Proceedings of the Seminar/Workshop on UTILIZATION AND MANAGEMENT OF INSHORE MARINE ECOSYSTEMS OF THE TROPICAL PACIFIC ISLANDS, November 24–30, 1979, University of the South Pacific, Suva, Fiji

Sponsored by

THE INSTITUTE OF MARINE RESOURCES

Institute of Marine Resources
University of the South Pacific
Suva, Fiji

International Sea Grant Program
University of Hawaii
Honolulu, Hawaii

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UTILIZATION AND MANAGEMENT OF INSHORE MARINE ECOSYSTEMS OF THE TROPICAL PACIFIC ISLANDS

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University of the South Pacific
Suva, Fiji

Edited by Philip Helfrich

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FOREWORD

This seminar/workshop inaugurated a joint program of the University of the South Pacific and the University of Hawaii under the International Sea Grant Program to seek solutions to marine problems facing the emerging nations of the tropical Pacific. Rapidly increasing populations, drift towards urban centers, and changing patterns of lifestyles have all placed added pressures on the traditional uses of marine resources of the island nations. The initial focus of this inter-university program is on the fragile inshore ecosystems. Thus, this proceedings of the seminar/workshop held on November 24-30, 1979 in Suva, Fiji was primarily concerned with deriving basic management guidelines.

Section I includes a brief overview of coral reef ecosystem research to date, a detailed discussion of the coral reefs of Fiji, and a general discussion of winds, waves, and currents in the tropical Pacific.

Section II is a brief summary of the traditional patterns of utilization of the ecosystems.

Section III consists of present patterns of utilization and development, with discussions of contemporary, non-fishery developments and their potential environmental effects.

Section IV is focused on the most important of inshore ecosystem uses--fisheries.

In Section V, some specific applications of technology transfer are considered.

Section VI is a summary of existing management guidelines.

PREFACE

The establishment of linkages across large geographic distances involving scattered cultures presents many challenges. The successful spanning of space and human relationships is indeed an achievement of vision and deep commitment of the participants. Such a linkage was established when the University of the South Pacific-University of Hawaii International Sea Grant Program was forged.

This volume is a compilation of papers presented at a seminar/workshop, the cooperative effort of the two institutions, which was held in Suva, Fiji, on the University of the South Pacific campus. Participants included government officials and university and private sector representatives from the Solomon Islands, Kiribati, Papua New Guinea, Fiji, Western Samoa, and Hawaii. In addition, two UN agencies, the World Health Organization and the Food and Agriculture Organization, were also represented.

The leadership of Dr. James Maraj, Vice-Chancellor of the University of the South Pacific, was invaluable in establishing the linkage between the two universities and for his contribution to the conceptual and fiscal framework for this international--inter-university program. He also contributed materially to the seminar/workshop as the moderator of the closing session.

Dr. Uday Raj, Director of the Institute of Marine Resources, the main anchor of the UH-USP International Sea Grant Program at the University of the South Pacific, provided much of the technical support and coordination for the seminar/workshop.

The contribution of Ms. Diane Henderson as the text editor of this volume is acknowledged with gratitude. She was also responsible for the

typing of the text. The cover design and printing was done under the supervision of the publications office of the UH Sea Grant College Program.

Valuable contribution to the seminar/workshop was made by Dr. Raj on the "Overview of Inshore Ecosystems" and "Development Patterns Impinging on Inshore Ecosystems" (Commercial Fisheries Developments) panels and Mr. Joseph Harris on the "Technology Transfer/USP and UH Plenary Session" panel. Unfortunately, these papers are not included in this volume. Pressing duties precluded Dr. Raj from completing his papers in time for inclusion in this volume and Mr. Harris' paper was lost in transit through the mail.

The contributions of Ms. Rose Pfund were invaluable. In addition to her active participation in discussions during the seminar/workshop sessions, she recorded the proceedings, assisted in their compilation, and coordinated many aspects of the planning and logistics.

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OPENING ADDRESS

by

The Hon. John P. Condon
The United States Ambassador to Fiji

There are very good reasons why I should be grateful for the invitation to open this seminar today.

As the American Ambassador not only to Fiji but to most of the countries of the South Pacific, I want to highlight the importance of this conference, not only from the point of view of the subject matter it is scheduled to explore, but also from the point of view of what it heralds. This conference should be seen as the initiation of what we hope will be an era of close cooperation between two major universities to the benefit of every one of the Pacific Island communities.

With regard to the subject matter, the participants in this conference are called upon to explore the depths of the largest of the planet's oceans and to exchange ideas on the possible answers to the many questions that lie under the vivid blues and greens of the Pacific. More important than that, the conference will focus on the research and educational programs best suited to enhance the exploration of the ocean's resources as a major contribution to the welfare of the Island peoples.

A University conference of this type, however, could not fail to pay special attention to the problem of how to preserve the marine resources of the region.

The logic of combining the intellectual resources and expertise of the University of the South Pacific and of the University of Hawaii is obvious to us now, but it has not always been so. The decolonization process of the South Pacific highlighted the need and importance of the USP as a regional institution, and at the same time brought home to the University of Hawaii that its natural vocation should be directed to the whole Pacific south of Hawaii.

The invitation to be here today gives me a most agreeable opportunity to confirm the hope and will of the people of the United States to welcome and encourage the University of Hawaii's interest and attention to the South Pacific. We see no better way of promoting and expressing this interest than through programs of cooperation between the University of Hawaii and the University of the South Pacific. In this particular instance this has taken the form of a Sea Grant of $92,800 to conduct joint exchanges with the USP to improve courses to be offered in Tropical Marine Science and to undertake a pilot Technological Transfer Project in a most promising area.

The broader objectives, however, of the UH/USP Sea Grant Program of which this seminar is only a part, are much more ambitious and are seeking to create the basis for a long term cooperation between the two institutions. These objectives are:

1) To bring about a joint facility and research exchange program designed to give the younger generation a better professional preparation in the marine sciences. This is a task which each university could not undertake by itself with the same guarantee of success;

b) To provide functional learning extension services to the entire region. Without such a program very few if any of the countries of the South Pacific could hope to draw effectively on the substantial but unique resources to be found in the waters around it;

c) To retrieve, properly organize, and administer information about these marine resources to the peoples of the region.

Only through the dissemination of such information can we introduce more realistic expectations arising out of the knowledge of the existence of these resources and instill a greater appreciation of the care with which such resources must be drawn upon. As part of this information program, it will be the hope of the Sea Grant to emphasize the training of regional people to serve as marine resource advisers with regard to both development opportunities and preservation of resources.

As I see it, there are two very important aspects of the ocean as it relates to Pacific Islanders.

The first aspect is the value of the oceans as commercial, large-scale fishing areas which should greatly enhance the national incomes of island countries.

There is another important aspect, however, smaller in magnitude, but equally important to the lives of Pacific Islanders: development of greater capabilities and interest of island peoples in exploiting the seas at the community level to improve both their economic standing and their health standards.

The peoples of the South Pacific have been favored by nature in many ways with plentiful supplies of foodstuffs. Unfortunately, today's island diets are sharply deficient in protein. In addition, there is a growing demand among island peoples for more than just a subsistence living.

This is particularly true among the young, many of whom have left their villages for the cities and even other countries in search of salaried jobs.

The encouragement of community fishing enterprises is an important step in addressing both these problems in one stroke. The goal is to increase the available cash in island communities and to improve the health of the people by increasing the consumption of fish internally within each island.

For the benefit of island peoples, I would hope that those who are concerned at all with fishing in any sense would be equally concerned with both important aspects of fishing: that of fishing in the large-scale commercial sense and that of encouraging local fishing activity and increased consumption of fresh fish by island peoples.

As I said before, the objectives of the Sea Grant program are ambitious and have been inspired by the growing awareness of the importance of the sea and the riches in and at the bottom of it for the small mass lands that constitute the Pacific Islands.

It will indeed take the talents and expertise of both UH and USP to do two things simultaneously: show the way to get the most out of the sea, and show the way to ensure that there is always something in the seas from which to draw.

In view of the significance of this project, it would be fitting to recall and pay tribute to one of my colleagues in the Foreign Service already known to most of the participants in this conference, who had the vision to anticipate the need and purpose to be served by a close cooperation between USP and UH. This colleague is Harlan Lee, who has served in Suva, and after a stint as Advisor to the Governor of Hawaii is currently assigned in the Office of Pacific Island Affairs in the State Department.

In conclusion I would like to say that it is particularly rewarding to me in my official capacity to applaud the Sea Grant which launches this era of cooperation between USP and UH, and to invite all of you present in this conference, and the leaders of the South Pacific, to look upon the Sea Grants as one more demonstration of the U.S. interest in the welfare and progress of the people of the South Pacific, but also in the opportunities for more effective dissemination of knowledge and higher education programs in such an important field as Tropical Marine Science.

SECTION I.

CORAL REEF ECOSYSTEMS

CORAL REEF ECOSYSTEMS: AN OVERVIEW

by

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and

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Coral reef ecosystems are complex assemblages of organisms in tropical seas of which the most conspicuous components are stoney and soft corals and coralline algae. These reef building components provide a physical habitat for a remarkable number of associated organisms and their numbers, diverse forms, intricate niche relationships, physical, chemical and biological interactions with each other and the adjacent marine and terrestrial environments are what prompt us to describe this as a truly complex ecosystem. Coral reef ecosystems have been intensely studied for only the past two decades.

Despite the investigations that have been occurring in many places throughout the world, we cannot state that there is sufficient knowledge of coral reef ecosystems to manage and utilize them for the welfare of mankind, although we are approaching such a position. The problem encountered in generalizing about coral reef ecosystems lies in their variability. No two are identical, and, even though we generally classify them in a geographical, geomorphological or physiographic sense, and we can measure a number of their parameters, it is difficult to broadly apply management techniques to reef ecosystems, because of the unique qualities each possesses.

We have inadequate knowledge to manage coral reef ecosystems in most instances, but it would be improper for us not to recognize the major contributions that have been made to their understanding. Therefore a very cursory review of the principal areas of study that have been pursued and a summary of results will be presented as an overview.

The descriptive and dynamic aspects of geomorphology have been studied for some time. Of special note is the deep drilling on atolls (Funafuti, Enewetak) to confirm that they developed on truncated volcanoes. This plus a better understanding of the effects of subsidence, plate tectonics, and changes in sea level have contributed substantially to our knowledge of the growth and demise of coral reefs.

Some of the ecological studies of major community components of coral reef ecosystems are worthy of note because of their broad approach and because the information generated gives us a basis from which to exploit the organic resources and to manage them in a sustained yield mode. But even on the reefs studied, we have only tentative answers that indicate management strategies. One such reef ecosystem investigation was that of Japtan Reef at Enewetak--possibly the most intensively studied coral reef in the world. It was investigated by Odum and Odum in the 1950's in their classical study, followed by many others including the Symbios team of 25 scientists that studied it intensively for three months with the aid of the vessel ALPHA HELIX. Some of the more significant results that may be applicable elsewhere are:

1. Coral reefs are highly productive, closed and self-sufficient ecosystems--on an areal basis the primary production of reefs in the Marshall Islands, Hawaii and the Caribbean exceeds that

of the most productive terrestrial cultivated crops--such as the best yields of sugar cane.

2. There is a positive net production of organic material--production over consumption--but we still have only rough estimates on the amount of that production that might be harvested as edible fish and invertebrates on a sustained basis.

3. There are organisms in the shallow coral reef communities studied that fix nitrogen--and therefore the reef is a manufacturer of this important plant nutrient. On the other hand, phosphorus may be limiting and is rapidly cycled in a reef community.

In other studies the role of symbiotic algae to corals has been elucidated and the important relationships of the algae to nutrient cycling, calcium deposition, and incident light utilization explained. These are but a few of the important facets of our knowledge of coral reef ecosystems that will allow us to better manage them as a resource.

Coral reef studies have been pursued at several research centers around the world: in the Pacific basin these are in Australia, the Philippines, on the islands of New Guinea, Palau, Guam, Enewetak (Marshall Islands), Fanning (Line Islands), French Polynesia, and Hawaii; in the Caribbean and Atlantic, on Jamaica, Puerto Rico, Barbados, Florida, and Bermuda. In addition this line of research has been pursued in Israel and at several places in the Indian Ocean. However, not all of this research is directly applicable and useful in environmental impact assessment, planning, and preparation of guidelines for wise use of coral reef systems.

In addition, useful information comes from site specific studies and surveys which are frequently unpublished.

It is appropriate that we should come together in this workshop sponsored by the Institute of Marine Resources of the University of the South Pacific and the Sea Grant Program of the University of Hawaii. We have come to a point where decisions have to be made regarding the management and utilization of coral reef ecosystems whether we are prepared to do it or not. It is therefore proper that we should address ourselves to guidelines for management--and in the process identify high priority areas for further research. We must recognize that there are probably no simple management strategies. Each situation must be approached on the premise that it is a separate and somewhat unique problem, to which we can apply knowledge of other coral reef ecosystems only in a restricted sense.

We need a variety of inputs to prepare ourselves to develop a strategy of utilization and management, and it is expected that the papers presented at this conference will provide valuable contributions toward that end.

INTRODUCTION TO THE CORAL REEFS OF FIJI

by

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University of the South Pacific

The Fiji Islands

The Fiji islands, of which about 360 may be shown on large-scale maps (Derrick, 1957), lie centrally in the head of a hatchet-shaped ocean platform, the Fiji Plateau. The archipelago lies entirely within the tropics, between latitudes 15°30' and 20°30'S, and straddles the 180° meridian. The hatchet handle is the Kermadec Ridge, linking the North Island of New Zealand with the Tonga and eastern Fiji archipelagoes. Eastwards this ridge is delimited by the deep Kermadec and Tonga trenches. The New Hebrides island chain is aligned along the westwards-facing blade of the plateau, and the deep New Hebrides trench separates these islands from New Caledonia. Between the New Hebrides and Fiji is the North Fiji Basin, with a depth of 1100-1800 fathoms (2000-3300 m), and similar depths are found between the eastern Fiji islands (Lau Group) and the Tonga archipelago. The South Fiji Basin, westward of the Kermadec Ridge, is deeper, mainly in excess of 2000 fathoms (3660 m). The shallowest part of the platform, less (generally much less) than 1000 fathoms (1830 m), surrounds the principal islands, Viti Levu and Vanua Levu, and extends southwards as the Lau Ridge toward the Kermadec Islands.

The prevailing winds are the southeast trades and the surface current, a continuation of the South Equatorial current, flows southwesterly through the New Hebrides, Fiji and Tonga archipelagoes. Air pressure is always low, about 1009 mb (at sea level) in summer and 1013-1014 mb in winter.

Monthly ranges are usually less than 10 mb and often less than 5 mb (from the Annual Meteorological Summary, 1969). Variations in tidal level resulting from changes in barometric pressure, cyclones excluded, are therefore very small. Precipitation is high, and related to land-form (see below). Water temperatures are always above 20°C, the approximate minimum for reef-building corals, with a summer ocean surface maximum of about 30°C and a mean annual variation of about 6°C (N. Penn, pers. comm.). Neap tides have a mean range of 0.90 m, and springs 1.30 m. Tides are semi-diurnal with the lower low-water springs falling during the night in summer but during the day in winter.

The Fiji islands are surrounded by a maze of reefs, the physical importance of which cannot be over-estimated: as barriers to the ocean they provide protective ramparts, harbors and anchorages; as traps they retain detritus from the land, provide productive lagoons supportive of various fisheries, and facilitate the formation of the alluvial coastal plains. Surprisingly, there is no recent account of these features.

Coral reefs are conveniently classified as fringing reefs, barrier reefs, platform reefs and atolls, though the distinctions are by no means rigid. The type of reef found is related to bathymetry, physiography of the land, and the relative position of mean sea level during late Tertiary and recent times. Ocean atolls are not typical of the Fiji Plateau, and will not be further considered, although a few shelf atolls (such as Wailagilala and Qelelevu east of Vanua Levu) occur.

Fringing reefs are narrow and skirt the margins of continental lands and "high" islands; barrier reefs are found further offshore, roughly paralleling the coast but separated from it by a channel or lagoon; and platform reefs rise from the continental shelf as discrete patches and do not follow the trend of the coast.

As Darwin originally proposed, the formation of barrier reefs is normally associated with subsiding land. Although raised reefs in parts of Fiji, particularly in the eastern Lau islands, provide evidence for land elevation, discontinuous subsidence after volcanic land origin best explains the presence of barrier reefs at the shelf margins (Davis, 1920). Contrary to the great age of some Pacific atolls, Fiji's barrier reefs are presumably only of late or post Tertiary origin.

The salient features of the bathymetry of the Fiji Plateau can be obtained from a hydrographic chart (British Admiralty chart 2691, Fiji Islands). Moderately deep water approaches close to the main islands from the west, with the 1000 fathom (1830 m) isobath situated less than 10 nautical miles (18 km) off Viti Levu in the southwest. The 100 fathom (183 m) isobath, which approximately delimits the continental shelf, is particularly important from the viewpoint of coral formations. The Great Sea Reef, extending for nearly 300 nautical miles, is one of the world's major barrier reefs. It delimits the shelf as a westwards-widening wedge to the north of Vanua Levu. Approaching the northernmost islands in the Yasawa chain, the Great Sea Reef is broken by a more than 300 fathom (550 m) deep channel, Round Island Passage, giving access to the enclosed Bligh Water between Vanua Levu and Viti Levu. Then, more fragmented, the Great Sea Reef follows the 100 fathom isobath west of the Yasawa and Mamanuca groups, enclosing an extensive area of shelf waters, scattered with platform reefs, lying west of the towns Ba, Lautoka and Nadi.

In the southwest of Viti Levu the 100 fathom isobath is adjacent to the coast, so that from the southern end of the Mamanuca group almost to Beqa island, fringing reef is developed. The shelf is present but rather narrow south of Bligh Water and around eastern Viti Levu, and much of the water is to some extent sheltered by other islands in the Fiji group. Fragmented barrier reefs prevail here, separated from the mainland only by narrow, shallow lagoon channels. The coasts of Taveuni plunge so steeply into the sea that reefs are largely absent in the southern half, except for a small area off Vuna Point. Taveuni is a relatively young volcanic island, and Davis (1920) considered that any fringing reef already present would have been overwhelmed in the most recent lava flows. The smaller islands to the south and east of Viti Levu and Vanua Levu have barrier reefs or exposed fringing reefs depending on the closeness to shore of the 100 fathom isobath. Lagoons, where present, however, preserve an oceanic character, not being subject to the freshwater input from large rivers. The complete encirclement of an island by one type of reef, however, is relatively unusual: often fringing reefs line one coast but the reef swings offshore as a barrier on the other. Gau has the barrier to leeward but at Lakeba it is to windward; bathymetry--not orientation--is decisive.

Viti Levu

This article refers mainly to the reefs around Viti Levu and they cannot be considered in isolation from the principal features of the island (Derrick, 1957). The central highlands, over 1000 feet (300 m), divide Viti Levu as a broad north-south spine from which slender ranges lead to the east and more extensive ones to the northwest. Hills to the southwest encircle the upper Navua valley and form the Southern Coastal Range. Vanua Levu and Taveuni also have high spines which, however, are aligned along the islands' length. Since the prevailing winds are southeasterly, these larger islands are characterized by a wet, windward southeast side and a drier leeward side in the rain-shadow of the mountains. In the central plateau of Viti Levu annual rainfall exceeds 5000 mm and is in excess of

3000 mm over much of the southeast. Along the southwest coast and over the Nadi plains, rainfall is less than 2000 mm. Taveuni's high rainfall (2500-5000 mm) is undoubtedly a factor in its poor development of reefs. The high rainfall area of Viti Levu drains to a very large extent through a system of four rivers which merge as the Rewa (drainage basin 3290 km^2), the outflow from which so greatly influences marine ecosystems in the southeast (as briefly noted by Squires, 1962). Other important rivers are the Sigatoka (basin 1760 km^2) discharging in the southwest, the Ba (1040 km^2) in the northwest, the Navua (1220 km^2) in the south, and the Nadi (750 km^2) in the west. (Catchment areas from Derrick, 1957.)

The flow in a number of the rivers is now being monitored, which permits figures for runoff to be estimated. Thus mean flow for the Rewa is about 156 m^3/sec (about 86,400 m^3 per day), Navua 45 m^3/sec, Sigatoka 44 m^3/sec, Ba 27 m^3/sec and Nadi 12 m^3/sec. (Data from Mr. Lloyd Harris, Public Works Department.)

<u>The fringing reefs</u>. Within the shelter of barrier reefs the shore itself is protected from wave action. Particles of silt brought down by the rivers settle in the lagoon channels, while colloidal material is precipitated as fresh water mingles with salt. The results are wide, grey beaches of gentle slope often backed by mangals dominated by *Rhizophora* and *Bruguiera*. Where the degree of wave exposure is higher the deposits are better sorted and larger particles derived from reefal (carbonate) material predominate. Such beaches will be whiter and steeper, as seen as for example at Pacific Harbor. In such places, particularly around headlands, fringing reefs which have a character quite different from those of the exposed southwest coast, may form. Good examples are seen at Pacific Harbor, Tailevu Point (northeast Viti Levu), and Vuda Point, near Lautoka.

Much of a fringing reef of this kind consists of a well consolidated flat of barren appearance (which in fact is commonly deposited on a wave-cut platform of soapstone or other soft rock). Where, as at Vuda, the reef flat is overlain by sand, zoanthids may cover large areas, but the most typical animals are brittle stars (*Ophiocoma scolopendrina*) and active, snapping squillid shrimps. Nearer the reef edge are various zoanthids (*Palythoa*), soft corals (*Xenia, Sinularia, Sarcophyton*), organ-pipes coral (*Tubipora*), fire-coral (the fine branched *Millepora tenera* plus the distinctive *M. platyphylla* (see Boschma, 1950), and small faviids, *Pocillopora* and stags horn, *Acropora*. Tailevu Point reef is notable for the abundance of mushroom corals (*Fungia*). There is no raised crest but the edge of the reef becomes increasingly honeycombed and three-dimensional with channels, hollows and caves. Coral growth is rich though not particularly diverse. The reef edge is sinuous and drops almost vertically for 2-4 m to a sandy bed. Water tends to be murky. The Tailevu Reef has many scarlet sea fans (gorgonians) just below low water mark of spring tides, while Pacific Harbor is characterized by an abundance of a white virulently stinging hydroid (possibly *Lytocarpus*). No detailed analysis of the seaward slope fauna has yet been made.

Westward of Beqa island and its barrier reef, as already explained, deep water comes close to shore. The 100 fathom isobath is only 1 km or so offshore, while soundings of 300-700 fathoms (550-1280 m) are indicated within about 3 miles (5.5 km) of the coast. This area is known as the Coral Coast, on account of the well-developed fringing reef extending almost unbroken for about 35 nautical miles (63 km). The only major break comes at the mouth of the Sigatoka River where the freshwater influence is inimical to reef-building corals. Instead, terrigenous sands have here built up into high dunes immediately westward of the river mouth, and the ocean breaks on an open beach.

The strip-like reefs, as can clearly be seen from a headland such as Silalevu Point or from the logging road above Tagaqe, extend seawards for 500-1000 m, before plunging down the continental edge. A spur-and-groove fore-reef slope is visible in photographs of the 1978 aerial survey. Their distinctive features visible at low tide (as presented in more detail by Morton and Raj, 1980) are a seaward breaker zone of coral and coralline algae rising to a slight ridge clothed with a sward of brown seaweeds (*Sargassum* and *Turbinaria*), behind which the reef monolith becomes increasingly dissected and broken into large flat coral heads (microatolls) lying in a 1-2 m deep moat. Robinson (1971) who visited Natadola reef in 1965 and again in 1969 found an increase in soft coral possibly associated with *Acropora* predation by *Acanthaster planci* (crown of thorns starfish) during the intervening years. The moat shoals shorewards as a white carbonate-sand beach.

At intervals, and clearly corresponding to the creeks which descend from the hills of the Southern Coastal Range, the continuity of the reef is broken by passages 100-300 m across. These passages provide semi-shelter, and a wealth of corals and other sessile forms at and below low water mark of spring tides. While the moat may become very hot by day (35°C or more), these passages preserve the cooler ocean temperature. Landwards in these passages water from the moat flows swiftly out through channels paralleling the shore or cascades over a miniature cliff, in a volume depending on the extent to which the ocean swell breaks over the algal ridge during the low tide period. With the attractive features of these reefs being combined with high insolation and low rainfall, not surprisingly the Coral Coast is developing as one of Viti Levu's premier tourist areas, with many hotels and unit-accommodation resorts.

<u>The barrier reefs</u>. The barrier reefs may be considered as of two basic types: first, the oceanic ribbon reefs such as the Great Sea Reef, Beqa Barrier Reef, Great Astrolabe Reef (northern Kadavu) and some of the Lau Group barrier reefs. These enclose lagoons or sea areas of normal salinity and their entire character is oceanic. They are biologically almost unknown and offer an exciting challenge for the future. The second category comprises barrier reefs that may be exposed, as off Suva, with well-developed spurs and grooves, or more sheltered as off Ba. The latter may not be ribbon-shaped and are perhaps more like large platform reefs. In both cases the reefs are separated from the mainland by a relatively narrow and shallow lagoon channel of neritic nature, which is generally turbid with surface water of low salinity extending out to or even over the reef. The general biological characteristics of such reefs near Suva are described by Morton and Raj (1980). Subjectively it is assumed that the productivity of the reef associated ecosystems must be greatly boosted by nutrients in the freshwater runoff, the deltaic and fringing mangals, and the sea grass beds; but that the concomitant low water clarity and fluctuating salinity will adversely affect coral diversity and the occurrence of non-neritic faunal assemblages on the reefs themselves. Comparative data, however, are lacking.

<u>The platform reefs</u>. The final category of reef important in Fiji is the platform reef. Restricted to shelf waters, platform reefs are most common inside, for example, the Great Sea Reef, including the Yasawa-Mamanuca island arc, and within the Mabualau-Ovalau series of barrier reefs, off eastern Viti Levu. Typically, platform reefs are of oval outline,

lengthened in the axis of the prevailing wind, and with a low island of white coral sand, the cay, at the leeward end. Their configuration may be influenced by neighboring reefs, especially where the system is complex, such as at Cagilai and Leluvia to the southwest of Ovalau, or off the Rewa delta. More typical are the platform reefs in Nadi waters and towards the Mamanuca Islands. Despite rarely having any ground water supply, and a minimal land area, coral cays are in great demand for tourist resorts. Insofar as Navini (near Malolo) is typical, the cay is surrounded by a reef flat which never or rarely dries and, because of the sheltered position, is not bounded by a ridge. The reef flat, therefore, though rich in coral, is not characterized by large microatolls to the same extent as the moats of Coral Coast fringing reefs. Coral growth becomes luxuriant on the seaward slope, and reef associated fish and invertebrates are conspicuously abundant. None of these reefs in Fiji waters has been adequately described, though the clear water and shelter from ocean swell make them particularly enjoyable to explore.

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WIND, WAVES, AND CURRENTS IN THE TROPICAL PACIFIC

by

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Introduction

It has been noted that coral reefs in the Pacific vary greatly in species represented and also in gross form. This may be due to differing ecological regimes, but ultimately this too must reflect different chemical and physical conditions. The important physical influences are rainfall, wave conditions, sea-water temperature, tides and tidal currents, etc., and all factors which influence the intensity of turbulence at growing reef, which exerts much influence on growth rates and biota types. In the open ocean the gradient of any physical property is mostly in the vertical direction--that is, the changes are small along any horizontal direction in comparison to changes along the vertical. This is the well-known feature of stratification, which is due to the earth's gravity. Along any horizontal surface the gradient of any physical property is mostly in the north-south direction. That is, the iso-curves tend to be parallel to latitude circles because of the earth's rotation. The foregoing is true with respect to the long-term mean distributions, and transient features often are associated with large local anomalies in these simple patterns. Near continents and islands there are also large deviations from the above-described patterns of property distributions.

Winds

Compilation of ship's observations over many years has provided a fairly accurate picture of the mean surface wind over the Pacific. The tropical seas are dominated by the northeast and the southeast trade winds, with a distinct minimum intensity near the equator (the doldrums). At higher latitudes the winds are from the west. Mean rainfall is related to this mean wind field. Where there is divergence in the surface wind, upper air descends and heats adiabatically producing a condition not favorable for precipitation. Where this divergence is negative (as in the case of converging surface flow) the air must rise, and cool adiabatically, which favors precipitation. An elongated region of negative divergence occurs just north of the equator. This is associated with the intertropical convergence zone, which is known to be a region of heavy mean rainfall.

Transient phenomena such as storms are just as important as the mean pattern. The well-known transient weather troughs at high latitudes are associated with storms in the north and south Pacific which contain small regions of very high winds which generate high waves. At low latitudes waves in the easterly winds become progressively more intense as they travel westward and sometimes shed vortices which become tropical hurricanes in the western Pacific. Thus there are fairly well-defined regions of frequency of occurrence of tropical hurricanes from very rare to never in the eastern tropical Pacific (except for those generated in the Atlantic and crossing over the continent), to very frequent in the western tropical Pacific.

Wind Waves

These are the usual waves which form sea, swell and surf. One feature of the Pacific Ocean which distinguishes it from all other bodies of water is the continual occurrence of long wind waves (as contrasted to short choppy waves, even though these can be very high at times). Almost everywhere in the Pacific Ocean there is usually appreciable wave energy at wave periods as long as 16 seconds. This is not the case in the Atlantic or other smaller bodies of water. The reason is the large size of the Pacific. There is almost always at least one very intense storm somewhere in the Pacific. Long wind waves, of 16-second period or longer, require extremely intense winds to generate. Also, the waves once they are generated travel almost without dissipation to all distant corners of the ocean until they are destroyed by breaking at the coastlines. (Waves generated off Madagascar Island have been detected at the Alaskan coast after having travelled more than half way around the world.) The long waves are important as they carry proportionately more power than the shorter waves.

The long waves are generated in the "roaring forties" in the south Pacific near Antarctica in the southern-hemisphere winter, and in the north Pacific in northern-hemisphere winter. Many Pacific islands are exposed to this swell, either on their northern or on their southern shores. In addition there is an almost constant tradewind sea of shorter waves battering the east shores of many of the islands. In the months October to January there are often westerly storms which are related to the monsoon winds off southeast Asia. These storms produce high winds and seas which in some years batter the western shores of tropical islands.

Wind waves may be very important in motu building and motu destruction. Typhoon Bebe in 1971 was extraordinarily intense at Funafuti and raised an impressive rampart along its eastern reef. This rampart was about 19 km long, up to 4 m high and 100 m wide and contains material comparable in amount to the already-existing motus. The fate of this material is being studied to see if most of it erodes away or consolidates to form a permanent feature similar to old ramparts, remnants of which can be seen on many Pacific atolls. On the other hand tropical hurricanes have been known to completely wash away motus. The conditions which determine whether material will accrete or erode are not well known, even though this problem is of critical importance to motu evolution.

Rainfall

The mean rainfall pattern in the Pacific shows considerable variation from place to place. Of particular interest and importance is an elongated maximum centered at around 7°N under the intertropical convergence zone, and an elongated minimum near the equator. This pattern is associated with the high mean rainfall at Palmyra and the dry islands of the Central Line, Northern Phoenix and Southern Gilbert Islands.

Variability of rainfall is almost as important as mean rainfall as far as inhabitability of any given island is concerned. Some of the dry islands have sufficient mean rainfall but experience severe droughts when subnormal rainfall can occur for several years. Professor Klaus Wyrtki of the University of Hawaii has shown that certain atmospheric and oceanic phenomena in the Pacific simultaneously occur over large distances which he calls "teleconnections." He found that the occurrence of the well-known El Niño phenomenon off the coast of Peru is correlated with certain sea-level signals in the Pacific Islands as well as with abnormally high rainfall in the equatorial region. El Niño is the condition in which warm equatorial surface waters intrude southward to replace the usually cooler water off the coast of Peru. This is associated with high mortality of fish and marine birds, and consequently also with bad economic conditions. This occurrence is associated with higher than usual eastward surface transport in the equatorial countercurrent system, which brings in the warm water. This surface transport is related geostrophically to the sea surface topography (except within about a degree of the equator), which in turn is measured by tide gauges on the Pacific Islands. It has been observed that the occurrences of El Niño tend to coincide with periods of high rainfall in the equatorial Pacific Region. Thus, poor fishing off Peru is correlated with good copra production in the Gilberts.

Distribution of Temperature and Salinity in the Ocean

The oceanic regions are characterized by a surface layer which is fairly homogeneous down to a certain depth at which the water properties usually change rapidly with depth. This depth of rapid change is the thermocline. In the tropical ocean the thermocline depth can be as deep as 300 m, and near the equator it increases toward the west as one might expect the trade wind to pile up the warm surface layer in the western Pacific.

Near coasts and islands, and in regions of surface current divergence, upwelling can occur, which brings colder nutrient-rich deep water up to the surface. Around islands, turbulence caused by currents running into or along a rough bottom produces vertical exchange, which again leads to cooling and enrichment of the surface waters. As a result islands are usually found in the midst of a region of cooler and richer surface waters than oceanic areas far from islands. Sometimes a surface "wake" of cool, rich water extends from the island in the direction of the current.

Currents

Ocean currents associated with the field of density in the water under the influence of the earth's rotation are called geostrophic currents. These currents as deduced from the density field usually represent an averaged current over a time span of several weeks, and over a geographic region whose size is of the order of about 100 km. Near the equator the geostrophic method cannot be used. Current determinations by drogues and other means have uncovered an extremely complicated regime of undercurrents just under the equator. The main Pacific equatorial undercurrent (or Cromwell current) is a jet of eastward moving water, whose axis is about 100 meters deep, width about one degree and maximum speed about one knot. Recent observations have discovered a multilayered series of zonal currents alternating in direction that are amazingly persistent with time. The dynamics of this phenomenon is not yet clearly understood. These currents probably enhance turbulent exchange on the deep slopes of islands near the equator such as Nauru, Kuria, Aranuka, Nonouti and Jarvis, and probably also the Galapagos.

Tidal currents are often important in the entrances of atoll lagoons. Their speeds can often be easily estimated by a simple conservation method by making use of observations of sea level within the lagoon, the area of the lagoon and the cross sectional area of the channel. At Canton Island the tidal current can reach a speed of about ten knots. Such strong currents are associated with considerable turbulence which exerts influence on diffusive exchange of water properties and nutrients, with strong biological consequences.

SECTION II.

TRADITIONAL PATTERNS OF UTILIZATION

TRADITIONAL PATTERNS OF UTILIZATION

by

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Introduction

Man arrived in the South Pacific at least 3,000 years ago. Archaeological evidence is scarce but in Fiji gives an occupancy of about this figure, though that of the more remote islands is more recent. This is a relatively short period of time compared with his occupancy of the continents but during this time he has become adapted to life on small islands. Because these islands were limited in size and resources, especially animal protein, he has long had a close association with the wetlands and coral reefs of the sea around him.

The inshore ecosystems are characterized by their high productivity, great species diversity, but generally low population of each species. How has man fitted into these complex ecosystems? How has be exploited them yet avoided the over-exploitation of their finite resources?

The answers lie mainly in the past, obscured by the present pattern of exploitation which followed the advent of Europe into the Pacific. It is necessary to look back, to assess man's traditional place in the marine ecosystems of the South Pacific. Culturally, it is important to document disappearing cultures for future generations of Pacific Islanders. Ecologically, we must evaluate the impact of post-European development in the region, and hopefully learn from the old ways which were molded over a hundred generations of living from the sea. It is difficult to generalize on things as complex as the coral reef ecosystem, or man himself.

Patterns of Exploitation

1. The sea provided almost all animal protein to the Pacific Islanders.

2. A great number of species were exploited, for food or other uses. Almost every fish, from fingerlings upwards, were eaten. Hundreds of species of molluscs and shellfish were also consumed. The numbers of food species reflects the great diversity in the ecosystem. It also poses special problems in exploitation and conservation.

3. A relatively few species accounted for the great bulk of organisms exploited. Mullet, trevally, bonefish, Indian mackerel and a few species of snappers (Lutjanids) and groupers (serrids) were the most important finned fisheries. Although hundreds of invertebrates were eaten only a handful were very important. Possibly the bivalve *Anadara* (te bun [Kiribati]; Kaikoso [Fijian]) is more important than all other marine bivalves combined.

4. The most important species are from the inshore ecosystem (mangrove, tidal flats, lagoons) rather than the coral reef. Nevertheless coral reefs were important for man, an opportunistic omnivore, and he must have placed them under some pressure in the past.

Over-Exploitation

It is probable that man has over-taxed the finite resources of his small islands and surrounding reefs, no doubt a reason for his ceaseless migrations in search of new islands to colonize. Specific examples are today difficult to identify. Some evidence comes from archaelogical studies of ancient middens, though these must be interpreted in context with climatic and other changes. A possible example is the abundance of the shells of the horseshoe clam *Hippopus* in some Fijian middens. These bivalves are today very uncommon in the region. Likewise in Samoa the spines of the urchin *Heterocentrotus* are abundant in middens while they are rare on reefs. Comparisons of inhabited and non-inhabited reefs in the Pacific indicate other examples. In the Pacific the green turtle *Chelonia* and giant clams *Tridacna* are today uncommon while these species are very common on the Great Barrier Reef.

Impact on Reef Ecology

Man's 3,000 year occupation of some of the Pacific Islands (and his 30,000 year occupation of Australia, New Guinea and perhaps the Solomons) is possibly long enough to have influenced the biology of some of his prey species. The period of his occupation is not insignificant when we look at the age of the coral reefs he occupies. Coral growth was limited in much of the South Pacific prior to the present interglacial era, some 20,000 years B.P., and the climate reached its present stable warmth only 8,000 years B.P.

As well as causing the decline of some species (above), man may have influenced the behavior of others. When I arrived in Fiji I noticed that one of the edible intertidals periwinkles *Nerita polita* had an avoidance reaction when approached. Sensing the vibrations of an intruder this snail immediately closes its operculum and drops off the rock it was attached to. The *Nerita polita* on the Great Barrier Reef and on Tarawa, Kiribati (where they are rarely eaten), do not have this reflex. Further studies will be needed to confirm this observation.

Patterns of Conservation

Although some resources were probably over-exploited in the past, there was less pressure on the environment than exists today. This was due to a number of factors.

1. Man took only what he could immediately eat, trade, or preserve. Preservation was inefficient.

2. Fishing technology was less efficient than today's. The catch/effort ratio was much higher.

3. Populations were lower in the past. The islands suffered an initial depopulation following European contact but have long since passed previous levels.

4. Fishermen were less mobile because of their hand- or wind-powered craft. Warfare and boundary disputes were normal.

5. Sacred beliefs, taboos, etc., provided an indirect means of conservation. In most islands certain edible animals were denied the community or a part of the community. Sharks and octopuses are taboo in much of Fiji. Dugongs, turtles, etc., are taboo to members of totemic clans in Torres Strait, Solomons.

6. Fishing boundaries, like land boundaries, were well defined among social groups, neighbors, and rivals. This was the most important means of conservation in the past but is today an important obstacle in most island countries to commercial fisheries development.

7. Some people actively conserved specific resources. In Samoa clams were conserved as emergency cyclone food. In Kiribati spawning bonefish were not netted. Often turtles were allowed to lay eggs before capture.

SECTION III.

PRESENT PATTERNS OF UTILIZATION AND DEVELOPMENT

CHANGES IN FIJIAN COASTAL LAND USE

by

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With a very high ratio of coastline length to total land area, archipelagic nations such as Fiji have a large proportion of their populations living and working in coastal areas. Consequently there is a great deal of pressure applied to the natural resources of the coastal land strip.

Coastal zones form an interface between wholly aquatic and wholly terrestrial environments, and have often fallen outside of the interests or control of agencies normally concerned with one or the other. It should be remembered that interactions are many and intimate, and activities in the watersheds of streams draining into the ocean, for example, will have their effects on coastal waters.

Changes in Vegetation Covering

One very important factor in land use, that affects the quality of the environment, is the covering of vegetation. The original, undisturbed formations in the Fiji islands were probably of three basic types, viz. dunes, beach forest and mangal.

Dunes. Although generally rare in the tropics, sand-dunes are well-developed near Sigatoka in southern Viti Levu. A recent survey indicated that, previous to the more intense settlement of the past 100 years, much of the dunes would have remained in an undisturbed state, covered by a modified beach forest. Remnants of this vegetation still remain, although current usage includes grazing, recreation, rubbish dumping, and road building, and the future may see mining of the system for iron. Modification to the system has taken place through repeat burning, introduction of weed species, and planting of grasses and other sand-building plants to contain any inland drift of the dunes.

Beach Forest. Behind microtidal, low-energy beaches, where the land slopes moderately into hills or sharply to form cliffs, and there is no coastal plain, beach forest is the most commonly found vegetation. These sites were first settled by the aboriginal Fijians, and modification through introduction of such species as coconuts and yams began with the planting of food gardens, and spread with the increasing population. The depletion of beach forests by shifting agricultural practices was then accelerated by the spread of plantation cultivation of copra, which continues today. Removal of vegetation can aggravate shoreline erosion. Presently the establishment of tourist resorts on coral cays, together with road-building, urbanization and concomitant industrialization, make it imperative that an inventory be made, and conservation considered, of this threatened vegetation type.

Mangal. The third major category of vegetation is the mangal community, which flourishes in Fiji along coasts with a flat coastal plain, protected shores, and in creek mouths and estuaries. It has a prime role in the detrital cycle and food web of the oceans, as well as providing protection to the land through reducing the strengths of storm surge and preventing erosion. Mangal appears to be efficient in buffering the effects of sewage discharge, particularly in removing nutrients. Estimations of total area of mangal in Fiji range from 30,000-50,000 ha, and the traditional uses by Fijians include firewood, building materials, and bark for tanning. Small settlements have also been made within the mangal, and much fishing continues to the present. Current usage remains largely traditional, but some areas are being destroyed by construction of road and causeways, tourist resorts, and reclamation for agricultural purposes. In the latter case, about 2,700 ha were reclaimed around the Labasa, Vanua Levu, sugar mill for the cultivation of sugarcane. Salt levels in the soil are monitored continuously, and maintenance of floodgates and levels is essential to prevent the intrusion of sea water. Efforts are underway to set aside tracts of mangal for scientific study and protection, particularly stands of hydrid species.

The Need for an Inventory of Natural Resources

Although three major categories of coastal land have been recognized here in terms of their vegetation, no quantitative data are available on the extent of each type, or their ecological relations with neighboring seaward communities. As a first step towards a rational coastal land use plan for Fiji, it is suggested that an inventory of natural resources incorporating an atlas at the 1:50,000 scale, be initiated as a matter of urgency. Only with basic knowledge such as this can ecologically sound progress be made towards rational development of the country.

CAUSEWAY CONSTRUCTION

by

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Many causeways have been constructed on Pacific islands, and many more are being planned. On atolls causeways can improve local economics by increasing the area accessible to land vehicles. Regardless of possible adverse effects on the environment causeways will continue to be built for this reason.

Palmyra atoll provides an example of the immense benefit that can result from causeway construction and similar modifications. Before World War II, the atoll consisted of about 25 small motus, the largest of which was barely a kilometer in length. After extensive modifications carried out during World War II, most of the land area is now connected and accessible by land vehicle. Furthermore the land area has been increased by about a factor of four. Besides providing more land for agriculture and other uses, this increase of area also improved the quality of the ground water (Dawson, 1959).

Many atolls have a similar cross section structure. The amount of "dry" land is very small in spite of the fact that the amount of lagoon mud flats occurring at about low-water springs is very large. A slight redistribution of the lagoon mud to form a larger "dry" region above high-water springs, does not require additional material. As the fresh-water lens is thickest near middle of dry land and thins out to zero at both shores, the amount of storable fresh water in the lens may be approximately proportional to the square of its width. The southeastern corner of Tarawa lagoon, the Temaiku Bight, has a configuration such that a short dike can keep seawater out of a fairly large area, approximately one km^2. A causeway was built there about 1972 with the hope that much of the enclosed area can be made suitable for agriculture.

Causeway construction can be thought of as consisting of two phases: (1) obtaining the material, and (2) the actual construction. The first phase is common to many other types of modifications, such as runway extension, dock construction, etc., and furthermore it need not always involve coastal modification. Where it does, however, its environmental impact can be as severe as the actual causeway construction.

Effects of Material Removal

One of the main deleterious effects of material removal from nearshore areas is habitat removal. The previously existing surface may have provided holes, crevices and other hiding places for fish and other life, or a substrate for sessile creatures, and may have been covered with edible growth. After it is stripped away a new substrate is formed which may or may not be as habitable as the original, and in fact may not support the same species mix as before. Whether or not the same species can reestablish themselves, it may take decades for new biota to become permanently established. After dredging a boat basin in Pou Bay, Moen Island, Truk, practically no new habitat appeared to be forming. Dredging also stirs up sediments which can greatly modify the environment. Fine sediments which can be deposited onto the sea floor both in the vicinity of the material removal and far away can cause the death of some bottom-dwelling life including corals. As many bottom dwellers require a hard surface for attachment such sedimentation may almost permanently alter the bottom in a way which precludes such life from reestablishing itself.

There is the possibility that nearshore modification, dredging, etc., may cause fish poisoning incidents. It is now known that the ciguatera poisons pass through a food chain from dinoflagellates to fish, but the ecological relationships are not yet well understood. Until it can be demonstrated that a certain coastal modification will not increase the probability of fish poisoning, a risk will be incurred. There is the danger that poisoning incidents may be blamed on the modifications, whether justifiably or not.

Often, especially in the Trust Territories, material is obtained by drag-line dredging on the lagoon side. To enable equipment to reach out from shore, dikes with roadways are often constructed perpendicular to the beach. These dikes often are paralleled by a deep trough where the dike material was scooped out. The system of dikes and troughs produces its own environmental consequences which need to be taken into account.

Consequences of Construction

The foregoing consequences arise from acquisition of material alone. Construction of the causeway itself produces another set of consequences. One of them is the obstruction of the usual water flow across the causeway site. This can be avoided by building an elevated causeway on pilings, but in the Pacific this is rarely done because of economic reasons. This obstruction to flow can be alleviated to some extent by having tunnels or culverts through the causeway.

Canton Island provides an example in which a very small obstruction to the normal flow seems to have produced relatively severe consequences. In the early 1940s the western lagoon and passes were modified: seaplane runways were dredged in the lagoon, three of four passes were closed by causeway construction; and the remaining pass was enlarged as a ship-turning basin. Smith and Henderson (1978) noted that certain corals had died. Although no direct cause-effect relationship could be proved, it seems very likely that the blockage of the three shallow channels (one wide and two narrow) diminished the water circulation in the lagoon sufficiently to cause the mortality, in spite of the fact that the new deep channel provides many times more transport than the blocked channels used to provide. This example provides evidence that small changes can produce unexpectedly large consequences. The proposed Beetio-B'airiki causeway on Tarawa may be a similar example in which the flow to be obstructed is much less than the nearby large transport over a deep reef.

Another consequence of causeway construction is the redistribution of people and their activities. For example, it may then be possible for people working on one motu to live on another distant motu. Thus, some decentralization may be induced, but on the other hand, the overall density of people and activity may tend to increase because of the overall enhancement of the economy brought about by the causeway.

The effect of a new causeway on shore processes can be considerable. As a general rule any structure that tends to increase turbulence at a particular place will encourage erosion and discourage sedimentation at that place. Where turbulence is decreased, sedimentation will be encouraged. Classic examples are seawalls which are hit by incoming waves producing much turbulence, frequently resulting in the complete stripping away of the sandy beach. The opposite example is provided by jetties which shelter their lee sides, and the resulting lower wave action leads to deposition and widening of the beach. Causeways are usually constructed on a wide shallow sill over which currents usually flow. These currents are caused by winds, or by wave set-up, or by the tide, etc. In the case of the Beetio-B'airiki causeway the northeast trade wind and accompanying sea usually generate a weak current flowing outward from the lagoon, while the flood tide is associated with a current in opposite direction. The other causeways on South Tarawa, which were built in the 1960s, have resulted in moderate deposition of sand on each side, probably because of the reduction of turbulence that ordinarily would have accompanied the cross-sill current. This deposition has made it possible to widen both of these causeways with minimum expense. On the other hand the sand trapped by the causeways would have been available elsewhere, so until a new equilibrium is reached there may be places where the outflow of sediments is exceeding the influx, producing a net loss of material. Such places may be far from the location of the causeways, and thus the erosion may not be readily recognized as resulting from the causeways. To understand such effects the sand-budget and sand-transport regimes should be studied.

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MINERAL/PETROLEUM DEVELOPMENT IN THE SOUTH PACIFIC

by

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Cooperative Exploration in the Pacific

Because most of the countries of the South Pacific are too small to have their own geological surveys and do not have the expertise to carry out off-shore explorations they have joined together to form a United Nations body called Committee for Coordination of Joint Prospecting in South Pacific Offshore Areas, abbreviated CCOP/SOPAC.

The CCOP/SOPAC body has now existed since 1972 and since that time they have carried out a number of surveys in the South Pacific regions. These have included exploration for manganese nodules in Cook Islands offshore areas which resulted in the delineation of a sizeable deposit of nodules. They have also searched for phosphates and phosphorites in the Cook Islands, Papua New Guinea, Fiji, and Solomon Islands waters. A survey of bauxite in Lake Te Nggano, Solomon Islands, has created considerable commercial interest in these deposits. The CCOP/SOPAC has carried out special surveys for precious corals in Western Samoa, Tonga, the Cook Islands, New Hebrides and the Solomon Islands. Special surveys have also been carried out in the Solomon Islands for gold; beach sands and the other types of sands for aggregates has also been surveyed in places like Tonga, the Cook Islands and Western Samoa.

In the field of petroleum exploration CCOP/SOPAC staff have carried out special interpretation of petroleum company data in Tonga, New Hebrides, Solomon Islands and Fiji and have also carried out seismic surveys in the

Solomons, Tonga and Western Samoa with some plans for surveys in Papua New Guinea during 1980. Their work in Tonga was significant in rejuvenating petroleum company interest in that area and similarly they were involved in the early interpretation of data in Fiji which led to a revival of exploration activity in 1978.

The primary objective of all CCOP/SOPAC programs is exploration; at the same time the opportunity is taken to collect physical and chemical baseline data so that adequate environmental safeguards can be built into any development phase. However, the present surveys have not yet resulted in any exploitation programs although they have delineated areas that could become economically viable in the near future. The CCOP/SOPAC beach sand/aggregate surveys in places like Tonga, Samoa and the Cook Islands are proving to be very helpful in delineating areas where beach sands can be mined safely without significant erosion of the beach profile which is a current problem from present beach sand mining operations.

Mining in Fiji

Several private companies have carried out extensive surveys for iron sands in the coastal zones of Fiji. Potential deposits have been delineated in the Mba delta area and in the Singatoka beach sands area but neither of these are viable for mining yet and may not be so for some years to come.

One other coastal zone problem expected within the next decade could be the disposal of tailings from copper mining operations at Namosi in the offshore area south of Viti Levu. In this case we have a very large low grade porphyry copper deposit on land which occurs along an active seismic zone. Therefore, it would appear unwise to construct tailings dams in valleys as these could burst their containments during seismic activity and flood the large river systems of the Waindina River. It therefore appears that the least damaging alternatives for tailings disposal would be to either place them in the Navua flats (a low-lying coastal area), or offshore beyond the reefs and below the thermocline as is done in Canada and the Philippines. The companies proposing this offshore tailings disposal system will be required to carry out extensive environmental impact studies before this kind of disposal will be allowed. These will include current and turbidity studies offshore as well as studies of the flora and fauna in the area to determine whether offshore tailings would really turn out to be the least damaging of the alternative tailings disposal plans available.

Petroleum Exploration in Fiji

Perhaps of most interest at this particular time is the petroleum exploration activity and planned drilling program in Fiji during 1980. In any discussions on petroleum operations the disasters such as at Santa Barbara, the North Sea and the Gulf of Mexico tend to feature prominently. It should be noted however that the Santa Barbara disaster occurred about 10 years ago and was perhaps one of the last petroleum disasters which was due to hazardous conditions in the shallow surface sediment area, whereas other recent drilling disasters have been due to operator error. The shallow hazard disaster such as Santa Barbara has now been overcome by special regulations and requirements for shallow geophysical site surveys to be carried out prior to any drilling operations, and with improved blowout preventer systems it has been possible to prevent the recurrence of such disasters in recent years. But as the North Sea and Gulf of Mexico experience shows us even the best blowout preventers will not work well when human errors are made. But when people think about oil pollution and the problems that they cause, they should note that most of the oil pollution problems are not caused by petroleum drilling or production accidents, but by tanker collisions, and this is perhaps one of the most critical areas where special controls need to be exercised.

Drilling precautions. In Fiji many thousands of line kilometers of seismic work have already been carried out over the past two years in the Bligh Water area, the Great Sea Reef area, the Yasawas area, and the Lomaiviti Group area. The seismic program has located a few areas that look promising and may be worthwhile drilling. Our 1978 Petroleum Exploration and Exploitation Act is modelled very closely after the Australian Petroleum Act and has a number of conservation measures. The controls of drilling operations are in the directions which are also very similar to the latest American and Australian Drilling Regulations. When companies propose drilling programs they are simultaneously required to carry out special surveys involving ocean current, swells, storms, hurricanes, sea salinity and temperature, air temperature, rainfall and other meteorological data to determine the effect of the drilling program on the general reef environment, and flora and fauna. Also as mentioned previously the companies are also required to carry out special detailed site surveys with high resolution sparker and side-scan sonar to delineate any shallow gas pockets, any faulting, slumping or unusual bottom features. These survey lines must be no more than 300 m apart over about a 4 km area surrounding the proposed drilling sites.

Oil spill contingency. Companies are also required to set up a special oil spill contingency plan which covers such items as inventory of pollution control equipment including containment booms, skimming apparatus, etc., provision for protecting areas of special biological significance, availability of additional rigs, alternative sites for drilling relief wells, predesignation of coordinator and specification of an oil spill response team. Our Directions also require very modern and rigid blowout prevention controls with daily and weekly tests of these systems and test drills on ship to ensure that all of the systems work properly and that the drilling staff are aware of the correct procedures. Any spills of oil up to 5 cu. meter have to be reported to the Director immediately. Concerning liquid disposal, no muds are to be disposed into the sea water, oil content of any liquid discharged from the drilling vessel should be less than 50 milligrams per liter, and sewage has to be macerated. No well solids, containers or equipment can be dumped into the sea. Thus every effort has been made to minimize any possibility of pollution. If oil is found, the company is required to submit a comprehensive environmental impact study of the area before any production license can be granted.

Thus, while the existing level of activity in the coastal zone in Fiji is not very high at present, it is recognized that any one large operation such as offshore tailings disposal or petroleum production could immediately create a major influence over a very wide area. The possible consequences of such developments have been recognized early and with proper planning we hope to be able to minimize any adverse effects from these activities.

CORAL SAND DREDGING

by

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The basic raw materials used for cement manufacture in Fiji are coral sand and river (silica) sand. The coral sand is dredged at the sandbanks near Nukuboco Island and the fine river sand is won by suction near the estuary of the Rewa River.

Dredging Operation

For coral sand dredging, we use a floating type grab dredger. This basically is a rectangular pontoon on which is mounted a revolving crane equipped with a grab. The dredging operation consists of lowering the grab to the bottom, closing the arms, raising the filled grab to the surface and discharging the contents onto a barge moored alongside.

For the fine sand (silica sand) we use a suction dredge. This basically is a pontoon with a ship-type bow and propulsion machinery. The sand is drawn by means of a suction pipe and a pump. It is then delivered through a pipeline and discharged onto the barge at the end of the pipeline.

Nature of Coral Sand

Mineralogically, the coral sand consists of magnesian calcite and aragonite. Most reef building organisms precipitate the carbonate in the form of aragonite which is another crystallographic modification of calcite. Studies show that the calcite contains up to 10 more percent magnesium carbonate in its structure. It is therefore named magnesian calcite. The silica sand (fine sand) mainly consists of quartz and feldspar.

Chemically we would prefer pure carbonate minerals but this seldom is the case. As the coral sand consists of aragonite and magnesian calcite there is a significant contamination by magnesia. We have found the magnesia content ranging from 2.6-3.4% in the sands we have dredged so far. Sand from the present dredging site, i.e., near Nukuboco Island contains only 2.6-2.7% MgO, and this is quite tolerable. An important feature of the coral sand is that the magnesia is distributed very evenly, quite unlike some limestone rocks which have bands of magnesia. The loose nature of the sediment contributes a great deal towards the ease of our dredging operation which basically is a grab dredger. Furthermore, because of the fine nature of the sand we are able to mill the sand directly in our raw mills thus obviating any precrushing.

Impact of Dredging Operations on the Environment

An extensive sampling and experimental program has been underway since 1979. Old and present dredging areas have been photographed and mapped; the hydrography of the coastal region is being studied; and the biology and ecology of the seagrass beds (where the dredging is carried out) is being examined. Already some information is available on recolonization of old dredging sites. The program, drafted with, and guided by, the officers of the Institute of Marine Resources of the University of the South Pacific, will allow (1) evaluation of the consequences of coral sand dredging, and (2) formulation of management guidelines for the siting and manner of future dredging operations.

WASTE DISPOSAL IN TROPICAL WATERS

by

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There is a steady increase in population in most population centers, and urban areas in the Pacific. This population growth results in an increased load of human wastes.

With small population, land disposal of waste was the most obvious solution (septic tanks and leach fields) but with increased densities there are areas that this solution may not be adequate for long.

There is also the problem that many population centers are built on low lying, flat coastal areas. In many of these areas ground water levels are high and ground levels are low. Thus, these areas are subject to seasonal floodings from high seas, high rainfall, or a rise in the water table. In flooded areas served by septic tanks flood water mixes with septic tank effluent. This effluent is very rich in fecal bacteria, some of which could be pathogenic. This is a potential health risk.

Alternate Disposal Methods

The question is what to do in these cases. There are well tried technologies for sewage collection treatment and disposal. But these are normally very expensive, need imported mechanical equipment and well trained operators.

Waste stabilization ponds are a very good alternative. But they require relatively large areas. This could be a problem in many of the Pacific Islands because of land legislation, high cost of land near town centers. In some areas of the Pacific there is also some cultural objection to this method.

One possibility is to have these ponds constructed in mangrove areas. But here we do not know what will be the impact on the mangrove ecosystem. Another possibility is to have these ponds constructed in conjunction with fish ponds for aquaculture.

One of the oldest and most efficient treatment and disposal methods is ocean disposal through properly constructed outfalls. For the loads we are talking about in the Pacific, it would seem that ocean disposal could be a very efficient and safe method. But is it so? We do not really know. We are told that fringing reefs could be very sensitive and could be affected by sewage. And this in turn may trigger dinoflagellates blooms and fish poisoning. Very little information is available on the impact of sewerage on coral reefs.

The Need for Guidelines

We are also seeing an increased industrial development - sugar mills, breweries, gold mines, copper mines, fish canning, oil palm processing, etc. All of these industries have some effluent discharging to the sea. Governments need to have some guidelines:

What are the permissible levels of pollution loads?

What should be the treatment requirements prior to discharge?

Should they impose strict EPA quality criteria (with the often prohibitive cost involved) or could the criteria for the Pacific, at present level of development, be less demanding?

Is a single outfall preferable to multiple (smaller) outfalls?

Could sewage be used beneficially in nutrient deficient Pacific Ocean waters?

Are lagoons nutrient deficient? Could lagoon ecosystems also benefit from sewage nutrients?

From a public health point of view there are established quality criterial for recreational waters, but most apply to temperate climates. Are these suitable for the tropical Pacific?

Proposed Regional Project

To answer some of the questions, to develop local expertise and for proper management of the nearshore marine resources a regional project is proposed. The project team, to be based at the Institute of Marine Resources of the University of the South Pacific, should include a marine biologist and a chemist assisted by a sanitary engineer/oceanographer. They will design and conduct a monitoring program around existing outfalls, proposed outfall sites, etc. With training of local staff in each area most of the frequent routine monitoring could be done locally. Some of the more complex parameters may require visits by the team 2-4 times a year.

This information will provide a base to begin developing guidelines and design criteria applicable to tropical waters.

INDUSTRIAL POLLUTION ON CORAL REEFS: AN OVERVIEW

by

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and

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Oil pollution is an omnipresent threat to inshore ecosystems, whether the cause is poor planning (siting and design of facilities), an at-sea collision and spill, or a drilling disaster. The effects of oil spills and pollution on coral reefs have been studied in several locations including the Gulf of Mexico, the Persian Gulf, the Red Sea, the Great Barrier Reef, and American Samoa. There have also been a number of laboratory studies and simulations.

One common source of oil pollution is the waste from oceangoing vessels pumping out their bilges near shore. The best solution is to have accessible pumpout facilities; or an alternative is to discharge bilge waste to the open ocean far from land and fishing grounds. Coral reefs are usually submerged except at low tide; it is when they are exposed that the floating oil does the greatest damage. However, there are components of some oils that sink, and may cause damage to submerged corals.

Municipal waste and sewage problems in tropical waters have been discussed earlier in this section (Dekel). Serious problems developed in Hawaii, particularly in Kaneohe Bay and Sand Island, where sewage wastes were discharged into confined waters. Deep ocean outfalls equipped with diffusers, as well as sewage treatment, have successfully curtailed these problems. The revised water quality standards of the state of Hawaii reflect this strategy.

Wastes from food processing have caused significant water and land pollution in the Pacific Islands. For example, the tuna wastes in American Samoa are treated, but sludge disposal on land remains a serious problem due to odor, unsafe sludge pits, and residual water pollution. Ocean disposal of the sludge is now being evaluated by the Environmental Protection Agency, and remains a feasible prospect.

Little is known about the effects of pesticides and herbicides in tropical inshore ecosystems. Results of studies in temperate oceanic and terrestrial environments certainly indicate the possibilities of biomagnification and accumulation.

Thermal discharge can significantly affect coral reefs, particularly if large amounts of heated water are discharged into shallow areas. Cooling waters from power plant generators and refrigeration systems are common sources of thermal discharges. Summer discharges are more damaging than winter's, since the receiving water temperature is also higher, and the combined temperature is more likely to approach sublethal and lethal limits of corals. A major study of thermal pollution in the Pacific has examined the thermal discharge from Kahe power plant on Oahu, which has had serious problems, as well as those in other areas of Hawaii and in Kwajalein. Often diesel fuel, oil, and other pollutants are discharged with the thermal plume, further aggravating the effects. The strategy is to keep the thermal plume from impinging on the bottom at the discharge site. This has the effect of confining impacts to water column marine life which should be only temporarily affected.

Among future developments considered for Pacific areas that could cause substantial industrial pollution are: (1) manganese nodule mining and processing (effects on inshore ecosystems are unknown); (2) geothermal energy conversion (effects on coastal ecosystems will generally be avoided); (3) biomass conversion and the possible distillation of industrial ethanol as a sugar byproduct (disposal of the molasses residue is a possible problem); (4) storage of spent nuclear fuel and processed radioactive waste on Pacific Islands (potential effects are incalculable); and (5) impact of ocean thermal energy conversion (OTEC) installations that bring enormous quantities of cold, nutrient-rich water to the surface (effects currently being studied in Hawaii).

PORT DEVELOPMENT IN FIJI

by

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Ports are the nation's gateways and are therefore important state assets. They have a strong influence on the national socioeconomic structure. Many of the port-related activities (such as shipping, cargo handling, transportation, bunkering, insurance, crewing, banking and ship repairs) are self-generative. These activities in fact provide a considerable input to the economy. The effective control and operation of ports is therefore of fundamental importance to the welfare and life of the community.

If a port is inefficient and congested, it becomes a liability instead of being a contributor to the economy. Trade flows are restricted and surcharges are imposed by shipowners, all of which in turn have an adverse effect on the ability to earn foreign exchange and add to the spiralling cost of living.

Port Development

The strategy of port development can vary under different conditions. In the context of rich and developed countries, ports sometimes have more berths than ships. However, in the case of developing countries with small economies and limited facilities, port congestion and shipping delay are are major problems to contend with.

In some countries, overdevelopment of ports results in a duplication of shore facilities. Different ports under different management make large investments in the development and expansion of their infrastructures and services, each hoping to capture a bigger slice of the cake. Some rich countries with immense financial capabilities created--almost overnight--large port complexes without immediate support of shipping or trade.

This attitude towards port development in small developing countries would be difficult to justify in view of other national priorities (e.g., housing, roads, electrification, water supplies, medical services and rural development). Despite the efforts of enthusiastic consultants and high-powered sales representatives, port development requirements have to be looked at in a pragmatic manner. Merely trying to mimic and keep up with the development and rich countries is not the answer.

Port Operations

Fiji ports had been plagued by problems of congestion, shipping delay and widespread pillage of cargo, for many years in the late 60's and early 70's. The shortcomings and defects in the past, and to some extent that still exist today, can be summed as follows:

a) Absence of organized and sustained manpower development and training facilities.

b) Strained relationship, distrust and misunderstanding between employers and labour arising from an absence of a coherent policy for the creation of an efficient and reliable work force.

c) Lack of coordination and understanding between different organizations and authorities in charge of the various aspects of shipping control, port operation, cargo handling, and warehousing.

d) Inappropriate charging policies and ad hoc decisions to vary or waive charges resulted in wharf facilities being used as private storage areas.

e) Ineffective control of berth utilization by vessels. Unrealistic tariffs created artificial bottlenecks and increased berthing problems.

f) Large union claims coupled with pressures from different quarters for special favours and priorities had a demoralizing effect on the staff and workers.

g) Lack of proper development and improvement programs including the provision of suitable equipment and new facilities to meet the increasing demands of shipping and trade.

A combination of these factors reduced Fiji port installations to mere "dumping grounds". Congestion and confusion became so chaotic that badly delayed ships threatened the imposition of surcharges. Warehouses and storage areas choked with undelivered cargo for weeks and months became breeding places and hideouts for thieves and undesirable elements.

Port Reorganization

A transport investigation team in 1968 recommended the construction of additional wharves in Suva to overcome the acute shortage of shore facilities. In 1972 a Fiji Ports Commission of Inquiry came out with a different solution to solve the same problems. It proposed the establishment of a port authority to reorganize port management, operational systems, and cargo handling methods. Some engineering and construction works were necessary to rehabilitate and upgrade existing infrastructures. But manpower development and training were essential parts of the overall development program.

Ports Authority of Fiji (PAF)

The Ports Authority of Fiji, since its inception on 1 November 1975, is the organization in charge of the administration of management of the ports of Suva, Lautoka and Levuka, which cater in the main for the receipt and dispatch of overseas shipping and trade.

Its port development program to meet the demands of shipping and trade over the next decade and beyond includes the Suva Port rehabilitation and improvement project at a cost of $10 million, with the Asian Development Bank assisting with the financing. Studies are being undertaken to expand and upgrade port facilities in Lautoka and Levuka.

Port Development Strategy

The development of port facilities in Fiji takes cognizance of two important criteria: a) Manpower training and development, and b) Infrastructure rehabilitation and improvement. In the context of a small economy of a developing country, it is vital that port development is kept in line with other national priorities. Port development does not necessarily mean the construction of new wharves and terminals. Manpower development and the training and grooming of an efficient and effective port management are essential aspects of PAF port development strategy.

It would be a folly if one tries to import lock, stock, and barrel a well tried out system from another country and expects it to work equally well in Fiji. Local conditions and requirements are important considerations.

In order to maximize and intensify the use of available port assets and manpower resources, a dynamic and dedicated management supported by a well groomed and experienced staff is essential. The provision of appropriate hardware and simplification of documentary procedures are important considerations. With self-reliance, experience and confidence, it is more likely that the port management of a developing country would succeed in planning and implementing its long-term expansion and development program in the best interests of the country and its people.

IMPLICATION OF DINOFLAGELLATES IN MARINE FOOD POISONING IN THE TROPICAL PACIFIC

by

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In the tropical Pacific it is only in recent years that the implication of dinoflagellates in etiology of ciguatera fish poisoning became known. Nevertheless, the organisms are drawing ever increasing attention by their involvement in ciguatera and paralytic shellfish poisoning which are the most important marine food poisoning in this region. In such dinoflagellates-originated poisonings, ecological studies will play an important role in assessing the endemicity, predicting the outbreaks, and even in reducing the incidence. A typical example for such ecological approach will be seen in the recent study on ciguatera.

The causative dinoflagellate of ciguatera was discovered in 1977 by the writer and his colleagues (Yasumoto *et al.*, 1977). Initially it was assigned to *Diplopsalis* sp. but later to *Gambierdiscus toxicus* gen. et sp. nov. (Adachi and Fukuyo, 1979). The organism is basically epiphytic, as the number attaching to algae far exceeds those that are free-swimming or those resting on the surfaces of inorganic materials such as dead corals or bottom sands. Thus, microscopic counting of the cells shaken from a known amount of attached algae easily tells us the distribution and population density (Yasumoto *et al.*, 1979). *Turbinaria ornata, Jania* sp., and *Sargassum crystafolium* were found to be a suitable assay substrate as they are common in many places and harbor more *G. toxicus* than most of other algae growing in the same place. Though the blue green alga *Lyngbya* sp.

also was found to be favored by the toxic dinoflagellate, this alga is difficult to collect in an amount necessary for quantitative assay. It also fragments producing a residue that interferes with microscopic counting. The distribution map of *G. toxicus* prepared for French Polynesia gave a clear account of the endemicity of ciguatera in that region. The advantage of this cell-counting method utilizing dinoflagellates shaken from algae lies not only in its simplicity but also in its applicability to the samples sent from remote areas. Expansion of a survey to the whole Pacific area similar to the one performed in French Polynesia will provide good information about ciguatera-endemicity and will contribute to the reduction of the incidences of poisoning. This survey method should also enable us to observe the fluctuations of *G. toxicus* populations during the environmental changes and to analyse the effects of environmental factors. Such studies are of special importance since alteration of a coral ecosystem is often followed by increased toxicity of fish (see preceding contributions by Groves and Dekel). A periodic survey conducted at Tahiti for two months revealed a remarkable variation of the dinoflagellate population after heavy rainfall, suggesting its susceptibility to environmental factors. We have been accumulating analytical data on sea water samples collected from various places in French Polynesia in order to assess the ecological factors influencing the prevalence of the organism. Field observations are being supplemented by nutritional studies on both unialgal and axenic cultures grown by the writer and his colleagues. The results will be reported after completion of the analyses.

During the survey of *G. toxicus*, the presence of a number of dinoflagellates with a similar habitat was observed. Several of them were isolated and cultured in unialgal state. After testing with mice, two species, *Prorocentrum lima* and *Amphidinium* sp. were newly found toxic. Especially interesting are the two toxins produced by *P. lima*. They were named PL toxins I and II because they are very similar to scaritoxin and ciguatoxin, respectively, not only in chromatographic properties but also in pharmacological properties (Miyahara and Rayner, pers. comm.). Although scarce in the Gambier Islands where the fish show highest toxicity, *P. lima* was found to have wide distribution in ciguatera-endemic areas and often outnumbered *G. toxicus*. The potential contribution of this species to infection of fish should be investigated. The variety and quantity of benthic dinoflagellates observed during our survey indicate the necessity to test them as the possible source of toxins known to occur in herbivorous or grazing invertebrates such as the silver-mouthed turban-shell, green turban shell, and toxic crabs.

Unlike ciguatera, paralytic shellfish poisoning (PSP) has long been considered as a phenomenon restricted to the northern hemisphere, where toxic dinoflagellates *Gonyaulax* spp. cause serious public health and economic problems. Recent reports by Maclean (1979) and by Kamiya and Hashimoto (1978) on the occurrence of PSP in Papua New Guinea, Sabah, Brunei, and Palau suggest that this poisoning, too, is a serious threat to the public health and fisheries in the tropical Pacific. Differing from PSP in the north, PSP in the tropics seems to be caused by the plankter, *Pyrodinium bahmense* and even fish seem to accumulate the same toxins. Since another form of fish poisoning known as clupeotoxism occurs as the result of the ingestion of fish which feed on plankton, the source of the clupeotoxin can be sought among plankton.

In view of the known and potential involvement of dinoflagellates in marine food poisonings, and the response of the organisms to ecological factors, special attention should be paid to the dinoflagellates community when alteration of a coral ecosystem is planned.

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SECTION IV.

FISHERIES

FISHERIES

CHANGING TECHNOLOGY IN SUBSISTENCE FISHERIES

by

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Introduction

The earlier paper "Traditional Patterns of Utilization" outlined in a general way the manner in which the people of the South Pacific used their marine resources in previous times. This pattern was to change with the advent of western technology.

Subsistence Fisheries

Introduction of cash economics in even the remotest part of the Pacific makes a redefinition of "subsistence" necessary. A subsistence fishery is basically one in which the catch is consumed by the fisherman and his family or social unit, stored for later use, or bartered for other products. Today part of the catch may be sold, but money provides a modern and convenient replacement of barter or exchange. As there is an unavoidable and confusing overlap with "professional" fishing, this paper overlaps with those following it.

New Fishing Technologies

Following contacts with Europeans in the Pacific came exposure to new fishing technologies, an exposure which continues to the present. Some of these simple technologies advanced Pacific fishing from the stone-age through iron and space age technology in a few decades. Major changes were:

1. Steel fish hooks and spear-heads replaced those of shell, stone, and timber. Steel hooks are more efficient and mass-produced for a low unit cost. In countries such as Fiji where line-fishing was unimportant it introduced a new way of fishing.

2. European twines and later monofilament polymers replaced traditional materials. These were stronger, lighter in weight and very efficient for line fishing.

3. Monofilament gill nets replaced cotton and traditional nets in the last decade. These represent a recent and world-wide revolution in fisheries. Class exercises in the Institute of Marine Resources demonstrated that these nets catch 2-4 times the number of fish of similar woven nylon nets. Monofilament gill nets are now in great demand in the region, and are replacing traditional stone traps and reed fish fences in many countries.

4. Outboard motors increased the range of the subsistence fishermen. Introduced after World War II, outboards have revolutionized fishing and travel in the Pacific. Traditional sailing canoes were replaced; new hull shapes were introduced. In Fiji the original crafts were almost completely replaced by outboards and Indian punts, whereas in Kiribati the impact was minimal.

5. Metal mesh nets replaced traditional netting, reeds, etc., in traps. Chicken wire arrowhead fish fences spread throughout the Pacific.

6. Spearguns, harpoons, diving masks made spearfishing more efficient and introduced it to new regions. The Japanese are credited with introducing low cost goggles in the 1930s.

7. Dynamite fishing became widespread in the early days of the century. Although still practiced, it is banned in most areas.

Associated Changes Affecting Fisheries

While these new technologies were increasing the catch/effort ratio, other changes were increasing the market and demand for marine products.

1. Increasing local populations: Pacific countries have amongst the highest birth rates.

2. Urbanization: Urban drift has increased in recent decades, creating a greater demand for marine products.

3. Industrialization and cash economies: Facilitated exchange for marine products.

4. Cooling, freezing and preservation: Increased storage life of products. Subsistence fishermen may catch more than their present needs.

5. New marine products are exploited for export: Overseas demand, efficient preservation and low-cost transport introduces industries such as pearl shell and beche-de-mer to the Pacific.

6. Traditional customs break down: Traditional laws and taboos conserving marine resources breakdown in some regions.

7. Dangers of over-fishing: Decline in mullet production in many countries is alarming. Decline in Fanga'utu lagoon in Tangatapu, Tonga, is attributed to over-fishing. Similar decreases at Lami, Lautoka (Viti Levu, Fiji) are possibly due to over-fishing, although some fisheries officers attribute these to siltation.

8. Industrialization and urbanization creates pollution hazards: Declining catches in Laucala Bay, Nadi and Ba (Viti Levu) have been attributed to siltation resulting from changes in land used. Contaminations of marine organisms have occurred in Kiribati where lagoonal bivalves important in the subsistence fisheries have been found to harbor human coliform bacteria and possibly cholera.

COMMERCIAL FISHERIES IN WESTERN PACIFIC ISLANDS

by

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Introduction

In many Pacific countries, governments are looking towards the fishing industry as a means of providing food, employment, and revenue. Of course, inshore marine species have traditionally been exploited by Pacific islanders and in the past, resources of nearby lagoons and reefs have been sufficient to satisfy local protein requirements.

During recent years, however, there has been a dramatic increase in the population of many island states. This, combined with a trend towards increasing urbanization and a cash economy, has resulted in heavy fishing pressure in many areas. Large quantities of tinned and other fish products are imported into many Pacific countries. In 1978, over $14.5 million worth of fish products were imported into Fiji (Fish. Div. Ann. Rep. Fiji, 1978). In all, there is an urgent call to develop Pacific island fisheries and increase the harvest from the seas.

Here we provide a general summary of the distribution of exploited or exploitable organisms in relation to various habitats, with a brief description of existing fisheries. Several options for increasing productivity are also discussed.

Habitats

Two main types of islands in the western Pacific can be recognized, namely high islands, often with rivers and mangroves, such as the New Hebrides, Solomon Islands and Fiji, and low islands, which include the coral atolls such as Kiribati and Tuvalu.

High islands usually offer a greater diversity of habitats for fisheries. These can be categorized from shore as follows:

1. fresh water
2. mangroves/estuaries/mud and sand flats
3. lagoons
4. reefs
5. outer reef slopes
6. offshore

Low lying atolls are, of course, without rivers and although mangroves may be present, these are usually unimportant from a fisheries viewpoint. Some low islands are also without shelter lagoons and offer only reef and outer reef slope habitats.

Distribution of Exploited Species

Freshwater. Rivers are generally used for subsistence fishing only. However some species such as the freshwater prawn (*Macrobrachium*) are marketed in islands like Fiji where they are caught by dipnets or multi-pronged spears. Freshwater clams such as *Batissa* are collected by hand.

Mangroves/estuaries/mud and sand flats. Generally mangrove areas, although important as nursery areas for many exploited species are not areas of major fishing activity. Nevertheless a number of fishing methods are used in such areas, including set nets (gill nets, verandah nets and blocking nets), seine nets and cast nets as well as large fish traps. Fish traps are generally set at right angles to the shore line to capture migrating fish. One such fish trap popular in Tonga is constructed of wooden stakes and chicken-wire mesh. The trap may be extended over hundreds of meters by adding further units on to the initial one. Using these methods a variety of larger fish including mullet (*Mugil* spp.), rabbitfish (*Siganus guttatus*) and silver biddies (*Gerres ovatus*) are caught. Other fish caught in such areas are small scats (*Scatophagus* spp.) and the small carnivorous crescent bass, *Therapon jarbua*.

Invertebrates collected in mangroves include oysters (*Crassostrea* spp.). Introduction of exotic species such as the Pacific oyster *Crassostrea gigas* appear to have resulted in the establishment of populations of this species in some islands. On mud flats the ark shell (*Anadara*) is collected, whereas on more exposed sandy areas small donacids (*Donax* spp.) are used as food. Crustaceans such as the mud crab *Scylla serrata* are often caught in baited box traps. In Fiji a novel method is used to capture the burrowing mud lobster *Thalassima anomala*; a noose and spring trap is made from hibiscus and mangrove and is set above the crustacean's mound which may be up to 1 m high (Pillai, unpublished thesis). The small crabs *Sesarma erethrodactyla* and *Cardisoma carnifax* are also collected by hand.

Penaeid shrimp (e.g., *Penaeus semisulcatus*, *P. monodon*, etc.), are widely distributed in the western Pacific but are relatively unimportant commercially. In at least two countries, Fiji and Tonga, trawling surveys have been carried out for penaeid prawns and in the 1970s there was a trawl fishery (one boat) in Fanga'uta lagoon, Tonga. In many areas the presence of coral prevents trawling from being carried out.

<u>Lagoons</u>. Most fishing activity appears centered on the lagoons where netting methods are similar to those mentioned in the previous section. In addition handlining and more active forms of fishing such as diving and spearfishing are used.

Larger pelagic fish such as barracuda, *Sphyraena* sp., and scombroids such as the mackerel *Rastrelliger kanagurta* and walu *Scomberomorus commersoni* can be caught by trolling baited hooks or artificial lures. In Fiji the cream colored membranes of the stem of the lily *Cronum asiaticum* is used as a towed lure (Wright, 1969).

Many fish congregate around isolated reef patches which become popular fishing locations within the lagoon. The most sought after fish include snapper (*Lutjanus* and *Lethrinus* spp.) and rock-cod (*Plectroma* spp. and *Epinephalus* spp.).

Holothurians (beche-de-mer) are collected by hand and diving; but this fishery has only recently been introduced to the Pacific Islands. Selected species (Gentle and Conan, 1979) are smoked and dried for south-east Asian markets.

<u>Reefs</u>. Many of the larger reef fishes such as trevally (*Caranx* spp.) are associated with deepwater passages in the reef. Smaller fish such as triggerfish (*Anacanthidae*) and parrotfish (*Balbometopon muricatus* and *Scarus* spp.) are caught on the reef flat. With the increase in tuna fishing in the western Pacific, a complementary bait fishery has developed around coral reefs. Small bait fish such as anchovies, *Stolepherus* spp.; sprats, *Spratelloides* spp.; and sardines, *Sardinella* spp. are caught using small mesh nets. These species are kept in seawater tanks on the fishing boats and used as live bait in pole-fishing for tuna.

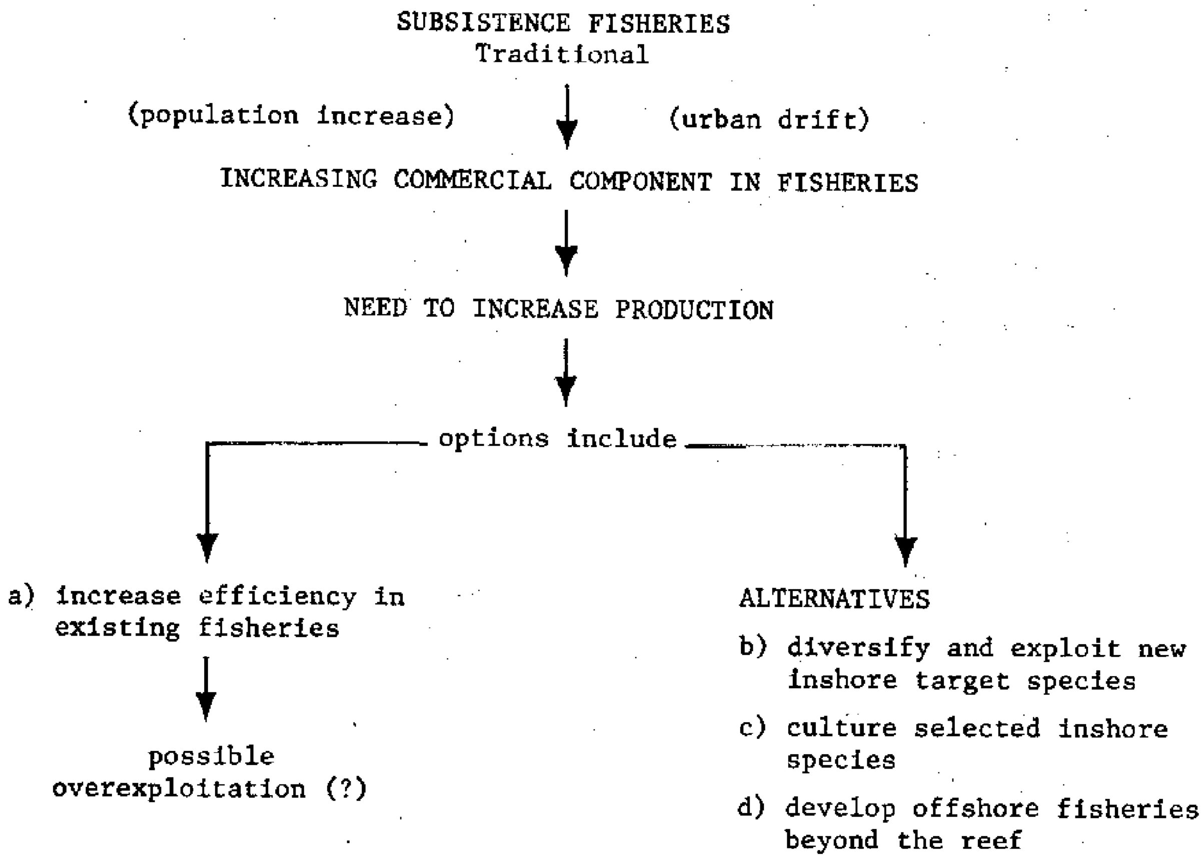
Some reef algae are also collected as food; *Caulerpa*, for example, is often sold with reef molluscs, such as spider shells (*Lambis* spp.) in Fijian markets. Other molluscs collected on reefs include *Trochus* and the giant clam, *Tridacna*. Crayfish or rock lobsters (*Panilurus* spp.) have to be collected by diving as the species appears to be difficult to capture in the baited traps commonly set for temperate water species.

Outer reef slopes. Although fishing on the outer reef slopes is often hazardous due to the breaking seas there are a number of fish species to reward the more daring fishermen. Carangids and numerous acanthurids including the large unicornfish, *Naso unicornis* may be caught. In Fiji large pufferfish (Canthigasteridae) are often speared by divers; those fish are favored for use as food in spite of their reputation of being toxic.

The hawksbill (*Eretmochelys imricata*) and green turtle (*Chelonia mydas*) are commonly caught beyond the reefs in many Pacific islands (M. Guinea, unpublished thesis); in Fiji, these species are often taken by diving with spears or by setting nets (approximately 22 cm square mesh size) on the outside of barrier reefs. In many countries the taking of nesting females and collecting eggs is illegal but, of course, hard to police on small islands.

Options for Increasing Fishery Productivity

How can our goal of increased productivity be reached? Several options exist and these are summarized below:



Increasing Efficiency in Existing Fisheries

Increased efficiency in a fishery will nearly always result in increased pressure on the resource. The question is, therefore, whether or not the resource can withstand any increase in fishing pressure. The method usually used to answer this question involves the use of basic biological and statistical data. Calculation of exploitation rates, for example, require estimates of total mortality and fishing mortality for exploited species. However, these parameters are usually not known in Pacific island fisheries.

The paucity of biological and statistical data on most target species appears to be nearly universal all over the western Pacific islands; exceptions are the pelagic species of international interest, such as the tunas.

This means we are usually not in a position to say whether or not a resource will be able to withstand increased exploitation.

It is worthwhile to put in a plea here to those representing small island states to ensure that at least basic catch and fishing effort figures are maintained for each fishery. These data would at least allow the traditional assessments of catch/effort relationships to be made. At low levels of fishing effort any increase in this effort will be rewarded by a corresponding increase in catch. At higher levels catch may not increase, and may even decrease, with any increase in fishing effort. It should be noted that an increase in effort may be the result of improvements in catching methods (i.e., effective effort) as well as increases in the number of fishermen.

So, in the absence of suitable data, we have to be content with some generalizations to answer questions on the ability of a species to withstand heavy fishing pressure. We know that some organisms lower down in the food chain are going to be present in larger numbers than high level carnivores, therefore, the former can presumably be fished more heavily. We can also base some generalizations on the type of ecosystem involved in a fishery. Estuarine fish, for example, which often school in large numbers and have short life cycles, will be less susceptible to heavy fishing than most reef species. The latter are often solitary (or territorial) and have long life cycles. One difference between short life-cycle/highly fecund fish and long life-cycle/less fecund fish is that if the spawning stock in short-lived, fecund species is reduced by heavy fishing, there is no change in the number of new recruits to the fishable stock until very low population sizes are reached.

Notwithstanding the underexploitation/overexploitation question, efficiency in many Pacific island fisheries is being increased. Efficiency obviously took a giant jump, for example, when monofilament gill nets were introduced into Fiji, where the Fisheries Division imports both multi- and monofilament nets (50% of each) which are sold at cost price. The multifilament net, which fishermen have to buy when the monofilament is sold out, acts as some sort of restriction on efficiency. Small outboard engines are free of duty in Fiji and the Fisheries Division here is making boats available to villagers at the cost of materials only. A 28 foot boat with a 20 hp diesel engine is being sold for about F$5000.

In several Pacific countries there is evidence (unfortunately anecdotal rather than as hard data) that some species are overexploited. The mullet fishery (*Mugil* spp.) in Tonga is an example where catches have dropped dramatically over the past few years. Whether this indicates long-term cyclic phenomena or a reduction in the reproductive capacity of the stock is not known.

It is interesting to note that whereas there is only one suitable nursery area for mullet in Tonga (Fanga'uta lagoon), the more mountainous volcanic islands such as Fiji, the Solomons, etc., contain many suitable nursery areas such as the mouths of large rivers. It follows that the fishery for these species may be especially fragile in low islands such as Tonga. Even in parts of Fiji (the Lau islands of Fulaga and Ono-i-lau), mullet catches are reported to be dramatically falling. In these islands, mullet--believed to be *Mugil cephalus*--are caught for salting and drying during the large spawning runs.

Another popular fish in Fiji, the salala or Indian Mackerel, *Rastralliger kanagurta* appears to be very heavily fished. One particular fishing family, which has receipts for fish sold, began fishing on the eastern side of Viti Levu 18 years ago. Catch per effort has decreased from about 11,000 lbs for a four day trip 10 years ago to the present when about 9,000 lbs are caught by 16 men in 11 days. The family is now leaving fishing and buying shops to sell imported canned fish!

Exploiting New Inshore Target Species

One way of reducing pressure on existing fisheries is by exploiting different inshore species. However, this is not always easy. It is the case in most countries that a small group of particular organisms have become the preferred targets. There are two main reasons for this: either the species is present in large numbers and easy to catch (e.g., a schooling fish which is susceptible to netting), or there is a social preference for the particular species. An example of social preference is the mullet; it is a highly desired fish in many Pacific islands, but is pretty well despised (for no good reason) in countries like Australia. To develop new fisheries there may be prejudices to overcome, in addition to introducing new markets and techniques.

However, before all this can occur, it is necessary to have an inventory of the potential resources available--and in most cases this has not been done. Resource surveys should be carried out--even if it is a species checklist with some index of abundance--in all island countries.

So, what alternative inshore species are available? Holothurians (beche-de-mer or sea cucumber), for example, are being collected in Fiji where villagers are being trained in processing and market requirements. The most valuable species, the "teatfish" (*Microthele nobilis*), when properly smoked and dried, is being sold for F$2.50 per lb. Over F$15,000 worth of bęche-de-mer were exported through Chinese merchants last year.

Some alternative species present special problems: penaeid prawns (*Penaeus monodon, P. semisulcatus, P. japonicus*) are abundant in coastal areas of Fiji and, it seems, many other Pacific islands. In Fiji, the juveniles or subadults are sometime caught on a subsistence basis by spear or hand net in estuaries or mangrove areas. Being highly fecund and, in many species, having a one-year life cycle, penaeid prawns are an ideal resource and, in effect, represent an annual crop to be harvested. The harvesting on a commercial scale, however, presents problems. Ideally the adults should be harvested, but penaeid prawns migrate out from the estuaries after the juvenile stage and it is not really known where they go to spawn. Almost certainly they stay within the reefs and in the lagoons where trawling may be difficult due to the presence of coral.

Culturing Selected Inshore Species

Aquaculture in tropical areas often appears to be an attractive proposition. Fish culture has been practiced for over 4,000 years in southeast Asia but is virtually unknown in other tropical regions such as Africa and the Pacific Islands. Positive aspects of tropical species include:

1. the fast growth rate and short life-cycle in many species
2. the possibility of continual breeding
3. the fast growth of plant material for herbivores.

The above points mean that culture can be more intensive or fish ponds can be smaller than those in temperate areas.

There are several negative aspects however which range through biological to sociological. Productive warm water ponds may be poorly oxygenated for example (although fish such as anabantoids which can use atmospheric oxygen, can be selected). Non-biological problems in aquaculture include the ownership of the cultivated resource--a resource which may have traditionally been regarded as a common property resource.

The wise choice of species to be cultured is most important, and should be based on practical and economic as well as biological considerations. There are some fairly unrealistic proposals--for instance, to farm some of the large reptantian decapods such as the mud crab, *Scylla serrata*, and the rock lobsters, *Panilurus* spp. In spite of their high market value, these species are poor choices; they generally have an extended life cycle and a complex larval biology. Nantantian decapods such as the penaeid prawns with their short larval phases and fast growth are more suitable. The giant tiger prawn *Penaeus monodon*, a favored candidate for culture, is present in Fiji at least. The cost of establishing prawn farms is very high, however; and most enterprises in developed countries like America could not survive without continual government assistance.

On a small scale it may be more suitable to choose a non-mobile species to farm; bivalve molluscs for example. Stick, tray or even raft culture of oyster and mussels is not expensive. The green mussel *Mytilus swaraydinus* is at present being grown experimentally in Fiji. The Pacific oyster *Crassostrea gigas* has been introduced into some Pacific Island countries. Contrary to firmly held notions on oyster farming, this species does not require brackish water and strong tidal exchange, and will even grow in enclosed ponds (King, 1977) and possibly enclosed lagoons to reach a marketable size in about ten months. More recent work in New Caledonia indicates that other species, such as *Crassostrea echinata* may be more suitable for Pacific Islands.

Developing Offshore Fisheries

Many Pacific Island countries are becoming involved in offshore fishing for pelagic species such as yellowfin and skipjack tunas. Many of the offshore tuna fisheries are being developed in cooperation with the advanced fishing nations such as Japan. It is worth pointing out that in such cooperative ventures, or in any "resource diplomacy," it is desirable that local fisheries personnel have access to independent stock estimates and catch statistics.

The development of trap and dropline fisheries on deep water lutjanids such as *Etelis* and *Pristipomoides* spp. is being investigated in several countries. Deep water caridean shrimp have been found in several Pacific countries (King, 1981). In Fiji, several species, including *Heterocarpus* spp., have been caught in encouraging quantities (Brown and King, 1979) and some fishermen are interested in commercial shrimp trapping.

Discussion

In most Pacific Islands there is an urgent need to increase the production of seafood. In this paper, some options available for future development have been presented. Increasing efficiency in existing inshore fisheries does not always represent the best of the available options. Several cases where overexploitation has occurred or is likely to occur has been given.

Alternative options are exploiting new species, inshore and offshore and by culturing selected species. However, these alternatives often require new techniques, training and technology. The alternatives should be carefully evaluated from market, economic and sociological aspects as well as from a strictly biological point of view.

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SECTION V.

TECHNOLOGY TRANSFER

PRESERVING AND PROCESSING FRESH FISH

by

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Introduction

I would like to point out some of the difficulties of making better use of marine resources for human food, but at the same time to attempt to show the options that are available to extend the keeping time of fish and fish products. By extending keeping time of fresh fish, or by processing it to a stable product, it is possible to improve the financial circumstances of fishermen.

My knowledge of the resources of the southwest Pacific and their present pattern of utilization is very limited and so I will avoid making direct references. However, experience from other parts of the world indicates that it is extremely difficult to make sudden and spectacular improvements by the introduction of sophisticated technology. This is particularly so in the situation of coastal/reef fisheries where there is, in general, a fragile resource base which is incompatible with the need of modern, capital intensive technology for high volume throughput.

Although this may appear to be an unencouraging start to a discussion on the introduction of better utilization systems for inshore fisheries, I believe that there are many simple steps that can be taken to increase incomes by reducing spoilage.

As an introduction to the available technology and the requirements of processing, let us consider the background to fish spoilage.

Spoilage

To take a simplified model: fish start to spoil as soon as they have been caught, because of the growth of bacteria. It is important to differentiate between these spoilage bacteria and the pathogenic organisms that cause food poisoning or disease. Fish may be spoiled without being a public health risk or vice versa. The rate of bacterial growth is dependent on temperature and so the rate of spoilage is controlled by a combination of storage time and temperature. Although the bacteria are responsible for spoilage, the actual cause is enzymes liberated by the bacteria. These enzymes break down protein and inorganic constituents giving rise to the characteristic softness and spoilage odors. The only way to prevent spoilage is to stop bacterial growth, as this stops the production of enzymes.

Food Processing Methods

All methods of food processing depend for their effectiveness in eliminating or suppressing bacterial growth. Despite the large number of food products that are available, they all depend on one of the three basic principles listed below for their stability:

1. Control of the amount of water that is available for bacterial growth and chemical reactions. Effectively this is by drying (removal of water) or salting (which makes water unavailable for reactions).

2. Reduction of temperature to levels at which bacteria cannot grow.

3. Sterilization, causing the death of bacteria by heat, chemical treatment, or irradiation.

These three principles, used either singly or in combination, are the only means of bacterial control.

Control of water activity. Fresh fish contains from 70-80% water. If the moisture content is reduced, with or without salting, bacteria cannot grow. Salted and dried fish are the most important traditional processed products, produced in all parts of the world in great quantities. Smoked fish comes in this category, as smoking dries the fish. The smoke adds flavor and also has an antibacterial effect on the surfaces. The disadvantages are that dried fish must be protected from flies and insects during production and storage. If the salt content is high it will pick up moisture during storage--becoming moldy. Unfortunately these products are regarded as poor man's food and thus have a poor market image. This is perhaps because quality standards are often low. However, in many instances the production can be improved and semi-industrialized at low cost. This can result in less waste, economic returns and improved nutrition in village communities. The use of locally produced salt and of simple solar driers can result in such improvements.

In many parts of the world artificial driers, using oil, electricity or gas as a source of heat, have been used. The increasing cost of energy is making this method increasingly uneconomic.

There are other techniques such as freeze drying which are even more energy intensive and are therefore, unsuitable for relatively cheap products such as fish. In freeze drying, the product is first frozen and then placed in a vacuum chamber, where the ice is sublimed as vapor. The quality of the resulting products is high but the costs are unacceptable, except perhaps for special applications.

Reduction of temperature. As stated previously the rate of spoilage is dependent on temperature. Figures taken from the spoilage curve show how relative rates of spoilage increase remarkably as the temperature rises.

Temperature (°C)	Rate of Spoilage
0	1
5	2.2
10	4.0
15	6.4
20	8.1
25	8.9

So holding fish for one day at 25°C will do as much damage as holding for 8.9 days at 0°C, the temperature of melting ice. This is the most significant fact in fish handling and points to the vital need to chill fish as soon as possible after catch. Integration of the storage history by time and temperature within the spoilage curve can easily give the amount of storage life which has been used up before the fish reaches the market. Or if storage trials in ice have been carried out, the amount of storage life remaining can be calculated.

It is essential to carry out such an exercise in all situations where the time and distance parameters of fishing operations and getting to market are known. This will determine whether the fish can be marketed fresh, in ice or whether it must be processed.

However, it must be remembered that in the tropics ambient temperatures are rarely below 25°C, and at that temperature a period of three hours is equivalent to the loss of more than one day's ice storage life.

It is generally true that species taken from warm tropical waters, on the surface or shallow coasts, will keep for extended periods. Storage times of more than four weeks at 0°C are not uncommon. Of course this is subject to correct handling and varies widely depending on factors such as size, fat content and the intrinsic properties of the species.

At ice temperatures (0°C) bacteria continues to grow slowly. When the temperature is reduced to -7°C, bacterial growth ceases, but enzymatic reactions continue. Not until temperature has been reduced to -15°C do enzymatic reactions become insignificant. Hence, fish must be frozen quickly to temperatures below -15°C. If storage is intended for more than three months, frozen fish should be held at -30°C.

The advantages of chilling and freezing are that the fish retains all the characteristics of fresh fish, whereas all other forms of processing change the form.

The disadvantage is the high energy cost of freezing and the high capital cost of frozen storage. Icing and chill storage (at 0°C) are not as energy or capital intensive and should in most cases be an absolute requirement in any fishery.

Sterilization. Sterilization is generally carried out by heat, but can in cases be accomplished by chemicals or ionizing radiation.

Traditionally sterilized products are put into cans on a large scale in a very capital intensive mechanized factory. Small scale canning is possible, but in general, the products from a small scale cannery cannot compete with the high volume production from a large mechanized plant. Canning is a complex technological process which requires trained staff and constant supervision. The penalties for failure are severe, including death from botulism or outbreaks of typhoid as well as considerable economic loss.

Because the cost of tin or aluminum cans is about two times the cost of the contents, there is always a constant search for alternative packaging material or products. There are indeed alternatives but at present their viability is questionable. The process of sterilization in glass jars has been known, and widely used domestically for many years. However, food technologists are reluctant to recommend it as a suitable process for developing country fisheries for the following reasons.

Fish, as a low acid product, has a high risk of being contaminated with spores of *Clostridium botulinum*. Strict supervision of seals, lack of chips or cracks on jars, and heat treatment are required. When producing for commercial, rather than home, markets the shelf life is undefined, and the consequences of causing sickness or death among the general public are more severe than within the family.

In general the best fish for canning are the higher fat content pelagic species, such as sardine, tuna and mackerel. White fleshed fish do not can well and almost invariably have a better market in the fresh or frozen form. Because of the high processing costs the price paid to the fishermen for raw material for the canning industry is generally low, indicating a lack of promise for small-scale fisheries. Fish for canning should be small, like sardine, so that a number can be put into the can or large like tuna, so that when cut up the overall yield is still considerable. In both cases the industry is labor intensive.

Major drawbacks are the high investment cost in a cannery (recent costs are given below), the high cost of cans and the technological complexity which demands highly trained staff. For a small-scale cannery there are added difficulties in competition. During feasibility investigations the possibility of integrating fish canning with other products should be investigated.

Recently a processing system has been developed which may prove to be suitable for small-scale production, although it has not yet been used for fish processing. The fish is cut up, perhaps brined or cooked, and placed in pouches made from polyester, aluminum or polyolefin material. The pouches are exhausted, sealed and retorted under pressure. The technology for flexible pouches is simple, but costs are still comparable to canning.

Conclusion

In conclusion it can be stated that it is vital to chill the catch as soon as possible. Each fishery or community should be studied to determine the need for improved handling or processing technology. The storage life of properly iced fish is sufficient to reach profitable markets, then the requirements are for ice production, provision of boxes and insulated or refrigerated buffer stores to collect fish. Together with insulated vehicles to transport to market and clean attractive markets, the economic conditions of fishing communities can be dramatically improved. Such schemes should include market promotion, emphasizing nutritional benefits as well as value for money.

If the community is beyond the range of a market or if seasonal gluts occur, then the fish must be processed. Freezing is an attractive option, either whole or as fillets, but the energy costs and capital costs of storage must be taken into account as well as transport difficulties to market. Better production of dried fish is especially suitable for seasonal surpluses but better packaging is required.

The demand for canned fish in the region assures a market for a local product but the costs, scale of operation, and technological complexity need very careful evaluation. Despite the benefits of import substitution, commercial viability of a small cannery is not a foregone conclusion.

Finally, it is important to add that each community and each scheme proposed requires careful evaluation before attempts are made to implement them. A characteristic of small-scale fishing communities all over the world is that they use little technology. They are economically disadvantaged to the extent that they cannot be "risk takers" in trying new technology, and so they should only be offered technology which can be guaranteed to succeed.

SEAWAVE ENERGY (PASSIVE) CONCEPT

by

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A concern of this seminar/workshop is the drift toward urban centers and changing patterns of lifestyles which are placing pressures on traditional uses of marine resources in the tropical Pacific Islands. A goal of this seminar is transfer of technology related to preservation of fish and fish products. The Seawave Energy (Passive) Concept has relevance to both these aspects.

This concept has been predominantly examined in Mauritius (Bott *et al.*, 1978) which has favorable physical and geological locations for its application. Apparently, while oil was so cheap the concept was not economically viable, but calculations indicate that cost of power from it could be competitive with, or lower than that from conventional hydroelectric schemes or thermal electrical facilities dependent on present and projected fossil fuel costs. The drawback is that, despite the technology being simple and well known (technical viability having been already proved), the concept has not yet been tested in pilot or operational plant form. It is, however, simply a system of impounding the potential of waves breaking over fringing reefs into large "ponds" constructed by walls on the fringing reefs and cross bunds from reef to shore. Low-head generating sets would convert direct to electrical power, or turboram pumps would pump to secondary storage reservoirs at a higher level which would then operate as a normal high head hydroelectric scheme. It is calculated that in the right conditions 4 KW could be generated from each meter length of fringing reef, more in high energy conditions.

Physical and Geological Site Requirements

In 1978 the Mineral Resources Department of Fiji recognized that Fiji probably had good physical and geological locations for the application of this concept. The features desired are, in rough descending order of importance:

A level fringing reef, the core of which provides a surface width of not less than 8 m and is reasonably straight without large overspill discharge gaps between reef sections.

The fringing reef should be within 1 km of shoreline and be of uniform non-porous rock structure.

Strong and persistent wave action with significant waves being preferably not less than 1.25 m high. This occurs often off coasts which have consistent and strong wind action and a long "fetch" over water.

A nearby coastal topography which is suitable for a secondary storage reservoir.

A tidal range of around 1 meter.

A transmission system conveniently already present in the proposed development area.

These above characteristics may be commonly found in many other Pacific and Indian Ocean islands. In Fiji's case many potential sites have been recognized and further work is intended to select the best sites for more detailed studies. On Fiji's Coral Coast alone, eight potential sites have been identified which, if all potential sites were developed, could supply a 130 MW capacity - well in excess of Fiji's present total electrical power capacity (Crown Agents Report 1979).

Project Advantages

If the concept were proved economically viable, the following advantages would accrue:

There is no need for importation of expensive and scarce fossil fuels.

The source of the power is inexhaustible. Waves represent solar energy in a stored form moving on a vast area of the earth's surface.

The concept is environmentally relatively innocuous since no burning of fossil fuels is involved.

There is no need for import of high technology and expertise. The construction is labor intensive.

The scale is flexible from about 1 MW to 20 MW or more capacity and could bring indigenous power to many remote island communities at a reasonable cost which will promote other business or occupational activity.

The impounded water area is an excellent foundation on which to base commercial fish farming for high quality fish or shellfish.

Simultaneously, energy is available on which to base freezing, drying, canning, packaging, etc., for fish and other products; or other types of light industry.

Fresh water could be made available from desalination equipment based on power output.

It is suggested that proven development of this concept could then be confidently repeated in numerous other more-or-less remote localities throughout Asia and the Pacific which have little or no other alternative power sources. At scales appropriate to the communities served, such a project would go far towards improvement of their energy, food, water, and employment needs; and thus largely release them from the inflationary effects of oil prices. Improvement in amenities and provision of employment may stem and even reverse the trend from island/rural to urban communities.

The concept is attractive and a regional supported project to demonstrate its worth by means of a pilot project at least is justified. Successful results would have particular relevance to many petroleum importing coastal and island nations.

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Project Update

The presentation of this paper at the November 1979 Workshop encouraged the funding of an expert in this form of energy to visit Fiji in April 1980. He confirmed the presence of good potential wave energy (passive type) sites in Fiji and also in Tonga and Western Samoa. While in Fiji a variation of the concept for small (village and coastal community) demand requirements, say 50 kw to 1000 kw was evolved. This may be termed the Fiji Modular Wave Converter Concept. "Modules" may be constructed, floated to site and added to sites as demand increases. Fiji has excellent constructional facilities to fabricate the structures involved. Subsequently there has been a strong bid to obtain approximately $250,000 from European Economic Community sources to fund a demonstration project, executed by University of the South Pacific, based on this modular concept. Funds if confirmed would be available from about October 1981.

AQUACULTURE IN HAWAII

by

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The state of Hawaii has made a major commitment to aquaculture in order to diversify its agricultural base and provide economically viable alternatives to existing agricultural pursuits (primarily sugar and pineapple). Consequently an Aquaculture Development Program was established by the State Legislature in the Department of Planning and Economic Development (DPED). The first state aquaculture development plan in the United States was produced in 1978 titled "Aquaculture Development for Hawaii." The purposes of the plan were:

1. To assess Hawaii's resources for aquaculture and identify the most important constraints to development.

2. To recommend goals for aquaculture development.

3. To define the objectives and policies necessary to realize these goals.

4. To recommend programs, an organization, strategies, a budget and time tables to achieve these objectives and policies.

This plan has been implemented and it has effectively interacting components: the commercial production component, and the research, training, and technology transfer component.

The production component is primarily in the freshwater prawn (*Macrobrachium*) with minor production of oysters, catfish, and other species with a current value in excess of $1.5 million. It is predicted that the species composition of this component will change markedly in the next decade with an increase in penaeid shrimp and oyster production. The current production of cultured freshwater prawns is 244,000 pounds valued at $915,000. These were grown in 271 acres of ponds by 20 commercial producers.

Several commercial growers are developing facilities for open pond and greenhouse production of penaeid shrimp, but large scale production is not yet a reality. A large scale facility has been completed for the raceway production of oysters with yields in excess of one million oysters per month anticipated.

Research represents a major component of the Hawaiian aquaculture endeavor with most of the activity taking place at Anuenue Fisheries Research Center (AFRC), the Oceanic Institute and in various departments and institutes of the University of Hawaii. The principal research thrust at AFRC is with the freshwater prawn, *Macrobrachium rosenbergii*, and covers areas of reproduction, nutrition, disease control, pond management and genetics.

The Oceanic Institute is conducting research on the mahimahi (*Coryphaena*), mullet (*Mugil*), milkfish (*Chanos*) and various species of penaeid shrimp. They have successfully induced spawning in the mullet and developed a method to utilize manures to enhance the production of penaeid shrimp.

At the University, the Department of Animal Science has concentrated on various aspects of the freshwater prawn research in conjunction with AFRC and other departments of the university. The Hawaii Institute of Marine Biology has been investigating aquaculture schemes to utilize the cold, nutrient rich water that will result from the operation of Ocean Thermal Energy Conversion (OTEC) installations presently being developed. The organisms being investigated are several species of salmon and Nori (edible algae).

HIMB scientists have also been culturing topminnows for live tuna bait, and investigations on the genetics of tilapia in order to allow selection and stock improvement.

Training in aquaculture has been carried out by all of the research institutions in the state. The University of Hawaii at Manoa and two of its satellite community colleges have conducted courses in aquaculture and have arranged and supervised students in research training. A formal degree in aquaculture is not offered, but an integrated curriculum is presently being considered. Much of the training in Hawaii has been *Ad hoc*, responding to the needs of everyone from local farmers to high level bureaucrats from overseas.

Technology transfer has been carried out by a number of agencies and individuals but mostly by the Marine Advisory Program (MAP) of the Sea Grant Program. MAP agents are trained in extension techniques, and all are given basic technical information on aquaculture activities. They have access to sources of more specific technical expertise in aquaculture. The Sea Grant Program sponsors research and development and through resulting publications enhances technology transfer. In the period of 1975-79, 213 publications were produced by the Sea Grant Program in the following forms: Technical, Advisory, Cooperative, and Misc. Reports; Journal and Misc. Contributions; Advisory and Misc. Brochures; Seminar, Technical, Working and Conference Papers, and Newsletters.

The State of Hawaii Aquaculture Development Program is another major source of technology transfer. They provide varied information in the form of publications, lectures, exhibits and counseling. They produce a newsletter and assist entrepreneurs in locating sites, securing permits, arranging loans, etc.

In summary, the State of Hawaii, with its favorable climate for aquaculture production, is pursuing a vigorous program of research, training and technology transfer that may well serve as an example for other Pacific Island countries interested in similar endeavors.

SECTION VI.

MANAGEMENT GUIDELINES

CONSERVATION AND ENVIRONMENTAL POLICIES

by

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The coastal zone, of which the inshore marine ecological systems are an important element, is widely recognized as a unique national resource of considerable complexity. Conflicts in the use of this area are most likely to arise because of population pressures which create multiple demands upon it, many of which are noncompatible. Because of the productivity of its resources, and since it is the site of much human activity, it is worth planning for and managing properly so that it will have continued usefulness. Acceptable goals for national policy would obviously be neither complete destruction of the natural environment nor prohibition of all resource development, but attempting to strike a balance between use and preservation.

A review of how Fiji and the State of Hawaii (U.S.A.) have approached the problems of coastal zone management, including that of many inshore marine ecological systems, can provide some guidelines taken from divergent points of view from two island groups which have considerable physical similarities.

In Fiji

Fiji's approach is summarized below from a series of policy statements and objectives contained in its Seventh Development Plan:

1) Coastal resources. These are recognized to be of special importance in the face of pressure from population growth and economic development.

2) Development. Proposals for coastal developments will be carefully evaluated in order to balance environmental costs against development gains.

3) Waste disposal. Development technologies which produce less waste will be encouraged. Stringent standards will be insisted upon for effluent quality at outfall locations.

4) Recreation. Legal access to beaches and the foreshore by the public must be ensured since it normally has no rights over the land above them. Potential parks and reserves, both terrestrial and marine, will be surveyed, and some set aside as natural areas.

5) Fisheries. These resources will be continually explored and management undertaken in order to avoid overexploitation. Commercial ventures for reef and lagoon fishing will be encouraged and supported; however, controls will be exercised over fishing areas for live tropical fish, rare corals and shells.

6) Reefs and estuaries. The biological consequences of dredging and reef passage blasting will be carefully reviewed before these activities are approved, and closer control over tourist activities will be exercised to prevent wanton destruction of choice reef locations. The vital functioning of estuaries should not be disrupted by toxic industrial wastes, and port facilities will be constructed and operated with due regard to ecological conditions.

7) Mangroves. The heightened awareness of the social, environmental, and economic values of mangroves has resulted in resistance to their removal. No extensive reclamation of mangroves will be made before completion of a thorough survey to fully assess their values.

In Hawaii

In contrast to Fiji, the State of Hawaii has taken a more comprehensive planning approach through the enactment of a series of laws over the past twenty years. This pattern was initiated in 1960 when a General Plan was prepared creating Conservation Districts to control land use within zones reserved primarily for beaches, parks, forests, and for the protection of plants and animals including fish life. About ten years later a Shoreline Setback Law established a setback line a short distance inland from the shoreline and extending approximately 1000 feet seaward. Within this area it is unlawful to remove sand, coral, rocks, or other beach composition except for reasonable domestic or non-commercial use.

In 1975, the Shoreline Protection Act became law, empowering the Land Use Commission to administer land and water use regulations in coastal zones, control development, and resolve conflicts among competing uses. It also authorized the preparation of a plan for the management of the coastal zone to guide public and private uses. Later, marine life conservation districts were established by law for the purpose of studying, preserving, protecting, conserving, and propagating all manner of marine life and geologic features.

Lastly, a Coastal Zone Management law was enacted in 1977 under the auspices of federal law that required policies to be established that were comprehensive, specific, enforceable, and included an adequate degree of predictability as to how coastal resources will be managed. Objectives and policies were set forth for recreational, historic, scenic, and open space resources; public and private economic uses; coastal hazards and ecosystems, and managing development.

The approaches taken by Fiji and the State of Hawaii differ considerably in their attempts to properly manage the coastal zone and the inshore ecological systems it contains. Fiji has specified certain actions that should be taken within the context of national development. Hawaii has legalized policies and objectives specifically for the purpose of coastal zone management. In the latter case, the approach probably reflects a more advanced state of island development, and thus a greater pressure for use and development of the shoreline and inshore waters.

U.S. POLICIES ON ENVIRONMENT AND CONSERVATION OF NATURAL RESOURCES

by

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Conservation of natural and coastal resources in the United States involves several strategies and several levels of government. There are procedural requirements (such as the Coastal Zone Management Act, and the National Environmental Policy Act) which insure that environmental considerations enter into decisions on economic development and construction. There are substantive requirements which spell out the specific policies, standards, and guidelines on environmental protection and conservation and which also involve regulatory responsibilities by certain agencies over other agencies and the public.

The Framework of Responsibility

There are three levels of government which provide the controls over coastal development, natural resource conservation, and environmental protection in the United States: the federal government and its agencies are concerned about matters of national or international interest or significance; state governments are concerned with matters of regional interest; while city, county and local governments are concerned with matters of local interest.

All three levels of government in the U.S. have a division of power among three branches. The legislative branch writes and passes the laws.

The administrative branch writes the regulations, guidelines, and procedures to implement the laws. The judicial branch of government enforces the laws, the regulations, and the guidelines through the court system.

Generally, federal laws will take precedent over state or local laws if there are conflicts, according to the "federal supremacy" provisions of the constitution. Long-range land use or resource planning initiatives by state and local governments are also effective mechanisms for natural resource conservation. Also executive orders by mayors, governors, and the President may provide additional guidance and instructions to administrative agencies on protecting the environment and conservation of resources. For example, executive orders on water conservation and floodplain management were recently signed by the President.

Procedural Laws

Of the federal procedural laws, the National Environmental Policy Act of 1970 has been the most significant and formed the basis for Environmental Impact Statement (EIS) requirements in the U.S. The EIS's are required when there is a major federal action which significantly affects the quality of the human environment. The determination on the need for an EIS is accomplished by preparing an environmental assessment. The assessment includes a description of the project, including engineering and economic information; a description of where the project is to be located, as well as similar descriptions of alternative locations that were considered; an appraisal of the environmental consequences or impacts of the project on the environment at both the proposed and alternate sites; reasons why alternatives were rejected; a summary of unavoidable environmental impacts; and a description of measures to be used to avoid or mitigate environmental impacts. If an EIS is required on the basis of the foregoing analysis, a comprehensive report addressing the above points in more detail is prepared and circulated for citizen and agency reveiw. The project sponsor must then respond to comments submitted by these entities and modify the project design and EIS, if warranted. Then a final version of the EIS is circulated for review prior to approval and construction of the project.

Substantive Laws

There are a great number of federal substantive laws which directly or indirectly involve conservation or protection of coastal and natural resources. These are administered by a variety of federal agencies. In addition to procedural, review, or coordination requirements, substantive laws also provide specific guidelines, standards, or criteria with which the proposed project must conform. For example, federal agencies cannot jeopardize the continued existence of an endangered species or violate water quality standards. Most substantive laws with environmental focus fall into one of three categories: pollution control laws, conservation or protection of natural (including ecological) resources, and protection of social and cultural resources. A partial listing of the laws is found in Table 1. Some of the broader or more important laws apply to more than one of the categories.

The Economies of Long Range Planning

The procedural laws have been important in changing the pattern of land and water development during the past 20 years, specifically in protecting the environment. The substantive laws have been effective in reducing adverse environmental effects on coastal resources, but the regulatory authorities are frequently inefficient because they take effect only after projects are proposed and in operation. In other words, the impact of the regulations isn't felt until later, when the planning process is completed or well advanced and when changes to projects to avoid impacts are unpopular, expensive, or ineffective.

Long range planning represents a more efficient and less costly approach towards coastal and natural resource conservation and protection. Inventories, detailed studies, policies, standards, and guidelines are executed well in advance of the implementation of specific projects allowing environmental problems to be identified very early in the planning process and easily avoided. As a consequence, the early consideration of alternative locations or designs for development projects is less expensive and more acceptable. Therefore, comprehensive long range planning studies should be given the highest consideration within the emerging countries of the insular Pacific. In addition, substantive and procedural controls will also serve as a check on protecting environmental resources and as the only effective approach until comprehensive water and land use plans are developed and implemented.

Table 1. Selected Procedural and Substantive Federal Laws of the United States Which Focus on the Protection and Conservation of Environmental Resources

Procedural Laws	Purpose
Water Resources Planning Act of 1965	Equal consideration to economic and environmental goals

(Table 1 - continued)

(Procedural Laws)	Purpose
National Environmental Policy Act of 1970	Environmental Impact Statement and Environmental Impact Assessment procedures
Coastal Zone Management Act of 1972	Preparation and implementation of coastal zone management plans
Marine Fisheries Conservation Act of 1972	Development of conservation/management plans for offshore marine resources
Substantive Laws - Pollution Control	**Purpose**
Clean Air Act of 1977	Air pollution controls and standards
Clean Water Act of 1977	Water quality and effluent standards
Resource Conservation and Recovery Act of 1976	Solid waste management, hazardous materials disposal
Ocean Dumping Act of 1972	Control of dredged and fill material and toxic substance disposal
Refuse (River and Harbor) Act of 1899	Control of refuse disposal and other work in navigable waters
Substantive Laws - Natural Resources	**Purpose**
Coastal Zone Management Act of 1972	Acquisition of estuaries for protection
Fish and Wildlife Coordination Act of 1959 as amended	Water resource project effects
Clean Water Act of 1977	Protection of wetlands and other water bodies
Endangered Species Act of 1979 as amended	Protection of threatened and endangered species and their habitats
Migratory Bird Treaty Act	Protection of migratory birds and their habitats
River and Harbor Act of 1899	Work in navigable waters

(continued)

(Table 1 - continued)

(Substantive Laws - Natural Resources)	Purpose
Marine Mammal Protection Act of 1972	Protection of marine mammals and their habitats
Scenic and Wild Rivers Act of 1968	Designation and protection of selected rivers and streams

Substantive Laws - Social and Cultural Resources	Purpose
National Parks Act	Designation, acquisition and management of parks
Archaeological Recovery Act of 1974 as amended	Protection of archeological and historic resources from water resource development
National Historic Preservation Act of 1966	Register and protection of significant sites
Relocations Act of 1970	Compensation to property owners displaced by federal development