and 1b in Munro, 1977). Gulland used a similar model to estimate a potential maximum yield of nearly 5 metric tons/km^2/year for areas of coral reef in East Africa (FAO, 1979 and see also Marten and Polovina, in press, Fig. 9 and Parrish, 1980).

Munro (1978) proposed the use of a similar model as a method of estimating the potential productivity of fishes of Western Pacific reefs and lagoons. Munro suggested that "... for islands or island groups without significant land area (particularly atolls) and without significant imports of preserved protein foods, that gross population density expressed relative to the area of harvestable shelf, reef or lagoon might be an adequate measure of fishing intensity.". This measure of fishing intensity plotted against catch statistics for" ... a minimum of thirty discrete island shelves ..." could provide a surplus yield curve resembling those for the South Jamaican study (Munro, 1977) and the East African study (FAO, 1979). The main assumption is that the ecological regimes of the various areas are similar (Munro, 1978). Despite the potential of this idea, there has been, to this author's knowledge, no attempt to collect the necessary information to apply the model suggested by Munro.

(5) How good is the evidence that the tabulated yields are sustainable? It is presumed that many of the reef areas tabulated have probably been fished for at least tens to hundreds of years. Whether and how fishing intensities and yields have changed over such time scales is virtually unknown. Munro (1969, 1973, 1977) cites yields from Jamaica which have not changed substantially between 1945 and 1971 and Alcala (1981) has shown that the high yields at Sumilon Island, Central Philippines have been maintained over a 5 year period. More extensive and accurate records of harvests (including indications of areas fished, types of fishes taken, etc.) and fishing intensities over a long period of time are needed.

6. RECENT TECHNICAL AND SCIENTIFIC ADVANCES

These have been reviewed by Munro (in press) and what follows is a brief outline of that review.

The recognition of daily growth rings in otoliths (Panella, 1971) has led to the development of a method for estimating the age of at least the younger stages of many coral reef fishes (e.g. Brothers, 1980; Ralston and Miyamoto, 1982).

The common availability of SCUBA facilities and the development of more quantitative visual census techniques have provided reef fisheries scientists with a method of stock assessment not normally available in fisheries studies.

One of the most important advances has been the development of methods of stock assessment based on length-frequency data. Pauly and David (1981) have developed a micro-computer program (ELEFAN I), which extracts growth parameters from length-frequency data. Pauly (1982) has also devised a micro-computer program (ELEFAN II), which converts length-frequency distributions into catch curves, given inputs of these growth parameters. Pauly and Ingles (1982) give an example of the application of these methods to species of exploited coral reef fishes. These developments, linked with the greater availability of programmable calculators and micro-computers, open the possibility of re-examination of existing sets of length-frequency data giving first or improved estimates of growth and mortality rates (Munro, in press). There is now an obvious need for collection of more data and the development of improved data storage and dissemination techniques to take full advantage of these new programs.

A fundamental objection to the use of traditional stock assessment models (such as those of Beverton and Holt, 1957) in multispecies fisheries is that a series of analyses of a large number of species, considered individually, will fail to give a correct evaluation of the state of the fishery as a whole because of failure to take account of the interactions between species. Nevertheless, the application of the traditional models to various species with a range of life histories, selected on the basis of their abundance within an assemblage, could give insight into management procedures for the assemblage. The results for individual species could, perhaps, also be extrapolated to other species having similar life histories.

The concept of multispecies models is receiving attention (Larkin, 1978; Pauly, 1979) but their application to fisheries management is in an early stage. With the advent of more sophisticated computers, simulation modelling has become common and Larkin (1978) has suggested that the ideal pattern of fisheries management may be alternate phases of modelling and field work.

Such an approach may be extremely useful for fisheries managers faced with the multiplicity of species on coral reefs.

7. MANAGEMENT

Larkin (1978) makes the point that fisheries science will not advance much further unless management becomes experimental. In this regard, coral reef fisheries have tremendous potential. Reefs, atolls and even small groups of islands provide independent units which are ideal for application of experimental management techniques. They have the additional advantage that, being small, they can be monitored closely and very good estimates of standing crop, yields, areas fished and fishing intensities can be made.

Perhaps a starting point is to look for "natural" experiments. Reefs, atolls or islands in the Pacific which are apparently similar in all except one or a few aspects could be considered as experimental units. One such "experiment" would be to compare units which were fished by traditional and modern techniques (Munro, 1980). A more fruitful approach would be to subject reefs, atolls or islands (or sectors thereof) to different levels and types of fishing and monitor the effects on short-and long-term yields and on the structure of the fish communities.

One of the simplest types of experiment would be to exclude all fishing from one sector of a reef so that stocks would remain close to their natural levels or be replenished if depleted. Stocks in such areas could then act as a reservoir replenishing stocks in adjacent areas subjected to fishing. This is the type of experiment carried out since 1974 by Alcala (1981) at Sumilon Island, Central Philippines. This additional factor may be contributing to the exceptionally high yields of coral reef fishes from the island (see earlier discussion). Temporary closure of certain areas of reef to allow replenishment of stocks has been practiced traditionally throughout Oceania for long periods (Johannes, 1978a).

A more complex experimental design would be to vary the levels and types of fishing on individual reefs. For example, in the recently declared sections of marine park on the Great Barrier Reef, there is a provision to selectively control both spearfishing and angling and, thus, to monitor the effects on particular target species (Craik, pers. comm.). An orthogonal and suitably replicated design, using spearfishing and angling as two experimental factors, could provide substantial insight into optimal management procedures.

There is also great scope for experimental assessment of various fishing techniques to ensure optimal management procedures. For example, Munro (1977) assessed the efficiency of various mesh sizes of Antillean fish traps and suggested that the adaption of a mesh size greater than that normally used would substantially increase harvests in areas which were subjected to moderate-to-heavy exploitation.

The effectiveness of management programs, particularly those involving restrictions on the level and type of fishing, could well depend on the effectiveness of educational (extension) programs designed to make local fishermen more aware of the need for and potential benefits of conservation measures. This could, perhaps, circumvent the need for stringent enforcement of management procedures. An example of such an extension program is provided by Cabanban and White (1982). Nevertheless, Munro (1978) makes the point that strict limitation of fishing effort will eventually become essential if the resources of island shelves are to be harvested rationally, particularly in the vicinity of urban areas. He suggests that the provision of marketable or inheritable fishing licenses may be the only rational solution to the problem of overfishing.

In a significant series of publications, Johannes (1978a, b, 1980, 1981 a, b) has argued convincingly for the use of traditional fishing knowledge and management procedures in the rational management of reef fisheries. For example, from extensive interviews with Palauan fishermen, Johannes (1980) learned that, during their spawning period, populations of reef and lagoon fishes gather in large, often docile aggregations at predictable times and locations. Johannes points out that these aggregations not only provide good opportunities for fishermen to make large catches but also present excellent opportunities for fisheries managers to study and manage these stocks. This use of traditional knowledge represents a method of stock assessment and management that could be applied for a relatively small investment of funds and manpower. As a second example, Johannes (1978 a, 1981 a, b) argues for the value of the traditional reef tenure system in conservation of reef fish stocks throughout the Pacific. Under such a system, one or a few fishermen are restricted by traditional law to fishing within a specified area and are responsible for protecting and managing their stocks. Johannes (1978, 1981 a, b) points out that the system is a particularly effective management procedure and that a similar "territorial" system operates effectively also for Maine lobster fishermen (Johannes, 1981 b).

This paper has emphasized aspects of coral reef fisheries such as potential yields and management programs. No attempt has been made to deal with the various economic and social factors, such as efficient marketing procedures for fishes and the raising of levels of income of fishermen (see Smith, 1980).

Much of the literature reviewed in this paper seems optimistic about the potential of coral reef fisheries. Populations and pressures on resources in the Pacific are now increasing very rapidly, particularly near the centers of population, and rational management of coral reef fisheries will thus attain greater significance.

8. CONCLUSIONS

Many characteristics of coral reefs and the assemblages of fishes associated with them suggest that the harvestable component of reef fish communities may be quite limited. Nevertheless, most yields of fishes from coral reefs and coralline shelves fall within the range 0.5 to 5.6 metric tons/km^2/year, with some very high yields recorded from small areas of relatively pure coral reef (8.0 - 23.7 metric tons/km^2/year).

It was pointed out in Section 5 that more extensive and accurate records of harvests (including indications of areas fished, types of fishes taken, etc.) and fishing intensities over long periods are needed. Collection of such data for management purposes is hindered by the numerous remote landing points and by the many diversified gears in operation. On the positive side, reefs, atolls and even smaller groups of islands have an advantage in that, being small, they can be monitored closely and very good estimates of standing crop, yields, areas fished and fishing intensities can be made. Many of these data probably exist already and need to be drawn together by, for example, a central co-ordinating management body. Where data do not exist, attempts should be made to at least collect estimates of fishing intensity and of abundances and types of reef fishes passing through various regional markets. This attempt to centralize information could provide a wide data base for management purposes and assist coral reef fisheries in receiving the amount of attention from fisheries managers that they deserve.

ACKNOWLEDGEMENTS

Peter Doherty, Bob Johannes, Angus Martin, John Munro and Dave Williams provided constructive comments on the manuscript. John Munro and Daniel Pauly provided copies of unpublished reports and papers.

REFERENCES

Alcala, A.C. 1981 . Fish yield of coral reefs of Sumilon Island, central Philippines. Nat. Res. Counc. Philipp. Res. Bull. 36: 1-7.

Alcala, A.C. and T. Luchavez. 1982 . Fish yield of the coral reef surrounding Apo Island, Negros Occidental, Central Visayas, Philippines. Proc. 4th Int. Coral Reef Symp 1: 69-73.

Alkire, W.H. 1965 . Lamotrek Atoll and inter-island socio-economic ties. Illinois Studies in Anthropology 5: 180 pp. Univ. Illinois Press.

Andrews, J.C. and P. Gentien. 1982 . Upwelling as a source of nutrients for the Great Barrier Reef ecosystems: a solution to Darwin's question? Mar. Ecol. Prog. Ser. 8: 257-269.

Bardach, J.E. 1959 . The summer standing crop of fish on a shallow Bermuda reef. Limnol. Oceanogr. 4: 77-85.

Bardach, J.E. and D.W. Menzel. 1957 . Field and laboratory observations on the growth of certain Bermuda reef fisheries. Gulf and Carib. Fish. Inst. 9: 106-112.

Bayliss-Smith, T. (in press). The price of protein: marine fisheries in Pacific subsistence. In H.C. Brookfield (ed.) Man's place in the island Ecosystem-Revisited. MAB Tech. Note, UNESCO, Paris.

Beverton, R.J.H. and S.J. Holt. 1957 . On the dynamics of exploited fish populations. Fishery Invest., Lond, Ser. 2, 19, 533 pp.

Brock, V.E. 1954 . A preliminary report on a method of estimating reef fish populations. J. Wildlife Mgmt. 18: 297-308.

Brothers, E.B. 1980 . Age and growth studies in tropical fishes. In S.B. Smith and P.M. Roedel (eds.) Stock Assessment for Tropical Small-Scale Fisheries. Int. Cent. Mar. Res. Dev. Univ. of Rhode Is., Kingston, R.I. pp. 119-136.

Buesa Mas. R.J. 1964 . Las pesquerias cubanas. Centro de Invest. Pesq. Contr.

Cabanban, A.S. and A. White. 1982 . Marine conservation program using non-formal education at Apo Island, Negros Oriental, Philippines. Proc. 4th Int. Coral Reef Symp. 1: 317-321.

Carpenter, K.E. 1977 . Philippine coral reef fisheries resources. Philipp. J. Fish. 17: 95-125.

Clark, E., A. Ben-Tuvia and H. Steinitz. 1968 . Bull. Sea Fish. Res. Stn. Hafa 49: 15.

Craik, Q. 1979 . Survey identifies trends in reef fish catches. Aust. Fisheries, December 1979: 29-32.

Cushing, D.H. 1971 . Survey of resources of the Indian Ocean and Indonesian area. FAO/IOFC/DEV/71/2.

Damman, A.E. *et al*. 1969 . Study of the fisheries potential of the Virgin Islands. V.I. Ecol. Res. Station Centr.1: 197 pp.

Doherty, P.J. 1982 . Coral reef fishes: recruitment limited assemblages? Proc. 4th Int. Coral Reef Symp.2: 465-470.

FAO. 1979 . Report of the FAO/IOP workshop on the fishery resources of the western Indian Ocean south of the equator. Indian Ocean Program Development Report 45.

Goldman, B. and F.H. Talbot 1976 . Aspects of the ecology of coral reef fishes. *In* Biology and Geology of Coral Reefs, Vol. III Biology, 2. pp. 125-154, Academic Press.

Gulland, J.A. 1971 . The fish resources of the ocean. Fishing News (Books) ltd., West Byfleet.

Hill, R.B. 1978 . The use of nearshore marine life as a food resource by American Samoans. Pacific Island Studies Program, Univ. of Hawaii, Miscellaneous Work Papers, 170 pp.

Huntsman, G.R. 1980 . The biological bases of reef fishery production. *In* J.B. Higman (ed.), Proc. Guld Caribb. Fish. Inst. 32.

Johannes, R.E. 1978 a . Traditional marine conservation methods in Oceania and their demise. Ann. Rev. Ecol. Syst. 9: 349-364.

Johannes, R.E. 1978 b . Reproductive strategies of coastal marine fishes in the tropics. Env. Biol. Fish. 3: 65-84.

Johannes, R.E. 1980 . Using knowledge of the repoductive behavior of reef and lagoon fishes to improve fishing yields. ICLARM Conference Proc. 5: 247-270.

Johannes, R.E. 1981 a . Working with fishermen to improve coastal tropical fisheries and resource management. Bull. Mar. Sci. 31: 673-680.

Johannes, R.E. 1981 b . Words of the lagoon. University of California Press, Berkeley. 245 pp.

Juhl, R. and J. Suarez-Caabro. 1972 . La pesca en Puerto Rico, 1971. Agro. y Pesq. 4: 1-52.

Larkin, P.A. 1978 . Fisheries management - an essay for ecologists. Ann. Rev. Ecol. Syst. 9: 57-73.

Marshall, N. 1980 . Fishery yield of coral reefs and adjacent shallow water environments. In S.B. Saila and P.M. Roedel (eds.) Stock Assessment for Tropical Small-Scale Fisheries. Int. Cent. Mar. Res. Dev. Univ. of Rhode Island, Kingston, R.I. pp. 103-109.

Marten. G.G. and J.J. Polovina.(in press). A comparative study of fish yields from various tropical ecosystems. In D. Pauly and G.I. Murphy (eds.) Theory and Management of Tropical Fisheries. ICLARM Conference Proc. 9: 255-285.

McCain J.C. and J.M. Peck. 1973 . The effects of Hawaiian power plant on the distribution and abundance of reef fishes. Seagrant Advisory report, NIHI-Seagrant.AR73-03.

Mathias, J.A. and N.P.E. Langham. 1978 . Coral Reefs. In Chua Thia-Eng and J.A. Mathias (eds.) Coastal Resources of West Sabah: An Investigation into the Impact of Oil Spills, pp. 117-151. Penerbit University, Sains Malaysia, Penang.

Moiseev, P.A. 1969 . The living resources of the ocean. Israeli program for scientific translations, Ltd. 1971. IPST No. 5954, Published by U.S. Dept. of Commerce, National Technical Information Service, 334 pp.

Munro, J.L. 1969 . The sea fisheries of Jamaica: past, present and future. Jamaica Jour. 3: 16-22.

Munro, J.L. 1973 . Actual and potential fish production on coralline shelves of the Caribbean. Abs. 10th Meeting Assoc. Island Marine Labs of the Caribbean, Mimeo.

Munro J.L. 1976 . Potential productivity of coral reef fisheries. In Lamb K.P. and J.L. Gressitt (eds.) Ecology and Conservation in Papua New Guinea. A symposium held at the Wau Ecology Institute, Nov. 1975. Wau Ecology Institute Pamphlet (2), 153 pp.

Munro J.L. 1977 . Actual and potential fish production from the coralline shelves of the Caribbean Sea. FAO Fish Rep. 200: 301-321.

Munro, J.L. 1978 . A method for the estimation of potential fish productivity of Western Pacific reefs and lagoons. Tenth Regional Technical Meeting on Fisheries, So. Pacific Commission. Nouméa, New Caledonia 13-17 March, 1978.

Munro J.L. 1980 . Southwest of Hawaii. In R.W. Grigg and R.T. Pfund (eds.) Symposium on the Status of Resource Investigations in the North-west Hawaiian Islands. Sea Grant Misc. Rept. UNIHI-SEAGRANT-MR-80-04. pp.325-328.

Munro, J.L. (in press). Some advances and developments in coral reef fisheries research: 1973-1982. Proc. Guld Caribb. Fish. Inst. 35.

Odum, H.T. and E.P. Odum. 1955 . Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecoll. Monogr. 25: 291-320.

Panella, G. 1971 . Fish otoliths: daily growth layers and periodical patterns. Science 173: 1124-1127.

Parrish, J.D. 1980 . Effects of exploitation patterns upon reef and lagoon communities. In J.L. Munro (ed.) Marine and Coastal Processes in the Pacific: Aspects of Coastal Zone Management. Proc. Seminar held at Motupore Is. Research Center, July 1980. UNESCO, Paris, pp.85-121.

Pauly, D. 1979 . Theory and management of tropical multispecies stocks: A review, with emphasis on the South East Asian demersal fisheries. ICLARM Studies and Reviews No. 1, 35 p.

Pauly, D. 1980 . A new methodology for rapidly acquiring basic information on tropical fish stocks: growth, mortality and stock recruitment relationships. In S.B. Saila and P.M. Roedel (eds.). Stock assessment for Tropical Small-scale Fisheries. Int. Cent. Mar. Res. Dev. Univ. Rhode Island, Kingston, R.I. pp.154-172.

Pauly, D. 1982 . Studying single-species dynamics in a tropical multispecies context. In D. Pauly and G.I. Murphy (eds.) Theory and management of tropical fisheries. ICLARM Conference Proc. 9: 33-70.

Pauly, D. and N. David. 1981 . ELEFAN I, a basic program for the objective extraction of growth parameters from length-frequency data. Meeresforsch. 28: 205-211.

Pauly, D. and J. Ingles. 1982 . Aspects of the growth and natural mortality of exploited coral reef fishes. Proc. 4th Int. Coral Reef Symp. 1: 89-98.

Ralston, S. and G.S. Miyamoto. 1982 . Estimation of the age of a tropical reef fish using the density of daily growth increments. Proc. 4th Int. Coral Reef Symp. 1: 83-88.

Randall, J.E. 1963 . An analysis of the fish population of artificial and natural reefs in the Virgin Islands. Caribb. J. Sci. 3: 31-47.

Sale, P.F. 1980 . The ecology of fishes on coral reefs. Oceanogr. Mar. Biol. Ann. Rev. 18: 367-421.

Smith, I.R. 1980 . Traditional fisheries development in the Philippines. In J.I. Furtado (ed.) Tropical Ecology and Development. Proc. Vth Int. Symp. Tropical Ecology. International Society of Tropical Ecology. 1980 pp. 1135-1140.

Smith, S.V. 1978 . Coral-reef area and contributions of reefs to processes and resources of the world's oceans. Nature 273: 225-226.

Stevenson, D.K. and N. Marshall. 1974 . Generalizations on the fisheries potential of coral reefs and adjacent shallow-water environments. Proc. 2nd Int. Coral Reef Symp. 1: 147-156.

Talbot, F.H. 1965 . A description of the coral structure of Tutio Reef (Tanganyika Territory, East Africa), and its fish fauna. Proc. Zool. Soc. Lond. 145: 431-470.

Wass, R.C. 1967 . Removal and repopulation of the fishes on an isolated patch coral reef in Kaneohe Bay, Oahu, Hawaii. Directed research report, Zoology Dept., University of Hawaii, 77 p.

Wass, R.C. 1980 . The shoreline fishery of American Samoa-past and present. In J.L. Munro (ed.) Marine and Coastal Processes in the Pacific: Ecological Aspects of Coastal Zone Management. Proc. Seminar held at Motupore Is. Res. Center, July 1980. UNESCO, Paris, pp.51-83.

Wheeler, J.F.G. and F.D. Ommanney. 1953 . Report on the Mauritius-Seychelles fisheries survey 1948-1949. Col. Off. Fish. Publ. 3: 145 pp.

Williams, D.McB. 1980 . Dynamics of the pomacentrid community on small patch reefs in One Tree Lagoon (Great Barrier Reef). Bull. Mar. Sci. 30: 159-170.

Williams, D.McB. and A.I. Hatcher. 1983 . Structure of fish communities on outer slopes of inshore, mid-shelf and outershelf reefs of the Great Barrier Reef. Mar. Ecol. Prog. Ser. 10: 239-250.

4.6 "Mangrove Ecosystem" Fisheries Associated with Mangroves and their Management. Mangrove Fishes in Wairiki Creek and their Implications on the Management of Resources in Fiji.

by

Padma Lal*, K. Swamy, and P. Singh

ABSTRACT

While the value of the mangrove ecosystem is known and realized by the indigenous population, it has only recently been acknowledged by the Government of Fiji. Mangrove ecosystems have been used by the indigenous Fijians as good fishing grounds and as a source of firewood, timber for canoes, dyes, etc. Although the Government acknowledges the importance of mangrove resources in its Development Plan, the main national objective of economic development and the present institutional structure have made it difficult to conserve mangrove resources. Since 1979, the officially recorded reclamation of mangrove areas for various purposes has been about 300 ha and there are over 400 ha for which decisions are still pending. One of the main drawbacks during arbitration hearings has been that not enough data is available. In an era of emphasis on economic development, the value of mangroves has been questioned.

This paper discusses the results of a fishery survey carried out in Wairiki Creek to obtain information on the fishes associated with the mangroves in a fairly undisturbed area. Monthly sampling of six stations in the creek over a six month period using a 2½" gill net recorded over 85 species from 46 families of fishes. Of this, at least 35 families and 70 species of fishes and 5 decapods are of commercial importance.

This paper also discusses the present management system and the problems associated with the conservation and management of resources in Fiji.

* Ministry of Agriculture and Fisheries
Fisheries Division
Suva
FIJI

1. INTRODUCTION

The value of the mangrove ecosystem as a habitat, as well as a source of fuel, timber for construction of houses and canoes, and nutrients for a variety of fish and crustaceans found in the estuarine and coastal waters, has long been realized by Fiji's indigenous population. Although its multipurpose value is acknowledged by the Government, the importance of mangrove resources has been overshadowed by short-term economic development. The management of mangrove resources has been piecemeal, problem-centered and unplanned. Decisions taken and government directives depend on the particular usage under consideration at the time (for details, see Lal,1981). This has led to over 3500 ha of mangrove reclamation. In addition, at least 1500 ha of reclamation is proposed under the drainage schemes.

Mangrove wetlands in the Fiji Islands have been estimated to comprise about 19,684 ha (Marshall, undated) to 49,777 ha (Fiji Government estimate). In Fiji, mangrove plants belonging to three families (Rhizophoracea, Meliaceae and Combretacea) and four genera have been catalogued. Although some attempts have been made to study the flora and macro fauna associated with mangroves (Richmond and Ackerman, 1975; Ward et al., 1977), detailed studies on the ichthyofauna have not been carried out. Even though detailed information on the value of mangrove, particularly as a source of nutrients for commercially important estuarine and coastal fish and crustaceans in Fiji, was not available, enough local knowledge and understanding, based on studies abroad, are available and have been recognized.

The importance of mangroves as a source of wood for construction (Macnae, 1968), firewood, dyebark and tanbark (Watson, 1928) has long been recognized. Mangroves are also valuable as land builders, shoreline stabilizers (Chapman, 1977; Fox, 1974) and as a source of nutrients for estuarine and coastal fishes (Odum and Heald, 1972; Sashtrakusumah, 1971).

The value of mangrove as a source of food and income, a fact appreciated by the indigenous Fijians, was the basis for demands for recompensation from prospective developers for loss incurred as a result of reclamation (Lal, 1981). The Government, by a cabinet decision, set up a procedure for the payment of this recompensation value in 1976. The value was to be determined by an independent arbitrator. Somewhat arbitrarily arrived at, the values have ranged between $900 for 20 ha and $9,500 for 7.6 ha.

Although the arbitrator's decision is partly based on an estimation by the Fisheries Division on one night's fish catch in the area concerned, it is recognized that the data base is very limited. Baines (1979) quotes that an economic value in the range of \$369 - \$1980 per annum per ha has been arrived at by other workers. But these values have not been used by the arbitrator, whose decision also takes other factors, such as the economic value of proposed usage, capacity of the developers to pay, etc., into account.

The present study was undertaken with the aim of obtaining information and data on the fishes associated with mangroves. The arbitrator might ultimately be able to use this information to arrive at a more realistic value of the mangroves and to encourage their conservation for rational multipurpose utilization. This study aims to obtain information during a twelve month period. Because of the sampling method, it is restricted to fishes of commercial size only.

2. PROJECT SITE

Wairiki Creek, which is about 15 km west of the Fisheries Division, Lami was chosen as the project site because of its relatively undisturbed catchment area, few houses, and its limited agricultural development. The mean annual precipitation is about 3048 mm with no marked dry season. The mean neap tidal range is about 0.9 m and the mean spring tidal range is 1.3 m. Mangroves in the Wairiki Creek area cover about 60 ha. Species belonging to all three families, Meliacea, Rhizophoraceae and Combretacea, that occur in Fiji, have been recorded there. The mangrove species recorded were *Rhizophora stylosa*, *R. samoensis*, *Bruguiera gymnorhiza*, *Xylocarpus granatum* and *Lumnitzera littorea*. Other flora associates, such as orchids, ferns and *Pandanus*, as recorded by Hassal (1981), were also found. The Wairiki Creek bottom is usually of mud, 0.3 m or deeper, along the main creek. Along the coast, however, coralline rocky surfaces were also present.

3. SAMPLING METHOD

Monthly sampling of 6 stations in the Wairiki Creek area was done using 2½" (6.3 cm) gill nets. The gill nets were invariably set in late afternoon or evening incoming or outgoing half tide and cleared at the following low or high tide. Other qualitative sampling methods, such as bushtraps and box traps which were used in Veisari River by Ward (1976), were not successful because of the strong current.

The fishes were generally identified using keys in Munro (1967), Weber and Beaufort (various volumes) and Fischer and Whitehead (1974). With some families, whose taxonomy is still under review, such as Mugilidae (Thompson), Leiognathidae and Lutjanidae (Allen), Sphyraenidae (Rose), unpublished keys were kindly made available and in some cases identifications were verified. Standard lengths, weight, gonad weight and stage of gonad development were noted. Gut was dissected and preserved in formalin for examination. The results presented here are for the period of May-October 1982.

4. RESULTS AND DISCUSSION

In the first six month period, 847 individuals belonging to 42 families of fish and two families of crustaceans were caught during seven sampling trips in the Wairiki Creek (Appendix I). Twelve families of fish and crabs comprised 92% of the catch by numbers and 86% by weight (Table 1).

Table 1. Dominant Fish Families caught in Wairiki Creek, May - October 1982

Families	Number of individuals	% composition	Total Wt. (gm)	% composition
Mugilidae	120	144	31925	22.8
Leiognathidae	119	14.3	4957	3.5
Mullidae	94	11.4	21351	14.8
Lutjanidae	83	9.2	15258	10.8
Lethrinidae	63	8.6	10789	7.6
Gerridae	58	6.9	5560	3.9
Carangidae	45	5.3	4361	2.9
Siganidae	45	5.3	6108	4.2
Polynemidae	24	2.8	3395	2.6
Acanthuridae	19	2.4	1648	1.1
Kuhliidae	14	1.7	1580	1.1
Portunidae	96	11.5	16585	11.6
Sub total	780	92	123516	86
Total	847		142920	

Of the 42 families of mangrove fishes recorded in Wairiki creek, 28 were also found in a recent study in PNG (but sampling methods were different) (Collette, 1980) and 12 in Florida Bay (Odum and Healt, 1976). The most speciose families were the Caranidae (21% (9); Lutjanidae - 17% (7);

Mugilidae - 14% (6); Lethrinidae 9.5% (4); Leiognathidae - 7% (3); Mullidae - 7% (3).

The result differs considerably from other studies in the Western Pacific. In New Guinea, smaller fishes such as Gobiidae, Apogonidae, were the most speciose families (Collette, 1980). A study in North Borneo (Inger, 1955) recorded Engraulidae and Gobiidae. The difference in sampling methods could account for these differences. Rotenone sampling favors small fishes, whereas use of a 2½" gill net naturally favors larger fishes. One day, rotenone sampling using a scoop net in Wairiki Creek caught mainly small fishes, such as Gobiidae, Apogonidae, Glennidae (Lal, unpublished data). Ward (1976), using bush and boxtraps in another mangrove swamp (Veisari Creek), found a dominance of Eleotridae and Gobiidae. The present results are, however, roughly comparable with Krishnamurthy's study of mangrove fishes in S. India (quoted in Collette, 1980).

In the case of crustaceans, the family Portunidae was one of the dominant groups by number (11.5%), as well as by weight (11.6%).

In all, the total number of species sampled was 87. These belonged to 63 genera, of which at least 70 species are of direct food value (these are indicated in Appendix 2). The most abundant species caught in the mangrove creek are listed in Table 2.

Table 2. List of species of which 10 or more individuals were caught during May - October 1982

*Species which were caught in at least 5 out of 6 sampling trips.

	No.	Av.wt(gm)	Av.Length(mm)	Length Range
MULLIDAE				
Upeneus sulphureus	20	210	207	125-256
*Upeneus vittatus	43	190	211	105-316
*Parupeneus indicus	31	296	217	112-305
GERRIDAE				
*Gerres macrosoma	58	96	156	140-185
CARRANGIDAE				
*Caranx sexfasciatus	19	97	165	140-215
C. papuensis	17	105	166	145-200
LEOGNATHIDAE				
*Gazza minuta	27	46	123	95-160
*Leiognathus equula	80	43	121	93-150
*L. fasciata	12	40	116	96-141

	No.	Av.wt(gm)	Av.Length(mm)	Length Range
SIGANIDAE				
*Siganus vermiculatus	45	139	157	100-290
ACANTHURIDAE				
*Acanthurus xanthopterus	19	87	132	110-185
KUHLIDAE				
Kuhlia bilunulata	14	121	178	160-230
LUTJANIDAE				
*Lutjanus argentimaculatus	24	366	259	140-450
*L. fulvus	39	130	174	92-255
LETHERINIDAE				
*Letherinus harak	59	172	201	124-265
MUGILIDAE				
Velamugil buchanani	11	202	233	170-265
*V. seheli	32	397	288	190-420
*Liza subviridis	65	211	235	185-340
POLYDACTYLIDAE				
Polydactilus plebeius	22	147	205	
CRUSTACEANS(PORTUNIDAE)				
*Scylla serrata	50			
Portunus pelagicus	10			
P. sanguinolentus	35			

Some species, such as Kuhlia bilunulata and Mesopristia kneri, were caught mainly after heavy rainfall. These species were also caught in Rewa River mangroves, where the freshwater runoff is high (Swamy, unpublished data).

Wairiki Creek and its environment appears to serve as feeding grounds for a number of coastal coralline species, such as Priancathus hamrur, Lutjanus rivulatus, Psuedopristipoma nigra, sp. of Triakidae, sp. of Chaetocontidae, etc. This is largely due to the presence of coral reefs and deeper water nearby. Salinity at the mouth at low tide was in the range of 20-332 ppm, even after heavy rains. During low rainfall days, there was little difference between surface and bottom salinities. Siganus vermiculatus and Lethrinus harak were dominant during the dry period, when the water was not muddy.

The crabs, Scylla serrata, Portunus pelagicus and P. sanguinolentus were among the most common species found. S. serrata, which was the dominant crabs species, is a highly priced fish food in Fiji and is normally caught by hand in mangroves or by 'dillies' in the estuaries. Though kuka

(Sesarma sp) was caught only once, their burrows were found in large numbers in the intertidal areas under the mangroves.

5. DISCUSSION

Commercial fisheries in the tropics are largely dependent upon coastal and estuarine fishes. In Fiji, over 70% of the fishes landed in municipal markets were coastal or estuarine species, mainly dominated by Mugilidae, Siganidae, Carangidae, Lutjanidae and Letherinidae (Fisheries Division 1979, 1980), of which over 60% of the species spend some time in the mangroves. Though the present project is not completed, some general observations can be made about the use of mangrove for feeding and as a nursery.

As evident from the results, a large number of fishes utilize mangroves as a habitat or nursery and feeding grounds. Juveniles of some of the commercially important fishes, such as Lutjanidae (L. argentimaculatus, L. fulvus) Siganidae (S. vermiculatus) Sphyraenidae (S. baracuda), Mugilidae (V. seheli) Carangidae (C. sexfasciatus, C. ignoblis, C. papuenuis) were collected in gill nets or while seining around in shallow waters. Ward (1976) also collected juveniles of Mugilidae, Mullidae, Siganidae, Lutjanidae and Sphyraenidae in box and bushtraps. Juveniles of other fishes, such as Muraenidae, Bothidae, Soleidae, were also caught in Wairiki.

Since mangroves are situated on the land water interface and in an area where fresh water mixes with saline water, the estuarine coastal zone is a highly productive area. Mangroves are a rich source of nutrients. Where present, they provide a major basis for the secondary productivity of the estuarine and coastal zone (Odum, 1970). The southern Florida mangroves, with 850 gm/m^2 /year on average of litter fall (Heald, 1969), provide an important source of nutrients. Bunt (1979) reported a higher litter fall of 1000gm/m^2/year in North Queensland, which compares with 1100gm/m^2/year of litter fall recorded in Wairiki Creek (Lal, unpublished data).

Detritus forms the basis of the food chain for the detritus consumers, either within the mangrove ecosystem or elsewhere, when washed into adjacent estuarine or coastal waters. Carter et al. (1973) estimated that at least 57% of the total energy budget of Fakha Union Bay, Florida was supported by exports from the mangrove forests. Export from tropical mangroves may be higher because of continuous productivity and higher rainfall (Bunt, 1979). Detritivorous fauna, in turn, provide food for organisms at higher trophic levels (Odum, 1970).

6. CONCLUSION

The mangrove ecosystem, apart from yielding other benefits, is a highly valuable economic resource. Reclamation will reduce the annual production of organic detritus in an estuary, which will thus lead to reduction in fish and other fauna of commercial importance.

Fiji's artisanal commercial fisheries, dominated by coastal estuarine species, are, to a large extent, dependent on the mangrove ecosystem. Over 60% of commercially important species, at some stage in their life history, may utilize mangrove areas. At least 83% of the fish species caught in Wairiki Creek's mangroves are utilized as a source of food, while at least two-thirds are of commercial importance.

REFERENCES

Baines, G. 1979. Mangroves for National Development. A report for the Government of Fiji, 29 pp.

Bunt, J.S. 1979. Primary Productivity - Litter Fall. Paper presented at the National Mangrove Workshop. April 18-20 at the Australian Institute of Marine Sciences, Townsville, Australia.

Carter, M.R. and collaborators, 1973. Ecosystem analysis of the big cypress swamp and estuary. U.S. E.P.A., Atlanta, Georgia.

Chapman, V.J. 1977. (ed) Ecosystems of the World. Vol. I. Wetland Coastal Ecosystems. Elservier Sci. Publ. Co. Amsterdam - Oxford - NY.

Collette, Bruce B. 1980. Mangrove Fishes of New Guinea. Paper presented at the International Symposium on Biology and Management of Mangroves. Port Moresby. 1980.

Fischer, W. and P.C.P. Whitehead. 1974 . FAO Species identification sheets for fishery purposes, Eastern Indian Ocean (57) and Western Central Pacific 71. Volumes I-V.

Fiji Fisheries Division. Annual Reports 1979-1981.

Fox, A.M. 1974. There is much binding in Marsh. Parks and Wildlife Vol. 1(4): 103-109.

Hassal, D. 1981. Variation in Fiji Mangrove vegetation and its response to development. Paper in preparation.

Heald, E.J. 1969. The production of organic detritus in a South Florida Estuary. Unpublished PhD thesis, University of Miami, Florida.

Inger, R.F. 1955. Ecological notes on the fish fauna of a coastal drainage on North Borneo. Ferldiana Zool. 37: 47-90.

Lal, Padma N. 1981. Institutional Aspects of the Management of Mangrove Resources. A paper presented at the Fiji Environment Management Committee, October 1981.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forest in the Indo-West Pacific Region. Adv. Mar. Biol. 6: 74-270.

Marshal, C. (undated) Yield management of the mangrove salt swamp forest of Fiji. Department of Forestry, Fiji, 19pp.

Munro, Ian S.R. 1967. The fishes of New Guinea. Department Agr. Stock, Fish, Port Moresby. 651p.

Odum, W.E. 1970. Pathways of energy flow in a South Florida Estuary. Unpublished PhD thesis, University of Miami, Florida.

Odum, W.E. and E.J. Heald. 1972. Tropic analysis of an estuarine mangrove community. Bull. Mar. Sci. 22: 671-731.

Richmond, T. and J. Ackerman. 1975. Flora and Fauna formations in Viti Levu and Vanua Levu, Fiji. Proc. Int. Sym. Biol. and Mgmt. of Mangroves, Honolulu. October 8-11 1976. pp. 153-169.

Sastrakusumah, S. 1971. A study of the food of juvenile migratory pink shrimp, Penaeus duorarum, Burkenroad. Univ. of Miami Sci Grant. Tech. Bull. No 9.

Ward, N.J.R. 1977. Small fishes in a Fiji mangrove. Unpublished ms. Fisheries Department, Fiji.

Watson, J.G. 1928. Mangrove forests of the Malay Peninsula. Malay. For. Rec. 6: 1-275.

Weber, M. and L.F. Beaufort. 1930. Fishes of the Indo-Australian Archipelago, Volumes I-X.

APPENDIX I

Number of Individuals in various Families
caught in Wairiki Creek
May-October 1982

FAMILIES	No.	%	WT (gms)	%
MUGILIDAE	120	14.4	31925.0	22.8
LEIOGNATHIDAE	119	14.3	4957.0	2.5
MULLIDAE	94	11.4	21351.0	14.8
LUTJANIDAE	83	9.2	15285.0	10.8
LETHRINIDAE	63	8.6	10789.0	7.6
GERRIDAE	58	6.9	5560.0	3.9
CARANGIDAE	45	5.3	4361.0	2.9
SIGANIDAE	45	5.3	6108.0	4.2
POLYNEMIDAE	24	2.8	3395.0	2.6
ACANTHURIDAE	19	2.4	1648.0	1.1
KUHLIIDAE	14	1.7	1580.0	1.1
TETRAODONTIDAE	8	1.0	2394.0	1.7
BOTHIDAE	6	.7	254.0	.2
SPHYRAENIDAE	5	.6	2886.4	2.0
MONODACTYLIDAE	5	.6	480.0	.3
BELONIDAE	4	.5	-1.0*	1.0
MURAENIDAE	2	.2	3830.0	2.8
SCOMBRIDAE	3	.3	1770.0	1.2
PLOTOSIDAE	2	.2	950.0	.3
CHAETODONTIDAE	1	.1	220.0	.2
KYPHOSIDAE	2	.2	183.0	.2
HEMIRHAMPHIDAE	2	.2	140.0	.2
TRICHIURIDAE	1	.1	562.0	.4
MEGALOPHIDAE	1	.1	600.0	.4
ELEOTRIDAE	2	.2	440.0	.3
DASYATIDAE	1	.1	150.0	.2
DACYLOPTERIDAE	1	.1	1576.0	1.3
TRIAKIDAE	1	.1	95.0	.1
PERIOPHTHALMIDAE	1	.1	1576.0	1.1
APOGONIDAE	1	.1	70.0	.1
EPINEPHELIDAE	2	.1	-1.0	1.0
PLATACIDAE	1	.1	200.0	
SCATOPHAGIDAE	1	.1	-1	
CHIROCENTRIDAE	1	.1	-1	
MURAENESOCIDAE	1	.1	-1	
SOLEIDAE	1	.1	-1	
PRIACANTHIDAE	1	.1	-1	
FISTULARIDAE	1	.1	-1	
SCORPAENIDAE	3	.3	-1	
SCARIDAE	1	.1	-1	
PLECTORHYNCHIDAE	1	.1	-1	
Crustacean				
PORTUNIDAE	96	11.5	16585.0	11.6
ZANTHIDAE	1	.1	-1	
TOTAL	847	100.0	141920.4	100.0

* -1 represents data not available

APPENDIX II

LIST OF FISH SPECIES CAUGHT IN WAIRIKI CREEK MANGROVES

\+ Food Species

Scientific Name	English Name	Fijian Name
ACANTHURIDAE		
+ *Acanthurus zanthopterus* (Valenciennes)	Ring-tail Surgeon fish	Belagi
ANTENNARIIDAE		
Antennarius nummifer (Cuvier)	Ocellated angler fish	
APOGONIDAE		
+ *Apogon ceramensis* (Bleeker)	Cream Cardinal fish	Tina
Sphaeramia orbicularis (Cuvier)	Polka-Dot Cardinal fish	Tina
BELONIDAE		
+ *Strongylura incisa* (Valenciennes)	Large-scaled Long Tom	Saku
BOTHADAE		
+ *Bothus pantherinus* (Ruppell)	Leopard flounder	Dabilai
CARANGIDAE		
+ *Gnathanodon speciosus* (Forskal)	Golden Trevalley	Bilu Saqa
+ *Carangoides oblognus* (Cuvier)	Coach-Whip Trevalley	Saqa
+ *Caranx melampygus* (Cuvier)	Blue fin-Trevalley	Saqa
+ *C. sexfasciatus* (Quoy and Gaimard)	Great Trevalley	Saqa
+ *C. ignobilis* (Forskal)	Lowly Trevalley	Saqa
+ *C. papuensis* (Alleyne & Macleay)	Brassy Trevalley	Saqa
+ *Trachinotus blochii* (Lacepede)	Snub-nosed dart	Qawa Qawa
* *Scomberoides tol* (Forskal)	Queen fish	Votonimoli

Scientific Name	English Name	Fijian Name
+ Scomberiodes lysan (Forskal)	Queen fish	Votonimoli
CARCHARHINIDAE		
+ Triaenodon obesus (Ruppell)	Blunt-head Shark	Qio
CHAETODONTIDAE		
Anisochaetodon auriga (Forskal)	Thread-fin Coral fish	Tivi Tivi
A. vagabundus	Vagabond Coral fish	Tivi Tivi
Chaetodon ephippium (Cuvier)	Saddled Coral fish	Tivi Tivi
CHIROCENTRIDAE		
+ Chrocentrus dorab (Forskal)	Wolf-Herring, Dorab	Voivoi
DACTYLOPTERIDAE		
Dactyloptena orientalis	Purple Flying-Gunard	
DASYATIDAE		
+ Amphotistius kuhli (Muller & Henle)	Blue-spotted stingray	Vai
ELEOTRIDAE		
+ Eleotris sp.		Bo
ENGRAULIDAE		
+ Stolephorus bateviensis (Hardenberg)	Golden-bellied anchovy	
EPINEPHELIDAE		
+ Epinephelus tauvina (Gunther)	Saddled Rock Cod	Kawa Kawa
+ Epinephelus tauvina (Forskal)	Greasy Cod	Kawa Kawa
+ Epinephelus fuscoguttus (Forskal)	Flower Cod	Delabulawa
FISTULARIIDAE		
Fistularia petimba (Lacepede)	Smooth Flutemouth	

Scientific Name	English Name	Fijian Name
GERRIDAE		
+ Gerres marosoma (Bleeker)	Silver Biddy	Matu
+ Gerres filamentosus (Cuvier)	Spotted Silver Biddy	Matu
GOBIIDAE		
Pandaka sp.		
Goby sp.		
HEMIRHAMPHIDAE		
Zenarchopterus dispar (Valenciennes)	River Garfish	Busa
+ Hemirhmpus far (Forskal)	Garfish	Busa
+ Kuhlia bilunulata (Here)	Flagtail	Mataba
+ Kuhlia rupestris (Lacepede)	Rock Flagtail	Ika droka
KYPHOSIDAE		
+ Kyphosus vaigiensis Quoy & Garmard)	Drummer	Sereniwai
LEIOGNATHIDAE		
+ Gazza minuta (Bloch)	Common tool - Pony fish	Kai Kai
+ Leignathus equulus (Forskal)	Common Pony fish	Kai Kai
+ Leiognathus fasciata	Thread-fin Pony fish	Kai Kai
LETHERINIDAE		
+ Letherinus harak (Bleeker)	Thumb-print Emperor	Kabatia
+ L. ramak		Kabatia
+ L. reticulatus (Valenciennes)	Reticulated emperor	Kabatia
+ Lethrinella miniata (Bloch & Schneider)	Long nosed emperor	Dokonivudi
LUTJANIDAE		
+ Lutjanus argentimaculatus (Forskal)	Mangrove jack	Dami Tiri
+ L. eherenbergi (Peters)	Eherenbergi sea perch	Kake

Scientific Name	English Name	Fijian Name
+ L. monostigmus (Cuvier)	One spot sea perch	Kake
+ L. lunulatus (Mungo & Park	Crescent sea perch	Kake
+ L. fulvus (Schneider)	Flame-tailed snapper	Kake
+ L. rivulatus (Cuvier)	Blue spotted sea perch	Regua
+ L. fulviflama (Forskal)	Black spot sea perch	Kake
MEGALOPHIDAE		
+ Megalops cyprinoides (Broussonet)	Ox-eye herring	Yavula
MONODACTYLIDAE		
+ Monodactylus argenteus (Linnaeus)	Silver Baitfish	Tivitivi
MUGILIDAE		
+ Valamugil seheli (Forskal)	Blue tail mullet	Kanace
+ Liza vaigiensis (Quoy & Saiinard)	Diamond Scale mullet	Kanace
+ Mugil cephalus (Linnaeus)	Mangrove mullet	Kanace
+ Liza subviridis		
MURAENIDAE		
+ Thysoidae macura		Nawalu
MURAENESOCIDAE		
+ Muraenox cinereus (Forskal)	Pike eel	Dubea
PERIOPHTHALMIDAE		
Periophthalmus valgaris (Eggert)	Barred mud-skipper	Tiloko
PLATACIDAE		
Platax orbicularis (Forskal)	Narrow banded bat fish	Dadrose, vunavuna, naqa yalewa

Scientific Name	English Name	Fijian Name
PLECTORHYNCHIDAE		
+ Psendop rstipoma nigra (Cuvier)	Brown Sweet lips	Sevaseva
PLOTOSIDAE		
+ Plotosus anguillaris (Bloch)	Cat-fish eel	Kaboa
POLYNEMIDAE		
+ Polydactylus plebeius (Broussonet)	Common thread-fin	Uculuka
+ Polydactylus microstomus (Bleeker)	Small mouthed thread-fin	Uculuka
PRIACANTHIDAE		
+ Priacanthus hamrur (Forskal)	Lunar tailed bulkeye	Dovodovo
SCARIDAE		
SCATOPHAGIOAL		
+ Scatophagus argus	Spotted scat	Batikau
SCOMBRIDAE		
+ Rastrelliger brachyosoma (Bleeker)	Striped mackerel	Salala
SCORPAENIDAE SP.		
Scorpaena aurita		
Dendroscopaena cirrhose (Thuuber)	Weedy stingfish	
Pterois volitans (Linnaeus)	Red-fire fish Scorpion cod	
SIGANIDAE		
+ Siganus vermiculatus (Valencieunes)	Vermiculated spine foot	Nuqa
+ Siganus spinus (Linnaeus)	Black trevalley	Nuqa
SOLEIDAE		
+ Achirus panoninus (Lacepede)	Peococil	Dabilai

Scientific Name	English Name	Fijian Name
SPHYRAENIDAE		
+ Sphyraena barracuda (Walbauma)	Great Barracuda	Oqo
+ Sphyraena forsteri (Cuvier)	Forsters barracuda	Oqo
SYNANCEIIDAE		
+ Synanceja trachynis (Richardson)	Estuarine stonefish	
SYNODONTIIDAE		
Saurida gracilis	Lizard fish	Utimate
TETRADONTIDAE		
+ Arothon immaculatus (Block & Schneider)	Narrow lined	Sumusumu
THERAPONIDAE		
+ Therapon jarbua (Forskal)	Crescent perch	Qitawa
TRICHIURIDAE		
+ Trichiurus haumela (Forskal)	Common hairtail	Tovisi
PORTUNIDAE		
+ Sçylla serrata	Mangrove crab	qari
+ Portunus pelagicus		qari
+ Portunus sanguinolentus		
XANTHIDAE		
+ Sesarma sp.		kuka

4.7 Bait Fisheries and their Possible Impact on Coastal Fisheries

by

A.D. Lewis*

ABSTRACT

A review of the bait fishery associated with pole and line skipjack tuna fishing operations in the Pacific is presented in this paper. Pole and line fishing still remains the primary option available to Pacific island countries wishing to develop sizeable commercial tuna fisheries.

Bait is generally captured in sheltered coastal waters, with the use of lights at night, with dip nets or small purse sein. Over 200 species have been identified from baiting at 22 sites in Papua New Guinea waters alone. Relatively few of these, however, are of any practical importance to catches. Great natural fluctuations in abundance are recorded in baitfish populations. Little is known, though, about the underlying processes inducing such charges.

On balance, it seems unlikely that bait fisheries have any significant impact on coastal fisheries in island states of the Pacific.

---

*Ministry of Agriculture and Fisheries
Suva
FIJI

1. INTRODUCTION

For most Pacific island countries, skipjack fisheries have long represented the best opportunity for significantly increasing local fish production and, in the longer term, generating export earnings from their marine resources. Narrow continental shelves and a virtual absence of inland waters restrict fishing opportunities to the coastal lagoons and reefs. In some of these areas, increasing population and environmental alterations are already placing these systems under stress. Papua New Guinea, and to a lesser extent, the Solomon Islands, Fiji and New Caledonia, may be possible exceptions to this.

Even in these countries, the potential offered by the skipjack resources cannot be ignored. Results of the SPC's three-year Skipjack Survey and Assessment Program (Anon., 1981a) indicated that, within the SPC area, current annual catches represent less than 10% of the standing stock. Skipjack schools tend to be most abundant close to islands. Methods for their capture are highly developed. Until the current recession, international demand for tuna had been doubling roughly every ten years. The long-term market prospects are still believed by most observers to be good. By the mid-seventies, Kearney (1979) estimated that skipjack accounted for 72% of the total fish catch recorded by coastal states and territories within the area of the SPC. Although somewhat biased by the large skipjack catches in Papua New Guinea and the Solomon Islands, it does not include the considerably larger catches made by distant water fleets. With the declaration of EEZs by many countries, the skipjack option has become more attractive.

Although highly developed artisanal tuna fishing skills and lore have long been an important part of many Polynesian and Micronesian societies (e.g. Nordhoff, 1930; Johannes, 1981), significant island-based exploitation of the resource of skipjack and other tunas has generally only come about with the development of local joint-venture operations, usually involving Japanese interests. The *bonitiers* of French Polynesia could be considered an exception, as they operate in a rather unique economic milieu. Such joint ventures were set up in PNG (1970), Solomon Islands (1973) and Fiji (1975). Several Micronesian islands, such as Palau, Saipan, Truk and Ponape, supported sizeable skipjack fisheries under Japanese occupation. Some of these have been revived in recent times. Encouraged by the relative success of such ventures, other Pacific island countries, notably Kiribati, Tuvalu, Tonga and New Caledonia are in the process of attempting to set up skipjack fisheries.

In all cases, the great majority of skipjack are caught by the pole and line method, which in a sense involves two fisheries- firstly, a capture fishery, generally carried out at night using lights and dip nets to capture small baitfish in the sheltered coastal waters. These are then kept alive on board in tanks with circulating seawater. Secondly, a daytime fishery involving the capture of skipjack from schools located by visual scouting and induced to take artificial lures by broadcasting live bait into the school to generate an active feeding response.

Great technological advances have been made recently in the use of the purse seining techniques applicable to the region. These do not require bait, but are technically highly sophisticated and require an initial capital investment beyond the capability of most island countries: a small vessel of around 350 tons capacity. Many now cost up to $5 million dollars to build and fully equip. A third method of tuna fishing, longlining for larger tunas, is labor-intensive (and, as such, has remained generally the province of East Asian fishing nations). With declining yields and increasing overheads, this is becoming an increasingly less attractive proposition. Pole and line fishing, therefore, may still develop sizeable commercial tuna fisheries, even though its technical requirements are not simple and the degree of commitment required is high.

The development of bait fisheries in island countries to support skipjack vessels has not been without its problems; as with most fisheries resources, the size of the baitfish resource tends to be a function of land mass size. Some larger countries, such as PNG and the Solomon Islands, have impressive resources sufficient to support sizeable fleets. Up to 51 pole-and-line vessels have operated in PNG at any one time, for example (Wankowski, 1980); others,such as Fiji, Palau and New Caledonia, have resources sufficient to support more limited fisheries. The smaller island countries either have insufficient baitfish resources to even consider starting pole and line fisheries (e.g. Cook Island, Niue, Nauru) or have attempted to supplement their natural stocks with cultured bait (e.g. Kiribati, Hawaii, Western Samoa).

Bait is captured in sheltered coastal waters. The fact that these waters are subject to traditional claims has created problems of access. Concern has also been voiced about the possible effect of bait fishing activities on other coastal fisheries. The present paper is primarily concerned with this issue, with particular reference to the Fijian situation.

2. BAIT FISHERIES

As mentioned earlier, bait is generally captured with the use of lights at night, with dip nets or small purse sein. Daytime operations, using beach seins or other nets, are of minor importance at present and are not considered here.

2.1 Species Composition

A wide variety of fish species is often captured during night baiting operations. Lewis et al.(1974), for example, list over 60 families and close to 200 species from baiting at 22 sites in Papua New Guinea waters. Relatively few of these are of any practical importance to catches, which are dominated in numbers and weight by the families Engraulidae (anchovies), Clupeidae (sardines, herrings and sprats), Atherinidae (silversides), Apogonidae (cardinals), Caesionidae (fusiliers) and Scrombidae (mackerels), with Carangidae (scads) and Leiognathidae (ponyfish) of lesser importance. Stolephorus anchovies are the most important group overall, dominating catches in the Papua New Guinea, Solomon Islands, Palau and Hawaiian bait fisheries. Catches in areas outside the 15ºS Zone (e.g. Fiji, New Caledonia) tend to be mixed, with several families contributing equally to catches. Seasonal fluctuations in abundance are also more marked in these areas. Lewis et al.(in press) provide a working key to the more common species in the region. There have been considerable taxonomic difficulties with many of the families in the past.

2.2 Biological Characteristics of Baitfish

2.2.1 Size and Ecological Affinities

The desired size of bait intended for use in skipjack fishing is normally in the range of 3 to 10 cm (Smith, 1977; Yuen, 1977; and various other authors). Fish larger than this generally elicit a poor biting response, possibly because of the disparity in size relative to the lures used, and naturally yield fewer "tails and bucket", an important consideration. The maximum size of most important baitfish species falls well within this range, with the sardines (Sardinella spp.) and mackerels (Rastrelliger spp.) the most obvious exceptions. Although some sub-adult recruitment of smaller baitfish, such as Stolephorus anchovies and sprats (Spratelloides) does occur, (Dalzell and Wankowski, 1980), catches are generally comprised of adults of schooling pelagic or midwater species. Only cardinals (Apogonidae) and fusiliers (Caesionidae) could be considered reef-associated, although they appear to move away from coral heads and reefs at night. It is a common misconception that baitfish catches primarily consist of juveniles of a wide range of commercially important reef species. This is clearly not the case, although small numbers of reef fish juveniles will be taken incidentally from time to time.

2.2.2. Life History

Few detailed life history studies on tropical baitfish have been carried out. Recent work on Stolephorus anchovies and the silver sprat (Spratoloidea gracilis) in Papua New Guinea (Dalzell and Wankowski, 1980) suggests that these smaller clupeoids are short-lived (3 to 4 months is typical, 6 months exceptional); they commence spawning at lengths as small as 4 cm and are highly fecund. Limited age and growth studies with gold spot herring (Herklotsichthys quadrimacupinguis) (Hida and Uchiyama, 1977; Williams and Clarke, in press) suggest that these species too rarely survive beyond 9 or 10 months. This is in contrast to temperate representatives of the same families in many cases (e.g. Engraulis). Combined with the fact that multiple spawning of the smaller species in particular probably occurs, it appears that rapid turnover and high natural mortality may be characteristic of tropical baitfish populations.

In Fiji and New Caledonia, where seasonal abundance is more marked, there is evidence that the larger species (Sardinella spp., Rastrelliger spp.) may spawn over a relatively brief period (MAF and ORSTOM, unpublished data), even though smaller species spawn over an extended period. It is not known whether this is true of equatorial populations.

2.2.3 Fluctuations in Abundance

Fisheries for schooling pelagics are known to show wide variations in annual catch. Sharp (1981) has recently tabulated examples of such fisheries (Table 1) where peak annual catches in the period 1970-1977 are five times the lowest catch. The Japanese anchovy (1.4 million tons to 17,000 tons) and the Peruvian anchovy (13 million tons to 800,000 tons) are the most spectacular and best known examples, but there are many others, mostly drawn from the families Engraulidae, Clupeidae, Carangidae, and Scombridae.

Because of this often unfavorable reaction to bait fisheries, any negative short-term variation in the catch from coastal fisheries nearby tends to be related back to the presence of bait fisheries. Needless to say, this is not necessarily true of positive variations. While some of these variations are probably attributable to variation in fishing efforts, underreporting of catches, etc., others must reflect real fluctuations in recruitment and biomass, which appear to be a common feature of populations of pelagic species. Baitfish populations can, therefore, be expected to undergo similar environmentally-induced fluctuations in abundance, independent of levels of fishing efforts.

Data from the PNG bait fishery have also shown that species composition may vary considerably between years. The contribution of silver sprat, for example, to catches during the years 1976-1979 varied between 7 and 57% (Dalzell and Wankowski, 1980). These fluctuations, also seen in the two anchovies, could be related back to influxes of new recruits.

Recent data from the multi-species Fijian fishery have shown that, during the 1981-1982 season at least, dominance patterns in the catch changed throughout the season. Blue sprats, herrings, sardines and cardinals all predominated in "pulses" throughout the year, as shown in Figure 1 (see also Lewis et al., 1953). It will be interesting to see whether this is a feature of most years.

Fluctuations in abundance and species composition can, therefore, probably be regarded as characteristic of baitfish populations, both within and between years. As yet, we have little understanding of the underlying processes which induce these fluctuations.

3. POSSIBLE EFFECTS ON COASTAL FISHERIES

Even though the value of tuna fisheries and their ancillary operations is generally recognized and accepted, such is frequently not the case with bait fisheries. Part of this stems from a lack of understanding of the fishing operation itself. This is new to most coastal people and seems enormously productive, even though a large vessel, with 25 or more men and sophisticated gear, may typically only catch 100-150 kg per night, a poor reward for 25 men fishing on the reef. Part of it stems from an understandable reluctance to see a large "outside" vessel operating independently in inshore areas. Unfortunately, experience has shown that, in tropical areas, with their relatively low catch per set, it is simply not economically feasible to operate the bait fishery as a separate entity, as is done in many temperate areas, even though it is highly desirable from other points of view to do so.

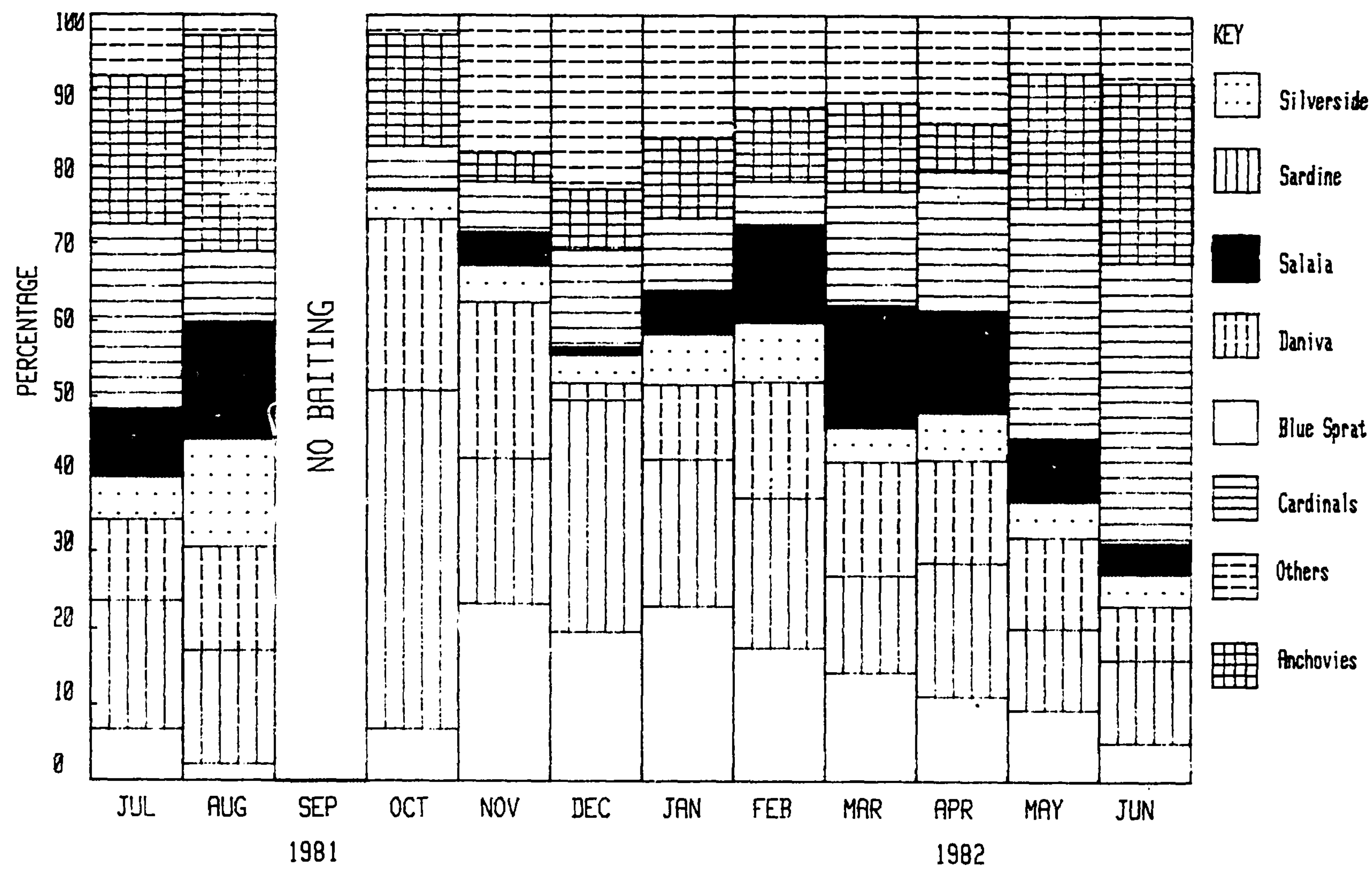
Table 1

TRAJECTORIES OF CATCH TRENDS FROM 1970-77

Species	Area	(A) Peak Catch	(B) Low catch	Ratio (A/B)	
Caranx hippos	West Africa	28 221	1 036	27.	+
Orcynopsis unicolor	West Africa	2 600	100	26.	-
Trachurus capensis	Southwest Africa	690 164	62 300	11.	+
Trichiurus lepturus	Southwest Africa	28 545	3 800	7.5	+
Trachurus trecae	Southwest Africa	273 700	31 298	8.7	-
Sardinella spp.	Southwest Africa	142 200	20 986	6.8	- +
Scomber japonicus	Peru	65 000	8 700	7.5	+
Scomber japonicus	Northeast Atlantic	39 000	6 262	6.2	-
Rastrelliger spp.	Eastern Indian Ocean	16 300	2 000	8.2	+
Rastrelliger kanagurta	Eastern Indian Ocean	203 100	35 403	5.7	
Anchovies	Western Indian Ocean	118 062	16 900	7.0	+
Psenopsis anomala	Northwest Pacific Ocean	13 000	1 994	7.0	-
Sardinops melanosticta	Northwest Pacific Ocean	1 420 512	16 900	84.	+
Engraulis mordax	Eastern Pacific Ocean	289 002	44 600	6.4	+
Cetengraulis mysticetus	Eastern Tropical Pacific	168 081	15 551	10.8	+
Trachurus symmetricus	Eastern Pacific Ocean	50 149	9 400	5.3	+
Sarda chiliensis	Southeastern Pacific Ocean	74 700	4 341	17.2	-
Scomberomorus sierra	Peru	2 279	400	5.7	+
Engraulis ringens	Peru	13 059 900	807 175	16.	-
Sardinops sagax	Peru-Chile	1 467 555	68 600	21.	+
Trachurus trachurus	Peru-Chile	839 805	111 300	7.6	+
Thyrsitops lapidopoides	Chile	7 200	630	11.6	-
Cetengraulis edentulus	Venezuela	4 96	850	5.8	- +
Decapterus russelli	Malaysia-Thailand	109 337	9 800	11.2	+
Scomberoides spp.	Indonesia-Philippines	5 186	500	10.	+

Plus and minus signs in the Table represent directions of trends during the reference period. The indication - + implies sharp changes in both directions in the order indicated.

Figure 1
SPECIES COMPOSITION OF TOTAL CATCH DURING THE 1981-1982 SEASON



Note: Salala - mackerel, daniva = gold-spot herring.

The possible harmful effect of bait fishing on these fisheries cannot be dismissed, however, and will be considered here under two categories :

direct , where there is a quantifiable cause and effect link between the two fisheries;

indirect , where effects are felt in the longer term, through an intermediate factor and are more difficult to quantify.

3.1 Direct Effects

3.1.1 Interference with Recruitment of Juveniles

It has earlier been pointed out that baitfish catches are essentially comprised of adults and sub-adults of schooling pelagics. Given the high natural mortalities amongst pelagic larval and juvenile stages due to predation, environmental effects, etc., it is unlikely that recruitment is affected by incidental catches of reef fish juveniles during baiting operations. In any case, not all species are attracted to lights.

3.1.2 Depletion of Common Stock

Very few of the species captured during bait fishing are the target of important coastal fisheries in the region. The gold spot herring (Herklotsichthys quadrimaculatus), mackerels (Rastrelliger spp.) and seasonal inshore concentrations of anchovies (Stolephorus spp.) are of some importance. There is, however, nothing comparable to the large well-developed night fisheries for coastal pelagics which supply much of S.E. Asia's coastal fisheries production. With the possible exception of the Rastrelliger fishery in Fiji, gear used to catch coastal pelagics in Pacific island countries is simple and levels of exploitation probably quite low. Fish are only caught when schools move close inshore; reasons for these movements are not understood but they do seem to show year-to-year variation in strength, timing and location, and are subject to depletion by coastal fishermen themselves (Johannes, 1981).

Although difficult to prove, it generally appears unlikely that bait fisheries would have any measurable impact on local fisheries for coastal pelagics, which essentially target only on a small vulnerable segment of the populations. The occurrence of large "natural" fluctuations in abundance has previously been demonstrated, making such proof more illusory.

Three other points, from the Fiji situation but presumably pertinent to other countries as well, are worth noting. Firstly, many of the important baitfishes are unknown to coastal fishermen and have no local names, good evidence that they are not directly fished. Secondly, the gold-spot herring, probably the most commonly seen baitfish inshore, is sometimes toxic (studies on this clupeotoxin are currently in progress) and is often not eaten as a result. Thirdly, species caught inshore are often similar in appearance to those caught in baiting operations. The gold anchovies (*Stolephorus apiensis*, *S. bataviensis* (inshore) and *S. devisi* (offshore)) are a good case in point, demonstrating that a precise taxonomy is needed when examining cases of "common stocks".

3.2 Indirect Effects

The most commonly voiced fear is, perhaps, that bait fishing is reducing the amount of forage available for desirable predatory species, both in deeper water and inshore. (The inshore concentrations of pelagics are of direct concern, since they attract predators inshore, rendering them more vulnerable to capture).

The large "normal" fluctuations in abundance of small schooling pelagics, as mentioned earlier, and the general lack of obvious fluctuations in the catches of predators known to utilize them as food suggests that the predators are, in most cases, unlikely to be food limited. In small island ecosystems, which may more closely approximate closed systems, direct interdependence between predator and prey may be more likely, but such situations would not normally support bait fisheries.

It is, however, important to look at this situation in more detail. The best available figures in the region for all sectors of the coastal fishery and a bait fishery in combination are probably those from Fiji (see various Annual Reports). Here, the maximum bait catch recorded has been 80,000 buckets. At a conversion rate of 1 bucket = 2 kgs wet weight of fish, an estimated bait catch of 160 tons is arrived at. Even if this is extended to 200 tons, assuming a rough conversion rate of 10 : 1 for prey weight to predator weight, this translates into an equivalent predator biomass at the next trophic level of 20 tons.

Fisheries Division surveys have estimated the subsistence fishery catch of Fiji at around 14,000 tons. Assuming the baitfish catch does produce such a direct effect on predator biomass (which is unlikely), this entails a "loss" of less than 0.2% of the existing subsistence catch. This is without considering the commercial catch, which probably approaches 3,000 tons.

Although a particularly naive analysis, it does attempt to put the catch of baitfish as forage in perspective, especially as bait fishing effort is widely and relatively evenly distributed over Fiji waters. In resource-rich PNG waters, bait catches have hovered around the 1,500 ton mark, all from several very restricted areas. I know of no demonstrable effect on coastal fisheries in waters adjacent to these areas of intensive bait fishing effort. The PNG Fisheries Division was examining this problem, but I have been unable to obtain any details as yet.

A less frequently discussed issue is the capture of predators (*Scomberomorus*, *Sphyraena*, *Caranx*, etc.) by hand line, as an adjunct to baiting operations. This is based on the habit of predators cruising around the periphery of the illuminated zone, where they are vulnerable to capture by baited lines. Nightly catches are often considerable, frequently exceeding the baitfish catch by weight. In addition to representing an important but poorly documented source of coastal fish production, this activity may conceivably have a measurable impact on local predator populations.

On balance, it generally seems unlikely that bait fisheries are having any significant impact on coastal fisheries in island states, although a detailed study in an area where such effects are most likely to be felt would be extremely useful. Given the multiplicity of factors involved, no one suggests that this would be an easy task.

A final point concerns the species composition of the coastal fisheries catch itself in island states. Using the Fiji Municipal Market data for 1981 as an example, the catch, an estimated 926 tons, has been broken down by arbitrarily categorizing species as higher trophic level predators, omnivores and herbivores respectively (Table 2). It can be seen that roughly one third of the catch is comprised of higher level predators. Catches sold directly to retail outlets (hotels, restaurants - 1300 tons) contain an even higher percentage of these predators (45.8%).

Table 2

Percentage Catch Composition by Trophic Category, Fiji

	Municipal Markets (926 tons est.)	Other outlets (1303 t. est.)
Higher level predators*	32.0	45.8
Omnivores +	28.9	29.2
Herbivores ¥	39.1	24.9

*Serranidae	+Lethrinidae	¥ Mugilidae
Sphyraenidae	Scombridae (Thunnini)	Siganidae
Carangidae	Mullidae	Chanidae
Belonidae	Leiognathidae	Hemirhamphidae
Lutjanidae	Gerridae	Scombridae (Rastrelliger)
Elopidae		
Scombridae (Scomberomorus)		

Subsistence catches, given the techniques commonly used (i.e. fish driers, traps), may contain a higher percentage of herbivores. It is, however, clear that commercial fishing activity, which will presumably account for the biggest future increase in the coastal (cf. offshore) fisheries catch, is largely directed toward higher level predators.

While the population dynamics of complex reef fish communities are poorly understood, it may not be out of place to suggest that current fishing practices and consumer preferences, which lead to the systematic removal of large quantities of these higher level predators, may in the long term be much more ecologically disruptive than bait fishing activity. The question seems worthy of detailed study.

REFERENCES

Anonymous. 1981a. Skipjack migration, mortality and fishery interactions. Regional Technical Meeting on Fisheries, 1981, 13: Working Paper No. 9, South Pacific Commission, Noumea, New Caledonia.

Anonymous. 1978. Annual Report 1977, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 58 pp.

Anonymous. 1979. Annual Report 1978, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 116 pp.

Anonymous. 1980. Annual Report 1979, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 116 pp.

Anonymous. 1981b. Annual Report 1980, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 99 pp.

Anonymous. 1982. Annual Report 1981, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 95 pp.

Anonymous. 1983. Annual Report 1982, Fisheries Division, Ministry of Agriculture and Fisheries, Suva, Fiji. 91 pp.

Dalzel, P.J. and J.W.J. Wankowski. 1980. The Biology, population dynamics, and fisheries dynamics of exploited stocks of three baitfish species, *Stolephorus devisi*, *Stolephorus heterolobus* and *Spratelloides gracilis* in Ysabel Passage, New Ireland Province, Papua New Guinea Res. Bull. DPI P. Moresby, 27: 124 pp.

Hida, T.W. and J.H. Uchiyama. 1977. Biology of the Baitfishes *Herklotsichthys punctatus* and *Pranesus pinguis* in Majuro, Marshal Islands. In Shomura, R.S. (ed.), Collection of Tuna Baitfish Paper, NOAA Tech. Report, NMFS Circular 408, December 1977. p. 63-68.

Johannes, R.E. 1981. Words of the Lagoon-Fishing and Marine Lore in the Palau District of Micronesia. University of California Press. Berkeley. 245 pp.

Kearney, R.E. 1979. An overview of recent changes in the fisheries for highly migratory species in the Western Pacific Ocean and projections for future development. SPEC (79) 17. South Pacific Bureau for Economic Cooperation, Suva, Fiji.

Lewis, A.D., B.R. Smith and R.E. Kearney. 1974. Studies on tunas and baitfish in Papua New Guinea Waters - II Res. Bull. DASF P. Moresby, II : 112 pp.

Lewis, A.D., S. Sharma, J. Prakash, and B. Tikomainiusladi. 1983. The Fiji Bait Fishery 1981-1982, with notes on the biology of the goldspot herring, Herklotsichthys quadrimaculatus (Clupeidae), and the blue sprat, Spratelloides delicatulus (Dussumieriidae). Tech. Rept., Fisheries MAF Fiji 6 : 50 pp.

Lewis, A.D., B.R. Smith, and C.P. Ellway. (in press). A guide to the common tuna baitfishes of the SPC area.

Nordhoff, C.B. 1930. Notes on the offshore fishing of the Society Islands. S. Polynesian Soc., 39 : 137-173, 221-262.

Sharp, G.D. 1981. Colonization: modes of opportunisms in the Ocean. In Workshop on the Effects of Environmental Variation on the Survival of Larval Pelagic Fisheries, Lima. 20 April -5 May 1980. IOC Workshop Report No. 28, p. 143-166.

Smith, B.R. 1977. Appraisal of the live bait potential and handling characteristics of the common tuna bait species in Papua New Guinea. In R.S. Shomura (ed.), Collection of Tuna Baitfish Papers NOAA Tech. Rept. NMFS, Circular 408, December 1977. p. 95-103.

Wankowski, J.V.J. 1980. Recent history and summarized statistics of the industrial fisheries for tunas and tuna-like species in the area of the Papua New Guinea Declared Fishing Zone, 1970-1979. Res. Bull. DPI. P. Moresby, 24 : 82 pp.

Williams, V.R. and T.A. Clarke. (in press). Reproduction, growth and other aspects of the biology of the gold spot herring, Herklotsichthys quadrimaculatus (Clupeidae), a recent introduction to Hawaii.

Yuen, H.S.H. 1977. Desired characteristics of a bait for skipjack tuna, Katsuwonus pelamis. In R.S. Shomura (ed.), Collection of Tuna Baitfish Papers, NOAA Tech. Rept. NMFS Circ. 408, December 1977. p. 52-54.

ANNEX I: Participants to the Unesco-IOC Special Sessions

Dr. J.T. BAKER
James Cook University, Townsville
Queensland
Australia

Dr. Brydgt BARKER-HUDSON
Biological Sciences
James Cook University, Townsville
Queensland 4811
Australia

Mr. E.J. BARNES
N.Z. Oceanographic Institute
Wellington
New Zealand

Mr. C. McP. BEVOLTZ
International Foundation, Downstate Medical Center
Physiology No. 31, 450 Clarkson Avenue, Brooklyn
New York 11203
U.S.A.

Mr. Denis BINET
ORSTOM
Nouméa
New Caledonia

Dr. Charles BIRKELAND
Marine Laboratory
University of Guam Station
Mangilao
Guam 96913
U.S.A.

Dr. Janet BRADFORD
N.Z. Oceanographic Institute, Box 12-346
Wellington
New Zealand

Dr. James W. BRODIE
1 Fettes Crescent
Seatown
Wellington
New Zealand

Dr. Juan C. CASTILLA
Universita Catolica Chile
Casilla 114-D
Santiago
Chile

Mr. Jeremy CAREW-REID
South Pacific Regional Environment Program
Nouméa
New Caledonia

Mr. J. CHABANNE
ORSTOM
Tahiti
French Polynesia

Mr. Dick CHILCOTT
Department of Agricultural Engineering
Lincoln College
Lincoln
New Zealand

Dr. Satish CHOY
University of the South Pacific
Suva
Fiji

Mr. Chung-Cheng LU
National Museum of Victoria
Melbourne
Victoria
Australia

Mr. Arthur L. DAHL
South Pacific Commission
Nouméa
New Caledonia

Mr. W.R.B. DALE
D.S.I.R.
Head Office
Private Bag
Wellington
New Zealand

Mr. Yves DANDONNEAU
ORSTOM
Nouméa
New Caledonia

Mr. E.W. DAWSON
N.Z. Oceanographic Institute, Box 12-346
Wellington
New Zealand

Mr. B. DELESALLE
French Museum of Natural History
B.P. 12
Mooréa
French Polynesia

Mr. J.V. EADE
N.Z. Oceanographic Institute
Box 12-346
Wellington
New Zealand

Dr. L.G. ELDREDGE
Marine Laboratory
University of Guam Station
Mangilao
Guam 96913
U.S.A.

Mr. John GENOLAGANI
National Parks Service
Boroko
Papua New Guinea

Dr. G.P. GLASBY
N.Z. Oceanographic Institute
Box 12-346
Wellington
New Zealand

Dr. Ed GOMEZ
Department of Zoology
University of the Philippines
Manila
Philippines

Dr. Richard W. GRIGG
Hawaii Institute of Marine Biology
Box 1346
Kaneohe
Hawaii 96744
U.S.A.

Dr. L.S. HAMMOND
Australian Institute of Marine Science
Townsville
Australia

Dr. R.A. HEATH
N.Z. Oceanographic Institute, Box 12-346
Wellington
New Zealand

Dr. Philip HELFRICH
Hawaii Institute of Marine Biology, Box 1346
Kaeohe
Hawaii 96744
U.S.A.

Dr. D.E. HURLEY
Director
N.Z. Oceanographic Institute, Box 12-346
Wellington
New Zealand

Dr. M. HUNGSPREUGS
Chulalongkorn University
Department of Marine Science
Bangkok
Thailand

Mr. Marae IRATA
Ministry of Natural Resource Development
Tarawa
Republic of Kiribati

Dr. R.E. JOHANNES
CSIRO Marine Laboratories
Box 20
North Beach
Perth
Western Australia 6020

Dr. J.B. JILLETT
Department of Zoology
Otago University
Box 56
Dunedin
New Zealand

Mr. M.G. KING
University of South Pacific
Suva
Fiji

Dr. Don KINSEY
Deputy Director
Australian Institute of Marine Sciences
PMB3 Townsville MSO
Queensland 4810
Australia

Mr. Karin KNEDLER
Chemistry Department
Victoria University of Wellington
Private Bag
Wellington
New Zealand

Dr. W.V. KORNEYEV
Institute of U.S. and Canadian Studies
Academy of Sciences
U.S.S.R.

Dr. E.V. KRASNOV
Far East Geological Institute
Vladivostok 690022
U.S.S.R.

Mr. Padma N. LAL
Ministry of Agriculture & Fisheries
Suva
Fiji

Dr. K.B. LEWIS
N.Z. Oceanographic Institute
Box 12-346
Wellington
New Zealand

Mr. Tony LEWIS
Ministry of Agriculture & Fisheries
Suva
Fiji

Mr. J.L. MARTIN
CNEXO, BP 2059
Nouméa
New Caledonia

Mr. Ian MILLER
Chemistry Division
D.S.I.R.
Private Bag
Petone
New Zealand

Dr. Stephen G. NELSON
Marine Laboratory
University of Guam Station
Mangilao
Guam 96913
U.S.A.

Ms. Helen NEWMAN
School of Biological Sciences
Universiti Sains Malaysia
Penang
Malaysia

Dr. James D. PARRISH
Hawaii Cooperative Fishery Research Unit
2538 The Mall, University of Hawaii
Honolulu 96822
U.S.A.

Dr. Boris V. PREOBRAZHENSKY
Pacific Institute of Geography
8 Radio Street
Vladivostok 690022
U.S.S.R.

Mr. Ridzwan A. RAHMAN
Faculty of Fisheries and Marine Science
Universiti Pertanian Malaysia
Serdang
Selangor
Malaysia

Dr. Uday RAJ
University of South Pacific
Suva
Fiji

Mr. Morris RAPSON
Airlie Beach
Queensland 4741
Australia

Mr. M. RICARD
French Museum of Natural History
B.P. 12
Mooréa
French Polynesia

Mr. Don ROBERTSON
Fisheries Research Division, MAP
Wellington
New Zealand

Dr. Garry RUSS
Australian Institute of Marine Science
Townsville
Australia

Dr. Sanga SABHASRI
Ministry of Science, Technology & Energy
Bangkok
Thailand

Mr. M.H. SACHET
Smithsonian Institution
Washington, D.C. 20560
U.S.A.

Dr. Bernard SALVAT
Centre de l'Environment
B.P. 12
Mooréa
French Polynesia

Dr. David STODDART
Department of Geography
Cambridge University
England

Dr. Royd H. THORNTON
Director
Cawthron Institute, Box 175
Nelson
New Zealand

Dr. Victor THITCHEV
Pacific Oceanological Institute
7 Radio Street
Vladivostok
U.S.S.R.

Mr. S.L. TONGILAVA
Department of Lands, Survey and Natural Resources
Nuku'alofa
Tonga

Dr. Roy TSUDA
University of Guam, UOG Station
Mangilao
Guam 96913
U.S.A.

Dr. Colin WOODROFFE
Department of Geography
University of Auckland
Private Bag
Auckland
New Zealand

UNESCO:

Dr. V. PRAKASH
Director
Unesco Regional Office for Science and
Technology for South East Asia
Jalan M.H. Thamrin 14
Jakarta, Indonesia

Dr. J.R.E. HARGER
Program Specialist in Marine Sciences
Unesco Regional Office for Science and
Technology for South East Asia
Jakarta, Indonesia

and IOC Assistant Secretary for WESTPAC II.

UNESCO REPORTS IN MARINE SCIENCE

Title of numbers which are out of stock

No.	Year
3 Benthic ecology and sedimentation of the south Atlantic continental platform Report of the seminar organized by Unesco in Montevideo, Uruguay, 9-12 May 1978	1979
13 Seminario Latinoamericano sobre Enseñanza de la Oceanografía Informe final del Seminario organizado por la Unesco en São Paulo, Brasil, 17-20 de noviembre de 1978	1981