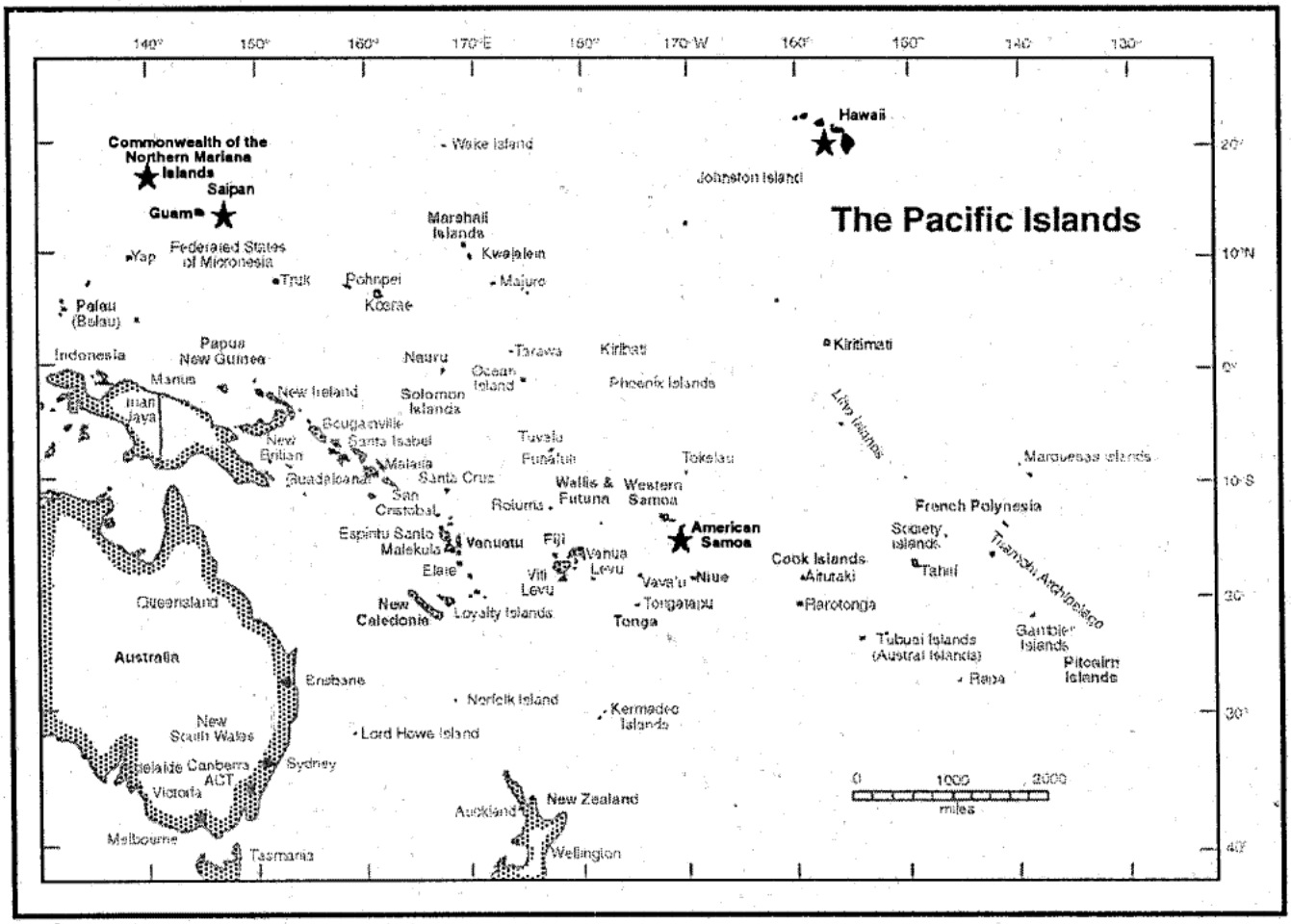
Insular Pacific Regional Marine Research Program

MARINE RESEARCH PLAN
1992 - 1996



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This paper is funded by a grant from the National Oceanic and Atmospheric Administration, project #M/PM-1, which is sponsored by the University of Hawaii Sea Grant College Program (SOEST), under Institutional Grant No. NA89AA-D-SG063 from NOAA Office of Sea Grant, Department of Commerce. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies. This is Sea Grant publication UNIHI-SEAGRANT-MR-94-01.

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November 1993

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PREFACE

1. Basis for Regional Marine Research Programs

In 1990, "Title IV-Regional Marine Research Programs" (Public Law 101-593) of the South Carolina Fish Hatchery Act was passed. This Federal Legislation mandated the establishment of nine regional marine research programs to:

1) set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region, and
2) carry out such research through grants and improved coordination.

One of the regions provided for in the legislation covers the marine and coastal waters of the "Insular Pacific Region." This regional program, called the Pacific Regional Marine Research Program (PRMRP), includes the State of Hawaii, the Territory of Guam, the Commonwealth of the Northern Mariana Islands (CNMI) and the Territory of American Samoa.

2. Regional Marine Research Program Boards

The legislation calls for the establishment of a Regional Marine Research Board for each region, composed of appointees of the National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), and the governors of the states (and territories or commonwealths) included in the region. The regional boards contract staff to assist them in undertaking their responsibilities.

The function of the Regional Marine Research Board, as mandated by the enacting legislation, is to:

1) develop and submit to NOAA and EPA a marine research plan,
2) provide a forum for coordinating research,
3) provide for review and comment on research plans by affected users and interests,
4) ensure that the highest quality of research projects will be conducted,
5) prepare a periodic report on marine environmental research issues and activities in the region.

NOAA and EPA have joint oversight responsibility for each of the RMRPs and must approve the Marine Research Plans and research proposals which are developed by each RMRP. In addition, NOAA provides administrative support for the RMRP at the national level.

3. Marine Research Plans

Each RMRP is required to prepare a comprehensive Marine Research Plan for the region. The Plan is required by the RMRP legislation to include:

1) an overview of coastal/marine environmental quality conditions and trends in the region;
2) an inventory and description of marine research related to water quality and ecosystem health expected to be conducted during the 4-year period;

3) a statement and explanation of marine research needs and priorities for the next 10 years, with emphasis on the upcoming 3-5 years;
4) an assessment of how the Plan will incorporate existing marine and coastal research and management; and
5) a description of marine research and monitoring objectives and timetables for achievement during the initial 4-year plan period.

4. Research Eligible for Funding by RMRP

The RMRP legislation outlines the kinds of research that are considered appropriate for support through the program. These include:

"(A) baseline assessment of marine environmental quality, including chemical, physical, and biological indicators of environmental quality;

(B) effects or potential effects of contaminants, including nutrients, toxic chemicals and heavy metals, on the environment, including marine and aquatic organisms;

(C) effects of modification of habitats, including coastal wetlands, seagrass beds and reefs, on the environment, including marine organisms;

(D) assessment of impacts of pollutant sources and pollutant discharges into the coastal environment;

(E) transport, dispersion, transformation, fate and effect of contaminants in the marine environment;

(F) marine and estuarine habitat assessment and restoration;

(G) methods and techniques for modeling environmental quality conditions and trends;

(H) methods and techniques for sampling of water, sediment, marine and aquatic organisms, and demonstration of such methods and techniques;

(I) the effects on human health and the environment of contaminants or combinations of contaminants at various levels, whether natural or anthropogenic, that are found in the marine environment;

(J) environmental assessment of potential effects of major coastal and offshore development projects in the region;

(K) assessment of the effects of climate change on marine resources in the region; and

(L) analysis and interpretation of research data for the benefit of state and local environmental protection and resource management agencies in the region."

5. Acknowledgments

Many individuals contributed their time to the development of the Marine Research Plan for the Insular Pacific Region through interviews with the PRMRP staff and participation at the scientific meetings. The authors are grateful for the support of the University of Hawaii Sea Grant College Program staff, especially the assistance of J. Ball, R. Goldstein and J. Yamada, who was essential to putting together the Plan in such a short time frame. The support and direction of the PRMRP Board and especially the Chair, Dr. J. Davidson, are acknowledged. The comments and corrections provided by those who reviewed the Plan are greatly appreciated and have been incorporated into the final document as much as possible.

CHAPTER I: INTRODUCTION

1. Unique Aspects of the Insular Pacific Region

The Insular Pacific Region is unique among the Regional Marine Research Programs in many ways. Four separate political entities make up the Pacific Regional Marine Research Program (PRMRP), the State of Hawaii, the Territory of Guam, the Commonwealth of the Northern Mariana Islands (CNMI) and the Territory of American Samoa (Figure 1). Except for Guam and CNMI, which are part of the same Mariana Island chain, large ocean distances separate the island groups of the region. The area spanned by the region is vast, extending into the southern hemisphere and across both sides of the international date line.

The area covered by the PRMRP is entirely tropical or subtropical in character and includes coastal and nearshore marine ecosystems that are generally not found in the other regions. The isolated setting of these oceanic islands has resulted in an extraordinarily high degree of endemism, especially among terrestrial organisms but also within marine species.

As a result of the island nature of the region, it has physical characteristics entirely different from continental land masses, e.g., there are no continental shelves and broad coastal lowlands and, other than Guam, which consists of a single principal island, each of the political entities is made up of a set of small islands. The influence of upland activities on the marine environment is greater on small islands than it is on larger continental land masses. The immediate proximity of watersheds to marine systems results in little opportunity for the dilution of land-based sources of pollution.

In addition to being unique relative to the rest of the U.S., the region is very heterogeneous with important differences among the island groups. Each island group has a distinct cultural and historical background that differs from other islands and from the rest of the U.S. All are recent additions to the U.S. federal system and each places high value on its unique cultural heritage.

Most critically, in the context of a RMRP concerned primarily with marine water quality and ecosystem health, it is imperative to note the dominance of the marine environment in the Insular Pacific Region and the entirely coastal nature of the small island land masses.

2. Importance of Coastal and Nearshore Marine Areas

Coastal and nearshore marine areas and resources are of critical importance to Pacific island peoples, cultures and economies. In the insular Pacific region, the preponderance of all human activities take place in the coastal and nearshore areas. This combination of factors has increasingly resulted in coastal habitats being destroyed or degraded, natural resources being over-exploited and water quality becoming severely degraded in areas, especially around the rapidly growing urban centers of the region.

The coastal areas of Pacific islands are also subject to the damaging effects of natural hazards. Extreme events such as typhoons, hurricanes, high storm waves and abnormally high tides cause extensive damage and destruction. Low-elevation islands and the low-lying coastal areas of

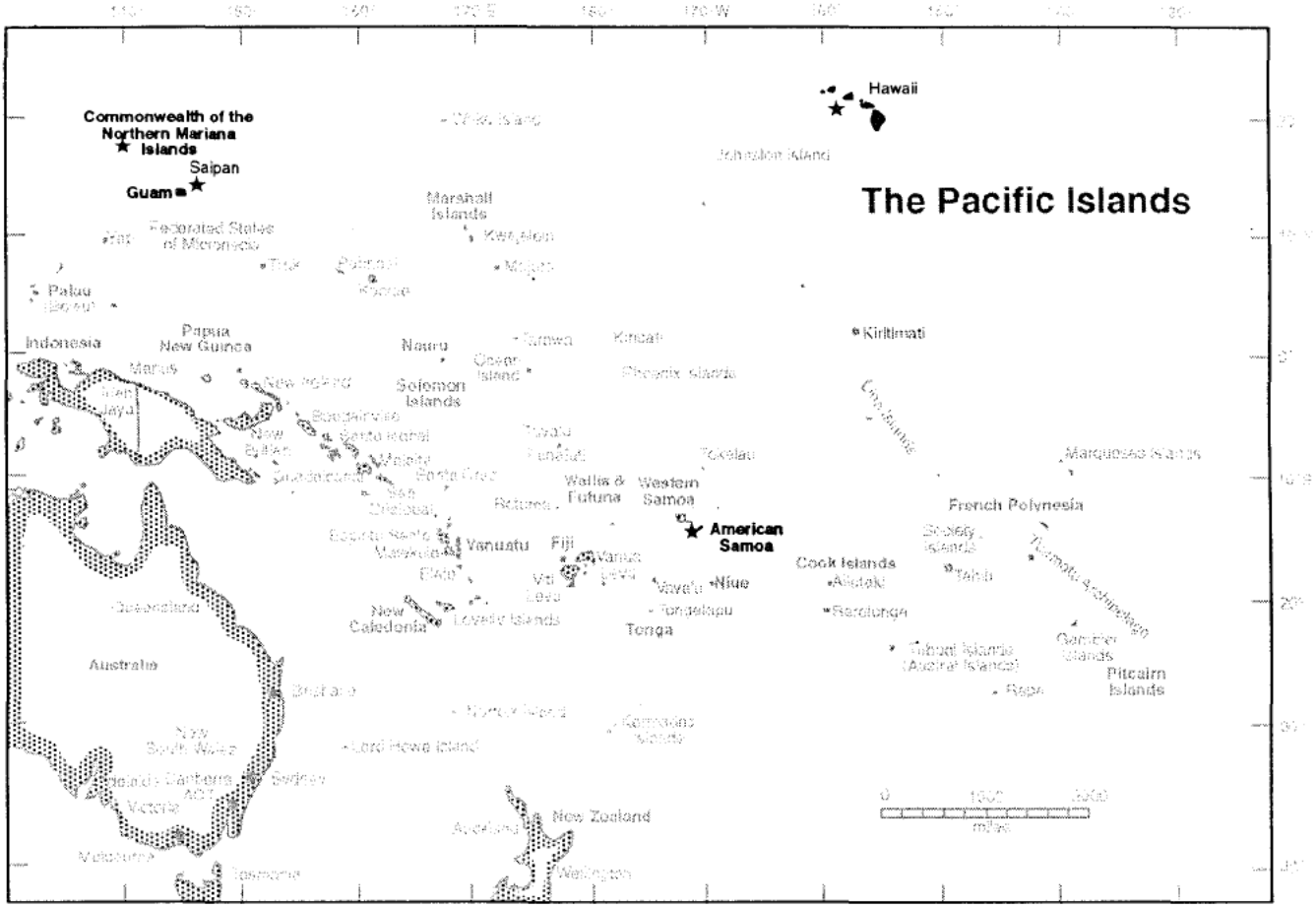

Figure 1.

larger, higher islands are particularly at risk. Global warming now threatens to exacerbate these hazards through accelerated sea level rise, increased frequency and intensity of storms and other changes to oceanographic conditions.

These coastal area problems are widespread in the region and in some areas require urgent attention. The potential for sustainable development of coastal areas and resources is being permanently lost or compromised. Extreme events continue to batter coastal developments and ecosystems and the use of coastal and marine areas and resources is increasing.

Information on the components, structure and functioning of marine ecosystems and the status and trends in water quality is limited. There are a number of federal, state and local agencies and a few higher educational institutions which undertake marine research or monitoring activities in the region. However, there is no mechanism or process for coordinating marine research among the four areas in the Insular Pacific Region, and only limited coordination of marine research within each of the areas.

3. Process for Developing the Pacific Regional Marine Research Plan

The Pacific Regional Marine Research Board was established, as called for in the legislation, with members nominated by the Governors of Hawaii, Guam, CNMI and American Samoa for each of these areas and with representatives of the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA). A list of the members of the PRMRP Board is found in Appendix I.1.

The first meeting of the PRMRP Board was held in January 1993 in Hawaii under the chairmanship of Dr. Jack Davidson, Director of the University of Hawaii (UH) Sea Grant College Program. The first function of the Board is to develop and submit a 4-year Pacific Regional Marine Research Plan to the Administrators of NOAA and EPA. UH Sea Grant provides administrative support and services for the initial phase of Plan development. Following acceptance of the Plan, the Board (through an Executive Officer) will administer grant funds it has received from NOAA for marine research projects which implement the Plan.

To formulate the Plan, a Plan development team was employed through UH Sea Grant. The team, and their responsibilities, were as follows:

Paul Holthus, coordinator, senior author, senior editor
Nancy Daschbach, contributor for American Samoa
Kim Des Rochers, editor, assistant contributor
Terry Donaldson, contributor for Guam/CNMI
Phil Moravcik, assistant contributor for Hawaii
Peter Rappa, contributor for Hawaii

A list of agencies and organizations involved or interested in marine research in the Insular Pacific Region was compiled by the team and the PRMRP Board. Most of these were government agencies at various levels or institutes and departments at institutions of higher education. In addition, private consultant firms, public interest groups and other private organizations involved with marine water quality and/or ecosystem health were invited to participate to help ensure that the Plan development involved as wide a representation as possible.

Each of the agencies and organizations was contacted by the PRMRP Board Chairman and asked to nominate a contact person for detailed discussions with the Plan development team. The contact person for each agency and organization was provided with an information sheet which outlined the background of the PRMRP and the process of Plan development. A questionnaire was included to guide and organize the collection of information (Appendix I.2). Representatives of the agencies and organizations which are physically based in the Region were interviewed by a team member.

Many agencies and organizations provided copies of research plans, annual reports and other documents which describe their research and monitoring activities. Federal or Pacific regional agencies and organizations not physically located in Hawaii, Guam, CNMI or American Samoa provided summary statements and documents.

Background information on the general characteristics of each area, including coastal and marine ecosystems, was compiled through a review of literature, technical studies and agency reports. A detailed outline of topics to be covered in the overview of environmental quality conditions and trends was developed. Information for the overview was obtained from published and "grey" literature as well as from the interviews with representatives of agencies and organizations.

A preliminary draft Plan was compiled by the Plan development team for the second PRMRP Board meeting in late April 1993. A revised draft Plan was subsequently developed incorporating the views of the PRMRP Board. Scientific workshops were then held in Hawaii, Guam (for the Mariana Islands) and American Samoa in order to provide scientific review and comment on the draft Plan by marine scientists in research organizations and management agencies.

Following the scientific workshops, the final draft of the Plan was sent out for review and comment to all of the agencies and organizations that contributed to its development. In addition, public review and comment were solicited by sending the final draft to public interest groups and marine resource user groups. Comments received from this review process have been addressed in the revised Plan. Following this extensive review and comment, PRMRP Board members were sent the revised draft for a final review of the Marine Research Plan for the Insular Pacific Region.

4. Characteristics of the Coastal and Marine Environment of the Insular Pacific Region

Because each island group in the Insular Pacific Region is biologically and geographically unique, an individual overview of the characteristics for each of the areas was compiled for American Samoa, the Mariana Islands and the Hawaiian Islands. These are presented in Appendices I.3, I.4 and I.5, respectively, along with references for the literature cited in each overview. A summary of the characteristics of the region as a whole is found below.

4.1 Geography

Islands in the Insular Pacific Region are categorized into three groups: 1) high volcanic islands, 2) low-lying islands or atolls and 3) raised limestone islands. Most of the region's islands are high volcanic islands. These include all of the main Hawaiian Islands, almost all of the islands in American Samoa and the northern islands of CNMI. These basalt islands typically have rugged interior mountain ranges and deeply incised valleys and are densely vegetated.

Low islands, which are composed entirely of coralline reef limestone sediments that have accumulated on a shallow coral reef platform, are rarely more than ten to fifteen feet above sea level. Atolls are ring-like coral reefs with low islands surrounding a central lagoon. Soil development on atolls is poor and fresh water is extremely scarce. Examples of low islands in the region include Rose Atoll and several of the northwestern Hawaiian Islands.

Raised limestone islands are composed primarily of coralline limestone from ancient reefs on a basalt foundation. Over time, these islands have been raised above sea level as a result of volcanic or tectonic activity. The northern half of Guam and the islands of southern CNMI are primary examples of raised limestone islands in the region.

American Samoa is composed of five high volcanic islands and two atolls comprising a total land area of 76 sq mi (Figure 2). Tutuila is the largest island (54 sq mi) and has a steep mountainous terrain and lush vegetation. The island is a narrow irregular volcanic ridge that rises steeply from the ocean to peaks ranging from 1,000 to 2,141 ft in altitude. Tutuila is about 20 mi long and from 1 to 6 mi wide, and is nearly bisected by the deep harbor at Pago Pago. The other volcanic islands of American Samoa are also rugged, although much smaller.

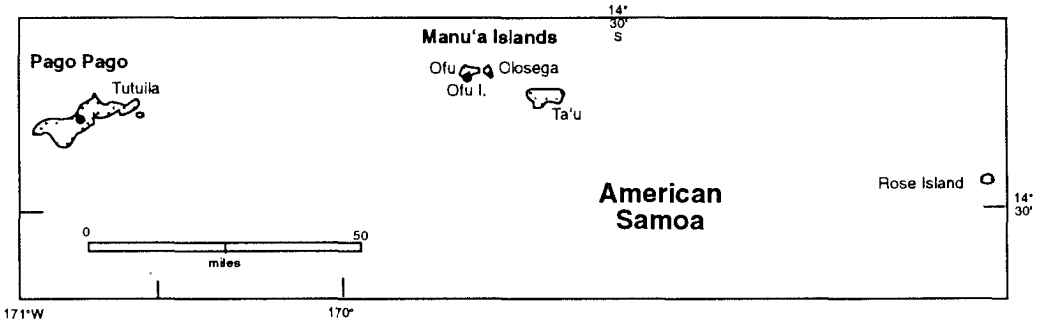

Figure 2.

Guam, the largest and southernmost island in the Mariana island chain, has a land area of about 212 sq mi (Figure 3). The island is about 30 mi long, varies in width from 4 to 12 mi, and is narrowest in the center. The southern half of Guam is a dissected upland of volcanic hills with peaks over 1,000 ft in altitude and valleys deeply incised by rivers. The northern portion of the island is a broad, undulating raised limestone plateau with steep vertical cliffs dropping directly into the sea. There are embayments associated with river mouths around most of the southern half of the island and two limestone plateaus extend out from the west coast to form the main harbor area.

The northern Mariana Islands rise more than 6,250 mi from the nearby Marianas Trench and mark the dividing line between the Pacific Ocean and Philippine Sea. The 14 islands of the archipelago stretch roughly 400 miles north from Guam and consist of 184 sq mi of land (Figure 4). The three southern islands; Saipan, Tinian and Rota, are primarily raised limestone and form most of the commonwealth's land area. Rota has an area of 33 sq mi and Saipan has an area of 47 sq mi with a peak elevation of 1,555 ft. The rest of the island chain consists mainly of small, towering volcanic islands, some of which are still active volcanoes.

The Hawaiian Islands are the most isolated archipelago in the world. The island chain stretches 1,000 mi in a southeast to northwest direction and is by far the largest part of the region (Figure 5). There are

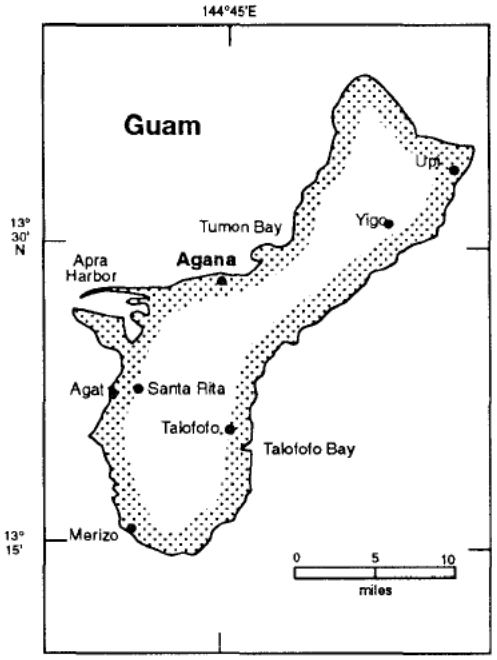

Figure 3.

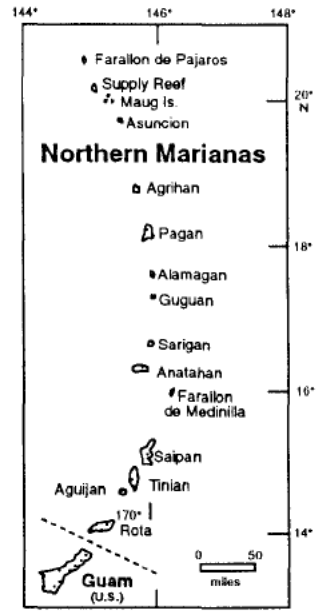

Figure 4.

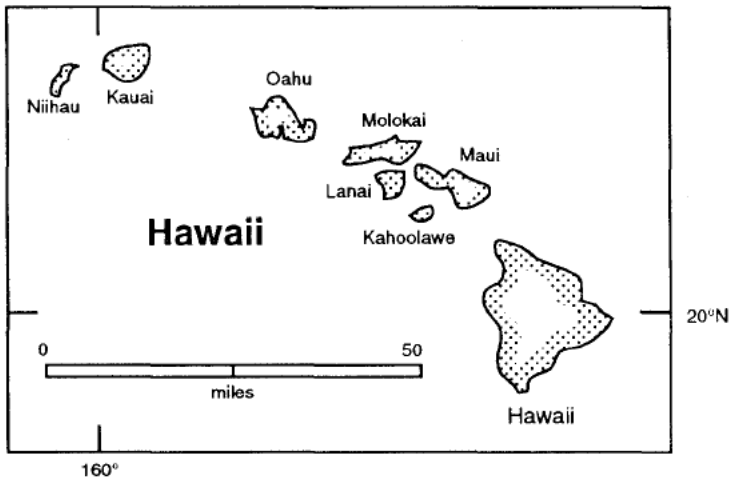

Figure 5.

eight main islands, each of which is built from one or more volcanoes with a total land area of 6,520 sq mi. Land areas are: Kahoolawe, 45 sq mi; Niihau, 73 sq mi; Lanai, 140 sq mi; Molokai, 261 sq mi; Oahu, 607 sq mi; Kauai, 627 sq mi; Maui, 729 sq mi; Hawaii, 4,038 sq mi. The highest points in the Hawaiian archipelago, at over 13,000 ft., are Mauna Kea and Mauna Loa, on the island of Hawaii.

4.2 Climate and oceanography

Seasonal climatic changes are slight in the tropical Insular Pacific Region in relation to temperate regions and the year is typically divided into rainy and dry seasons. Relatively uniform temperatures and humidity prevail year-round in the region. Temperatures range roughly from 72°F to 90°F. Warm temperatures and high humidity are tempered

by the cooling properties of the tradewinds on the windward sides of high islands.

South of the equator, the heaviest rainfall tends to occur from June to October; north of the equator, the rainy season is November to March. Rainfall levels vary from island to island according to topographical differences, island size and geographical location. High islands, such as Tutuila in American Samoa, generally receive greater amounts of rainfall than do low islands or atolls. This occurs when warm tradewind air is forced up and over peaks causing condensation of atmospheric moisture and rainfall.

Rainfall levels in the region are generally high. For example, rainfall levels on Tutuila Island vary between 100 and 200 inches annually, with the Pago Pago Harbor area receiving the highest amount. Mean annual rainfall for Guam is between 80 and 95 inches and 75-120 inches for the CNMI. Rainfall levels in Hawaii vary considerably; from 400 inches at the tops of mountains to as little as 10 inches at lower elevations on leeward sides.

Tradewinds, which bring moisture-laden maritime tropical air masses to the islands, are the predominant winds in the Insular Pacific Region. North of the equator, tradewinds blow from the northeast, predominately between the months of May and September. South of the equator, the tradewinds blow from the southeast and are more consistent between the months of April and November. The northeast and southeast trades converge in the equatorial trough of the intertropical convergence zone. Some islands (e.g., the Mariana Islands) also come under the influence of the Asiatic monsoon system. Hurricanes or typhoons in the Pacific can occur at any time of the year but tend to be more frequent during the rainy season.

Three major ocean currents dominate the broad pattern of seawater movement in the Insular Pacific Region: the north equatorial current, the south equatorial current and the equatorial counter-current. The equatorial counter-current flows from west to east between the other two currents. These currents are significant in determining which species of ocean-borne plants and animals reach the islands in the region.

The nearshore marine area around each island is influenced by surface ocean currents that are modified by island configuration, bathymetry, tides and seasonal patterns. The islands are surrounded by deep ocean basin waters. The Marianas Trench, an extremely deep ocean feature, extends along the ocean floor east of the Mariana Islands.

The open ocean surrounding the islands of the region generates waves that affect the shore depending on season, orientation of the coast and degree of exposure to open seas. Tsunamis are an occasional threat in the region, especially in the Hawaiian Islands.

4.3 Population and economic conditions

Population figures for the Pacific vary between and within island groups. Population is concentrated on the main islands of each group and

is typically centered around a principal urban area, where population density can be very high. Outer islands are often underpopulated or uninhabited. There is much migration from outer islands and rural areas to the growing urban centers and into Hawaii. Birth rates are also high, especially outside of Hawaii. The economies of the region are dominated by tourism, agriculture, military expenditure and local government employment, with some important differences among the four political entities. Indigenous cultures continue to be very important to each area, although the relative level of importance varies across the region.

Although all five islands in American Samoa are inhabited, Tutuila Island has the highest population of the territory with roughly 46,000 inhabitants in 1990. This is about 98% of the population and is a 40% increase since 1980. This dramatic increase is due to immigration and a high birth rate (approximately 59% of the population is under the age of 18). American Samoa is in transition from a traditional subsistence society to a cash economy, largely fueled by employment with the government and two large tuna canneries. Although 92% of the land is still communally owned and subsistence agriculture and fisheries continue to be important, self-sufficiency is being replaced by dependence on imported goods with a weakening of cultural traditions and a modernization of living standards and housing.

Guam has a population of about 133,000, one-fifth is comprised of military personnel. Most of the civilian population is centered around Agana, the capital, with the rest in the two dozen villages scattered throughout the island, mostly along the coast. The population is growing rapidly; approximately 35% of Guam's population is under the age of 15. Tourism is Guam's leading income producer from the private sector, based mainly on Japanese visitors, and there has been a major increase in foreign investments in recent years, especially for resort development. Guam has a large military presence that provides major economic benefits to the territory. Local government employment and some light manufacturing are also important to the economy. There is some agricultural production in the south and there are many recreational fishermen, but no major subsistence fisheries.

The population of the CNMI is approximately 45,000 and is expanding rapidly. Over 95% of its population is on the island of Saipan and is situated primarily along the eastern coastline. Most of the rest of the inhabitants live on Tinian and Rota. The northern islands have very few permanent inhabitants. Tourism is also the leading sector in the CNMI economy, with rapid expansion in the past few years to accommodate visitors, primarily from Japan. As with Guam and American Samoa, government employment is important to the economy. Light manufacturing has also been developed, using mainly imported labor. There is only limited agriculture and fisheries development, although there has been some expansion of commercial fisheries operations recently.

Hawaii has the largest population of the region, with 1.1 million residents, who are joined by millions of visitors each year. About 80% of

the inhabitants live on the island of Oahu, with half of these in the city of Honolulu. The other main islands are a mix of urban and rural populations. The population is growing, with continued migration into the state and about 25% of the population under the age of 18. The economy of Hawaii is based on tourism, military expenditures and agriculture. Tourism has leveled off in recent years and agriculture continues to decline, with plantation lands converted to residential and commercial use. Light industry and manufacturing are important in major towns. Commercial fishing is limited but widespread around the state, along with a very large population of recreational fishermen.

4.4 Coastal and marine ecosystems and biodiversity

Due to the small size of the islands, all land area of the islands in the Insular Pacific Region lies within the coastal zone. Watershed habitats in the high volcanic islands of the region range from cloud and rain forests at high elevations to dryland forest at lower elevations. The less topographically varied limestone islands support less diversity and the low islands support little more than littoral habitats.

The relative isolation of these islands and a range of local environments has led to high levels of ecosystem and species diversity and endemism. Hawaii, for example, has approximately 1,000 species of plants and 45 species of birds found nowhere else in the world. American Samoa, Guam and CNMI also have a diverse assemblage of plants and animals. Introduced plants and animals pose a serious threat to these communities and species.

The marine environment of the region supports a number of species of national and global importance, including marine turtles, a large number of whale, dolphin and porpoise species, the very rare Hawaiian monk seal and all species of giant clams. The general pattern of marine biodiversity in the tropical Pacific is a decrease in diversity from the west to the east. The Mariana Islands, for example, have a very rich and diverse marine biota. Superimposed on this regional pattern are sites of high endemism, reflecting the degree of isolation of certain islands. Hawaii, as the most isolated archipelago in the world, has a relatively high level of marine endemism.

Shoreline composition varies between and within the islands of the Insular Pacific Region. High islands which are geologically recent in age generally have rugged basalt shorelines with some sandy pocket beaches in the lee of bays or inlets. The more eroded volcanic high islands have shorelines ranging from extensive sandy beaches, composed of coralline sediment, to estuaries and mangroves, to rocky cliffs which drop steeply and directly into the sea.

The shoreline of the raised limestone areas, particularly the southern Mariana Islands, consists of sandy beaches and extensive limestone cliffs. The southern part of Guam, however, has lateritic, highly eroded soils. The low islands consist entirely of coralline sediments derived from the surrounding coral reefs. There is limited development of mangroves, coastal wetlands and estuaries in the region.

Coral reefs or coral communities surround portions of nearly all of the islands in American Samoa, Hawaii, Guam and CNMI. In most areas, there is a narrow fringing reef with a reef flat that extends seaward from the shore several hundred yards before dropping off into a spur and groove zone or a steep reef slope. In a few locations, a barrier reef and lagoon system is found, although these are relatively limited in the region.

The tropical marine ecosystems of Hawaii are relatively impoverished due to sub-optimal environmental conditions (i.e., a subtropical climate) and geographic isolation. Coral communities (including associated fish, algae and invertebrates) are widespread but best developed in wave-protected, shallow waters away from riverine discharges. Other important coastal ecosystems include marshes, stream and stream-mouth estuaries (confined to most of the high islands), lagoons (confined to the atolls and one bay off Kaneohe, Oahu) and beaches. Seagrass beds are very rare and poorly developed; mangroves were absent until *Rhizophora* was brought in at the turn of the century.

Guam is bordered by fringing reefs of various widths. A triangle-shaped barrier reef encloses a shallow lagoon (Cocos Lagoon) at the southwest corner of the island. A submerged coral bank, barrier reef and Cabras Island enclose a deep lagoon at Apra Harbor. Reefs along the northeast coast of the island are not well developed. Coral communities are highly diverse, but reef development is affected by frequent tropical storms. Sandy beaches also surround much of the islands except where steep cliffs are found. Important mangrove stands are found only in the municipality of Merizo and Apra Harbor. Small but important beds of seagrass occur in a number of sheltered locations. Stream-mouth estuaries are found off several rivers.

In CNMI, the entire shorelines of most smaller northern islands are bordered by steep rocky slopes and volcanic sea cliffs, without coral reefs. Well-developed fringing reefs occur along the western coasts of the southern islands, while the eastern shorelines are generally rocky and cliffbound. Rota, Tinian and Saipan have both steep and low-lying shorelines. Their beaches are bordered by fringing reefs or erosional benches of various widths and origins. Saipan has the only well-developed barrier reef and lagoon system in CNMI.

The coastal ecosystems of CNMI are similar biologically to those of Guam and are strongly influenced by volcanism and by frequent tropical storms and typhoons. Living coral communities are found along most shorelines of the larger (and older) southern islands, but well-developed growing reefs are generally confined to the west coasts. Streams and estuaries are poorly developed or absent. Seagrass beds are rare outside of the inner lagoon of Saipan's west coast. Mangroves are almost absent, with a few stands found around Saipan.

In American Samoa all coral reefs are the fringing type except for the barrier-like reef and lagoon system at Pala Lagoon. Much of the northern coast of Tutuila Island has steep cliffs and lacks structural reefs.

Important structural reefs occur as offshore banks south of Tutuila and in several other locations. Rose Atoll consists of a typical atoll reef enclosing a lagoon. Coastal marshes and small mangrove forests occur in several areas on a number of the islands in the territory, with the mangrove forest in Pala Lagoon the only large mangrove stand.

CHAPTER II: MARINE ENVIRONMENTAL CONDITIONS

Because each island group in the Insular Pacific Region is biologically and geographically unique, an individual overview of the marine environmental conditions was compiled for American Samoa, the Mariana Islands and the Hawaiian Islands. These are found in Appendices II.1, II.2 and II.3, respectively, along with references for the literature cited in each overview. A summary of the marine environmental conditions for the region as a whole is found below.

1. Coastal Area Development

The islands in the Insular Pacific Region are relatively small and the rugged interiors of many of the islands usually are covered with native vegetation. On the limited coastal lowlands of the main islands in the region, public amenities, hotels, resorts, golf courses, government and commercial facilities and residences all compete for space.

In American Samoa, much of the nearshore reef area and mud flats of Pago Pago Harbor on Tutuila Island have been dredged or filled for port and cannery development. The infrastructure which lines the southern coastal road on Tutuila is under constant threat from wave and storm damage and from shoreline erosion. These areas have been reinforced with rocks and boulders or with seawalls, especially in places where the road runs parallel to the beach.

In the Mariana Islands, shoreline development, particularly hotels, resorts and military facilities, is substantial on Guam and Saipan and more is proposed. Most of the development on Saipan borders the lagoon and includes residences, a commercial port and a major industrial area. On Guam, major shoreline development is concentrated along the tourist and urban areas around Agana, the capital, and along the main highway where it skirts the coast.

Much of the shoreline in Hawaii has been developed for military installations and facilities, commercial ports and harbors, and hotels and mega-resorts. A large portion is also privately owned. Of the 750 miles of shoreline in the main Hawaiian Islands, there are less than 124 miles of open or undeveloped coastline.

There are no major forestry activities in American Samoa. However, loss of rainforest from clearing for housing and plantation expansion is an increasing problem. Agriculture tends to be primarily for local markets or family subsistence, as only 14,000 acres are considered suitable for production. There are currently three terrestrial protected areas (e.g., national or local parks) in American Samoa.

Land use changes have been extensive on Guam and Saipan. Residential, resort, commercial, industrial and government (including military) development occurs at or adjacent to flowing waters, standing waters, ephemeral water courses, wetlands, springs, and over much of the aquifers on both islands. There are a number of terrestrial protected areas in CNMI and Guam.

In Hawaii land is zoned as urban, rural, agriculture or conservation with criteria for allowable uses in each zone. Half of the urban lands in the state are in the City and County of Honolulu (Oahu Island).

Agricultural lands are mainly in large plantations (e.g., pineapple, sugar cane), with the development of golf courses another major use of these lands. Much of the upland areas in Hawaii are protected as watershed preserves, or state and national protected areas.

The degree to which hydrologic cycles are manipulated on each of the islands in the region varies considerably. Hawaii has twenty hydropower dams on Kauai, Maui and Hawaii, and three dams on Oahu for the impoundment of fresh water. In addition, many of the lower reaches of streams in Hawaii have been channelized. In contrast, there has been no major damming of streams in American Samoa for hydroelectric production or water supply.

2. Land-Based Pollution Sources

2.1 Point pollution sources

Land-based point sources of pollution in the Insular Pacific Region can have serious impacts on marine water quality and ecosystem health. Point sources of pollution occur at urban and industrial wastewater treatment facilities; power plant outfalls; rivers, streams, and drainage ditches; and solid waste disposal sites.

In American Samoa municipal wastewater is treated at the primary level in only one village. More than half the households on Tutuila Island are connected to the government sewer system or rely on septic tanks, cesspools or other methods of waste disposal. Sewage outfalls are located in Pago Pago Harbor and on the southern coast. In the Mariana Islands, septic tanks are the primary means of waste disposal on Rota, Tinian, much of Saipan and a significant portion of Guam. Leachate from septic tanks, transmitted by surface run-off or by groundwater intrusion, contributes a substantial amount of nutrients to the coastal waters. There are over 25 public and 140 private wastewater facilities in Hawaii. The level of treatment necessary at some of the public wastewater facilities on Hawaii is currently a much debated subject.

The main sources of industrial pollution in the region include waste products from public utilities, military facilities and operations, light industries, port and harbor related operations and service industries (automobile body shops, car repair shops, gasoline stations, shipyards and small manufacturing). Outside of Hawaii, industrial pollution sources, other than the military, are limited, but growing. One exception is the canneries in American Samoa. Until recently, wastewater from the two canneries was pumped directly into inner Pago Pago Harbor. As of 1992, cannery discharges are pumped into the outer harbor at a depth of 180 feet via a pipeline. This has resulted in a noticeable increase in water clarity in the inner harbor. Cannery sludge is transported to an ocean disposal site offshore from Pago Pago Harbor. Thermal effluent from power plants is discharged into coastal waters in numerous locations in the region with potential impacts on adjacent coral reefs.

Streams are the major vehicle of transport in American Samoa for household garbage, piggery waste, seepage from cesspools and hazardous wastes. Streams also carry away soil from hillsides which are

exposed during earth moving processes, agricultural activities and landslides. In CNMI rivers, streams and drainage ditches carry discharges from treatment facilities and wastes from agriculture and industry. Similarly, in other parts of the region, hazardous and toxic wastes, crankcase oil and other petroleum products often end up in storm drains and nearby streams.

Outside of Hawaii, official sanitary landfills are limited. For example, on Tutuila Island in American Samoa, there is a single upland site managed by the government public works office, and many unofficial dump sites, generally along the shoreline. There is concern that pollutants from the major sanitary landfill facility on Guam, located next to two river systems, are being discharged into the nearby bay. On Saipan, the dump is located directly adjacent to a lagoon, harbor and principal mangrove area. Various materials have been accumulating at this site since the 1940s, making this area a serious threat to environmental and public health. The dumping of household refuse and automobiles is common practice on Guam and CNMI. The military has operated dumps throughout CNMI since World War II and has dumped materials directly into the sea, but there is very little information on the kinds and amounts of materials which have been discarded.

2.2 Non-point pollution sources

The major sources of non-point pollution in the Insular Pacific Region are fertilizers, pesticides, herbicides, sediment and septic tank seepage. Fertilizers and pesticides are commonly used on a large scale for agriculture, golf courses and hotel and resort grounds in the parts of the region supporting these activities. Pesticides are not considered to be a significant source of non-point pollution in other parts of the region due to their high cost, low levels of use and strict regulation by the EPA. However, where they are being heavily used, these manufactured chemicals have leached into some groundwater supplies and nearshore waters.

Sediment carried downslope from surface run-off is a significant source of non-point pollution on nearly every Pacific island. The primary cause of sediment run-off is inappropriate land use practices and poor erosion control measures during construction, road building and other land-clearing activities. On nearly all islands, sedimentation has had deleterious effects on nearshore coral reef ecosystems.

3. Ship-Based Pollution Sources

Most Pacific islands depend heavily on imported oil and petroleum products. Oil tankers generally moor offshore and transport cargo to onshore storage facilities via a flexible pipeline. In CNMI and Hawaii, response to an oil spill during the ship-to-shore transfer of petroleum products is included in an oil spill contingency plan.

There is often a certain amount of spillage during offloading operations in some areas which may be due to lax procedures and inadequate containment measures. Coastal and estuarine habitats, especially the intertidal region, are very sensitive to oil pollution.

These areas are habitats for a great number and diversity of nearshore marine organisms, as well as many oceanic species during their juvenile life stages. Only recently have there been data produced on the impacts of oil in tropical areas, particularly on coral reefs and mangroves.

The ports and harbors and coastal waters of the region are subject to fuel spills, bilge pumping, ballast water discharge and solid waste dumping from fishing boats, cargo ships, tankers and occasional cruise ships, and the dumping of brine water from fishing boats. There are several examples in the region of ships running aground and releasing fuel and oil into the surrounding waters. Solid waste disposal from ships is a chronic low-level problem when ships are in port. Most ships are supposed to dispose their garbage in accordance with the provisions of Annex V of MARPOL 73/78, but there is often no surveillance to monitor whether ships are properly disposing their wastes.

Military ship operations in the region result in sources of pollution that are similar to those of commercial shipping operations, but may also include other materials such as chemicals associated with the ship repair facilities. The potential for pollution by smaller pleasure craft and fishing vessels also exists and the debris thrown overboard by boaters and fishermen is significant in some areas. Resident and visiting yachts often discharge all wastewaters into enclosed harbors if no pumpout facilities are available.

4. Marine Contaminants in Water, Sediment and Biota

Pollution levels of heavy metals have been detected in the rivers, canals and nearshore waters of American Samoa, Guam, CNMI and Hawaii. In American Samoa, high levels of copper, lead, mercury, cadmium, arsenic and silver were found in Pago Pago Harbor and Pala Lagoon. In sampled fish tissues, chromium, copper, mercury, lead and zinc were found to be high and the government has since issued warnings against the consumption of fish from inner Pago Pago Harbor. High concentrations of aluminum, manganese, iron and calcium have been found from four rivers on Guam which empty into coastal waters. Extremely high levels of lead, PCBs, pesticides, chromium, copper, nickel and zinc have been recorded from the Ala Wai canal sediments in Honolulu, Hawaii.

The increased development of golf courses in the region, especially in Hawaii, Guam and Saipan has led to concerns regarding the impacts of pesticides and herbicides on the groundwater supply and nearshore environment. PCBs and chlorinated hydrocarbons are not considered significant pollutants outside of the major urban areas in the region. The major sources of petroleum hydrocarbons are fuel offloading stations, small boat harbors, harbor and port operations and storm sewer outfalls.

5. Use of Living Marine Resources

The exploitation of nearshore fisheries is great on many Pacific islands in the region, particularly those with high population densities. In general, it appears that nearshore fish resources in some parts of the Insular Pacific Region are declining due primarily to overharvesting and

habitat destruction. Many fishermen and women are indiscriminate in their fishing practices, often catching and collecting any species of fish, mollusc or crustacean regardless of its size. The harvesting of fish and other marine organisms before they reach sexual maturity will eventually have impacts on future fish yields.

The harvest from the nearshore subsistence fishery in American Samoa has decreased substantially over the last decade and overexploitation is assumed responsible, in part, for this decline. Overharvesting has eliminated one species of giant clam in American Samoa and has significantly reduced other giant clam populations. Lobster and certain crab populations are much reduced from what they were 12 years ago in American Samoa.

A decline in some of Hawaii's nearshore fishery has been reported and may be due to heavy commercial and recreational fishing. Recreational fishermen outnumber commercial fishers significantly; however, their per-trip landings are considerably lower. Surveys indicate that there may be as many as 187,000 recreational fishermen in Hawaii. Because there are no licensing or reporting requirements, it is difficult to estimate the total fish catch from recreational sources.

The commercial reef fisheries in Guam and Saipan, other than bottomfish, are also declining in catch rate and average fish size. As in Hawaii, there are a large number of recreational fishing enthusiasts in Guam and CNMI. Data from Guam and Saipan indicate major reductions in both population sizes and rates of harvest of certain fish species, especially groupers, snappers, jacks, parrotfish and wrasses.

Offshore pelagic and deep bottom fisheries in the Mariana Islands are managed in conjunction with the Western Pacific Regional Fishery Management Council; however, enforcement and data collection are handicapped by a lack of resources. Some commercial fishing ventures have operated in the Mariana Islands with only a business license and without permission from the CNMI Department of Fish and Wildlife, which sets local regulations and limits.

Destructive fishing practices, such as fishing with dynamite or poison, poaching and other illegal fishing practices, are decreasing in the region. Dynamite fishing was once commonplace, but is now illegal. Fishing with the use of chemical and natural poisons is also widespread in the Pacific. Naturally occurring poisons, made from either the root or leaves of certain plants, and chemical poisons, such as household chlorine bleach, are used to kill a variety of reef fish. Both types of poison affect many non-target species of marine organisms as well as the targeted fish.

Some endangered and protected marine species are also subject to harvesting. Green turtles are listed as threatened and hawksbill turtles as endangered under provisions of the U.S. Endangered Species Act. Despite efforts by local enforcement agencies, sea turtles, primarily green and hawksbill, continue to be the target of poaching activities. Raiding turtle nests for eggs also continues in some areas.

Introductions of exotic species have been accidental and deliberate, the latter primarily for purposes of aquaculture. Introduced species often compete with native species for food and space. The top shell, *Trochus* sp., was introduced into the coastal waters of the Mariana Islands and species of giant clam (*Tridacna* sp.) have been introduced for mariculture. A parasitic gastropod and protozoan inadvertently accompanied the introduction of *Tridacna* and may have deleterious effects on native marine species. A variety of fish also have been introduced and some, such as tilapia, are well established on nearshore reef flats in Hawaii.

6. Use of Non-Living Marine Resources

The extraction of beach sand for a variety of purposes has occurred historically throughout the Insular Pacific Region. Currently, however, it is illegal to remove sand from beaches in American Samoa, Guam, CNMI and Hawaii. The mining of sand from marine waters does not occur in American Samoa, Guam or CNMI. Sand mining within 1,000 feet of the shoreline and in water depths less than 30 feet is prohibited in Hawaii. However, a limited amount of sand mining by several state and county agencies occurs for the purpose of beach replenishment.

Dredging and filling activities associated with the development of military facilities, infrastructure (e.g., airports, and roads), commercial or residential areas and for creating or improving boat channels, harbors and marinas, have had considerable impacts on coral reefs throughout the region. More recently, the dredging of inshore reefs for tourism facilities has also occurred. For example, a significant impact to coral reefs on Tutuila Island resulted from the expansion of the commercial airport into Pala Lagoon, where dredging and quarrying activities seriously degraded an important reef area. Since then water circulation within the lagoon has been severely reduced and sedimentation has degraded reef and mangrove habitats.

7. Ecosystem Level Changes

The combined impacts of pollution, habitat destruction and heavy use of resources is resulting in cumulative ecosystem effects in many nearshore marine areas in the region. For example, during the 1970's, Kaneohe Bay in Hawaii received heavy sedimentation and sewage effluent inputs. The marine ecosystems in this area recovered to some extent following the implementation of land use management measures and the relocation of the main sewage outfall to a discharge site outside the bay.

In much of the region, however, combined impacts are resulting in serious, long-term degradation of nearshore marine ecosystems. Pago Pago Harbor is seriously degraded from sedimentation, cannery waste, sewage, garbage and frequent oil spills. The reefs in the inner harbor are dead and those in the outer harbor are degraded to some degree. Until recently, algal blooms seriously reduced visibility in the harbor. In Hawaii, the island of Maui is experiencing a major algal bloom along the west coast. In embayments near villages throughout the region, sediment deposition from terrestrial erosion and nutrients from sewage and

freshwater run-off are major sources of marine habitat damage and destruction. On Guam, approximately 95% of the nearshore reefs along the southwest coast are estimated to be damaged from road construction, land clearing and channelized streams. The outbreak of coral-eating crown-of-thorns starfish populations and coral bleaching have been linked to human impacts on coral reef ecosystems.

8. Public Health Effects

There are some concerns about the potential human health effects from polluted waters and contaminated marine resources in the region. For example, cholera in finfish from east Agana Bay in Guam has been identified as a potential threat to public health. There has been at least one case of cholera in Hawaii in recent years, allegedly caused by the ingestion of contaminated locally caught seafood.

While much of the evidence in support of these cases is not clear, there is concern that seafood taken from certain waters is susceptible to contamination by bacterial and viral pathogens. In American Samoa, increased sewage from piggeries and cesspools is entering the lagoon and seriously degrading water quality adjacent to fast growing areas of population on Tutuila. Coliform counts in Pala Lagoon are attributed to piggery waste which may threaten shellfish harvesting. Recreational waters in numerous locations in the region, particularly around urban areas, are frequently contaminated by point and non-point sources of bacteria and viruses.

Ciguatera poisoning is another serious problem experienced in varying degrees throughout the tropical Pacific. The toxin is produced by dinoflagellate algae (*Gambierdiscus toxicus*) which attach themselves to larger algae which are eaten by reef fish. The toxin bioaccumulates in the tissue of reef fish and larger carnivorous fish which prey on the reef fish. Humans are poisoned when they eat the toxin-contaminated fish. Non-point source pollution and habitat disturbance have been suspected by some to be related to ciguatera occurrence.

9. Water Quality Control and Ecosystem Management

9.1 Pollution control

The control of land-based pollution in the Insular Pacific Region lies primarily in complying with federal and local regulations and water quality standards. This has mostly addressed point sources of pollution and receiving waters. Actions to tackle non-point pollution sources are only now beginning. Ship-based pollution sources are less well controlled, but there are Regional Response Team Contingency Plans for handling pollution emergencies in each of the region's four political entities.

9.2 Marine resources management

Marine resource management agencies in the region generally have the authority to manage fisheries by regulating fishing gear, catch size and methods and establishing limits and restricted areas. Permits or

licenses are often required for specific activities, such as commercial fishing, commercial aquarium fish collection, fish weirs, commercial trapping, commercial coral harvesting, commercial shell harvesting, scientific collecting and the importation of living aquatic organisms. The agencies also conduct surveys of fishing effort and undertake activities to enhance fisheries (Fish Aggregation Device [FAD] and artificial reef installation). Non-living coastal resources, including sand, minerals and coral aggregate are often managed by local agencies as well.

Traditional marine resource management practices in the region have been eroded by the influence of outside cultures and increased population density. In American Samoa, the control and management of nearshore marine areas and resources by local villages persist to some extent, but is not actively practiced.

9.3 Protected areas

There are a number of protected marine areas in the region, although management varies and the resources available for management are usually less than sufficient. Hawaii has nine Marine Life Conservation Districts that were established to protect unique marine areas of special interest. In addition, the State has created Fisheries Management Areas which have special conditions, such as the closure of the areas every other year, to allow fish stocks to recover. A National Marine Sanctuary has been declared in the waters of Hawaii to protect the humpback whale.

In CNMI, the marine areas around four of the northern islands have been protected, but enforcement is difficult. Guam has a number of protected marine areas, including portions of a National Park, some of which are adjacent to military reservations. The effectiveness of these protected areas in conserving marine resources has not been well documented. Nine marine reserves had been established by Guam but these have been repealed and no longer exist. American Samoa has a National Marine Sanctuary at Fagatele Bay, and has a National Wildlife Refuge at Rose Atoll, which includes the shallow marine habitat.

The Western Pacific Regional Fishery Council establishes closures for fisheries in parts of the region. Nearshore waters, 25-75 miles offshore, are closed to longline fishing in Hawaii and Guam. The northwest Hawaiian Islands are closed to lobster fishing as of 1993.

10. Ecosystem Recovery and Rehabilitation

There are a number of examples of water quality recovery in the region following the removal of pollution sources or improvement of the discharge situation. The improvements of water quality in Kaneohe Bay, Hawaii, and in Pago Pago Harbor, American Samoa, have been notable exceptions to the degradation of coastal water quality in most of the region.

The removal of wastewater disposal from shallow water sites to deeper areas has resulted in the recovery of reef ecosystems in those shallow areas. The extension of the outfall pipes into deep water has also

resulted in the establishment of communities of marine organisms around the pipes and associated structures.

Coastal ecosystems have also been rehabilitated or enhanced in a number of instances. In Hawaii, the state has created three artificial reefs on Oahu. Some wetlands have been created in CNMI as mitigation measures, and a mangrove area was replanted in Guam following destruction by an oil spill.

11. Ecosystem Perturbations and Catastrophic Events

The region is subject to a number of cyclical perturbations of varying scale and magnitude. El Nino affects the entire Pacific Basin and impacts the four areas of the Insular Pacific Region with a variety of changes to meteorological and oceanographic conditions. Hurricanes and typhoons have a major impact on the coastal ecosystems of the region. Guam is struck frequently by typhoons, CNMI somewhat less frequently, American Samoa is infrequently hit by hurricanes and Hawaii rarely is affected.

Human-induced catastrophic events are also a threat to the islands of Hawaii, Guam, CNMI and American Samoa. Although there have not been any major oil or chemical spills in the marine environment of the four areas, the potential for such a disaster exists. The possible effects of global warming on the region are of concern due to the limited amount of land in the islands. Sea level rise accompanied by tropical storms of increased frequency and intensity would have a devastating effect on the islands of the region, as population and development are concentrated in the narrow, low-lying coastal zone. Increased water temperature is also of concern as it may result in the bleaching and death of corals, which are the primary structural components of coral reefs. Degradation of coral reefs through the death of corals would exacerbate the above problems, as the reefs are natural breakwaters and provide much of the sediment for the beaches around the islands.

CHAPTER III: INVENTORY OF MARINE WATER QUALITY AND ECOSYSTEM HEALTH RESEARCH

1. Process for Undertaking Marine Research Inventory

An inventory of marine water quality and ecosystem health-related research, which is ongoing or planned for the four-year period of the initial Marine Research Plan (1993-1997), is required by the 1990 Fish Hatchery Act. The inventory provides a basis for determining the current and near future status of marine water quality and ecosystem health research in the region.

A list of agencies and organizations involved or interested in marine research in the Insular Pacific Region was compiled by the PRMRP team (Appendix III.1). Most of these were federal, state and local government agencies or institutions and departments at tertiary institutions. In addition, private consultant firms, public interest groups and other private organizations involved with marine water quality or ecosystem health were asked to participate in order to ensure that the inventory of research was as inclusive as possible.

The PRMRB Chairman contacted each of the agencies and organizations and requested that they nominate a contact person for future discussions with the PRMRP team. The contact person for each agency and organization was provided with an information sheet which outlined the background to the program and the process of Plan development. A questionnaire was included to guide and organize the collection of information (Appendix I.2). The agencies and organizations, which are physically present in the Insular Pacific Region, were visited by a team member to obtain the information sought.

Many agencies and organizations provided copies of research plans, annual reports and other documents which described their research and monitoring activities. Federal or Pacific regional agencies and organizations not physically located in Hawaii, Guam, CNMI or American Samoa provided summary statements and documents.

A summary of the marine research programs undertaken by each of the agencies and organizations is presented here. A more detailed description of programs and projects has been compiled for each of the four political entities in the region and is provided in Appendices III.2-III.5.

2. Scope and Limits of PRMRP Marine Research Inventory

The scope of the PRMRP, as mandated by the legislation, is "regional marine and coastal research in support of efforts to safeguard water quality and ecosystem health." The research inventory of the Insular Pacific Region thus focused on current or planned research concerned with these topic areas. "Water quality" is a fairly well defined topic and research related to it can be identified readily, although the extent to which land-based sources of contamination are considered appropriate for inclusion can broaden the scope substantially. "Ecosystem health," on the other hand, is not as well defined and a vast array of research issues can be included in this topic area.

The review of the environmental quality conditions in the coastal and marine waters of the Insular Pacific Region and the expected trends in these conditions (Chapter II), revealed that the majority of the priority marine water quality and ecosystem issues are concerned with coastal

and nearshore areas and resources. The scope of the research inventory was thus geographically limited to coastal areas and the nearshore marine environment. Research concerned with water quality and ecosystem health only in the open ocean or the deep sea bed was not systematically sought out and documented. Within this geographic scope, the topics considered appropriate for the inventory were generally those which were directly concerned with the physical, chemical and biological features and characteristics of coastal nearshore marine areas and the causes and effects of changes to these.

For the Insular Pacific Region, "research" was considered to include monitoring, i.e. the regular, systematic observation and recording of features and characteristics. In addition, research which is management-driven or oriented is considered appropriate for inclusion in the inventory of marine research, particularly when addressing water quality, habitat or ecosystem level questions. Research for the management of individual stocks or species of marine organisms was not sought out and aquaculture and mariculture research was not included in the research inventory.

The inventory is comprehensive enough to provide a basis for developing a Marine Research Plan for the Insular Pacific Region and to indicate the level and detail of interaction needed with existing programs, in the context of the coordination role of the PRMRP.

3. Marine Water Quality and Ecosystem Health Research - American Samoa

3.1 Introduction

The American Samoa Government conducts most of the water quality and marine ecosystem health-related research in American Samoa. Of these investigations, the majority represent monitoring efforts to characterize and follow trends in areas impacted by anthropogenic perturbations. Many monitoring efforts address water quality problems associated with tuna cannery wastes or sewage effluent entering Pago Pago Harbor.

Although there is some agency interaction in the territory, with some projects performed jointly, there is no overall research plan or set of goals for marine environmental research in American Samoa. Each agency develops its own set of goals based on the directives of its office. A summary of marine water quality and ecosystem health-related research in American Samoa is found below, with a more detailed listing of on-going and future research in Appendix III.2.

3.2 American Samoa Environmental Protection Agency (ASEPA)

ASEPA has an issues-oriented research program that responds to identified problems on a two- or three-year planning horizon. The focus of ASEPA centers on water quality, with the majority of monitoring and research on land-based pollution sources. This involves the marine environment as the ultimate destination of watershed waters and

nearshore coastal water quality is a major impetus for these studies, reflecting the recognized need to reverse current water quality trends.

The primary water quality monitoring effort by ASEPA assesses 18 sites in Pago Pago Harbor on a monthly basis and additional sites around Tutuila annually. Basic water quality parameters are measured for determining the compliance with the National Pollution Discharge Elimination Standards (NPDES) permit conditions and for ASEPA's annual Water Quality Report. Some of the parameters are measured *in situ* and the analysis of others, such as nitrogen and phosphorus, require samples to be sent off-island. ASEPA regularly monitors the two permitted sewage outfalls for coliform bacteria at Utulei, in Pago Pago Harbor, and at Fagagogo, near the airport. ASEPA has proposed a study for 1994 to investigate alternative microbiological water quality standards for American Samoa.

The findings of a preliminary toxicity study of the sediments, waters, and fish of Pago Pago Harbor resulted in health advisories, warning people not to eat fish caught in the inner harbor and to eat only the cleaned flesh of fish caught in the outer harbor. ASEPA and the Department of Marine and Wildlife Resources (DMWR) are continuing the investigation in order to verify the preliminary study findings and develop a human health risk assessment. A follow-up project is investigating possible sources of the toxic components found in Pago Pago Harbor and when the sources are identified, remediation measures will be designed and implemented.

ASEPA's village watershed demonstration project focuses on one reef front village and will assess the target village's non-point source problems and will implement remediation practices aimed at eliminating pollution sources. ASEPA and the American Samoa Coastal Management Program (ASCMP) are cooperating on a review and evaluation of the management guidelines for non-point source pollution to determine whether they are appropriate for non-point source problems in American Samoa. Another proposed ASEPA project will investigate the fate of leachate from the landfill at Futiga on Tutuila. ASEPA plans to fund a stormwater quality assessment and management plan for densely populated, highly polluted watersheds and will also assess the impact of the stormwaters on sensitive habitats such as coral reefs and wetlands.

3.3 Department of Marine and Wildlife Resources (DMWR)

DMWR research and monitoring efforts will focus on three main areas in 1993 and 1994: biology of reef fishes, fisheries and mariculture. Fisheries research and development supported in 1992 and 1993 focuses on: a) documenting the current use of the pelagic fishery; b) studying the current use of the inshore fishery; c) obtaining biological information on key reef fishes to determine distribution, abundance and life history of these fishes; and d) monitoring and replacing fish aggregation devices (FADs). The DMWR giant clam experimental hatchery program

currently cultures *Tridacna derasa* and *Hippopus hippopus*. DMWR grant funds also cover a technical assistance project and scientific exchange. DMWR's five-year planning cycle ends in 1993, and there are plans to hold a research planning workshop to develop their next five-year research plan.

3.4 American Samoa Coastal Management Program

The American Samoa Coastal Management Program funds research that investigates coastal resources, however, most of their projects are land-based.

3.5 Fagatele Bay National Marine Sanctuary (FBNMS)

The Fagatele Bay National Marine Sanctuary has a mandate to perform scientific research that will support management decisions. However, funding has not been forthcoming in the last few years and no research is currently being performed. The National Marine Sanctuary Program has ranked research topic areas for all sites, placing site characterization as a top priority. In addition, appropriate monitoring programs are recommended for each site. However, funding for this program has been limited and the situation is unlikely to change in the next year. A proposal to investigate the role of predatory fish on coral reef fish populations is under consideration for 1994. FBNMS also plans to begin a water quality monitoring project to be run in-house with assistance from ASEPA and DMWR.

3.6 Star-Kist Samoa, Inc.

The cannery is responsible for monitoring its outfalls and wastewater and ensuring that they meet the National Pollution Discharge Elimination Standards. Monitoring is on-going.

3.7 VCS Samoa Packing Company

The cannery is responsible for monitoring its outfalls and wastewater and ensuring that they meet the National Pollution Discharge Elimination Standards. Monitoring is on-going.

4. Marine Water Quality and Ecosystem Health Research - Guam

4.1 Introduction

The University of Guam Marine Laboratory, the University of Guam Water and Energy Research Institute and the Government of Guam conduct most of the marine environmental research on Guam. Most agencies outside of the University, with the exception of the Division of Aquatic and Wildlife Resources, limit their work to monitoring some aspect of ecosystem health. This work, which includes efforts by the U.S. Navy and U.S. Air Force, is primarily in the area of water quality.

There is some inter-agency cooperation regarding marine environmental research, but there is no overall plan or system of cooperative effort. Each agency or institution has a distinct mandate from which a set of goals is developed. A summary of marine water quality

and ecosystem health research is provided below, with a more detailed listing of ongoing and future research in Appendix III.3.

4.2 University of Guam (UOG) Marine Laboratory

The Marine Laboratory is a leading institution in the study of the ecology, evolution, behavior, physiology, chemistry and management of marine and insular aquatic systems and organisms in the region. Faculty members, research affiliates, staff and graduate students conduct original research and monitoring programs in a number of areas. The Marine Laboratory is also called upon to conduct research in applied areas such as monitoring programs and assessments. Much of this work is conducted outside of Guam, principally in other areas of Micronesia. The Marine Laboratory has published over 340 peer-reviewed articles in scientific journals and 98 technical reports describing the results of their investigations of over 20 years.

4.3 UOG Water and Energy Research Institute (WERI) of the Western Pacific

WERI conducts basic research and monitoring of marine and fresh waters. Areas of expertise include chemistry, biology, geology, hydrology, sedimentation and resource management. Their laboratory facilities have the capability to measure a number of parameters, including nutrients, fecal coliform and heavy metals, as well as assessing various forms of toxic contamination. WERI also undertakes a number of projects related largely to groundwater resources, alternate energy resources and marine monitoring in other parts of Micronesia.

Areas of special concern include the quality and quantity of groundwater, groundwater-sea water interactions, estuarine processes, impacts from run-off, heavy metal levels in sediments and toxic contamination levels in aquatic and marine organisms.

4.4 Guam Environmental Protection Agency (GEPA)

GEPA does not conduct research programs on its own, but rather provides monitoring, regulatory and enforcement services. In addition, GEPA designates funding for studies of specific problems, to be undertaken by outside institutions, particularly the UOG Marine Laboratory and various private consulting firms. Due to the large military presence on Guam, GEPA is also seeking more cooperation from military agencies regarding environmental impacts and hazards, and in obtaining the results of an Ecological Risk Assessment Report of military facilities. With in-house capabilities, GEPA samples a network of fixed marine environmental monitoring stations to assess the overall environmental health of beaches, bays, harbors and estuaries. Basic parameters are measured, including dissolved oxygen, nutrient levels, turbidity, temperature and fecal coliform levels. The agency is attempting to utilize a Global Positioning System (GPS) in conjunction with monitoring at fixed stations.

4.5 Guam Division of Aquatic and Wildlife Resources (DAWR)

DAWR is the lead agency on matters concerning marine, freshwater and terrestrial resources and both basic research and management activities are undertaken. Funding for the fisheries work comes from various sources, but principally the U.S. Fish and Wildlife Sportsfish Restoration Program. Other support and interaction comes from the Western Pacific Regional Fishery Management Council and the National Marine Fisheries Service. DAWR conducts basic research in areas such as fish biology, fisheries processes and habitat requirements, in order to formulate effective management strategies.

4.6 Guam Department of Public Health and Special Services - Office of Epidemiology and Research (DPH & SS-OER)

DPH & SS-OER does not have a marine research program but does monitor the incidence of human illnesses, including those caused by marine pathogens, in particular, ciguatera food poisoning and vibrio infections.

4.7 Department of the Navy, Navy Public Works Center and Public Utilities Agency of Guam, Fena Water Laboratory

The Fena Water Laboratory does not have a marine research program but actively monitors water quality from the Fena Sewage Treatment Plant, the Navy Ship Repair Facility and the Navy landfill.

4.8 Bureau of Planning, Coastal Zone Management Office (CZMO)

CZMO annually participates in the coastal planning and review process, and can commission or request that specific projects be undertaken.

5. Marine Water Quality and Ecosystem Health Research - Commonwealth of the Northern Mariana Islands (CNMI)

5.1 Introduction

A number of agencies address different aspects of environmental issues in CNMI and some interaction through the environmental review process, coordinated by the Coastal Resources Management Office, takes place. The UOG Marine Laboratory and the UOG Water and Energy Research Institute conduct various research projects, both in cooperation with the CNMI Government and on their own initiative. A summary of marine water quality and ecosystem health research is provided below, with a more detailed listing of ongoing and future research in Appendix III.4.

5.2 Department of Fish and Wildlife (DFW)

DFW is the lead agency for fish and marine biological resources, and fisheries management and research in CNMI. Projects are funded

annually through the U.S. Fish and Wildlife Service, under the Sportsfish Restoration Program. Additional funding is provided from a number of agencies, e.g., the National Marine Fisheries Service and the Western Pacific Regional Fishery Management Council.

DFW conducts research into fish biology and fisheries activity and provides input in the environmental review process. Areas of special interest include general reef fish biology, bottomfish biology, pelagic fish biology, habitat requirements, size and creel limits and catch per unit effort. DFW also has some resource enhancement programs. Some wildlife research programs are marine-related, including studies of seabirds and shorebirds.

5.3 Department of Public Health and Environment, Division of Environmental Quality (DEQ)

DEQ does not conduct marine research, but rather provides monitoring, regulatory and enforcement services, and participates in the environmental review process. DEQ has joined the Coastal Resources Management Office in a grant application for Geographic Information System (GIS) utilization in non-point source pollution monitoring.

5.4 Coastal Resource Management Office (CRMO)

CRMO coordinates environmental review activities, issues permits and provides regulatory and enforcement services. CRMO can commission research and has conducted some of its own when a marine biologist is on staff. CRMO and DEQ have applied for funding to conduct a GIS non-point source pollution monitoring study to better identify these sources. CRMO will also apply for funding to develop a multi-year Strategy Plan to assess coastal hazards, cumulative and secondary impacts, wetlands, marine debris, ocean resources, public access, special area management plans and energy and government facility siting. A third proposal will seek the development and implementation of a watershed and wetland protection plan for the Magpo Valley on Tinian island (with DEQ).

5.5 Commonwealth Utilities Corporation (CUC)

The CUC grants office secures funding to meet compliance with federal standards. The water laboratory provides monitoring and analysis services relevant to CUC's water and sewer division services. The U.S. Geological Survey is conducting a comprehensive groundwater study of Saipan and Tinian with CUC cooperation.

6. Marine Water Quality and Ecosystem Health Research - Hawaii

6.1 Introduction

The responsibility for addressing marine water quality and ecosystem health is divided among a number of federal, state and county agencies. In addition, there are a number of businesses which conduct monitoring and habitat preservation activities because of federal, state and county regulations or as conditions for doing business. Much of this type of work is carried out by private consultant firms.

Research on water quality and ecosystem health is conducted by a number of departments at the University of Hawaii, either in response to federal, state and county needs or as academic research. Applied research is also conducted by federal, state and county agencies in response to management concerns, and occurs in-house, through the university or with private consultants. A summary of marine water quality and ecosystem health-related research is found below, with a more detailed listing of on-going and future research by major agencies and organizations in Appendix III.5.

6.2 Hawaii State agencies

6.2.1 Environmental Health Administration, Department of Health (DOH)

The Environmental Health Administration is the state's primary environmental protection agency. Within this division of DOH is the Water Quality Standards Program, which is managed by the Environmental Planning Office and the Monitoring Section of the Clean Water Branch. These programs primarily enforce federal and state water quality standards and policies. Through the Water Quality Standards Program, the U.S. EPA and the State of Hawaii fund contracts for applied research projects, designed to provide DOH with data necessary to support revisions to the Hawaii Water Quality Standards and other water pollution control activities. Bacterial and chemical monitoring of coastal waters is carried out by the staff of the Monitoring Section of the Clean Water Branch.

Major marine research initiatives within the Water Quality Standards Program, which may continue into 1997, include projects to elicit more information on seasonal macroalgal blooms observed in shallow coastal waters along the west coast of Maui, and projects designed to collect data in support of area-specific water quality standards. Area-specific standards are being developed for parts of the Kona coast on the island of Hawaii.

6.2.2 Division of Aquatic Resources (DAR), Department of Land and Natural Resources (DLNR)

DAR manages the state's marine and freshwater resources through programs in commercial fisheries and aquaculture, aquatic resources protection, enhancement and education projects and aquatic recreation. Major program areas include maximizing commercial fishery and aquaculture productivity, protecting native and resident aquatic species and their habitats, and providing facilities and opportunities for recreational fishing consistent with the interests of the state.

There are three programs within the Division: Commercial Fishery and Aquaculture, Aquatic Resources Protection and Aquatic Recreation. Major ongoing programs include monitoring the Marine Life Conservation Districts (MLCD) and Fisheries Management Areas (FMA), assisting federal agencies in implementing endangered marine mammal recovery plans, developing and monitoring artificial reefs at several locations, continued monitoring of the closure and opening of the

Waikiki-Diamond Head Shoreline Fisheries Management Areas (SFMA) and maintaining statistics on commercial fishing. New initiatives to continue through 1997 include the Main Hawaiian Islands Marine Resource Investigation which is examining the decline in the nearshore fish catch and is determining the effectiveness of FADs and artificial reefs in enhancing fish habitat, including locating sites for artificial reefs in waters near the neighbor islands.

6.2.3 Coastal Zone Management (CZM) Program, Office of State Planning

The Hawaii CZM Program was established as a management guide for the beneficial use, protection and development of the land and water resources in Hawaii's coastal zone. CZM acts as a policy umbrella and provides the state's perspective on activities affecting coastal resources. An important component of the CZM Program is the county-administered special management areas (SMAs). SMAs cover the coastal strip along the shoreline and were established to avoid permanent loss of valuable resources and the foreclosure of management options. The CZM office monitors agency decisions on development projects in the state's coastal zone for compliance with the goals of the Program. The Program also undertakes planning, policy development and management studies related to coastal management issues.

A range of projects is currently underway or planned for the period through 1997. Regional ocean resources planning will continue with assistance to the Department of Land and Natural Resources in implementing the Kaneohe Bay Master Plan, a prototype plan that integrates both land and water use management. Another ocean region will be chosen for planning and management analysis in 1993. The Program also has a multi-year beach management study and a report on the viability of beach nourishment from offshore sources is expected soon. Additional work will be done on the relationship between the shoreline certification process, beach erosion and human use of the shoreline area. The CZM Program is also involved in reviewing private marina developments and their public benefits relative to the use of ocean public trust resources.

Beginning in 1993, the CZM Program will develop a comprehensive database and mapping system of coastal resources and their uses that will be included in the statewide GIS. This information will later be used to develop management options for sensitive coastal resources. The CZM Program will also be adding to its public education materials and increasing its public education efforts. Education materials will focus on coastal hazards, non-point source pollution and the need for coastal management. From 1993 to 1997, the CZM Program will be developing a program to control non-point source pollution in collaboration with DOH.

6.2.4 State Harbors Division, Department of Transportation

The Harbors Division is responsible for the administration, development and maintenance of the state's commercial harbors,

including seven deep-draft and two medium-draft harbors. The Division has long-range master plans which describe future developments for each harbor under their jurisdiction. The Harbors Division is required to test their dredge spoil materials for heavy metals and toxic substances content and report the results to the U.S. Army Corps of Engineers. In addition, the Division conducts water quality sampling when required by the Department of Health for proposed improvements that may impact the coastal and ocean waters of the state. Specific projects to collect oceanographic data on wave characteristics for particular harbors are planned for the future.

6.2.5 Ocean Resources Branch, Department of Business, Economic Development and Tourism (DBEDT)

The Ocean Resources Branch is the lead agency for DBEDT in protecting and strengthening the ocean-related sector of Hawaii's economy, which produced a total estimated revenue of $1.5 billion in 1992. The Branch has also played a central role in creating the state's Ocean Resource Management Plan. As part of their mandate to assist in the development of ocean industries, the Branch provides matching funds to four Sea Grant projects, primarily in the area of deep ocean mineral mining. The Branch also undertakes periodic studies of the sectors that make up Hawaii's ocean industries including: marine research and development, seafood marketing, ocean recreation, shipping, commercial fishing and aquaculture.

6.3 University of Hawaii

Although the University of Hawaii is a state supported institution, it is reported separately because of the many departments with an interest in marine water quality and marine ecosystems. Within the University, the School of Ocean and Earth Science and Technology (SOEST) has several departments conducting research in these areas and each department is discussed below.

6.3.1 Hawaii Institute of Marine Biology (HIMB), SOEST

HIMB conducts research in a variety of marine-related fields, primarily at the marine laboratory on Coconut Island in Kaneohe Bay. Research at HIMB is focused in five areas: coral biology, fish ecology, animal behavior, animal physiology and aquaculture pond management and dynamics.

Current and near future (to 1997) efforts in coral biology include studies on the effects of physical parameters on: 1) the biology of corals and their symbionts; 2) periodicity in coral growth and reproduction; 3) coral energetics, predation and dispersal; and 4) long-term dynamics of coral reefs. Research on fish ecology focuses on the reproductive biology of pelagic and carangid fish and systematics and ecology of small cryptic species such as blennies and gobies. Research on animal behavior will focus on the movement, physiology and energetics of tunas and sharks; developmental and motivational behavior of coral reef fish and green sea turtles; and behavioral ecology of coral-reef organisms. Research into

animal physiology will focus on the reproductive biology of marine wildlife with special attention to the Hawaiian monk seal and on the role of hormones, environment and nutrients in the culture of ornamental fish. Aquaculture research will focus on stimulating the use of hormones.

6.3.2 Sea Grant College Program, SOEST

The Sea Grant College Program supports a program of research, education and extension services directed to the improved understanding, management and use of marine resources in Hawaii and the Pacific. Through 1995, Sea Grant will be supporting research into marine resource development including aquaculture, marine natural products, ocean minerals and fisheries. They will also support the following marine environmental research: ecodynamics and nutrient uptake in coral reefs, the Maui algal problem, the rate of recovery of the Hamakua coast after the closure of the sugar mill and the cause and effects of bubble algae in Kaneohe Bay.

6.3.3 Sea Grant Extension Service (SGES), SOEST

SGES, drawing upon the diverse technical expertise available throughout the Sea Grant network, assists state agencies, private industry and the general public in the management and development of the state's ocean resources. SGES's core program includes five areas: 1) aquaculture; 2) commercial and recreational fisheries; 3) ocean recreation and tourism; 4) coastal resource management in the US-affiliated islands and; 5) global environmental issues.

The current extension effort to 1997 includes: aquaculture - increasing industry diversity; fisheries - developing artificial reefs to replenish nearshore fish stocks; ocean recreation - enhancing recreational area quality through better management practices; and coastal resource management - working with island governments to complete coastal resource management plans.

6.3.4 Department of Oceanography, SOEST

Research is being undertaken by the Oceanography department in a number of long term projects in the region. These include the Joint Global Ocean Flux Study (JGOFS), the Hawaii Ocean Time-series (HOT) program to furnish time series data on oligotrophic ecosystem variability and the Equatorial Pacific Study (EQPAC). Future research projects in Hawaii include a Mamala Bay Ecosystem response study and a study of nutrient uptake in Kaneohe Bay.

6.3.5 Waikiki Aquarium, SOEST

The Aquarium displays more than 1,000 specimens representing 250 vertebrate and invertebrate species with a focus primarily on Hawaiian and South Pacific marine life. Research activities include nutrient uptake by corals, mahimahi larval studies and the reproduction of chambered nautilus. The Aquarium is also conducting research on the physiology of sharks and the life history of the tiger shark.

6.3.6 Water Resources Research Center (WRRC)

WRRC conducts water quality research, provides information on the state's water resources, develops technology for water resources research, assists in education and provides input for water policy and management decisions to the state and Pacific-Asian countries. WRRC is a member of the Water Research Institutes' network, coordinated by the U.S. Department of Interior, Geological Survey Water Resources Division. WRRC has programs in nine areas: 1) water supply and sources development; 2) coastal water environment biomonitoring; 3) water quality indicators, toxins and infectious marine vibrio bacteria; 4) in-stream water uses; 5) water allocation and values; 6) wastewater treatment; 7) hydrologic knowledge; 8) alternative water sources including reuse, recharge, desalting and coastal reservoirs; and 9) Asia-Pacific island water management.

6.3.7 Environmental Center

The Environmental Center coordinates education, research and service efforts of the university relating to maintenance, protection and improvement of environmental quality in Hawaii. It is a conduit for the transfer of interdisciplinary academic research and expertise in environmental matters from the university to the government. Current research activities include hazardous waste site evaluations for DOH and development of a public information database of hazardous waste sites around the state. The Center does not have a research program on marine water quality or ecosystem health, but the review of Environmental Impact Statements gives the Center the opportunity to comment on major monitoring issues around the state.

6.3.8 Pacific Biomedical Research Center (PBRC)

The Pacific Biomedical Research Center conducts interdisciplinary research in cell structure and function, Hawaiian evolutionary biology, neuro-behavioral biology, arbovirology, biotechnology and molecular endocrinolgy. Marine related research is carried out at the Kewalo Marine Laboratory. The research has three main thrusts: 1) understanding population movements by examining the genetics of marine species around the world; 2) determining how species remain differentiated; and 3) utilizing molecular techniques to determine water quality. This last thrust is of potential interest since it deals with new techniques for determining water quality.

6.3.9 Department of Botany

The Botany Department has a focus in phycology, the study of seaweeds and marine algae. The thrust of the phycology research program is to understand diversity in tropical plant communities. One area of focus is in collecting information on seaweeds and marine algae within Hawaii that are less well known, i.e. those of the neighbor islands, with a focus on habitat dynamics as a basis for conservation. The department has research projects investigating: 1) the molecular structure of the common *Sargassum* seaweed; 2) the physiological/ecological

adaptations that allow plants to survive in the presence of stressful conditions; 3) testing for non-toxic antifouling bottom agents that are produced by algae; 4) identification of marine algae associated with ciguatera and related toxins.

6.3.10 Hawaii Cooperative Fishery Unit (HCFU)

HCFU promotes graduate training and research in fisheries biology and aquatic resources by providing students with support, counseling and research facilities. The research program draws support from a variety of outside sources and involves students and staff from various university programs. The scope of the research is diverse and centered on fisheries biology and ecology of inshore marine and inland waters.

The Unit responds to research opportunities from federal, state and local government or jointly with other university departments. Plans for the next three to five years are a continuation of the current emphasis on multi-species coastal fisheries. This involves research on the ecology of whole communities or interacting groups, especially aspects relevant to fishery concerns. Particular interest will be on trophic relationships and maintenance of the populations that support the inshore mixed-species fishery.

6.3.11 Department of Geology and Geophysics

The Geology and Geophysics Department conducts research in six areas: 1) marine geology and geophysics; 2) volcanology; 3) planetary geosciences; 4) high-pressure geophysics-mineral physics; 5) hydrogeology-engineering geology; 6) seismology and solid earth geophysics. Coastal research focuses on the mapping of coastal hazards (tsunamis, flooding, beach erosion, sea level rise, volcanic/seismic hazards, seasonal high waves, storms and high winds) and understanding the impact of coastal development on coastal processes.

6.4 County agencies

6.4.1 Department of Public Works, City and County of Honolulu

The department is responsible for the management of the municipality's four wastewater treatment facilities. The city is required to monitor discharges to: 1) demonstrate compliance with state water quality standards; 2) evaluate the impact on the marine biota; and 3) measure toxic substances in the discharge and determine impacts.

The department's ongoing monitoring efforts consist of monitoring treatment plant effluent and effluent limits and assessing plant performance by measuring conventional pollutants such as BOD, TSS, pH, oil and flows. The department also monitors water quality in receiving waters both at the end of the outfall pipes and in nearshore waters to determine compliance with state standards. The department does not carry out or fund original research in the area of marine water quality.

6.5 Private sector and non-government organizations

6.5.1 AECOS, Inc.

AECOS, Inc. is a private consultant firm with two specialty areas: 1) laboratory services for water quality characteristic analysis (heavy metals, pesticides, etc.) and 2) marine biology and water quality monitoring. They have most recently completed a project for Maui County assessing the impacts of leachate from the Molokai landfill.

6.5.2 Envirosearch International

Envirosearch International is a U.S.-based environmental consultant firm with a Pacific area office in Honolulu. The Pacific office has undertaken several studies recently in Hawaii and the Pacific dealing with water quality and habitat protection, including: the Malaeimi Valley Watershed Study, a survey of land-based pollution sources of the South Pacific region and a risk assessment and toxicity study of inner Pago Pago Harbor, American Samoa.

6.5.3 Bishop Museum

Bishop Museum is a non-profit organization dedicated to the research, collection and exhibition of Hawaiian and Pacific biological, cultural and historical resources. The museum's biological research is focused on systematics and biological surveys in areas where information is lacking, in order to develop collections to assist researchers in identifying specimens and organizing biological systems information. An interactive computerized data base is being developed to tie all the information on entomology stored at the museum. Potential future developments include databases for all marine invertebrates, marine mollusks and marine vertebrates.

6.5.4 Sierra Club Legal Defense Fund (SCLDF)

SCLDF is a national, non-profit environmental law firm with a regional office in Hawaii. SCLDF has been the legal representative in litigation concerning water pollution in Hawaii, particularly concerning sewage treatment. A lawsuit in 1991 over the violations at the City and County of Honolulu Sand Island Treatment Facility resulted in the creation of the Mamala Bay Commission and an $8 million fund to conduct research in this bay.

6.5.5 Hawaiian Electric Company (HECO)

HECO is an electric utility company that supplies electrical power to the island of Oahu, while subsidiaries, Maui Electric Company and Hawaii Electric Light Company, provide power to the islands of Maui and Hawaii, respectively. The Environmental Department of HECO monitors for compliance with federal discharge permits at all HECO sites. Monitoring is required to document potential impacts to the marine environment around power plant sites and will probably continue through 1997. Baseline water quality and biological community monitoring is also required for proposed power plant sites and may be

undertaken in 1993-1995. In addition, HECO has a full-service, contract analytical lab that specializes in water quality analyses.

6.5.6 Oceanic Institute

Oceanic Institute is a private non-profit research institute that conducts aquaculture-related research and outreach education. Recently the institute has studied aquaculture effluent and its impact on nearshore receiving waters with funds from the Center for Tropical and Subtropical Aquaculture. Oceanic Institute is currently working with the Division of Aquatic Resources on a stock enhancement program for striped mullet and plans to begin a stock enhancement project using moi.

6.5.7 The Nature Conservancy

The Nature Conservancy is a national, private non-profit conservation organization with Hawaii and Pacific programs that focus on the protection of endangered ecosystems. In Hawaii, The Nature Conservancy has undertaken a coral reef survey of Molokai. The Nature Conservancy, in collaboration with the East-West Center and the South Pacific Regional Environment Programme, has developed an Ecosystem Classification System for the Tropical Island Pacific including a thorough consideration of coastal and marine ecosystems. An ecosystem inventory of U.S. territories and U.S.-associated island countries has been conducted for the U.S. Fish and Wildlife Service in order to determine priorities for conservation. No marine environmental research is currently planned by The Nature Conservancy for Hawaii.

6.5.8 Conservation Council of Hawaii

The Conservation Council of Hawaii is the local affiliate of the National Wildlife Federation with a special interest in the protection of endangered species and their habitat in Hawaii.

6.5.9 Surfrider Foundation

Surfrider Foundation is a national public interest group based in California with a chapter in Hawaii. The primary focus of the organization is to monitor coastal water quality for signs of pollution. Through the Blue Water Task Force program, members are trained to test water quality, primarily for bacteria. The Foundation works with volunteer scientists to verify the quality of results. Once areas are found to contain high bacteria counts, volunteers try to identify the source of pollution while the Foundation works with local officials to plan remedial action. The Blue Water Task Force program is planning to commence operations in Hawaii in 1993.

6.6 Interagency programs

A number of programs dealing with water quality and habitat protection involve more than a single agency. Four such programs in Hawaii are reported below.

6.6.1 West Hawaii Coastal Monitoring Program

The West Hawaii Coastal Monitoring Program is a volunteer effort that collects baseline data on the coastal conditions of West Hawaii, from Upolu Point to Ka Lae. The information gathered is used for: determining potential impacts of proposed coastal development projects, resource management and enabling decision makers to make informal decisions regarding possible impacts of proposed coastal projects. Data collection is on-going.

6.6.2 Maui Algal Bloom Project

The project is investigating the occurrence and causes of algal blooms off the west coast of Maui. The project is on-going and coordinated by the State Department of Health.

6.6.3 Mamala Bay Study Commission

The Mamala Bay Study Commission was formed by an out-of-court settlement between the Sierra Club Legal Defense Fund and the City and County of Honolulu. The purpose of the Commission is to determine the impacts of primary treated effluent from the Sand Island Sewage Treatment Facility on the marine environment of Mamala Bay. The program will run two years beginning July 1993.

6.6.4 Main Hawaiian Island Marine Resource Investigation (MHI-MRI)

MHI-MRI is coordinated by the Division of Aquatic Resources of the Department of Land and Natural Resources. MHI-MRI was developed to evaluate factors affecting the abundance of living marine resources and to provide information necessary for the design of appropriate resource management policies.

7. Marine Water Quality and Ecosystem Health Research - Federal Agencies

7.1 Introduction

A number of federal agencies and programs have responsibilities and mandates which include marine water quality and ecosystem health research and/or monitoring in the Insular Pacific Region. A summary of these research and monitoring activities is provided below and a more detailed list is found in Appendix III.6.

7.2 U.S. Army Corps of Engineers

The Corps' Honolulu District, through the Operations Division, has jurisdiction and issues permits for work in the navigable waters and wetlands of the U.S., (including Guam, CNMI, American Samoa and the Republic of Palau) under authority of the Rivers and Harbors Act of 1899 and the Clean Water Act. Environmental assessments or Environmental Impact Statements with their attendant studies or monitoring, may be required prior to issuing a permit. In addition to the permit process, the Honolulu District is beginning an investigation on the fate of dredged spoil disposed in approved deep ocean disposal sites in the Pacific. The District also develops civil works projects such as flood control, shore protection and navigation improvement, in cooperation

with state and local governments. These projects require environmental assessments or environmental impact statements with their attendant studies, prepared by the Environmental Resources Branch. Environmental monitoring, usually for water quality, is also performed during construction and occasionally post construction.

7.3 U.S. Fish and Wildlife Service (USFWS)

USFWS is responsible for the protection and recovery of endangered and threatened species, management of national wilderness and refuge areas, enforcement of federal wildlife protection statutes and protection of wetland areas. The Honolulu field office, part of the regional headquarters in Portland, Oregon, covers Hawaii, Guam, CNMI, American Samoa and several other smaller U.S. insular possessions.

7.4 U.S. Geological Service (USGS)

USGS's mission is to conduct a systematic and scientific classification of public lands and examine the geological structure, mineral resources and products of the national domain. Within USGS, the Water Resources Division is responsible for describing the water resources of Hawaii and the U.S. island areas of American Samoa, Guam and CNMI. The Division carries out a number of cooperatively funded USGS-local government studies as well as its own federally funded program in these geographic areas.

USGS undertakes research on potable groundwater, recharge and fresh water flux in the region and is determining the magnitude and location of this flow. By 1996, the Hawaii Water Resources Division will be involved in a nationwide study on water quality that seeks to standardize methods of data collection. In American Samoa USGS has conducted a survey of Tutuila's ground and surface waters in an effort to characterize the hydrology of the island's streams, to summarize existing groundwater data for the Manua islands and to recommend sites for wells.

7.5 U.S. Coast Guard

The 14th Coast Guard District includes Hawaii, Guam, CNMI and American Samoa. The responsibilities of the Coast Guard include: maintaining statistics on oil and chemical spills, inspecting boats for oil leaks, aerial surveying for vessels leaking oil or dumping their bilges, licensing mariners, certifying passenger vessels and responding to marine oil spills.

Coast Guard-sponsored research is coordinated from its headquarters in Washington, D.C. Currently no research projects dealing with water quality are being carried out in the Insular Pacific Region. The Marine Environment Protection Office of the U.S. Coast Guard is developing public information leaflets on marine debris and garbage discarded by pleasure boats. They are also working with Sea Life Park Hawaii, the University of Hawaii Sea Grant Extension Service and other agencies on the effects of marine debris on the environment.

7.6 U.S. Environmental Protection Agency, Region IX, Office of Pacific Islands and Native American Programs (OPINAP)

OPINAP is a unique organization in EPA Region IX. The program staff manage all of EPA's involvement in the Pacific Island areas (except Hawaii) and serve as a link between the islands and EPA. OPINAP regional program includes Guam, CNMI and American Samoa. EPA Region IX awards a Consolidated Environmental Program Grant to the local environmental program in each of these areas through OPINAP. The block grants are equal to the sum total of funds allocated under the various EPA programs to which each island office is eligible.

Some programs for which the island agencies receive funds and have implementation responsibilities are: 1) Public Water System and Supervision Program; 2) Water Quality Management Program; 3) Groundwater Program; 4) Underground Storage Tank Program; and 5) Pesticide Program. OPINAP also has been administering the wastewater construction grant programs in each of the islands.

OPINAP is currently working with the American Samoa Government to determine the presence of heavy metals in inner Pago Pago Harbor and to discover the source of contamination. OPINAP assists the Guam EPA in maintaining the quality of their drinking water, and in CNMI, OPINAP assists with the development of sewage treatment facilities through the Construction grant program.

7.7 U.S. Forest Service, Institute of Pacific Islands Forestry

The U.S. Forest Service, Institute of Pacific Islands Forestry (U.S. Department of Agriculture) is responsible for restoring and conserving forests, changing land-use practices that cause deforestation and protecting watershed areas. The Institute works on forestry problems in Hawaii, Guam, CNMI and American Samoa. They assess existing forest resources and provide assistance to island foresters and land managers. They also serve as a test information center for the Pacific areas, and assist many public and private agencies with forestry issues.

Although their duties include the protection of mangrove forests, mangroves are not well developed in Hawaii, Guam and CNMI. The Institute works to promote erosion prevention practices through watershed management and tree planting in the region. During the next five years, the Institute will investigate how koa forest and mid-forest restoration can help reduce sedimentation by restoring groundcover in marginal agricultural lands in Hawaii.

7.8 NOAA Sanctuaries Program

The Marine Protection, Research and Sanctuaries Act established the National Marine Sanctuary Program in order to designate and manage nationally significant marine areas. There are two national marine sanctuaries in the Insular Pacific Region, the Fagatele Bay NMS in American Samoa (see Section 3.5) and the Hawaiian Islands Humpback

Whale NMS, which was created in November 1992.

The primary purpose of the Hawaii sanctuary is to protect humpback whales and their habitat and to provide for the identification of marine resources and ecosystems of national significance for possible inclusion in the sanctuary. Negotiations to determine the precise nature of the sanctuary, i.e. whether it will include only humpback whales or other marine resources, are currently underway and are expected to last until late 1994. Marine resource inventories, for parts of the sanctuary, will begin in August 1993 and a research and monitoring program will likely be developed when the sanctuary is fully established.

7.9 NOAA Pacific Island Network (PIN)

PIN provides technical assistance on coastal and marine problems and the development of marine education in all of the U.S.-affiliated Pacific Islands, including Guam, CNMI and American Samoa. As a consortium of U.S. federal agencies working with a variety of other organizations, PIN coordinates the transfer of existing federal programs, services and expertise to island governments. PIN acts as a focal point for U.S. agency response to island needs, supplying technical assistance and linkages to the marine expertise of the Sea Grant and Sea Grant Extension Service network. PIN supports a network of on-island extension agents in each of the island territories or countries within the network. PIN has undertaken several projects and through the PIN extension agents, marine-related business planning actions in marine recreation, community-based tourism, ecotourism and coastal aquaculture have been developed as well as marine conservation educational programs.

7.10 NOAA National Marine Fisheries Service (NMFS); Southwest Fisheries Center, Honolulu Laboratory

The Honolulu Laboratory is the second largest of four fishery research laboratories comprising the NMFS Southwest Fisheries Center. The Honolulu Laboratory has four research programs:

1. Insular Resources Investigation
2. Pelagic Resources Investigation
3. Fishery Management and Performance Investigation
4. Protected Species Investigation

Field research is conducted throughout the central and north Pacific region. Research is conducted aboard the NOAA vessel, *Townsend Cromwell*, and several smaller vessels. A 200,000 gallon oceanarium and experimental tank facility is located on Honolulu's waterfront at the Kewalo Marine Laboratory Facility.

The Insular Resources Investigation Program conducts research on island related fishery resources, mainly crustaceans (shrimp and lobster), bottomfish (snappers and groupers) and fish on the seamounts in the central north Pacific. In order to manage pelagic fish species, the Pelagic Resources Investigation conducts research on the biology and population ecology of tunas, billfish and other migratory open ocean fish species.

The Fishery Management and Performance Investigation program provides the Western Pacific Regional Fishery Management Council with status reports on most of Hawaii's major commercial fisheries, including the condition of the biological resources, and how management decisions affect Hawaii's fishing industry and recreational fishing community. The Protected Species Investigation Program monitors the status of endangered marine species (e.g., sea turtles, Hawaiian monk seals) and aids in their recovery.

7.11 Western Pacific Regional Fishery Management Council (WESPAC)

WESPAC was established by the Magnuson Fishery Conservation and Management Act in 1976 to develop Fishery Management Plans for the U.S. Exclusive Economic Zone around American Samoa, Guam, CNMI, Hawaii, and other U.S. possessions in the Pacific. The Council is made up of 16 members representing each of the U.S. Pacific island areas and the state of Hawaii. WESPAC has completed fishery management plans for four types of fisheries: crustaceans, bottomfish and seamount groundfish, precious corals and pelagic fish and has undertaken management actions based on the plans.

In addition, the Council has instituted a five-year tuna research program that will:

1. Define the spatial and temporal dimensions of the pelagic species to be managed;
2. Understand the interdependence of different types of tuna fisheries;
3. Determine the optimum size of the tuna fleet;
4. Define variability in year class, strength and recruitment;
5. Understand the principal oceanographic factors that govern the ecology and dynamics of pelagic fishery stocks; and
6. Enforce management measures.

7.12 U.S. Soil Conservation Service (SCS)

The SCS's mission covers three major areas: soil and water conservation, natural resource surveys and community resource protection and management. To carry out its mission, the SCS has a nationwide network of conservation specialists which provides technical assistance to private land owners primarily involved in agriculture. Land users receive help through a locally organized and managed soil conservation district.

SCS Hawaii directs seven different programs: 1) Water quality; 2) Conservation Operations; 3) Watershed Protection; 4) River Basin Study; 5) Plant Materials; 6) Soil Survey; and 7) Resource Conservation and Development. The Water Quality, Conservation Operations and Resource Conservation and Development programs are the most relevant to marine water quality and habitat protection. The programs are designed to reduce non-point source pollution to receiving waters bounding a watershed and SCS has several projects in this area. Future

research includes two projects that will investigate non-point source pollution reduction on Maui and Molokai.

8. Marine Water Quality and Ecosystem Health Research - Regional Organizations

8.1 Pacific Basin Development Council (PBDC)

PBDC is a regional organization designed to foster communications among the governors of the four U.S. Pacific island areas: Guam, Hawaii, CNMI and American Samoa. The organization has been primarily interested in economic development in the four areas but has undertaken collaboration with state, territory and federal agencies to address issues concerning the environment, aquaculture, fisheries and coastal resource management. Projects include oil spill contingency planning throughout the region, studies on ocean disposal of hazardous and toxic waste and the protection of unique habitats in the four island areas.

8.2 East-West Center, Program on Environment

Formerly the Environment and Policy Institute, the Program on Environment addresses problems associated with the management of environmental resources of Pacific Island and Pacific Rim countries. In the past, the program conducted projects regarding the management of mangrove areas and environmental impact assessment in Micronesia and the South Pacific. A Hazardous Risk Ranking Project for Hawaii has recently been completed.

8.3 South Pacific Regional Environment Programme (SPREP)

SPREP is the coordinating unit and clearinghouse for environmental activities in the South Pacific region, including those concerned with the marine environment. Guam, CNMI and American Samoa are members of SPREP. SPREP programs include those developed through the initiative and support of the United Nations Environment Programme (UNEP) Regional Seas Programme to address the shared coastal and marine issues of the South Pacific Region, as well as more recent initiatives from SPREP itself. There are two ongoing programs which include marine research: 1) the program to assess, monitor and control marine pollution (SPREP-POL), and 2) the Regional Marine Turtle Conservation Programme. SPREP is seeking funding for additional regional programs in Integrated Coastal Zone Management and marine mammal conservation, and is proposing to develop regional programs in coral reef management and mangrove management. However, the level to which these will include research has not been determined.

The SPREP-POL program is focussed on assessing levels of marine pollutants (e.g., pesticides, heavy metals, organochlorines, sewage pollutants) at a number of polluted and reference sites around the South Pacific region. Marine pollution information collected through SPREP-POL is required to use UNEP Regional Seas Reference Methods to ensure global compatibility of data. Guam, through the Guam EPA,

Table 3.1 Areas of Research and Monitoring Undertaken by Major Agencies/Organizations Contacted During Inventory

Agency/Organization	Nearshore Physical Oceanographic Processes		Nearshore Water Quality		Nearshore Species and Habitat		Coastal Development and Resource Use		Contaminant Sources Transport, Fate, Effects	
	Research	Monitoring	Research	Monitoring	Research	Monitoring	Research	Monitoring	Research	Monitoring
AMERICAN SAMOA										
ASEPA				x				x		x
DMWR					x	x		x		
Fagatele Bay Nat. Mar. Sanctuary				x		x				
Star-Kist Samoa & VCS Packing				x						
GUAM										
UOG Marine Lab	x		x	x	x	x				
UOG WERI	x	x	x	x					x	x
GEPA		x		x		x		x		x
DAWR					x	x				
CNMI										
DNR					x	x				
QEC				x						x
CRMO								x		
HAWAII										
Department of Health			x	x						x
Department of Aquatic Resources					x	x		x		
Coastal Zone Management							x	x		x
Department of Transportation		x		x						
UH Hawaii Institute of Marine Biology	x		x	x	x	x	x		x	
UH Sea Grant College Program	x		x		x				x	x
UH Sea Grant Extension Service	x				x	x	x	x	x	x
UH Oceanography Department	x									
UH Hawaii Institute of Geophysics	x						x	x		
UH Waikiki Aquarium					x	x				
UH WRRC			x	x					x	x
UH Environmental Center				x		x		x		x
UH Pacific Biomedical Research Center					x					
UH Botany Department					x					
UH Hawaii Cooperative Fishery Unit					x					
Honolulu C&C Dept. of Public Works				x				x		x
AECOS, Inc.				x						
Envirosearch				x		x				x
Bishop Museum					x					
Sierra Club Legal Defense Fund										
HECO				x						
Oceanic Institute				x	x					
The Nature Conservancy										
Conservation Council										
Surfrider Foundation				x						
West Hawaii Monitoring Program		x		x				x		
Maui Algal Bloom Project				x	x					
Mamala Bay Study Commission			x	x					x	x
Main Hawn. Islands Mar. Resource Invest.	x				x	x	x			

Table 3.1 Areas of Research and Monitoring Undertaken by Major Agencies/Organizations Contacted During Inventory (continued)

Agency/Organization	Nearshore Physical Oceanographic Processes		Nearshore Water Quality		Nearshore Species and Habitat		Coastal Development and Resource Use		Contaminant Sources Transport, Fate, Effects	
	Research	Monitoring	Research	Monitoring	Research	Monitoring	Research	Monitoring	Research	Monitoring
FEDERAL										
U.S. Army Corps of Engineers		x				x		x		x
U.S. Fish & Wildlife Service					x	x		x		
U.S. Geological Survey	x									x
U.S. Coast Guard										x
U.S. Environmental Protection Agency			x	x				x	x	x
U.S. Forest Service					x	x		x		
NOAA Sanctuaries Program		x			x	x				
NOAA Pacific Island Network					x		x	x		
National Marine Fisheries Service					x	x				
WESPAC					x	x				
U.S. Soil Conservation Service			x	x				x	x	x
REGIONAL										
PBDC										
SPREP			x	x	x	x			x	x
SPC					x	x				
SOPAC	x	x								

CHAPTER IV: RESEARCH NEEDS AND PRIORITIES

1. Process for Determining Marine Research Needs

Research needs were determined through interviews with agencies and organizations concerned with marine water quality and ecosystem health in the region. The PRMR Board developed a list of agencies and organizations to be contacted. The list was augmented with suggestions from the PRMRP staff and suggestions from the agencies and organizations themselves. The approach of the PRMRP staff was to be as inclusive as possible in order to give any and all agencies and organizations the opportunity to contribute to the identification of research needs.

Most of the agencies and organizations interviewed were those which had been identified and contacted to provide information for the inventory of marine research in the region. These were primarily government agencies or tertiary institution departments or programs. Due to their role in conducting, funding or administering marine research programs, these agencies and institutions were able to provide well defined input into the determination of marine research needs and priorities for the region. The contact individuals nominated for these bodies were asked to identify research which their agency or institution should be, or would like to be, conducting, as well as to identify any other research needs which should be addressed in the region.

The PRMRP staff also identified other organizations concerned with the state of marine water quality and ecosystem health, which were contacted to provide input into the determination of research needs. These were usually non-government organizations, which generally do not conduct, fund or administer marine research programs, but are active in seeking to protect the public interest and ensure environmental quality. Due to their active interest in water quality and ecosystem health, these organizations provided valuable insights into the marine research needs of the region.

2. Scope of Marine Research Needs Considered

In identifying research needs with agencies and organizations, an expansive definition of research was used. Research was considered to include monitoring and management-driven or management-oriented research. For PRMRP, monitoring refers to goal-oriented, cost-effective sampling which is conducted for a defined period of time in order to answer specific research questions, define cause-and-effect relationships and contribute to long-term trend analyses. Monitoring does not refer to programs of random sampling of parameters for an indefinite time period to determine if standards are being exceeded.

In addition, the consideration of research appropriate for inclusion in this Plan was not limited to natural science concerned with physical, biological or chemical aspects of water quality and ecosystem health. Research to address social and economic aspects of marine water quality and ecosystem health, and research to address educational, policy and regulatory needs were also included in the compilation of research needs.

3. Determination of Priority Issues

The agencies and organizations contacted identified a large number and wide range of research needs which they considered to be important. These were summarized into a list for each agency and organization contacted. A large number of research issues were identified as important by more than one agency or organization, with some topics considered a priority by many agencies and organizations. The listed needs were analyzed to determine the actual research being suggested and its relation to the kinds of research eligible for inclusion in the program, as indicated by the RMRP legislation.

The PRMRP staff developed a set of Guidelines for Determining Priority Issues, which were revised and approved by the PRMR Board. The Guidelines provide a means to screen the large number of research needs which have been identified and focus on those priorities for research which are appropriate for inclusion in the Marine Research Plan for the Insular Pacific Region.

Guidelines for Determining Priority Issues (not in order of priority)

Is the issue:

1) a problem important to the region, i.e., the issue is important scientifically or is it important due to public perception of a risk or problem in some part of the region;
2) related to the ecological uniqueness of the region, i.e., the combination of factors composing the issue are particular to the region and cannot be addressed by research conducted elsewhere;
3) a widespread or regional problem, i.e., the issue is important in most or all of the region;
4) identified as a strong need and immediate problem, i.e., there is compelling evidence that there is a problem and that timely investigations are required to clarify the issue and/or develop solutions in the near future;
5) not likely to be undertaken otherwise, i.e., there are not likely to be other plans, programs or funds allocated which will otherwise address the issue in the foreseeable future.

4. Development of Research Themes and Topics

Following the application of the Guidelines for Determining Priority Issues, the research needs appropriate for inclusion in the Marine Research Plan were compiled into a series of groups containing similar research topics. Analysis and compilation of the groupings resulted in the identification of four major themes: 1) Assessment and Monitoring; 2) Sources, Transport, Fate and Effects of Contaminants; 3) Effects of Coastal Development and Resource Use; and 4) Analysis and Application of Research Results.

Within these themes, more specifically defined topics were identified from the information, based on research needs. These are listed in Table 4.1. The themes and topics are not presented in order of priority, but instead the themes as a group represent the overall priority needs for

research in the Insular Pacific Region, as identified by the agencies and organizations which contributed to the Plan development.

A draft version of the priority research needs was reviewed and revised at three scientific workshops. The one-day meetings covered: 1) Guam and the Northern Mariana Islands; 2) American Samoa; and 3) Hawaii. A list of participants is found in Appendix IV.1. The scientific workshop also reviewed and revised Guidelines for Determining Priority Issues and the Guidelines for Evaluating Research Proposals. The workshop participants were generally in agreement with the themes, topics and priority research needs proposed. However, it was felt important that the Marine Research Plan not list specific research activities other than as examples of the kinds of projects which might be proposed under each topic area to avoid giving a false sense of prioritization or importance to specific activities.

This chapter presents each of the topics within the four themes. For each topic, the general background is outlined, followed by a discussion of aspects which are unique to the Insular Pacific Region. The priority research needs within each topic area are presented, with an indication of research activities to illustrate the kinds of projects which might be included in the topic area.

Table 4.1 PRIORITY RESEARCH NEEDS: Themes and Topics

I. Assessment and Monitoring
   1. Development of Integrated Water Quality and Ecosystem Health Assessment and Monitoring Programs
   2. Assessment and Monitoring of Nearshore Physical Oceanographic Processes
   3. Assessment and Monitoring of Nearshore Marine Water Quality
   4. Assessment and Monitoring of Nearshore Marine Species and Communities
   5. Assessment and Monitoring of Nearshore Marine Habitats
   6. Assessment and Monitoring of Coastal Development and Resource Use

II. Sources, Transport, Fate and Effects of Contaminants
   1. Sources, Transport and Fate of Contaminants
   2. Effects of Contaminants

III. Effects of Coastal Development and Resource Use

IV. Analysis and Application of Research Results

5. Theme I: Assessment and Monitoring

5.1 Development of integrated water quality and ecosystem health assessment and monitoring programs

A. Background to the Topic

An effective baseline assessment and monitoring program with clearly stated goals and objectives is required to understand the status and trends in marine environmental quality. Such a program would

provide a comprehensive database on the marine and coastal environment and should expand on, or integrate, existing programs wherever possible. A review of existing monitoring programs is required to determine what kind of monitoring is already taking place for marine water quality, species or habitat.

A comprehensive marine environmental monitoring program for coastal waters would integrate the monitoring of chemical, physical, biological and habitat parameters relating to both water quality and ecosystem health. Monitoring would ideally take place in a range of sites, from those which are polluted or disturbed to pristine sites, where disturbance and contaminants are absent or negligible. The latter would serve as reference or control sites, which will allow natural variation, cycles and perturbations to be measured.

Although there is sufficient sampling of some parameters, adequate and appropriate statistical analysis is sometimes lacking. The design of sampling plans should take into account the research question to be answered and the type of statistical analysis which will be used to answer the question. Any assessment and monitoring program should ensure that the data collected is analyzed and results made available for planning and management. An integrated assessment and monitoring program which covers a range of topics will require coordination among the various agencies and organizations which have interests and responsibilities in these topics. Monitoring should be goal-oriented, focusing on repeated sampling for a defined period of time, to answer specific research questions, define cause-and-effect relationships and contribute to long-term trend analysis.

B. Aspects Unique to the Insular Pacific Region

In spite of the importance of the nearshore marine environment to the economies, cultures and life styles of the people of Hawaii, Guam, CNMI and American Samoa there is very little systematic monitoring of marine water quality and ecosystem health. Much of the region is lacking adequate baseline information on which to base monitoring projects or programs. Within a relatively confined geographic area, there is a high degree of variation in the characteristics of the coastal zone of the small islands of the region. For example, within the context of a single island, there may likely be a semi-enclosed lagoon with estuary and wetlands, a barrier reef system, a fringing reef coast, cliffed coasts, deep oceanic depths just offshore, extensive beaches and a major urban coast.

Marine research capabilities are very limited in the Insular Pacific Region. There are permanent marine research laboratories in only one location in Hawaii and one location in Guam. Access and transportation are major constraints to sampling in a wide range of locations in some areas. Laboratories have limited facilities for analysis of water-quality, sediment and tissue samples. Even urbanized areas may not have adequate laboratory testing capabilities or sufficient expertise to independently test and analyze nearshore waters. In other areas (e.g., American Samoa), there are few local resources for undertaking marine research and work must often be contracted off-island. The establishment

of a marine laboratory in these areas would address many needs and could be used by a variety of agencies and organizations.

There are some efforts underway to conduct multi-disciplinary investigations of nearshore marine areas. For example, the Guam Environmental Protection Agency has a series of sites which are monitored for water quality and for biological indicators. In Hawaii, the Main Hawaiian Islands Marine Resources Investigation, a major 5 to10 year study, was initiated in 1988 to understand the factors affecting the abundance of Hawaii's nearshore living marine resources. In addition, a multi-disciplinary study of Mamala Bay, Oahu, recently has commenced.

C. Priority Research Needs

There is a priority need in the region for integrated baseline assessment and monitoring programs for nearshore marine water quality and ecosystem health. While the development and operation of such programs are beyond the purview of the PRMRP, there is much research to be done in determining parameters, sites, methods, techniques and data analyses appropriate for the region.

More specifically, there is a need to determine methods and criteria for selecting sites to be assessed and monitored. For example, the kinds of site types to be monitored can be selected, based on types and levels of use (e.g., recreational, fishing, port), or on likely pollution levels (e.g., highly polluted, average, pristine) or on other factors. Potential monitoring sites will need to be evaluated, based on agreed upon criteria to determine if they are appropriate to the goals, objectives and capabilities of an assessment and monitoring program. The selection of reference sites, in particular, may require research to identify the strict criteria which should be used to identify these areas. New tools and technology should be assessed and utilized where appropriate, such as Global Positioning Systems (GPS), satellite imagery and Geographic Information Systems (GIS).

The selection of sampling parameters and techniques appropriate to the region is another aspect of developing an integrated assessment and monitoring program which requires investigation. These are discussed further under each of the more specific topic areas on the assessment and monitoring of physical oceanographic processes, water quality, species and habitat. In addition, research may be required to develop or ensure selection of appropriate statistical analysis techniques, such as those which can indicate long-term trends. The collection, management and transfer of data and information resulting from baseline studies and monitoring should be established as a function of the PRMRP.

5.2 Assessment and monitoring of nearshore physical oceanographic processes

A. Background to the Topic

The physical oceanographic character of the marine environment is critical to marine environmental quality. Oceanographic processes, particularly ocean current and circulation patterns, upwelling and

mixing, strongly influence water quality, ecosystem health and human use and development of the coastal and nearshore marine environment. A baseline description of oceanographic conditions is required to understand temporal and spatial variation in these conditions, and to develop predicative capabilities and models. This is the case generally for nearshore waters, where human inputs and alterations to the marine environment are concentrated, and particularly true for certain specific locations, where water quality and ecosystem health are of concern.

Understanding wave and sea level dynamics, and the interaction between weather and oceanography, is essential to addressing the impacts of these forces on the coastal zone. Natural forces such as wave action and periodic tropical storms have major impacts on marine ecosystem health and on water quality.

B. Aspects Unique to the Insular Pacific Region

The small islands which comprise Hawaii, Guam, CNMI and American Samoa are surrounded by oceanic waters with a variety of nearshore marine configurations, ranging from open ocean to nearly enclosed embayments. The oceanographic conditions of some areas, particularly ports, harbors and important embayments, have been relatively well studied, especially in Hawaii. Elsewhere in the region, oceanographic data for nearshore areas is often only available for specific sites for limited time periods. Otherwise, even one-time baseline information is usually completely lacking for most coastal waters in the region.

Information on ocean current patterns, water mass mixing patterns and upwelling zones, and calculations of the assimilative capacity of coastal water bodies would provide a basis for making management decisions about pressing issues in the region. These include decisions such as selecting effluent disposal methods and selection of disposal areas, siting and designing coastal development and targeting fisheries development projects. In addition, the transport and recruitment patterns of larval stages of many of the region's important nearshore marine organisms are dictated by these oceanographic processes.

The importance of the coastal area in general, and the narrow area of shoreline in particular, makes the understanding of the erosion and deposition of sediment along the shore of critical importance to the small islands of the region. Unfortunately, the patterns and processes of shoreline sediment movements, and the effects of shoreline structures on these movements, are not well known in most of the region.

The tropical and sub-tropical location of the islands in this region means they are affected periodically, and in some cases regularly, by cyclones, major oceanic storms and large ocean swells. These events have catastrophic effects on human health and welfare, on the island economies, and on coastal habitats and resources. In addition to freshwater run-off and flooding, much of the damage is due to wave activity. There is a need to better understand wave dynamics in order to predict and plan for wave impacts in the coastal zone.

Sea level rise is particularly important to the small islands of this region which are entirely coastal in nature. Monitoring of sea level fluctuation is essential for determining trends and predicting potential sea level rise. Information on wave and sea level dynamics will provide a basis for addressing important issues, such as clarifying shoreline erosion processes, regulating sand mining and determining shoreline protection needs and approaches.

C. Priority Research Needs

The high priority research need in this area is developing an understanding of oceanographic conditions critical to the movement of materials in the nearshore zone. In particular there is a need to document circulation patterns, such as long-shore currents, water movement in embayments and partially enclosed marine waters and circulation in ports, harbors and marinas. The long-term, seasonal and tidal variation of these patterns is important also.

Linked to the baseline study of water movement is the need to determine the assimilative capacity of shallow nearshore coastal waters for contaminants. Predictive modeling of oceanographic conditions, especially water movement, is also needed to assist in minimizing the impacts of pollution events on water quality and ecosystem health. For example, the modelling of nearshore currents to predict the movement of spilled oil under various conditions is important as an aid to oil spill contingency planning.

Information on nearshore circulation is also related to shoreline sediment erosion and deposition. There is a need to better understand the processes and long-term, annual, seasonal and tidal patterns of coastal erosion and accretion. Understanding the effects of shoreline structures on erosion and accretion processes and patterns is also critical. For example, structures which are intended to prevent erosion or maintain shoreline stability may have effects on erosional and depositional processes that require investigations.

In order to improve our understanding of the effects of natural hazards on water quality and ecosystem health, it is necessary to monitor wave activity and sea level in a variety of areas (e.g., by installing wave gauges at harbors and open ocean sites). Efforts are also needed to predict wave dynamics, such as wave heights and run-up, especially for developed coastal areas (e.g., harbors, urban areas) as a part of contingency planning for natural disasters. Studies are also lacking on the effects of tropical storms on nearshore marine organisms and biological communities of importance.

5.3 Assessment and monitoring of nearshore marine water quality

A. Background to the Topic

Only with a clear understanding of the baseline water quality conditions and regular monitoring on a systematic, standardized basis, is it possible to detect and locate changes in water quality. A baseline

assessment and monitoring program would help to understand changes in water quality due to natural variation and perturbations and aid in identifying changes due to anthropogenic inputs. Water quality standards are an important measure of water quality, and these are needed to determine when corrective or regulatory action is required. However, standards must be appropriate for the areas in which they are used. Various methods have been developed for evaluating water quality. Some of these may not be appropriate for the conditions and capabilities in the Insular Pacific Region.

B. Aspects Unique to Pacific Insular Region

Water quality parameters and standards which are appropriate for the small tropical and sub-tropical islands of Hawaii, Guam, CNMI and American Samoa need to be developed. The kinds and levels of economic development, land use and industry in the region, and the pollution sources, levels, types, treatment and discharge modes occurring in the region are a unique combination. A better understanding of chemical, physical and biological conditions and trends in the marine environment is needed as a basis for the review and possible revision of water quality regulations. New criteria on which to base the management of water quality may be required. For example, one of the problems with present standards is that groundwater seeping into nearshore waters already exceeds water quality standards in places.

Regionally comparable water quality criteria and standards, which can be used to monitor water quality cost effectively, are lacking. Existing water quality monitoring programs should first be reviewed and evaluated to determine what is appropriate for the region. For example, the Kona coast of Hawaii, between Kawaihae and Kailua-Kona, could be used to test the monitoring protocol developed by the West Hawaii Task Force for 2-3 years to evaluate its effectiveness. If local regional standards prove workable, then these can be scaled up to include the rest of the islands.

Where planned or mandated programs are appropriate and sufficient, these should be fully implemented. For example, in Hawaii the water quality monitoring program of the DOH Clean Water Branch should be fully implemented. In other parts of the region (e.g., American Samoa) the lack of water quality testing facilities, resources and capabilities is hampering the establishment of more extensive programs.

C. Priority Research Needs

There is a need to evaluate existing and potential water quality standards and parameters for their appropriateness to the Insular Pacific Region. It may be necessary to develop water quality standards tailored to the region, or even specifically developed for sub-regions or local areas. Existing water quality data should be fully analyzed and interpreted before new programs and standards are proposed. Likewise, water quality sampling and monitoring methods need to be evaluated for their applicability to the region. For example, research is required to determine

whether excess benthic algal biomass or excess phytoplankton biomass in specified areas is a useful measure of nutrient input from land.

More studies are needed to clarify whether certain indicator organisms common in the region (e.g., crabs, mussels, oysters and perhaps snails) can be used to indicate the presence of a particular contaminant or whether more sensitive bioassay techniques (e.g., fertilization success of sea urchins) is appropriate. New methods and technologies need to be evaluated for their effectiveness and appropriateness in addressing water quality issues in the region. These include the use of infrared remote sensing of run-off and the use of mixing models which assume a certain background level of pollution, and indicate when an area exceeds that background level.

There is a need to standardize water quality sampling methods and protocols so that results will be comparable and will allow cumulative trends to be identified. This could start with an assessment of existing monitoring programs and an assessment of sampling protocols for particular situations (e.g., stream sediments, stream waters, outfalls, storm drains, canals). In developing sampling parameters and protocols, it is important that sources of error be identified and evaluated and that levels of confidence are determined as part of quality control. There is also a need to develop methods to determine sampling and analytical variability in comparison to environmental variability.

5.4 Assessment and monitoring of nearshore marine species and communities

A. Background to the Topic

A baseline assessment and regular monitoring of the biological components of the marine environment must accompany the present predominantly physical and chemical evaluation of marine environmental quality. The assessment and monitoring of biological parameters provide a means to measure the health of the marine ecosystem. These include measures of the biological diversity of organisms, the status of species populations and species interactions. A basic understanding of taxonomy, life history and ecology of individual species, as well as population dynamics and community ecology, are often prerequisites for understanding which species and parameters should be assessed and monitored and what constitutes "normal" or "healthy" population levels and environmental conditions.

B. Aspects Unique to the Insular Pacific Region

The marine flora and fauna of Hawaii, Guam, CNMI and American Samoa have been partially documented. Because of the region's insularity, there is a higher level of endemism in the region than in marine areas of the continental U.S. Superimposed on the regional pattern of decreasing marine biodiversity from the western Pacific to the east, are sites of high endemism, reflecting the degree of isolation of certain islands. Hawaii, the most isolated archipelago in the world, has a relatively high level of marine endemism. An inventory of marine

biological diversity is a basic component of any comprehensive biological assessment and monitoring program.

Several groups of species are of particular importance to the islands of the Insular Pacific Region and require special attention. Many of these are rare, threatened or endangered, including all of the marine turtle species. Fishery resources are very important in the region for their subsistence use, commercial and recreational value and importance to the cultures of the region. The status and condition of important fishery stocks that are under pressure from harvesting are often not known. These same populations, as well as many other species, are affected by water quality and ecosystem degradation.

C. Priority Research Needs

As a basis for assessment and monitoring of marine species in the region it is important to review and assess which biological parameters are important in the Insular Pacific Region. The region consists of small tropical and sub-tropical islands with a narrow nearshore zone and large Exclusive Economic Zone. Each island is at a different location within the broader pattern of Pacific island marine biological diversity, with numerous species that are locally important as commercial, subsistence and recreational marine resources. In particular, there is a need to review and assess biological diversity of the marine environment in each of the areas. This could include assembling a thorough bibliography of marine flora and fauna and a systematic inventory of museum reference collections. This would form the basis for a taxonomic database of marine biodiversity, identifying introduced, native and endemic species, and indicating the unique characteristics and value of important species. Where information is limited or lacking, there may be a need to gather additional information directly through field surveys. For particularly important marine species, it may be necessary to compile information on life histories and species biology.

Species or populations of particular importance may need very specific studies. This may include baseline assessments and monitoring, taxonomic work and ecological studies, such as reproductive ecology, larval dispersal and recruitment. The organisms of importance include fish and invertebrates of high commercial value, endangered or protected species, species of subsistence or cultural value and organisms which are important to reef health (e.g., the coral-eating starfish *Acanthaster planci*) or to public health (e.g., the toxic dinoflagellate which causes ciguatera poisoning, *Gambierdiscus toxicus*). Organisms which may be useful as indicator species, and species which have been introduced, may also require detailed studies.

Beyond the study of single species and populations, there is a broader need to understand and characterize nearshore marine community structure, function, interaction and ecology. This includes a variety of needed research topics, such as studies into critical habitat factors (i.e., physical, chemical, biological), seasonal variations and trophic level connections. These may lead to the ability to develop conceptual models of nearshore marine communities which can assist in resource

management. Other studies with more direct links to species management techniques, such as the effects of seasonal closures or the value of protected areas for important stocks, are also needed.

5.5 Assessment and monitoring of nearshore marine habitats

A. Background to the Topic

Coastal and nearshore marine habitats are generally highly productive areas of considerable ecological and economic importance. In addition to harvestable resources, many habitats provide a buffer between terrestrial and marine ecosystems. Unfortunately, these areas are also subject to a high level of human use and consequent degradation, as a result of activities in the immediate area and activities in the adjacent watershed.

The degradation or destruction of the nearshore marine habitat has serious consequences for the species they support, and the humans which depend upon those organisms. Severe economic consequences also result when habitat important to fisheries or tourism resources are lost. The loss of ecosystem function may lead to long-term impacts. Establishment of marine protected areas is one of the most effective ways to protect habitat as well as the species they support.

B. Aspects Unique to the Insular Pacific Region

Coastal and nearshore marine habitats provide the basis for the bulk of the commercial, subsistence and artisanal fisheries, tourism interest and recreational activities of Hawaii, Guam, CNMI and American Samoa. Most of these habitats are found only in the limited tropical and sub-tropical areas of the U.S. There have been inventories of some of the coastal and marine habitats in the Insular Pacific Region, however, there is no comprehensive planning for these areas in order to balance protection and use of marine habitats. A comprehensive ecosystem classification system for the tropical insular Pacific has been recently developed and is being applied to Guam, CNMI and American Samoa based on tertiary information sources.

Some habitats are of particular importance in the Insular Pacific Region, especially coral reefs, mangroves, wetlands and estuaries. Coral reefs, for example, serve as critical juvenile habitat for commercially valuable fish and their prey, as well as for recreational and subsistence species. Nearshore and inshore fisheries depend on the health of the surrounding coral reef, yet information on the composition and characteristics of the coral reef habitat is often inadequate for the management of these fisheries. Coral reefs are indicators of the nearshore marine ecosystem's health, as they are particularly sensitive to environmental change and are easily degraded in response to relatively small changes in conditions.

C. Priority Research Needs

In many parts of the Insular Pacific Region, there is a need to conduct a comprehensive, systematic inventory of marine habitat. Such

an assessment could also indicate the status value of marine habitat areas (e.g., identification of habitat in existing protected areas and identification of critical, unique and representative habitats). However, beyond the need to take stock of the marine habitat of the region, there is a need to undertake research in support of the conservation of habitats of particular importance. Such habitats notably include: coral reefs, estuaries, wetlands and mangroves for which assessment and monitoring studies are lacking in many areas.

For these habitats of particular importance there is a need to undertake specific studies. Some of these include inventorying the kinds of organisms associated with the habitat or determining the components and function of undisturbed examples of the habitat. Other studies are more important to the conservation of specific site occurrences of the habitat, such as determining sources of degradation, identifying examples suitable for protection, evaluating whether mitigation methods for habitat loss work or examining restoration techniques. The importance of coral reefs to the region cannot be overstated and an integrated coral reef monitoring program should be developed and coordinated with other national, regional and international coral reef monitoring programs.

With the importance of nearshore marine habitats to the Insular Pacific Region, research to identify, establish and develop marine protected areas is a particularly critical need. A comprehensive approach should both expand upon the existing protected areas and incorporate new types of marine protected areas for such features as unique underwater geological formations and archeological sites, as well as coastal recreation areas. These needs include a number of potential research areas, such as developing criteria to evaluate sites for potential inclusion in marine protected areas, determining the kinds of protected areas required (e.g., large remote zones closed to most uses versus smaller multiple use zones near heavily used areas or open access zones). In addition, studies are needed to evaluate proposed protected area sites and determine the value of protected areas as refuges and sources of stock replenishment for disturbed areas.

At the other end of the spectrum, research is required to guide efforts to restore or rehabilitate habitats that have been destroyed or degraded. This could include evaluating techniques such as coral transplantation and construction of artificial reefs.

5.6 Assessment and monitoring of coastal development and resource use

A. Background to the Topic

The development of coastal areas and the use of nearshore resources may result in reduction of water quality, the degradation or destruction of habitat and the depletion of resources. The level and kind of impact are related to the type, amount and location of coastal development and resource use. Assessing and monitoring these patterns contribute to the basis for understanding the effects of these activities on water quality and ecosystem health.

Most coastal development is related to major infrastructure needs (roads, ports, airports) and commercial and residential development associated with growing urban areas. In addition, smaller residential development and tourist resorts occur in locations removed from built-up areas. Many kinds of coastal development often require clearing of slopes in coastal watersheds, dredging or infilling of shoreline wetlands or intertidal areas, shoreline stabilization and protection structures. The impacts of construction activities are followed by impacts of the operations of the development which may affect water quality and ecosystem health (e.g., industrial or sewage discharges), increased terrestrial erosion and sediment run-off and shoreline erosion.

The use of nearshore resources is related to coastal development patterns as well as to the distribution and abundance of the resources being used. For example, recreational use of nearshore resources is linked to population distribution, with much greater use of coastal resources near population centers. Commercial shipping and pleasure boating patterns and impacts are a function of the location of shoreline facilities. Other uses, such as commercial and subsistence fishing, however, are more dependent upon the location of the sought-after resources.

B. Aspects Unique to the Insular Pacific Region

The topography and small size of the islands of Hawaii, Guam, CNMI and American Samoa dictate that most, if not all, development occurs along the narrow, low lying coastal strip. Nonetheless, development and resource use are concentrated in certain areas. The coastal areas of four of the eight main Hawaiian islands, central Guam, the island of Saipan in CNMI and the island of Tutuila in American Samoa are all heavily developed. Other parts of these islands have much less coastal development, but major resorts have been proposed for many undeveloped rural areas, especially in Hawaii, Guam and CNMI. The situation is somewhat different in American Samoa, where the major coastal development is residential.

On some islands available land area is insufficient to meet residential and commercial needs, requiring infilling of coastal wetlands and reef flats which degrades water quality in the immediate vicinity and destroys important nearshore habitat. In many instances the material used for fill is dredged from nearshore coral reefs, causing additional destruction of inshore habitat.

Major coastal uses in the Insular Pacific Region include resort hotels, harbors and marinas; commercial, subsistence and recreational fishing; beachfront residences and marine recreation. The different and often competing uses all have impacts depending on the location, kind and level of use. In addition to the deleterious effects of coastal development on habitats and resources, in the small island context the concentrated use of resources by growing populations can more easily lead to over-exploitation due to the limited supply of a particular resource.

C. Priority Research Needs

As part of the baseline understanding of conditions, there is a need to assess the levels, kinds and patterns of coastal development and nearshore marine resource use in the region. The various kinds of living resource harvest being conducted in the region are poorly documented. For example, there is little information evaluating the various kinds of fishing pressure, particularly subsistence fishing and recreational fishing. The economic value of most of the important marine resources in the region has not been well-defined and requires study.

The kinds, levels and patterns of recreational use of the nearshore marine environment have not been evaluated. Certain coastal areas of the region are subject to very heavy use which is not well documented. For example, there is a need to identify ocean recreational use patterns and determine the kind and levels of beach park use which affect water quality, especially in coral reef areas.

6. Theme II: Sources, Transport, Fate and Effects of Contaminants

6.1 Sources, transport and fate of contaminants

A. Background to the Topic

Substances which are transported into the nearshore marine environment in greater quantities than are present naturally may be considered "contaminants." These contaminants often have deleterious effects on water quality and ecosystem health. These include a variety of substances, such as petroleum oils, heavy metals, pesticides, nutrients and terrestrial sediment. In order to understand the cause and effects of these contaminants, it is necessary first to document the natural source and amounts of materials which are entering the nearshore marine environment. A systematic inventory of pollution sources, types and levels is thus required as a basis to understanding the effects of anthropogenic contaminants on marine water quality and ecosystem health, and to identify potential solutions and controls.

In order to determine the effects of contaminants and develop effective control measures, it is necessary to know more than the location and kind of contaminant source. It is often necessary to understand the movement of substances from source to sink and document the pathways and ultimate fate of materials entering the marine environment.

B. Aspects Unique to the Insular Pacific Region

Land-based pollutants are responsible for most of the degradation of marine water quality and ecosystem health in Hawaii, Guam, CNMI and American Samoa. The small island nature and often steep topography of the land areas in the region, and the seasonally high rainfall, mean that contaminants are quickly transported to the surrounding marine environment with little dilution, filtration or alteration. Substances which enter the groundwater also may not be changed substantially before entering the marine environment through seepage, due to the relatively short distance the water travels.

Although there have not been any major oil spills in the region, the potential for such a disaster exists. Since the region is heavily dependant upon marine transport, pollution of harbors and major sea lanes from chronic spills, bilge water and dumping is common. In addition, there is always the threat of collision and spillage of bunker fuel.

The oceanic waters surrounding the islands of the region are generally clear and nutrient poor, conditions which support the development of coral reefs. Sedimentation and heavy nutrient input from terrestrial activities are particular threats to the health of coral reefs. There is little information in the region on the transport, pathways and fate of contaminants in any particular location. Without such information, it is difficult to identify or implement control measures.

C. Priority Research Needs

The primary research need regarding contaminants is a comprehensive inventory of the sources of point and non-point pollution input into the marine environment, with an emphasis on land-based pollution sources. There is a particular need to determine the kinds and levels of non-point pollution entering the marine environment (e.g., pesticides, oils, heavy metals, sediment, nutrients) including freshwater run-off patterns. The evaluation of existing water quality monitoring data may assist in identifying point and non-point pollution sources.

Non-point sources need to be related to the type of land use from which they are emanating, such as agricultural lands, golf courses, cleared lands, construction sites and stormwater run-off. Groundwater seepage sources need to be identified, especially near areas where cesspools, leach fields, dry wells or injections wells are used for wastewater disposal. The sources and amounts of surface water input into the marine environment also need to be determined. Understanding the chemical composition of surface and groundwater entering the marine environment (e.g., BOD, dissolved solids, temperature, nitrogen, phosphate) is an important aspect of assessing contaminant sources.

Beyond knowing where the sources of contaminants are, there is a need to determine the pathways, dispersion and fate of specific contaminants of particular interest. These include human pathogens from various sources, nutrients which affect ecosystem balance and sediments and contaminants which may be carried in stormwater and stream run-off (e.g., pesticides, heavy metals, hydrocarbons). The relation between land-based sources and the presence of contaminants needs to be elaborated further, for example, by clarifying the correlation between stream or storm water flow and the types of nearshore marine pollution present.

6.2 Effects of contaminants

A. Background to the Topic

Contaminants in the nearshore marine environment occurring in greater quantities than are present naturally often have deleterious effects on water quality and ecosystem health, and may affect human health.

Research is required to understand the effects of these contaminants on nearshore marine biota and habitats. The effects of specific pollution sources on the water quality, ecosystem health or human use of a particular area are often not known. Information on contaminant effects will aid in land-use planning and management of coastal watersheds, shorelines and nearshore marine ecosystems.

B. Aspects Unique to the Insular Pacific Region

Very little is known about the effects of contaminants on tropical and sub-tropical flora and fauna under the conditions typically found around the small oceanic islands of Hawaii, Guam, CNMI and American Samoa. This is particularly true for the habitats of special importance, notably coral reefs and mangroves, and the species which they support. The heavily used harbors of the region, especially those associated with military and industrial activities, are highly contaminated and have had limited studies concerning the kinds and extent of impacts from pollution.

There is little information on the impacts of actual point and non-point pollutant sources in the region on the marine environmental quality of specific locations, especially locations which have fisheries, recreational or tourism values. Because of the high value of the nearshore marine environment to recreation and tourism in the islands of the region, it is particularly important to identify the effects of contaminants on public health (e.g., contaminated receiving waters, fish). Options for reducing the effects of contaminants through treatment or control of pollution sources, especially non-point sources, have often not been fully explored in the region.

C. Priority Research Needs

The overall priority need in this area is to determine the effects of contaminants on coastal water quality and ecosystem health in the region. Understanding the effects of specific pollutant types is especially needed for pollution sources such as: treated sewage, sediments, nutrients, surface water run-off, aquaculture effluent, spilled oil, groundwater seepage and leachate from landfills. There is a high priority for determining the effects of the contaminants from these sources on coral reefs and lagoon systems, and the species they support.

There is a need to determine both short-term, acute effects and long-term chronic, cumulative effects of contaminants. Examples of the latter include the change in community structure and food web relationships caused by nutrients, and the effects of low levels of contaminants on fish and invertebrate reproduction.

The effects of contaminants in the nearshore marine environment on human health require additional research. It is necessary to assess the risk to human health of human pathogens and toxic substances. For example, there is concern about the human health risk of using nearshore recreational waters or in consuming harvested marine resources in much of the region.

7. Theme III: Effects of Coastal Development and Resource Use

A. Background to the Topic

Almost all but the most passive use of coastal areas or resources will bring about change. It is important to determine the extent of the changes that will result from development of coastal areas and the use of resources and how these affect water quality and ecosystem health. Different kinds of development will result in different effects, many of which are strongly influenced by the details of project siting, design, technology and construction and operation activities. Similarly, different kinds of resource use can have very different effects depending upon the location and amount of use, the technology and methods employed and the status of the resource base.

With an understanding of the likely impacts of development and resource use on coastal areas and resources, it is possible to develop management planning approaches or more specific management measures to avoid or mitigate adverse impacts. However, mitigative measures have often not been evaluated to determine if they work.

B. Aspects Unique to the Insular Pacific Region

Coastal development activities and the use of nearshore resources have a substantial effect on marine water quality and ecosystem health in the Insular Pacific Region. This is due to the limited extent of nearshore marine areas around Hawaii, Guam, CNMI and American Samoa and the very important role coastal areas and resources play in the economy, culture and life style of the islands. The situation is exacerbated by the fact that almost all development is in the narrow coastal strip surrounding most of the islands. Thus land use policies (e.g., for shoreline setbacks, settlement ponds) have an important influence on coastal ecosystem health.

Tourism is the leading industry in Hawaii, Guam and CNMI. Pristine environmental conditions, and a rich diversity of marine fauna and flora, are important factors which attract visitors to these islands. Protecting these assets, by limiting the damaging effects of coastal development and resource use, requires an understanding of those impacts. Marine recreation is also a very highly valued amenity service provided by nearshore waters and coastal lands of all the islands of the region. Overuse of the valuable coastal recreation space and values can lead to serious degradation of these amenities and values.

American Samoa and, to a lesser extent, CNMI, still support an important subsistence fishing economy. Recreational fishing is popular throughout the region. Maintaining water quality and habitat integrity are important aspects of maintaining subsistence and recreational fishing. Long-term degradation of the inshore marine ecosystem due to inappropriate development or over use of resources will contribute to the decline of fish populations and seriously impact those dependent on subsistence fisheries.

C. Priority Research Needs

The impacts of specific development project types on water quality and ecosystem health must be determined. The development activities of

interest vary around the region. For example, major concerns include: the discharge of saline wastewater from desalination facilities in CNMI; the infilling of nearshore reef flats and shoreline wetlands in American Samoa; golf courses built in coastal areas in Hawaii, CNMI and Guam; and dredging on coral reefs throughout most of the region.

It is usually necessary to conduct project evaluation, such as monitoring before, during and after construction of coastal developments, to clearly identify the effects of specific projects. In addition, post-project monitoring may be needed to determine whether mitigation measures are effective and should be applied to other similar projects.

There is also a need to evaluate the effects of resource harvesting on ecosystem health. This includes the impacts of various kinds of fishing, such as the impacts of tropical reef fish collectors on fish stocks, the impacts of game fishing and the impacts of gillnets on the nearshore fisheries. Resource use also incudes the increasing kinds and levels of recreational activities. Research into the impacts of visitor and recreational activities on marine water quality and ecosystem health is required to determine the kinds and level of uses which are sustainable.

It is not enough to merely understand the effects of development activities and resource use. Research is required to develop and evaluate mitigation and planning measures. Examples of these include determining: cost effective measures to limit siltation during construction, methods to protect adjacent habitats from the impacts of dredging, carrying capacity of particular areas to sustain the development or exploitation of resources, the value of closing areas to exploitative use and the role of traditional resource management practices in modern management.

There is a particular need to develop techniques to reduce the effects of contaminants. Land use policies need to be evaluated to determine the impacts of various land use practices on nearshore marine environmental quality. This includes evaluating different options to control and treat pollution, such as assessing alternative methods of wastewater disposal and determining the level of sewage treatment necessary. Pollution emergency response needs and capacity are also a subject of needed research, for example, determining whether Regional Response Team Contingency Plans adequately protect marine resources.

8. Theme IV: Analysis and Application of Research Results

A. Background to the Topic

The results of research and monitoring which improve the understanding of marine water quality and ecosystem health are often not available to the public, decision makers and managers. Scientific research must be subject to rigorous review and communicated through conferences and peer-reviewed publications. The results of research must be applied to educational, management and policy needs. Research can be specifically conducted to help determine the most effective educational, management or policy uses of information on the marine

environment. A better understanding of research results would also improve the ability of government agencies with regulatory responsibilities to develop appropriate and enforceable laws, regulations and standards to protect water quality and ecosystem health.

B. Aspects Unique to the Insular Pacific Region

Although there has been research undertaken on the nearshore marine environment in the Hawaiian Islands, Guam, and, to a lesser extent, CNMI and American Samoa, the public needs to be better informed about the ecology of nearshore marine environments, the status of the marine waters and ecosystems and the impacts of human activities on these. Improved efforts to inform the public of the results of research and monitoring, the status of marine water quality and ecosystem health and human effects on natural systems are important. Research can often play a role in identifying the most appropriate means to communicate this important information to the public in the Insular Pacific Region. Studies can also evaluate the ramifications of policy and regulatory options.

C. Priority Research Needs

There is a need to determine appropriate education programs that use the information obtained from marine environmental research conducted in the region. The need for appropriate educational programs in a number of areas has been identified, such as: the importance of the nearshore marine environment as a recreation area and a habitat for marine life; coral reef systems; the benefits of marine protected areas; citizen involvement in fisheries management; sewage disposal; and the role of streams and storm drains in transporting pollutants into the marine environment.

Policies are proposed by government agencies in Hawaii, Guam, CNMI and American Samoa on a variety of marine environmental issues. There is often a need to evaluate the effects these policies will have on marine environmental quality. Similarly, there is a need to identify ways to improve adherence to existing regulations and standards related to marine environmental quality, such as determining methods of defining violations of regulations or standards.

CHAPTER V: COORDINATION WITH EXISTING MARINE RESEARCH PROGRAMS

1. Nature of Existing Marine Research

An inventory of existing research programs concerned with marine water quality and ecosystem health in the region is presented in Chapter II and related appendices of this document. Most marine environmental research being conducted in the Insular Pacific Region is not regional in scope. Although some of the research undertaken may be potentially regional in application, most is fairly site specific.

Furthermore, most marine environmental research in the region has limited and finite temporal scope and does not address issues at the ecosystem level.

Marine environmental research is usually a function of, and oriented towards, the legislative mandate and mission of the funding or implementing agency. Research activities are typically conceived and developed on a project-by-project basis, without an interest in design, methodology or outputs which have regional applicability. There is currently no structure or mechanism which provides a framework for developing marine environmental research which is regional in scope or applicability.

At present there is limited sharing of the results of research on marine water quality and ecosystem health across the region. Information emanating from the marine environmental research which is taking place, even if it does have potential regional interest or applicability, often does not get widely circulated. Part of the reason for this is the limited interaction and coordination among agencies and organizations within each part of the region, as well as the very limited interaction and coordination among agencies and organizations within the region as a whole. There is no program or process to encourage, facilitate or coordinate the exchange of information and research results among those conducting marine environmental research within the region, although this does occur to some extent within each of the four political areas.

Overall there is a lack of coordination of research planning and implementation within the Insular Pacific Region. There has not been a process for identifying shared, regional needs and priorities, there is no single agency or organization which has the mandate or capacity to provide the coordination and planning of marine environmental research at a regional level. Because of this there is a potential for duplication of effort with a concomitant waste of resources.

2. Nature of Existing Information and Data

In many parts of the region, studies of marine environmental quality have been taking place for limited times and only in specific areas. For example, water quality monitoring data has been collected for a number of years at some sites in Hawaii and Guam, and, more recently, in CNMI and American Samoa. Numerous site specific studies of water quality and ecosystem conditions have been conducted as part of research projects, permit conditions or environmental impact assessments. However, the type of monitoring required and applied may not be sensitive enough to understand the cause of short-term perturbations. In addition, sampling design may not be sufficiently rigorous. The monitoring data may also not be collected or analyzed in a manner to identify cumulative impacts or long-term trends.

Currently there is no mechanism or process for ensuring that the results of research and monitoring activities are compiled or analyzed appropriately to provide the answer to pressing questions regarding marine water quality and ecosystem health. For example, although there are some monitoring programs in the region, particularly for water quality, there is a often a lack of appropriate analysis of monitoring data to provide information to managers.

Finally, the results of investigations are not always made available or presented in such a way as to assist managers and policy makers. The results of many of the monitoring programs are usually reported through "grey" literature. As a result, they may not find their way to scientists and researchers. On the other hand, scientific literature may not be readily available to managers and decision makers in a form that is useable. Although marine environmental problems experienced in Hawaii, Guam, CNMI and American Samoa are often similar, the response to these problems on one island may never be known to scientists and managers on another island, due to the lack of a process for coordinating and communicating this kind of information.

3. Need for Coordination with National, Regional and Global Programs

PRMRP must be well coordinated with existing marine research and management activities in the region. The coordination of research carried out by agencies and organizations actually located in the region will hopefully be achieved fairly readily, due to the direct input these bodies have had in developing the PRMRP Plan. The representation of each geographic area of the program on the PRMRP Board should ensure coordination with local agency programs.

It will be important for PRMRP to ensure the integration of related marine research activities conducted or supported by territorial, state or federal agencies and programs into the regional program. Although many of these programs are not as active in the Insular Pacific Region as they are elsewhere in the nation, most of them apply to the State of Hawaii, CNMI and the Territories of Guam and American Samoa. These activities include: the National Estuarine Research Reserve Program, the National Marine Sanctuaries Program, National Trends and Status Program, Natural Resource Damage Assessment, NOAA/EPA National Coastal Monitoring Act, National Sea Grant College Program and the National Ocean Pollution Planning Act. In addition, the EPA's Environmental Monitoring and Assessment Program, which is slated to be implemented in the Insular Pacific Region in a few years, will develop and standardize sampling and analysis protocols as well as identify indicator organisms and new technologies. This program will integrate well with proposed PRMRP programs.

The coastal and marine waters of Hawaii, American Samoa, Guam and CNMI are isolated from each other, except for the latter two which form a contiguous island chain. However, all of the island areas covered by PRMRP are part of the marine environment which is shared among all of the Pacific island countries and territories and is part of the entire Pacific Basin. Development and implementation of PRMRP should take

into consideration wider regional marine environmental quality research and monitoring programs. Marine research undertaken within the context of PRMRP should be coordinated with and, where possible, contribute to appropriate regional efforts and programs. Where regional programs form part of global programs, PRMRP likewise should seek to coordinate with, and contribute to, global efforts.

CHAPTER VI: RESEARCH PROGRAM AND PLAN IMPLEMENTATION

1. PRMRP Goal and Objectives

PRMRP goal

To increase our knowledge of the status, trends, functions, processes and components of marine ecosystems in the Insular Pacific Region through the development and implementation of a research program that will contribute to the maintenance and improvement of marine water quality and ecosystem health.

PRMRP objectives

Within the context of marine water quality and ecosystem health in the Insular Pacific Region, the objectives of the PRMRP are:

1) to encourage and enhance a regional approach to marine research, and improve regional coordination of marine research;
2) to support appropriate research on priority issues in all parts of the region, as determined by PRMRP Board and Guidelines;
3) to facilitate the collection, management and exchange of data and the synthesis, interpretation, dissemination and application of results and information.

2. Coordinating Role of PRMRP

PRMRP has been established to set priorities for regional marine and coastal research in support of efforts to safeguard water quality and ecosystem health. It has also been established to carry out research through grants and improved coordination. The overall role of PRMRP is to function as a coordination and clearinghouse program, with more specific functions in supporting research and managing data and information. The PRMRP Marine Research Plan provides direction for carrying out this mandate and role. The Plan reflects regional needs and priorities as identified by those agencies and organizations involved and concerned with these issues.

The program encourages and facilitates a regional approach to marine environmental research. It also provides a system for identifying research priorities and putting them in a regional framework. This provides an opportunity to link ongoing activities into a more comprehensive and better integrated framework, and should assist agencies and organizations in developing work programs, designing proposals and seeking funding.

Regular interaction of researchers, managers, educators and other parties interested in marine water quality and ecosystem health in the region will be fostered by the program. PRMRP should foster and sponsor scientific meetings and workshops on special topics, as part of its coordinating role. Such meetings and workshops can serve to identify topics of focus for the program and develop a more detailed research agenda for these topics of importance. In addition to aiding interaction among researchers, the program should foster exchange between scientists, educators and managers.

Overall, a coordinated regional marine research program will result in reduced duplication of effort, increased efficiency of research

investment, increased pooling and sharing of resources, increased potential for co-funding and a higher profile for marine environmental research.

3. Research Function of PRMRP

The resources of the program will not likely be sufficient to support a large amount of research in all of the priority themes and topics which have been identified. It will, however, provide support to appropriate projects in selected high priority topics as determined by the PRMRP Board. At the level of project identification and selection, PRMRP provides a process which identifies regional research needs, a comprehensive research framework which identifies gaps in research effort and a process for focusing on important research.

Projects which integrate ongoing efforts into the comprehensive regional framework will be encouraged, such as: projects which integrate research with monitoring, projects which lead to a long-term ecosystem perspective and projects which ensure methods and outputs are regionally applicable.

The implementation of projects will also benefit from coordination at a regional level. Project timetables could be coordinated so that projects with similar goals could be implemented in a coordinated fashion. Communication among agencies and organizations involved in related research could be improved and facilitated by the regional program.

4. Information and Data Management Function of PRMRP

PRMRP presents an opportunity to develop a process and structure for coordinating and managing marine research data and information on water quality and ecosystem health in the region. This could include developing and maintaining a regional data system and database, updating data sets, ensuring the compatibility of results and disseminating research results.

A regional marine research program should conceivably manage existing data, new data from planned projects not supported by PRMRP, new data generated by PRMRP supported projects and long time series data. The development of these capabilities will require consideration of data validity and compatibility. If research and monitoring data are to be comparable and compatible, the regional program will need to ensure the use of standardized reference methods and materials and standardized analytical procedures.

To handle the information and data, a coordinated, regional marine research program would require a data management system, a data management infrastructure and data exchange policies and procedures. The data management system should rapidly provide data results and analyses to managers and decision makers. It should also keep the research community and the broader community concerned with marine environmental quality informed through various methods. This could include a newsletter and dissemination of relevant research and studies (e.g., continued publication of the Pacific Research Titles [a current contents of Pacific island research journals]). More sophisticated

possibilities include the development of on-line Pacific database services (i.e., PRAIS, Bishop Museum collection on-line catalog) and an interactive program networked among agencies and organizations to allow rapid access to information and data.

5. Program Operations

PRMRP will require a staff to implement the role and functions of the program in close consultation with the PRMRP Board. Initially this will primarily consist of completing the annual research plan, including soliciting and reviewing proposals, and developing the annual research plan for submission to NOAA and EPA. This will be followed by project administration, management, tracking and reporting.

Every two years the program is required to provide a report on PRMRP. The report is to describe the research supported by the program, recommendations for improving the design or implementation of programs for the protection of the marine environment and available data and information concerning ecosystem health in the region. After four years it will be necessary to review and revise the PRMRP plan.

Fulfilling the broader, ongoing role of PRMRP, as a coordination and clearinghouse unit, will require the development of specific capabilities. In particular, it will be necessary to consider the extent of the PRMRP data and information management role. The PRMRP Board will need to determine the level to which these activities could and should be undertaken by the program, develop a strategy for developing the capacity and provide the resources and staff to undertake the functions.

PRMRP should be evaluated and revised as necessary throughout the implementation of the program by the staff and the Board. Especially in the initial stages, it will be important to have constructive feedback on the processes and mechanisms which are being developed. The Board may wish to build a more formal review and evaluation process into the operations of the program or for particular aspects of PRMRP.

6. Marine Research Plan Implementation

The themes and topics which have been identified as priority research needs for the Insular Pacific Region represent only a small portion of what might be included in a research program to address marine water quality and ecosystem health. Nonetheless, the research projects possible within even these limited number of categories are enormous. PRMRP will only be able to support research in a subset of the priority topics, largely as a function of the resources which are made available each year. The PRMRP Board will be required to narrow the focus of the Program to a scope and level which is manageable, practical and appropriate to the level of funding.

In determining a focus for the Program each year, the Board will strive to select a reasonable number of topics, or a cross-cutting subject area, and not restrict potential research to a single, limited topic area. Consideration will also have to be given to an appropriate time frame for the selected topics of focus, in order to ensure that support will be

available long enough to allow meaningful research to be undertaken. After the program has been in operation for a few years, it is likely that there will be some projects terminated and initiated each year, with a majority of multi-year projects underway in any given year. In addition, the Board will seek to achieve a balance of basic research and applied research which will address management questions.

A Request for Proposals (RFP) will be sent out by the PRMRP Board outlining the subject area and topics of focus determined by the Board for the coming year, and the broader focus for the current four-year period. The likely level of funding available will be indicated, along with the time table for the proposal process.

The proposal process will include the following stages: submission of preproposal; preproposal screening; notification and, if successful, request for full proposal; submission of full proposal; peer review of proposal; and, if required, revision of proposal. The PRMRP staff will compile completed project proposals into an annual research plan proposal for review by the Board and submission to NOAA.

7. Evaluation of Research Proposals

Proposals that are received by PRMRP will be evaluated according to a set of Guidelines that have been prepared by the Board. The Guidelines will be included in the RFP information to give prospective researchers an indication of the criteria upon which their proposals will be evaluated.

Guidelines for evaluating proposed research

(not in order of priority)

Does the research:

1) address a priority research need identified in the Marine Research Plan;
2) propose a project that is applicable to solving the problem or addressing the issue;
3) address the issue at a regional scale or produce results that are regionally applicable;
4) initiate, encourage or facilitate the involvement and cooperation of other agencies and organizations, particularly those within the Insular Pacific Region;
5) present a cost effective and sound research strategy, of reasonable scope and scale, which can be accomplished within a reasonable budget;
6) present a project that is appropriate to the capabilities, qualifications and mandate of the individuals and agency or institution involved;
7) present a project that will produce results in a reasonable time frame, while also addressing a long-term perspective on the issue;

8) complement or follow up on previous or current research;

9) present a multi-disciplinary, collaborative ecosystem level study;

10) include the appropriate and qualified institutions, agencies and expertise within the region and involve local scientists as much as possible;

11) respond to management needs and provide results that are applicable and useful to management and decision making?

8. Marine Research Plan Implementation Timetable (1993 - 1997)

Year one (FY 1993)

1) Establish Insular Pacific Regional Marine Research Program.

2) Initial Board meeting to organize Board and PRMRP Marine Research Plan development process (January, 1993).

3) Employ plan coordinator and staff (February, 1993).

4) Prepare Insular PRMRP Marine Research Plan.

5) Second Board meeting to review draft Pacific Regional Marine Research Plan (April, 1993).

6) Finalize draft Pacific Regional Marine Research Plan for review (September, 1993).

Year two (FY 1994)

1) Submit Final Insular PRMRP to NOAA/EPA (November, 1993)

2) Commence PRMRP coordination and information functions.

3) Develop 1995 Research Institutional Proposal (*)

   a) Issue request for proposals for FY 1995 funding.

   b) Acquire peer and agency reviews of proposals.

   c) Hold board meeting to consider FY 1995 proposals and reviews and select entries for Insular PRMRP Institutional Research Proposal.

   d) Complete final FY 1995 Insular PRMRP Institutional Research Proposal for NOAA/EPA approval.

4) Submit final FY 1995 Insular PRMRP Institutional Research Proposal for NOAA/EPA approval.

5) Commence early starts on research projects for approved projects as appropriate.

Year three (FY 1995)(**)

1) Continue PRMRP coordination and information functions.

2) Coordinate, manage and administer 1995 research program.

3) Develop 1996 Insular PRMRP Institutional Research Proposal.(*)(***)

4) Submit final FY 1996 Insular PRMRP Institutional Research Proposal for NOAA/EPA approval.
5) Initiate planning for second 4-year Insular Pacific Marine Research Program Plan.

Year four (FY 1996)(**)

1) Continue PRMRP coordination and information functions.
2) Coordinate, manage and administer 1996 Research Program.
3) Continue planning for second 4-year Insular Pacific Marine Research Program.
4) Develop 1997 Insular PRMRP Institutional Research Proposal.(*)(***)
5) Submit secnd 4-year Pacific Regional Marine Research Plan to NOAA/EPA.
6) Submit FY 1996 PRMRP Institutional Research Proposal for NOAA/EPA approval.

Years five - ten (FY 1997-2002)

Assuming that the Regional Marine Research Program will receive continued funding, the implementation of PRMRP will continue based on the second 4-year Insular Pacific Region Marine Research Plan.

* Includes proposals for national competition

** Pending congressional appropriation of FY 1995 funds for the National Regional Marine Research Program

*** See steps 1-4 under item 3 in FY (1994)

APPENDICES

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Appendix I.2 Information Sheet and Questionnaire

In 1990, "Title IV—Regional Marine Research Programs" of the South Carolina Fish Hatchery Act was passed. This Federal Legislation mandates the establishment of regional marine research programs to:

"(1) set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region" and

"(2) carry out such research through grants and improved coordination."

One of the regions provided for in the Legislation covers the marine and coastal waters of Hawaii, Guam, the Northern Mariana Islands and American Samoa.

The Pacific Regional Marine Research Board has been established, as called for in the Legislation, with members nominated by the Governors of Hawaii, Guam, the Northern Mariana Islands and American Samoa. The first function of the Board is to develop and submit a 4-year Pacific Regional Marine Research Plan to the Administrators of NOAA and EPA. Following acceptance of the Plan, the Board (through an Executive Officer) will administer grant funds it has received from NOAA for marine research projects which implement the Plan. The kinds of projects eligible for funding, after the Plan is approved, are listed in Attachment A.

Our immediate priority is to develop the Plan by May 1993 in order to gain access to the grant funds. The Plan is required to consist of:

1) An overview of coastal/marine environmental quality conditions and trends in the region;

2) An inventory and description of marine research related to water quality and ecosystem health expected to be conducted during the 4-year period;

3) A statement and explanation of marine research needs and priorities for the next 10 years, with emphasis on the upcoming 3-5 years;

4) An assessment of how the Plan will incorporate existing marine and coastal research and management; and

5) A description of marine research and monitoring objectives and timetables for achievement during the initial 4-year plan period.

We particularly need your assistance in addressing items 1) and 2) above in order to ensure that the Plan accurately represents the coastal/marine environmental situation in your area and incorporates all ongoing and projected marine research in the region. In addition, it is important that the marine research needs and priorities of your agency or organization are expressed so that these can be incorporated into the Plan's development. The Pacific Regional Marine Research

Plan will thus reflect needs and priorities of those tasked with understanding and protecting marine environmental quality and will lead to increased funding support for those activities.

The development of the Plan is being coordinated by Mr Paul Holthus, former Scientific Officer with the South Pacific Regional Environment Programme (SPREP), and a team: Dr Terry Donaldson for Guam/Northern Mariana Islands, Ms Nancy Daschbach for American Samoa and Mr Peter Rappa and others for Hawaii. These individuals will be following up with you directly with an telephone call to set up a visit, if your office is physically located in the region covered.

We have developed the attached questionnaire (Attachment B) to assist you in pulling together the information required. Much of the information may already be available in the form of annual reports, grant proposals or other documents. It would greatly assist us if copies of documents which assist in addressing items 1) and 2) could be made available to us. Documents which support any other aspect of the Plan would of course be most welcome as well. Information and documents which respond to the questionnaire can be provided during the visit to your office.

Those agencies/organizations involved in marine environmental research in Hawaii, Guam, Northern Mariana Islands or American Samoa, but which are not based in these areas, are requested to provide information and documentation in response to the questionnaire by mail or fax as soon as possible. If necessary, we will seek further information by telephone.

We must have your input in the very near future in order to develop a Plan which reflects your region's needs and priorities and still meet the May 1 deadline.

Thank you for your assistance. We look forward to your early response.

Paul Holthus

Coordinator, Pacific Regional Marine Research Plan Development
University of Hawaii Sea Grant

Attachment A

Projects Eligible For Funding Under Section 405 of Title IV, Regional Marine Research Programs

"(A) baseline assessment of marine environmental quality, including chemical, physical, and biological indicators of environmental quality;

"(B) effects or potential effects of contaminants, including nutrients, toxic chemicals and heavy metals, on the environment, including marine and aquatic organisms;

"(C) effects of modification of habitats, including coastal wetlands, seagrass beds and reefs, on the environment, including marine organisms;

"(D) assessment of impacts of pollutant sources and pollutant discharges into the coastal environment;

"(E) transport, dispersion, transformation, and fate and effect of contaminants in the marine environment;

"(F) marine and estuarine habitat assessment and restoration;

"(G) methods and techniques for modeling environmental quality conditions and trends;

"(H) methods and techniques for sampling of water, sediment, marine and aquatic organisms ,and demonstration of such methods and techniques;

"(I) the effects on human health and the environment of contaminants or combinations of contaminants at various levels, whether natural or anthropogenic, that are found in the marine environment;

"(J) environmental assessment of potential effects of major coastal and offshore development projects in the region;

"(K) assessment of the effects of climate change on marine resources in the region; and

"(L) analysis and interpretation of research data for the benefit of State and local environmental protection and resource management agencies in the region."

Attachment B

QUESTIONNAIRE

I. INVENTORY AND DESCRIPTION OF ALL MARINE RESEARCH RELATED TO WATER QUALITY AND ECOSYSTEM HEALTH EXPECTED TO BE CONDUCTED FROM 1993-1997

1) Agency/Organization Name; Program Name
2) Responsible Officials (head of agency section; program supervisor/implementor)
3) General Purposes of Research Sponsored by the Program (problem/issue addressed; goals/objectives; scope; time frame; proposed outputs)
4) Administrative Character of the Program (other agencies/ organizations involved; cooperation/decision making body and process; advisory/review bodies and process)
5) Technical Character/Funding Levels of the Current Research Program (project description - including title, project leader, project outline; actual activities of each year; funding level by year)
6) Technical Character/Funding Levels of the Projected Research Program through 1997 (project description for planned activities and funding levels; project proposals/projections; indicate probability of proposals/projections being implemented)

II. RESEARCH NEEDS AND PRIORITIES

1) What are the marine environmental research needs and priorities which this agency/organization would like to address or should be addressing?
2) What are the other marine research needs and priorities which should be addressed in the region?

III. INTEGRATION OF RESEARCH INTO REGIONAL RESEARCH PROGRAM

1) How can the Regional Research Program best integrate current and projected research with research needs and priorities in the region?

IV. OTHER AGENCIES/ORGANIZATIONS WHICH SHOULD BE CONTACTED

Appendix I.3 Characteristics of the Coastal and Marine Environment - American Samoa

1. Characteristics

1.1 Geography

American Samoa is located at 14°S 172°W, approximately 2,500 miles southwest of Hawaii. Composed of six inhabited islands and one uninhabited atoll, the territory comprises 76 sq mi. Five of the islands, including the political center, Tutuila, are high volcanic islands about 10 million years old. These five islands are part of the larger Samoan archipelago which also includes several islands in Western Samoa. The islands are rugged and steep with very limited coastal lowlands. The windward sides of the high islands have steep cliffs which drop directly into the sea. American Samoa also includes two outlying low islands, Rose Atoll and Swain's Island, a small, slightly raised atoll.

Tutuila and the other high, volcanic islands have numerous short, steep streams, but no large rivers. There are extensive freshwater lenses close to sea level, as well perched lenses at higher elevations. The only source of freshwater on the atolls is a very shallow, brackish water lens of groundwater.

1.2 Climate

Rainfall on Tutuila averages between 100 and 200 inches a year with the Pago Pago Harbor area receiving the highest recorded rainfall (U.S. Department of Commerce, 1992). The hurricane season is from October through March although the winter is also subject to storms and rain. Severe storms occur almost every year and there have been three hurricanes in the last seven years.

1.3 Oceanography

Other than bathymetric charts and water temperatures for Pago Pago Harbor, there is little information on the oceanographic conditions of American Samoa. There is some data on currents in Pago Pago Harbor and areas near the deep ocean dump site for the tuna cannery sludge.

1.4 Demography

Tutuila has the highest population of all the American Samoan islands with 46,773 inhabitants in 1990, representing an increase of 40% since 1980 (U.S. Department of Commerce, 1990). The rapid population increase is due to immigration and a high birth rate. The largest immigrant population in American Samoa consists of Western Samoans (over 14,000), followed by non-Samoan U.S. citizens and Tongans. Most Pacific Island and Asian immigrants come to American Samoa for jobs and a more Western standard of living.

Approximately 59% of American Samoa's population is below the age of 18, putting a serious strain on schools and public health services. More American Samoans live in the U.S. than in American Samoa. The largest employers are the two tuna canneries, Star-Kist and Samoa Packing, which pack about 75% of the tuna consumed in the U.S. Three-quarters of the cannery workers are Western Samoan. The largest employer of American Samoans is the territorial government with over 4,000 employees (U.S. Department of Commerce, 1990).

2. Coastal and Marine Ecosystems and Biodiversity

2.1 Coastal watersheds

Due to the small size of the Samoan islands, the entire land area is included in watersheds which open to the coast. The watershed on the five high islands of the territory include rock or sand beach, wetlands, lowland rainforest, upland rainforest and, on Tau, cloud forest. The two atolls have a low diversity of terrestrial flora and fauna typical of mid-Pacific low islands.

American Samoa enjoys the most diverse plant and animal assemblage in Polynesia. There are three native mammals, all bats, one species of which, Pteropus samoensis, is endemic (Amerson et al., 1992). These populations have suffered serious depletions in the last few years, primarily due to hurricane effects, habitat loss and hunting. Forty-five bird species, representing 24 families, make birds the most diverse group of animals in the terrestrial fauna (Muse and Muse, 1982). Native pigeon and dove populations declined precipitously following the hurricanes in 1990 and 1991 and hunting of these has been banned as well. There are 17 species of amphibians and reptiles, including three introduced species (Amerson et al., 1982). Feral populations of introduced mammals include pig, four rodents species (three rats and the house mouse) and domestic cats.

2.2 Shoreline

2.2.1 Beaches

Beaches around American Samoa are limited and are generally rocky with sandy pockets in the lee of bays. The major rock type is basalt. Beach sand is composed primarily of coralline sediment (Aquatic Farms, 1980).

2.2.2 Mangrove/Wetland

Over 400 acres of wetlands, including mangrove swamps, freshwater swamps, saltwater marshes, freshwater marshes, cultivated wetlands and ruderal or disturbed wetlands, are found on Tutuila and Aunuu (Biosystems Analysis, Inc., 1992). Some of these have been identified as special management areas. These areas have a rich plant diversity and many are nurseries for coral reef and pelagic fishes. There has been a loss of approximately 10-20% of wetland areas since European contact.

2.3 Nearshore

2.3.1 Coral reefs

All the Samoan islands are surrounded by fringing coral reefs. These characteristically have a reef flat that extends 100-300 yards seaward before dropping off to a spur and groove ridge or reef wall. There are some offshore banks (remnants of barrier reefs) which rise to within 50 feet of the ocean's surface. The waters around American Samoa support approximately 200 species of coral representing 50

genera, 991 species of fish representing 113 families, and 50 algal species (Aquatic Farms, Inc., and AECOS, Inc., 1980; Wass, 1984).

2.3.2 Lagoons

There are two relatively small, shallow lagoon areas on Tutuila, Pala Lagoon and Leone Pala.

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Appendix I.4 Characteristics of the Coastal and Marine Environment - Guam and Commonwealth of the Northern Mariana Islands

1. Characteristics

1.1 Geography

The Mariana Islands are located in the western Pacific along a line that straddles the Pacific and Philippine seas. The archipelago consists of two separate arcs, the older (35-45 million years before present) southern islands (Guam, Rota, Aguigan, Tinian, Saipan, Farallon de Medinilla and associated islets), and the younger (1-1.5 mybp) northern islands (Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug and Uracus or Farallon de Parajos). The southern islands are composed of raised limestone on a basalt foundation, with mixed laterite and carbonate soils. Southern Guam is volcanic, however, with strong laterite development. The northern islands are volcanic with some laterite development. Pagan and Uracus islands are regularly active and all but Maug and Sarigan display some form of recent activity. Active seamounts also occur offshore (Emery, 1962; Randall and Eldredge, 1976; Eldredge and Randall, 1980).

1.2 Climate

The Mariana Islands lie north of the intertropical convergence zone and experience westerly trade winds. The weather is tropical, with a dry season from December to May and a rainy season from June to December. Temperatures and rainfall vary with latitude and season; Guam's average annual rainfall is approximately 80-90 inches.

1.3 Oceanography

The archipelago is bordered by the Marianas Trench to the southeast and the Marianas Trough to the west and depth increases rapidly offshore of all of the islands. Water temperatures, currents and water circulation patterns have been studied mainly around Guam (e.g., Lassuy, 1979; Amesbury and Babin, 1990). However, baseline data are lacking for much of the archipelago.

1.4 Demography

Guam has a population of approximately 125,000 people. The population of the northern Mariana Islands (excluding Guam) is approximately 45,000 of which less than 50% are U.S. citizens. Saipan has a population of 45,000. The northern islands are virtually uninhabited.

Both Guam and the other Mariana Islands (especially Saipan, Rota and Tinian) receive several thousand tourists annually, which contribute significantly to resource utilization and environmental health problems.

2. Coastal and Marine Ecosystems and Biodiversity

2.1 Coastal watersheds

There is only limited surface water drainage from the limestone plateaus of the southern Mariana Islands (Saipan, Tinian, Rota and northern Guam). Numerous streams cut through the erodable lateritic soils which compose the low mountains of the southern half of Guam and deposit considerable sediment loads in the nearshore marine

environment. The terrestrial flora and fauna of these islands is highly altered due to disturbance during the war, grassland fires and modern development activities. The small northern Mariana Islands have short, steep watersheds, some of which are relatively undisturbed by human activity.

2.2 Shoreline

The shoreline of the southern islands consists of alternating beaches, estuaries, mangroves, raised limestone platforms at lower elevations and extensive cliff development at higher elevations (especially northern Guam and Aguigan). In the northern islands, shorelines consist of beaches, raised platforms of eroded volcanic rock and cliffs. Information on the shorelines of the Mariana Islands have been compiled in a number of reports (Emery, 1962; Randall and Holloman, 1974; Randall and Eldredge, 1976; Eldredge and Randall, 1980).

2.2.1 Beaches

Beach development is moderate to low on all of the Mariana Islands, but is more pronounced on Guam, Saipan and Rota. Most beaches are comprised of coral sands and rubble. Beaches of the northern volcanic islands consist of black volcanic sand and cobble. The beaches of Guam are described in Randall and Eldredge (1976), and those of Saipan, Tinian and Rota, in Eldredge and Randall (1980).

2.2.2 Estuaries/Mangrove

Estuaries occur only in the southern and south-central portion of Guam where extensive mangrove development occurs, and at a single site on Saipan where mangrove development occurs to a lesser extent. Mangrove development is largely limited to estuarine areas of Guam, including Apra Harbor, and within Saipan's lagoon (Randall and Holloman, 1974; Stojkovich, 1977).

2.3 Nearshore

Nearshore marine habitats consist of reef flats, coral patch reefs, rubble fields, sand and mud flats, boulder fields, reef pavement and seagrass and algal beds. Nearshore marine areas have been surveyed to some extent on Guam, and some work has been done on Saipan, Tinian, Rota and the northern islands, usually in relation to proposed or actual human activities and impacts (e.g., Marsh and Gordon, 1972; Jones and Randall, 1973; Eldredge, 1979; Randall et al., 1988).

2.3.1 Coral reefs

Coral reefs are well developed in the southern islands but are less extensive in the northern islands, where limited coral communities occur on submerged basalt. Most reefs are fringing or patch reefs, however, barrier reefs are found on Guam, Tinian and Saipan. Extensive coral reef development has been discovered off western Anatahan and off southern Sarigan, in the northern islands. Surveys of coral reefs have largely been restricted to the southern islands (Coigan, 1982; 1987).

2.3.2 Lagoons

Lagoons are well developed on Saipan and Guam (Cocos Lagoon) only. Apra Harbor, which is protected by a barrier reef upon which a breakwater has been constructed, has many characteristics of a lagoon. Lagoon systems in the Mariana Islands have been described in Randall and Holloman (1974), Gawel (1974), Randall et al. (1975) and Randall and Sherwood (1982).

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Appendix I.5 Characteristics of the Coastal and Marine Environment - Hawaii

1. Characteristics

1.1 Geography

The Hawaiian Archipelago is comprised of 132 islands, reefs and shoals stretching 1,523 miles southeast to northwest. The islands range in latitude from 18° 54' to 28° 15' N. There are eight main high, volcanic islands: Hawaii, Maui, Molokai, Lanai, Kahoolawe, Oahu, Niihau and Kauai of which only Kahoolawe is uninhabited. The total land area of the archipelago is 6,425 sq mi. The islands and submerged reefs north of Kauai to Midway Island, known collectively as the Northwestern Hawaiian Islands, are uninhabited and are a National Wildlife Refuge.

Each of the main islands is volcanic in origin. The island of Hawaii has two volcanic peaks over 13,000 ft high. The rugged interior of each of the main islands renders about 12 percent of the land unusable for development or agriculture (University of Hawaii, 1983).

1.2 Climate

The prevailing winds are northeast tradewinds which are present about 75% of the year. Between October and April, the Hawaiian Islands come under the influence of the southerly or kona winds which bring increased moisture and storms (University of Hawaii, 1983) bringing as much as 20 inches of rainfall in a 24 hour period (Stearns, 1946). Rainfall amounts vary throughout the islands with some areas receiving as little as 10 inches and some receiving as much as 400 inches a year (University of Hawaii, 1983). Average temperatures vary little in Hawaii; the average for March, the coolest month, is 74-75°F and for September, the warmest month, 79-80°F (Carlquist, 1980).

1.3 Oceanography

Current patterns around the Hawaiian Islands, as well as wave, salinity and water temperature patterns, vary moderately with the seasons and in relation to the cyclonic storms of the North Pacific which are closer and more frequent in the winter. Local surface currents are modified by the shapes of the islands and tides. In addition to the wind waves generated by the northeast tradewinds most of the year, Hawaii is affected by large ocean swells from the north in winter, by moderate south swells in summer and by west/southwest swells generated by more localized storms in winter and spring (University of Hawaii, 1983). Tsunami waves rarely affect Hawaii, but can be devastating when they do occur.

1.4 Demography

The population of the State of Hawaii was over 1.1 million in 1990. This represents a 15.3% increase during the decade 1980-1990 (Hawaii Data Book, 1991). The majority of the resident population, 841,000, lives on the island of Oahu in the City and County of Honolulu. The average population density for the islands is 197 people per sq mi with the high on Oahu Island of 1,536 people per square mile and a low on Hawaii Island of 34 people per sq mi.

2. Coastal and Marine Ecosystems and Biodiversity

2.1 Coastal watersheds

The Hawaiian Islands are characterized by mountainous interiors with steep amphitheater-headed valleys extending from the top of the ridges to the ocean. The climatic variability due the dramatic rise of valley walls and the direction of the prevailing winds provide for a range of habitats, e.g, from rainforest and bogs in the higher elevations to dryland forest and desert at the lower elevations. Below 500 meters in elevation, watersheds have generally been disturbed with most native species being replaced by introduced species. Upland forested areas are held in forest reserve for watershed protection and are generally less disturbed.

There are approximately 2,500 species of endemic plants in the Hawaiian islands. There are representatives of 10 families of birds and one family, the Hawaiian honeycreeper, which is endemic to Hawaii. However, of the 67 uniquely Hawaiian birds 40% are thought to be extinct and another 40% are thought to be endangered. There is only one native land mammal, the hoary bat. The Polynesian rat, domesticated dog and pig accompanied the early Polynesians to the islands.

2.2 Shoreline

2.2.1 Beaches

There are approximately 750 miles of coastline around the main Hawaiian islands. Of that 185 miles are listed as sandy shoreline (Hawaii Data Book, 1991).

2.2.2 Mangrove/Wetlands

There are no native mangroves in the Hawaiian Islands although introduced species can be found in several isolated places throughout the island chain, most notably on Oahu in Kaneohe and Kahana Bays. There are several small wetlands and lakes in the Hawaiian islands. Together they add up to approximately 25 sq mi of inland waterways. Kealia Pond on the island of Maui and Kawainui Marsh on Windward Oahu are the two most significant shoreline wetland areas in the State (Hawaii Data Book, 1991).

2.3 Nearshore

2.3.1 Coral reefs

With the exception of Hawaii Island, the main islands are partially ringed by fringing coral reefs. The island of Hawaii has a developed subtidal reef off the west coast. The Hawaiian Islands are at the northern extreme for reef building coral development and therefore has fewer species of corals (roughly 60) than other areas in the Pacific. Reef growth is slow due to cool water temperatures.

2.3.2 Lagoons

There is only one major lagoon area in the main Hawaiian Islands, Kaneohe Bay on the windward side of Oahu. The Northwestern Hawaiian Islands include several atolls with lagoons.

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Appendix II.1 Marine Environmental Conditions - American Samoa

1. Coastal Area Development

1.1 Watershed land use

Due to the small size of the American Samoan islands, all land area is contained within the coastal zone. Because several of the islands have rugged terrain which is covered by native vegetation, options for changes in land use are limited. The human population is concentrated in villages in low-lying coastal areas, particularly around Pago Pago Harbor on Tutuila Island.

Tutuila, the governmental and population center, has an extensive road system with one main road along the entire southern shoreline, extending partway around to the north on the west and east ends of the island. There are very few roads on the northern shoreline and only a few villages or other development exists there. Road building has slowed in recent years due to lack of funding.

Other than an agroforestry project at the community college Land Grant program, there is no concerted forestry production in the territory. However, the clearing of rainforest for housing and plantation expansion is an increasing problem. Agriculture tends to be primarily for family subsistence although there are larger plantations that supply small local markets with bananas, taro, pineapple, coconut and a few garden vegetables. There is limited use of commercial pesticides although occasionally land will be cleared by first spraying with an herbicide, followed by cutting and burning.

1.2 Manipulation of hydrologic cycles

There is no major damming of streams for hydroelectric production or water supply. Most villages on Tutuila are connected to the government water system which draws from the groundwater lens. Those that are not, rely on village wells or on rainwater catchment. Groundwater continues to be uncontaminated, although during drought years there is noticeable saltwater intrusion. There is concern that the increasing population pressure on the groundwater resource will begin to compromise the freshwater lens by overtaking the recharge rate. Local manipulation of stream beds is a fairly common response to the frequent flooding during downpours and virtually every village has incorporated some stream control measures.

1.3 Shoreline development

On highly populated Tutuila, the coastal road, along with phone and power lines, follows much of the southern shoreline of the island. This infrastructure has been under increasing threat from shoreline erosion, primarily due to storm damage. Many areas have been reinforced with rock fill or seawalls, particularly where the road is next to the beach.

A large percentage of the shoreline and shallow nearshore reefs and mud flats of Pago Pago Harbor have been dredged and filled. A rigorous coastal management program now regulates, though in some cases does not prohibit, shoreline development. Pago Pago Harbor has a large port including a large container yard, fuel dock and marina. The canneries also have docks in Pago Pago Harbor and there is a large commercial

marine railway in the harbor. There are also small harbor sites elsewhere on Tutuila and Aunuu, as well as at Tau and Ofu. Airports on Tutuila, Tau and Ofu are built near the shoreline and include landfill and shore protection structures.

Mangroves, which were formerly much more extensive and found on all the high islands of the territory, have been reduced to two remnant forests on Tutuila (Biosystems Analysis, Inc., 1992). Mangrove clearing and filling of wetlands is now prohibited by law, though violation is not uncommon. A more vigorous enforcement and education program has helped improve the situation in the last few years. The two remaining mangrove forests at Pala Lagoon and Leone Pala are designated by the American Samoa Coastal Management Program (ASCMP) as special management areas, as is Pago Pago Harbor. There are three shoreline parks on Tutuila, including one along Pala Lagoon.

2. Land-Based Pollution Sources

2.1 Point sources

A significant amount of freshwater enters the ocean around the islands of American Samoa from streams and drainage ditches. With the storm waters come sediment and garbage which fan out in a plume over the reef following heavy rains. Streams and drainage ditches are major transport vehicles for non-point sources of pollution carrying household garbage and yard waste of all kinds. It also is not uncommon for piggery waste to be washed into the streams, though this practice is illegal. Human waste, aside from soiled diapers, is probably no longer a direct product in most streams, but seepage from cesspools may be significant. Hazardous materials and waste oil may be dumped in streams on occasion. Streams also carry soil eroded from hillsides exposed during road building, construction or agricultural clearing, or by natural causes such as landslides.

Seventeen percent of Samoa's households are connected to the government sewer system (U.S. Department of Commerce, 1990); over 65% of the households around Pago Pago Harbor are connected and all households around Pala Lagoon are connected. More than half of the households have indoor plumbing and those that are not connected to public sewage have septic tanks (although these are often improperly installed), cesspools or some other method of waste handling. There are sewage outfalls in Pago Pago Harbor at Utulei village and at Fagagogo, near the airport runway and waste is treated at the primary level. The primary waste treatment plant in Utulei is being renovated and is expected to reopen in 1994.

The only power plant outfalls in American Samoa are storm drains that may occasionally collect some oil, but are not a significant source of oil or fuel pollution. The fuel dock in Pago Pago Harbor does not have properly maintained containment equipment (Lt. R.Clark, U.S. Coast Guard, pers. comm.). This, coupled with reportedly lax fuel transfer practices, results in some spillage makes its way into the harbor during fuel transfers.

Until recently, cannery wastewater, high in nutrient content, was pumped directly into the inner harbor near the canneries. Since 1992, a new pipeline discharges the water in the outer harbor at a depth of 180 feet. The cannery plume is predicted to stay below 60 feet and to wash out of the harbor (S. Wiegman, American Samoa Environmental Protection Agency, pers. comm.). Since the pipeline began operation, there has been a notable increase in water clarity in the inner harbor. Cannery sludge is transported twice daily to an ocean dump site 5.5 miles from Pago Pago Harbor. Both of these sites are subject to routine water quality monitoring.

There is one official landfill on Tutuila, an upland site, which is managed by the government public works department, and there is one official metal dump. American Samoa has a waste oil collection scheme whereby waste oil can be taken to designated sites from where it is collected and burned in one of the canneries. Currently, the only recycled products are aluminum cans and some glass beer bottles. There are many unofficial dumps, mostly along the shoreline or in streams. Solvents, paints, household cleaners and other potential hazardous waste materials are not a significant element in the waste stream. The U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers have each periodically sponsored hazardous waste cleanup collections and taken the collected materials, primarily pesticides and chemicals, off-island.

2.2 Non-point sources

Fertilizers are not considered to be a significant non-point source pollutant in American Samoa as they are too expensive for use by most farmers. Pesticides are not a significant non-point source pollutant in American Samoa. Their use is discouraged by the Land Grant program and alternative "natural" pesticides, such as intercropping or Dipel (a microbial pesticide), are promoted. The most commonly used herbicide is paraquat and the most commonly used insecticide is malathion. All pesticides are regulated by the ASEPA and Land Grant. Farmers must first take a pesticide applicator course to obtain any pesticide. Pesticides have never been detected in groundwater monitoring (S. Wiegman, American Samoa Environmental Protection Agency, pers. comm.). Sediment is a significant non-point source pollutant. Virtually every village has some sedimentation problems primarily due to poor erosion control measures during construction or road building. In many villages sedimentation has led to marked degradation of the nearshore reefs.

Perhaps as much as 75% of all septic tanks are improperly sited (M. Dworsky, American Samoa Power Authority, pers. comm.). These act essentially as cesspools and may be contribute to the pollution of groundwater, surface waters and, potentially, nearshore marine waters. Recently, the American Samoa Power Authority (ASPA) took this matter under their purvey and now grant power and water hookup only to new houses that have properly installed septic tanks.

3. Ship-Based Pollution Sources

3.1 Petroleum hydrocarbon transport/offloading

Fuel is offloaded from tankers at the fuel dock and is pumped to storage tanks about one-half mile away. Handling procedures during offloading are reportedly lax and there is usually some spillage. The dockside containment measures are inadequate, allowing any large overflow or other spillage to run into the harbor. There is currently a grant to repair the fuel dock and work is expected to be completed in 12 to 18 months. Fuel for the canneries and power plant is taken over land by truck and there has been little problem with this method of transfer thus far.

3.2 Ship operations - fuels, wastewaters

Although strictly regulated and patrolled by the U.S. Coast Guard and the Department of Public Safety's Marine Enforcement Division, Pago Pago Harbor is subject to many fuel spills primarily from fishing boats that service the canneries. These include Korean and Chinese longliners and American purse seiners which can number from 10 to over 80 vessels. Cargo ships, tankers and the occasional cruise ships also visit the harbor but stay no longer than a few days and are only infrequent violators.

Bilge pumping by some vessels is common inside Pago Pago Harbor during the night even though there is a local company that operates a bilge reception service. According to the U.S. Coast Guard, there are over 100 petroleum spills per year in the harbor. The average size for a spill is from 100-150 gallons and the largest spills are in the 300-400 gallon range. The Coast Guard investigates larger spills and will access federal funds to clean up those which they can. Brine water from fishing boats is a regulated wastewater and could potentially cause problems when this hypersaline cold water, which also contains some fish wastes such as blood, is dumped into the harbor.

3.3 Ship operations - solid wastes, dumping

Solid waste disposal from ships is a chronic low-level problem when ships are in port. Most ships dump the majority of their solid wastes when they return to sea. There is no surveillance for determining whether these ships are dumping in proper areas.

3.4 Pleasure boats

There is a small resident population of yachts (<20) in Pago Pago Harbor. During hurricane season, as many as 50-100 yachts are in the harbor, most of which remain for up to six months from November through March. These boats, for the most part, discharge all wastewaters into the harbor as there is no pumpout facility. However, all boats must have a marine sanitary device. Solid waste discharge into harbor waters from these vessels is not a significant problem.

4. Marine Contaminants in Water, Sediment and Biota

4.1 Trace metals

A preliminary toxicity study of Pago Pago Harbor and Pala Lagoon found high levels of some heavy metals in some locations. High levels of copper, lead, mercury, cadmium, arsenic and silver were each found in at least one of the sediment samples, although there were no high lead levels reported from the Pala Lagoon samples (AECOS, Inc., 1991). In water samples, copper and zinc exceeded criteria values. In fish tissue samples, chromium, copper, mercury, lead and zinc levels were found to be high. As a result of this testing, the government has issued warnings against eating fish from the inner harbor and a more detailed study will be conducted in the near future.

4.2 PCBs and chlorinated hydrocarbons

PCBs are not a significant pollutant. All but one transformer containing PCB have been moved off-island. There were some PCBs (Arochlor 1260) detected in the soil in front of the power plant and in sediment samples from the inner Pago Pago Harbor (AECOS, Inc., 1991). There has been some detection of DDT derivatives (p,p-DDE and p,p-DDD) in the liver of mullet caught in the inner Pago Pago Harbor, however, this finding was from a single sample.

4.3 Petroleum hydrocarbons

High levels of oil and grease were detected in Pago Pago Harbor during the preliminary toxicity study, but because polynuclear aromatic hydrocarbons were not found in the study, the speculation in the preliminary report is that most of the oil and grease is from fish cannery wastes (AECOS, Inc., 1991). Aua Village along Pago Pago Harbor was used by the U.S. Navy to store fuel and oil, contaminating the soil beneath the site. Because the site is in a village and a large-scale project removing the contaminated soil is impractical, the U.S. Army Corps of Engineers is implementing an experimental project to clean up the site that will allow natural breakdown of the contaminants.

4.4 Radioactivity

Radioactive contamination has not been recorded in American Samoa and there is little likelihood of there being any. Radon testing was conducted by the American Samoa EPA and there were no significant findings.

5. Use of Living Marine Resources

5.1 Use levels and patterns

Reef resources, especially from reef tops and reef fronts, are heavily harvested by subsistence and artisanal fishermen and women. People gleaning resources on the reef tops will take virtually anything alive, although octopus, certain molluscs, large crabs and tidepool-bound fish are preferred. The shoreline subsistence fishery has dropped by 50% over the past decade and it is assumed that part of that decline has been due to overexploitation (Craig et al., in press). Artisanal pelagic fisheries have also declined precipitously for several reasons: hurricane-related

damages to ships and gear, a decline in the number of fishermen and competition with imported fish. However, there is no evidence that the pelagic fisheries have ever been resource limited (Craig et al., in press).

There is a small, but active, bottom and offshore pelagic fishery. The bottom fishery is resource limited as proved by failed attempts to develop this fishery in the early 1970s and the mid-1980s. With each attempt, there was an initial high catch that declined over time (in 1983 20,000 lbs were landed but by 1985 the catch had declined to 6,000 lbs even though catch effort rose).

5.2 Overharvested species

Overharvesting has eliminated one species of giant clam (Hippopus hippopus) and has seriously reduced other giant clam populations. Creel surveys in the last two years have reported no clam catch. Lobster and perhaps some crab populations show serious overharvesting effects and creel surveys show the catch to be 20% of 1981 levels.

5.3 Destructive fishing practices

Dynamite and poison fishing occur on all the inhabited islands of American Samoa even though both practices are illegal throughout the territory. Poison fishing takes one of several forms: the traditional use of juice from the seed of the *futu* (*Barringtonia asiatica*) or the root of the *ava niukini* (*Derris malaccensis*), or the modern use of bleach (Ponwith, 1991).

5.4 Exploitation of endangered species

Marine turtles are a traditional food source and, although rigorous enforcement of regulations by the Department of Marine and Wildlife Resources (DMWR) has curtailed their harvest, the taking of turtles has not been entirely eliminated. Both hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) nest in American Samoa and their eggs are subject to illegal harvesting. The sale of turtle products is strictly prohibited although there continues to be violations. Killing or harassing marine mammals has not been reported as a problem in the territory. Humpback whales (*Megaptera novaeangelica*) calve and may mate in Samoan waters.

5.5 Introduction of exotic species

There have been several mariculture programs introducing exotic species. In the mid-1960s ciclids (*Tilapia* sp.) were introduced to fresh and brackish waters on Aunuu and that population continues to thrive. A giant clam (*Tridacna derasa*) mariculture project is currently run by DMWR.

6. Use of Non-living Marine Resources

6.1 Beach sand extraction

Samoans have traditionally extracted beach sand and larger broken coral for a variety of uses in the village and, although sand mining is illegal, the practice continues. There is virtually no enforcement of the

law prohibiting beach sand mining and therefore no way to monitor the amount of beach sand which is being removed. There are no extensive sand beaches on Tutuila making the incidental mining of beach sand a potentially serious problem.

6.2 Coral reef dredging

Coral reef dredging was significant in the past particularly in the Pago Pago Harbor area, in the vicinity of the airport and at the small boat harbors. Now, however, dredging proposals are subject to rigorous environmental review. A current project in Manua for the Faleasao Harbor will blast and dredge approximately 10 acres. As a mitigation measure, the government is setting aside 40 acres at another site as an underwater reserve.

6.3 Marine sand mining

There is no offshore removal of sand from lagoon deposits or other submerged sediment areas of American Samoa.

6.4 Deep seabed mining

There are no deep seabed mining projects in American Samoa waters.

7. Ecosystem Effects

7.1 Water quality degradation

Water quality degradation is a problem at several locations on Tutuila. Sedimentation has caused water quality problems at many reefs (AECOS, Inc., 1991). Pago Pago Harbor water quality is seriously degraded from many sources: sedimentation, years of cannery operation and waste discharge, 50 years of marine railway operation, sewage, garbage and frequent oil spills. Until recently, algal blooms limited visibility in the inner harbor to a few inches.

The water quality of Pala Lagoon, the location of the largest mangrove area in American Samoa, has been compromised by the extension of the airport runway which inhibits water transport in and out of the lagoon. Increasing sewage from piggeries and cesspools going into the lagoon from adjacent villages also contaminate the water. Twenty years ago a primary treatment station was opened in Tafuna and all the households around Pala Lagoon were connected to the government sewer line in the late 1980s. However, high coliform counts in Pala Lagoon due to piggery waste may threaten shellfish harvesting.

7.2 Habitat damage/destruction

Habitat damage due to both human and natural causes is widespread in the nearshore marine environment of American Samoa, particularly for the coral reefs and mangroves. Most of the reefs in American Samoa have been damaged by recent hurricanes and some suffer additional abuses from land-based pollution sources, primarily sedimentation and nutrient release. Much of the coral reef in Pago Pago Bay has been dredged or filled and in embayments where there are

villages, sediment deposition from terrestrial erosion is a major source of degradation. The formerly extensive distribution of mangrove has been reduced to two main stands due to harvesting and clearing and there continues to be illegal encroachment along the margins of the remaining mangrove stands.

An outbreak of the coral-eating crown-of-thorns starfish, *Acanthaster planci*, occurred on Tutuila in the late 1970s. In some areas, over 90% of the coral cover was destroyed and few reefs were left unaffected (Birkeland et al., 1987). Except for occasional fish kills in Pago Pago Harbor, there is no information on population die-offs. Coral bleaching has been observed, but is not yet considered to be a serious problem and there has been little or no coral mortality.

7.3 Species depletion/extinction

The giant clam, *Hippopus hippopus*, is extinct in American Samoa and other clam species are seriously depleted. Lobsters, and probably crabs, are depleted; there is no information on other coastal species.

8. Public Health Effects

8.1 Marine food pathogens

"Fish poisoning," as reported in local public health records, refers to any illness that resulted from eating fish and requiring medical attention whether that illness be due to pathogenic or ciguateric causes. Statistics at LBJ Tropical Medical Center's Public Health Department from 1982 to 1992 reported 279 cases of fish poisoning. Yearly totals ranged from 0 in 1992 to 90 in 1982 (Dr. E. Reid, pers. comm.). It appears that there is a trend for fewer cases even as the population has increased over the 10 years, but numbers may be too low to identify a statistically meaningful trend.

8.2 Contaminated recreational waters

Utulei beach on Tutuila is a popular recreational area and there are many anecdotal reports of people, especially children, contracting ear infections after swimming in this area. Coliform counts also have been reported to be high in the area.

8.3 Paralytic shellfish poisoning

Paralytic shellfish poisoning is not reported to be a problem in American Samoa.

8.4 Ciguatera

There are rare reports (<5 incidents per year) of ciguatera fish poisoning. Samoans generally do not eat the large fish of species, such as barracuda, which commonly are ciguatoxic.

9. Water Quality Control and Ecosystem Management

9.1 Land-based pollution control

As an American territory, American Samoa is subject to the federal Clean Water Act, the National Pollution Discharge Elimination Standards and local Water Quality Standards. The one landfill and one metal dump on the island are both operated by the American Samoa Government and a local company is contracted to pick up trash and deliver it to the landfill. There is also a company which contracts to pick up solid waste in the harbor waters. There are little or no efforts to control non-point pollution sources, particularly soil erosion and run-off.

9.2 Ship-based pollution control

In 1992, American Samoa revised its Oil Spill Response Protocols. The 1979 Oil Spill Contingency Plan is currently being revised by the Regional Response Team in Honolulu. A waste oil reception facility was installed some years ago on the fuel dock to allow boats to dispose of their waste oil. However, because fittings were placed incorrectly, the facility has never been used. It is currently being retrofitted as part of the fuel dock renovation. The local U.S. Coast Guard liaison is the on-site coordinator in the event of a major oil spill. A local company offers services to pump out boat sewage and bilge water. Since boats are not required to do this, most do not and boat wastes and bilge water often end up in Pago Pago Harbor.

9.3 Fisheries management

The Department of Marine and Wildlife Resources (DMWR) has a mandate to manage, protect, preserve and perpetuate the marine and wildlife resources in the territory. Through its legal authority, DMWR regulates fishing gear, catch size and limits, methods, restricted areas and coral harvesting. DMWR has the authority to issue permits or licenses for those activities that require them. Permits are required for commercial aquarium fish collection, fish weirs, commercial trapping, commercial coral harvesting, commercial shell harvesting, scientific collecting and the importation of living aquatic organisms. Licenses are required for commercial fishing within American Samoa waters.

9.4 Non-living resources management

The American Samoa Coastal Management Program (ASCMP) is responsible for administering and enforcing regulations regarding sand mining and shoreline development. Sand mining is prohibited, but the law is not well enforced. Shoreline development is restricted to beyond 30 feet from streams and ASCMP restricts coastline development to 50 feet from the shoreline.

9.5 Protected areas

Rose Atoll National Wildlife Refuge is completely protected under federal U.S. Fish and Wildlife Service (USFWS) regulations. Landing or anchoring near the reef requires a permit from the USFWS. Fagatele Bay National Marine Sanctuary regulations prohibit taking, damaging or possessing invertebrates, coral, marine plants, disturbance of the benthic

community, discharges and some types of fishing (U.S. Department of Commerce, 1986). Regulations also delimit fishing zones and regulate vessel operations within the sanctuary. A National Park has been designated and will include a significant portion of land on the north slope of Tutuila and the south slope of Tau as well as reef area on Tutuila and Ofu. Land negotiations have not been settled and the park is not yet functioning.

9.6 Traditional management

In Samoan tradition, a family's land holdings began at the mountain top and extended out beyond the reef edge. Samoans managed valuable resources, including fisheries and if a resource was seen to be declining, a village could put a sa (taboo) on that resource. This was an effective means of controlling overexploitation, at least when the resource in question was in obvious decline (Ponwith, 1991).

Today, however, it is unusual for a sa to be placed on any resource. Village controls have been eroded and use of resources is not so easily delineated. Many users come from outside the village or family and cannot be as readily controlled by the village council. This method of control has been eroded by contact with outside cultures but might yet be an effective way for resource protection if utilized properly with government, island and village cooperation.

10. Recovery and Rehabilitation

10.1 Water quality recovery

The operation of the cannery waste pipeline has resulted in some improvement in the water clarity in the inner Pago Pago Harbor and it is now in compliance with EPA standards.

10.2 Ecosystem recovery

Studies have documented that the coral communities of Fagatele Bay are slowly recovering from destruction by the crown-of-thorns starfish (Birkeland et al., 1987).

10.3 Ecosystem rehabilitation

There are no programs to rehabilitate ecosystem damage in American Samoa.

11. Ecosystem Perturbations and Catastrophic Events

11.1 Marine pollution emergencies

No major marine pollution catastrophes have occurred in American Samoa waters.

11.2 Large storms and cyclones

Hurricanes have struck all the islands twice in the past ten years and Manua suffered two additional hurricanes over the last 12 years. Major hurricanes struck Tutuila in 1990 and 1991, severely impacting the coral reefs. Many reef areas appeared to have been denuded with only remnants of once larger coral communities.

11.3 El Nino

There is no specific information available regarding the effects of El Nino on American Samoa.

11.4 Global climate change

Extreme condition scenarios for accelerated sea level rise would have a serious impact on the coastal ecosystems of American Samoa and would virtually inundate Rose Atoll and Swains Island. Almost all of the inhabited land in American Samoa is along the coastline and much of it is only a few feet above sea level. The additional coastline erosion that might result from any sea level rise would be significant. Severe storms coupled with spring tides already occur almost every year and erode portions of the coastline. The addition of sea level rise would exacerbate the damage.

There has been a recorded rise in sea water temperature in Pago Pago Harbor but it is too early to determine if this is a trend (D. Jones, NOAA, pers. comm.). Several coral bleaching events have been observed and could become more common with a real increase in sea water temperature, which will contribute to the degradation and decline of the coral reefs of the territory.

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Appendix II.2 Marine Environmental Conditions - Guam and the Commonwealth of the Northern Mariana Islands

1. Coastal Area Development

1.1 Watershed land use

Land use changes have been extensive on Guam and Saipan with lesser amounts on Tinian and Rota. Residential, resort, commercial, industrial and government development occurs at or adjacent to flowing waters, standing waters, ephemeral water courses, wetlands, springs and over much of the aquifers on both islands.

1.2 Manipulation of hydrologic cycles

All of Guam's surface flowing rivers occur in the mountainous south of the island and a number of reservoirs have been developed. The limestone substrate of northern Guam and Saipan limit surface waters in those areas.

1.3 Shoreline development

Shoreline development is substantial on Guam and Saipan, with hotels and resorts, infrastructure, businesses, government facilities and residences all competing for shore space. On Saipan, most of the development is on the west coast, bordering the lagoon and on the south coast near the airport. Shoreline development on Tinian and Rota is less pronounced, mainly consisting of villages and the commercial ports. There are many proposals for resort and golf course development along coastal areas. Most of the islands have commercial docks and some have tourist boat and recreational boat facilities.

2. Land-Based Pollution Sources

2.1 Point sources

Waste water effluent from most sewage treatment plants in the Mariana Islands is discharged into the sea. Rivers, streams and drainage ditches on the Mariana Islands carry discharges from treatment facilities and receive agriculture, commercial and industrial wastes as well. There have been a number of studies on the impact of secondary treated effluent on the coastal waters of Guam (e.g., Tsuda and Grosenbaugh, 1977; Borja and Wood, 1986; Matson, 1990a, Zolan et al. 1978). The impact of freshwater runoff on marine environmental quality due to reduced salinities and terrestrial sediments is not well known in the Mariana Islands.

Thermal effluent from power plants is discharged into coastal waters of Guam in two locations and has had impacts on adjacent coral reefs (Neudecker, 1976; Marsh et al., 1977). Toxins associated with power plant operations on Guam have also been shown to affect nearshore marine life.

Numerous solid waste disposal sites in the Mariana Islands have potentially serious effects on the marine water quality and ecosystem health. For example, the Puerto Rico dump on Saipan, located directly adjacent to the lagoon, harbor and a principal mangrove area, has received various materials since the 1940's and does not operate as a sanitary landfill. The range of materials deposited there include explosive ordinance, petroleum products, toxic wastes, household chemicals,

automobile batteries, various metals and plastics, styrofoam, paper products, paints and organic refuse (including animal carcasses).

The large Ordot landfill facility, located adjacent to the Ordot-Pago river systems, accepts most refuse on Guam and does not have a liner. There is a strong concern about the impact of the landfill on the watershed which discharges into Pago Bay. The U.S. Navy and Air Force have operated various dumps on military land in the Mariana Islands since World War II and have dumped materials directly into the sea. There are many non-sanitary landfill dumps where refuse is periodically deposited and burned. In addition, Guam and the other Mariana Islands suffer from excessive littering, including casual littering, the dumping of household refuse and the discarding of automobiles in rural or secluded areas, including coastal areas and beaches.

The U.S. Navy Ship Repair Facility on Guam uses or produces a number of waste products which may enter Apra Harbor and the Navy Public Works Center monitors for these. No specific information was available regarding the composition and amounts of industrial wastes currently or historically generated on military installations. Saipan and Tinian both support garment factories which dye the fabrics used, and dump the dyes directly into the sewage treatment system. At least one factory has been repeatedly cited for dumping dye wastes directly into an adjacent wetland.

Many hotels and businesses on Saipan have installed reverse osmosis desalinization systems which discharge brine and membrane cleaning wastes directly into the sea via surface drainage ditches or dispose of these wastes by deep well injection. Direct discharges are prohibited and have resulted in localized fish kills.

2.2 Non-point sources

Fertilizers and pesticides are utilized on Guam, Rota, Tinian and Saipan for agriculture, golf courses and hotel grounds. Monitoring programs are not presently in force although they have been specified in permit conditions for new or proposed developments in the CNMI. Terrigenous sediments released into inshore waters via runoff from streams, ditches, ephemeral streams, storm sewers or other means, are considered to be a serious threat to coastal habitats on Guam and Saipan (Pring-Ham and Kirby, 1989). Poor land use practices, including land clearing for resort, residential, industrial and military development, failure to control soil erosion in agriculture and alteration of coastal areas, result in increased erosion and sediment run-off into the nearshore marine environment.

Leachate from septic tanks and fields throughout the southern Marianas (Guam, Rota, Tinian and Saipan) contributes a significant amount of nutrients to coastal waters, either by transmission via surface waters, surface runoff or by groundwater intrusion. Septic systems are the primary means of waste disposal in Rota and Tinian. On Saipan, all but 2000 people rely on septic tanks or fields and a large portion of Guam's population also relies upon this method of waste disposal. The

limestone geology characteristic of these islands and the strong interaction between groundwaters and inshore coastal areas promotes the active transmission of nutrients and wastes into coastal waters. On Guam, non-point source pollution accounts for 46% of fecal coliform pollution in coastal waters.

3. Ship-Based Pollution Sources

3.1 Petroleum hydrocarbon transport/offloading

Fuel off-loading operations in the CNMI occur in Tanapag Harbor (Saipan), or Tinian Harbor and Sasanhaya Bay (Rota). Vessels moor offshore and transfer fuel via flexible pipeline to storage facilities ashore. Fuel offloading on Guam occurs at Apra Harbor at a number of civilian oil companies and military sites. Fuel includes gasoline, diesel oil, fuel oil and aviation fuels.

3.2 Ship operations - fuels, wastewaters

Most ships discharge wastewaters at sea rather than in port although bilge water is discharged inshore. CNMI ship operations occur at Tanapag Harbor, Tinian Harbor and Rota Harbor, including docking, loading and off-loading of commercial goods at the main pier and fuel transfers (gasoline, diesel and fuel oil, and aviation fuels). Potential sources of water pollution include incidental or accidental leakage, bilge pumping and littering.

Guam's ship operations occur in Apra Harbor at the commercial port and at Naval Station. Commercial operations include off-loading/on-loading cargo, fish transhipment, commercial fishing operations and tourist vessel operations. Naval operations occur across the harbor and include submarine tending in Inner Apra Harbor, homeporting of fleet support vessels, ammunition transfers at Orote Point and ship repair and refitting at the Ship Repair Facility. Sources of pollution are similar to these commercial operations but may also include radioactive materials and numerous chemicals associated with the ship repair and submarine ending facilities.

3.3 Ship operations - solid wastes, dumping

No information was available on the disposal of solid wastes by ships. Solid wastes, if off-loaded, are transported for deposition at local dumps.

3.4 Pleasure boats

Guam has five major small boat harbors and a number of boat launching facilities. Saipan has one small boat harbor, completed in 1991, for recreational and commercial boats. Tinian and Rota also have small boat harbors on a smaller scale, adjacent to their commercial ports.

4. Marine Contaminants in Water, Sediment and Biota

4.1 Trace metals

Research and monitoring of trace metals in Guam and the northern Mariana Islands indicates the levels of metals in run-off (Zolan, 1981) and provides data from Guam on concentrations of more common metals (e.g., iron and aluminum) and their effects (Matson, 1990b; 1991; in press).

4.2 PCBs and chlorinated hydrocarbons

A PCB storage area was discovered in Tanapag, Saipan adjacent to wetland areas that seasonally drain into coastal waters. Otherwise, no information was available on marine water contamination by PCBs and chlorinated hydrocarbons.

4.3 Petroleum hydrocarbons

Likely sources of petroleum hydrocarbons at both Guam and the CNMI include fuel piers, fuel off-loading stations, small boat harbors, harbor/port operations, offshore operations, power-plant operations and storm sewer outfalls. Saipan's Lower Base power plant oil storage facility experienced an oil spill of undetermined volume in 1989 that impacted an adjacent beach, seagrass bed and cove. No effects on flora and fauna were determined.

4.4 Radioactivity

Nuclear submarine repair and servicing operations take place in Inner Apra Harbor and the Ship Repair Facility at Apra Harbor is capable of servicing nuclear powered vessels. Data on levels of radioactivity present in the waters of Apra Harbor are not currently available and the military will neither confirm nor deny the presence of nuclear weapons at the U.S. Naval Magazine on Guam although the facility is likely capable of storing them. Information is unavailable on the potential for intrusion of accidentally released materials into ground or surface waters. No data is presently available regarding actual releases, if any have occurred. In the CNMI, port calls by nuclear vessels are extremely rare.

5. Use of Living Marine Resources

5.1 Use levels and patterns

Commercial reef fisheries on Guam and Saipan have subjected the reef fish populations to sustained high levels of harvesting and the fisheries nearly have collapsed. Offshore pelagic and deep bottom fisheries are presently managed in conjunction with WESPAC but enforcement activities and accurate data collection operations are handicapped by a lack of resources. In the CNMI some commercial fishing ventures have operated only with a business license issued by the CNMI Department of Commerce and Labor and not with the permission of the Division of Fish and Wildlife, which would set local regulations and limitations.

5.2 Overharvested species

Published and unpublished data from both Guam and the CNMI indicate large reductions in both population sizes and rates of harvest of a number of species from the waters of Guam and Saipan. These include groupers (*Serranidae*), jacks (*Carangidae*), parrotfishes (*Scaridae*), certain wrasses (e.g., *Cheilinus undulatus, Labridae*) and some snappers (*Lutjanidae*). Size distributions of many of these are skewed towards small body size and species diversity within these groups is relatively low.

5.3 Destructive fishing practices

Both Guam and the CNMI suffer from poaching activities, both within inshore and offshore waters. Destructive fish practices include dynamite fishing, poison fishing, illegal net fishing, illegal long lining, suspected purse seining, coral harvesting and turtle poaching.

5.4 Exploitation of endangered species

Sea turtles, primarily green and hawksbill turtles, are the targets of aggressive poaching activities in both the CNMI and Guam even though they are officially protected. Poaching includes the taking of eggs and adult females during nesting season. Enforcement efforts on Guam are relatively effective in comparison to Saipan, Tinian and Rota where poaching occurs openly. Turtle poaching in the CNMI has spread to the northern islands of Anatahan and Sarigan where larger, more powerful boats can now visit during calm weather. The taking of protected seabirds and their eggs at nesting sites also occurs although data on rates are lacking.

5.5 Introduction of exotic species

The topshell Trochus nilotica (*Trochidae*) was introduced into the Mariana Islands with variable success. Other invertebrate introductions include some giant clam (*Tridacna*) species, usually as a result of mariculture development. Side effects have included the introduction of a parasitic gastropod and parasitic protozoan, which may have destructive effects on other marine organisms. Introductions of fishes have included various tilapias (*Cichlidae*) which have become established in nearshore reef flats as well as in freshwater.

6. Use of Non-Living Marine Resources

6.1 Beach sand extraction

The extraction of beach sand on Guam and in the CNMI has occurred historically but is no longer legal. Previously on Saipan, sand was removed from the east coast, deposited along tourist beaches on the west coast, and replaced with sand taken from inland quarries. Presently, beach sand extraction is limited to small scale taking, usually at night or on weekends.

6.2 Coral reef dredging

Dredging occurs occasionally on Guam and Saipan and, historically, on Tinian and Rota primarily for creating or improving commercial and recreational harbors or other infrastructure (Marsh and Gordon, 1974). Dredging of inshore reef flats to benefit tourist operations has also occurred. Recent or proposed dredging operations have occurred in Rota (port and park), Saipan (hotel swim area, dock channel), and Guam (tourist areas).

6.3 Marine sand mining

Coral sand mining presently does not occur in waters of the Mariana Islands.

6.4 Deep seabed mining

No deep seabed mining occurs in the waters of Guam or the CNMI, although exploratory research occurs occasionally.

7. Ecosystem Effects

7.1 Water quality degradation

Water quality degradation is pronounced in Saipan and Guam, but has not been well measured.

7.2 Habitat damage/destruction

Damage and destruction to habitat is extensive on Saipan and Guam although very little quantifiable measurement of habitat damage and destruction in the coastal and nearshore areas of Guam or Saipan has been made. Qualitative assessments on Saipan indicate significant destruction along the western and southern coasts, both inside and outside of the lagoon and fringing reef systems. Sediment and nutrients (from sewage and freshwater runoff) are the main causes of habitat damage and destruction and harbor dredging will soon contribute to this.

On Guam, the extent of damage is more quantifiable. For example, it is estimated that 95% of the nearshore reefs between Facpi Point south to Merizo have been damaged by sediments and run-off released following land clearing and road construction in adjacent watersheds. Nearby rivers have been channelized, which allows considerable sedimentation of adjacent reefs, as well.

7.3 Species depletion/extinction

Most cases of species depletion and extinction in the Mariana Islands have not been well documented despite numerous examples (e.g., sea turtles, commercially important fishes, shellfish) (Hedlund, 1977). Numerous species of microinvertebrates and small fishes may be lost from reef and coastal habitats, including marine cave faunas, when habitats are damaged or destroyed.

8. Public Health Effects

8.1 Marine food pathogens

In Guam, cholera in East Agana Bay finfish has been identified as a potential threat to public health as seafood contamination was likely.

8.2 Contaminated recreational waters

Several inshore recreational areas in Guam and Saipan routinely tested by GEPA on the CNMI Department of Environmental Quality are contaminated by fecal coliform from point and non-point sources. Insufficient treatment of sewage, sewage treatment bypasses, "ghost" sewage outfalls, runoff in streams, drainage ditches and septic field leakage have all been implicated as sources of human and agricultural fecal coliforms and Vibrio sp. pathogens which have been detected.

8.3 Paralytic shellfish poisoning

No information was available on the occurrence of paralytic shellfish poisoning in the Mariana Islands.

8.4 Ciguatera

Ciguatera occurs throughout the Mariana Islands with poisonings occasionally reported from both Guam and Saipan.

9. Water Quality Control and Ecosystem Management

9.1 Land-based pollution control

Land-based pollution controls include the implementation of federal air and water quality standards, erosion containment, freshwater runoff containment, toxic waste management and coastal zone management. Nearshore waters in the CNMI are managed by the Coastal Resource Management Office, with the participation of the Division of Environmental Quality and the Division of Fish and Wildlife. The Commonwealth Utilities Corporation also participates with respect to wastewater questions and has constructed two secondary treatment plants to cope with chronic sewage treatment problems.

On Guam, the inability for infrastructural development to keep pace with rapid growth has led to serious environmental impacts. Effort is being made by GEPA and WERI to address various other problems associated with non-point source pollution but the lack of departmental resources often means a lack of monitoring and compliance. Nearshore waters are managed by GEPA, with the participation of WERI, the Marine Laboratory, DAWR, the Bureau of Planning (Coastal Zone Office), the U.S. Navy Public Works Center and the Public Utilities Authority of Guam.

9.2 Ship-based pollution control

Vessels in port must adhere to federal regulations regarding pollution control. Oil spill contingency plans are in place for Guam and CNMI.

9.3 Fisheries management

The CNMI Division of Fish and Wildlife and the Guam Division of Aquatic and Wildlife Resources are responsible for fisheries management. This includes creel surveys of inshore and offshore fishing effort and commercial fishing activities, fisheries enhancement (including boating access and the deployment of fish aggregation devices), sportsfish promotion, educational activities, conservation and enforcement (Amesbury et al., in press).

9.4 Non-living resources management

Non-living marine resources in the CNMI are managed by the Coastal Resources Management Office and the Department of Natural Resources with input on management practices from the Division of Fish and Wildlife, the Division of Environmental Quality, the Division of Parks and Recreation, the Office of Civil Defense and the Governor's Office. Submerged lands in the CNMI are administered by the Department of Natural Resources, with leaseholds requiring legislative approval.

On Guam, non-living resources are managed by the Territorial Planning Commission, Bureau of Planning (including the Coastal Zone Office) and the Governor's Office, with input from the Division of Aquatic and Wildlife Resources, GEPA, the Territorial Archeologist, the Marine Laboratory, WERI, and Parks and Recreation. Submerged lands are administered with the approval of the Territorial Planning Commission with input from the Bureau of Planning, GEPA, DAWR, the Marine Laboratory, WERI and the Governor's Office.

9.5 Protected areas

The CNMI currently has four protected refuges mandated by the Commonwealth's constitution. These are located on the islands of Uracus (Farallon de Parajos), Maug, Ascuncion and Guguan. Protection is extended over each island in entirety and in all marine habitats to a depth of 1000 fathoms. Refuges are off limits to all persons except designated local and federal government personnel and scientists. Access is controlled by the Division of Fish and Wildlife (this extends to all of the northern islands) but enforcement, particularly against transient fishing vessels, is poor since the Division lacks the resources to conduct activities in the northern islands. In addition, Bird Island (Saipan) is a designated wildlife sanctuary.

On Guam, a new refuge along the northern coast was designated by the U.S. Air Force. The remoteness of the area, in part a consequence of high surf throughout much of the year, has helped to maintain the area in a relatively pristine state. Elsewhere on Guam, significant portions of terrestrial shoreline and nearshore habitat are protected as part of the Territorial Seashore Park and the War in the Pacific Historical Park (Eldredge, 1979) although management of marine areas is limited.

9.6 Traditional management

Traditional management practices which resulted in the conservation of marine resources are no longer in practice in the Mariana Islands.

10. Recovery and Rehabilitation

10.1 Water quality recovery

No information was available on documented water quality recovery in the Mariana Islands.

10.2 Ecosystem recovery

The recovery of coral reefs on Guam following catastrophic predation by the crown-of-thorns starfish has been documented (Colgan, 1982; 1987).

10.3 Ecosystem rehabilitation

Plans to restore or create wetlands as mitigation occur from time to time in the Mariana Islands. The CNMI Division of Fish and Wildlife is currently monitoring a wetland constructed in the Lower Base, Saipan area. Some efforts have been made to use coral transplantation to restore coral communities damaged by environmental impacts (Birkeland et al., 1979).

11. Ecosystem Perturbations and Catastrophic Events

11.1 Marine pollution emergencies

A spill of oil from a broken pipeline at the Guam power plant reached the marine environment and killed off an area of mangrove. Otherwise no catastrophic marine pollution emergencies have occurred in the Mariana Islands.

11.2 Large storms and cyclones

Guam is affected regularly by large oceanic storms and cyclones (typhoons) which have a major impact on coastal habitats, especially coral reefs. However, the coral reefs and corals of Guam appear to be adapted to frequent storm wave activity (Randall and Eldredge, 1977). The northern Marianas are affected much less frequently than Guam by large storms and cyclones.

11.3 El Nino

No specific information was available on the effects of El Nino events on the coastal and marine areas of the Mariana Islands.

11.4 Global climate change

Sea level rise, increased water temperature and the increased frequency and intensity of tropical storms would have serious impacts on the coastal and nearshore marine ecosystems of the Mariana Islands. The steep cliff coast along many of the islands make sea level rise and storm waves less of a concern in those areas. There was no specific information on the effects of global climate change on marine ecosystems in the Mariana Islands.

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Appendix II.3 Marine Environmental Conditions - Hawaii

1. Coastal Area Development

1.1 Watershed land use

Hawaiian watersheds typically run from the tops of the interior mountains to the coastal plains. The interior, including the mountain ridges and slopes over 20% gradient and the upper elevations of most valleys, lies within forest reserve and is protected from land use changes. Outside the forest reserve, land use is regulated by the state through a classification system which divides the land into four categories: Urban, Rural, Agriculture, Conservation. A State Land Use Commission controls the allocation of land in each category. Each of the four areas have criteria for allowable uses identified in legislation.

Most development is situated within five miles of the shoreline and development is heaviest in the urban districts in each of the counties. Over half of all urban lands are found within the City and County of Honolulu (which includes all of Oahu Island). However, even on Oahu, more than 70% of the land is in conservation or agriculture. Prime agricultural lands are intensively developed for sugar and pineapple production on approximately 100,000 acres throughout the state. Another use of agricultural lands is golf courses, with over 100 golf courses in development or proposed. Many golf courses are sited along the coast near or as part of resort development.

1.2 Manipulation of the hydrological cycle

The City and County of Honolulu, the most urban and densely populated of the four counties, gets the bulk of its water, about 89%, from groundwater sources. As the population continues to grow, demand for fresh water for domestic use may exceed the sustainable capacity of existing sources. Very little surface water is diverted for agricultural uses on Oahu. A major source of manipulation to the hydrological cycle on Oahu has been the channelization of streams for flood control purposes. Surface water, especially for agricultural purposes is the main source of water in the other three counties. The impact on the stream flora and fauna and on the receiving ocean water may be significant.

There are twenty hydropower dams on Kauai, Hawaii and Maui. These small facilities generate about one % of the total amount of electricity generated in the Hawaiian Islands (Department of Business and Economic Development and Tourism (DBED), 1991a). There are three other dams on Oahu for the impoundment of fresh water.

1.3 Shoreline development

Much of the shoreline is privately owned by large land owners or other private developers. Federal military bases and state owned commercial facilities (docks and marinas) take up another large portion of the shoreline. Altogether there is less than 124 miles of open shoreline out of 750 miles of shoreline in the main Hawaiian Islands. Tourism is the primary economic activity in the state. Tourism requires the development of resort hotels and related facilities and most resort developers prefer locations on or close to the shoreline. Many of Hawaii's prime beach areas are fronted by resort or hotel/condo

development. Visitor counts are now at 6.5 million per year and are expected to rise to 11.4 million by the year 2010 (DBED, 1991b).

2. Land-based pollution sources

2.1 Point sources

There are 26 public wastewater treatment facilities in the Hawaii, 11 on Oahu, 5 on Maui, 4 on Kauai and 6 on Hawaii. There are an additional 140 private wastewater plants located throughout the state (Commission on Employment and Human Resources, 1993). In addition to sewage treatment facilities there are other point sources of pollution such as canals and storm drains. Public wastewater facilities have recently come under the scrutiny of the state's courts which have decided that additional studies need to be done to determine the impacts of treated effluent on the environment.

Hazardous and toxic waste, crankcase oil and other petroleum products are being dumped into storm drains which empty into nearby steams and the ocean. Pesticides, herbicides, paints, batteries and other hazardous materials which are improperly disposed of by uninformed residents and unscrupulous businesses likely have a substantial impact on the marine environment.

2.2 Non-point sources

Erosion and sedimentation from agricultural operations, sewage leacheate from injection wells and septic systems and run-off from construction are some of the non-point sources of pollution that affect the nearshore waters of Hawaii. Little information is available on the location, composition and impact of non-point sources of water pollution since most water quality management efforts focus on point sources. However, the Coastal Zone Management Act Reauthorization Amendments of 1990 require the state to develop EPA and NOAA approved Coastal Non-point Pollution Control Programs by 1996. Other environmental impacts likely related to non-point source pollution, such as the recent algal blooms off Maui and in Kaneohe Bay, have heightened awareness of non-point source pollution issues.

3. Ship-Based Pollution Sources

3.1 Petroleum hydrocarbon transporting/offloading

Hawaii depends on imported oil to meet 90% of its energy requirements. With little prospect for developing an alternative, it is likely that Hawaii will continue to import 2.5 billion gallons of oil products each year. Since 1984, Hawaii has experienced one large oil spill (over 100,000 gallons) and 12 other spills greater than 5,000 gallons. Statistically, Hawaii can expect a 0-20,000 gallon spill every 2.25 years, a 40-50,000 gallon spill every 4.5 years and a catastrophic spill of 10-11,000,000 gallons every 135 years (Pfund, 1992).

3.2 Ship operations - fuels, wastewater

During 1988 there were a total of 13,480 ships that arrived at the various ports in the Hawaiian Islands. In addition, there are 13,501 state registered vessels in Hawaii (Pfund, 1992) ranging from large container ships and passenger liners to small pleasure craft. To a varying degree they all present a potential threat to inshore marine habitats. Large container vessels and passenger liners have the potential to cause substantial oil spills of over 5,000 gallons of fuel. Disposal of bilge and other waste water products from these vessels is another source of pollution.

3.3 Ship operations - solid wastes, dumping

The dumping of solid waste is prohibited by federal regulation. However, the EPA and the U.S. Army Corps of Engineers allows for a limited amount of dredge spoil disposal into deep ocean waters at approved sites. The Corps will be conducting follow-up studies to determine the impacts of the deep ocean dumping.

3.4 Pleasure boats

There are a large number of smaller pleasure craft and fishing vessels in Hawaii which are also potential sources of pollution. Improper fueling can cause localized spills resulting in serious cumulative impacts; however, no data exists on this.

4. Marine Contaminants in Water, Sediment and Biota

4.1 Trace metals

Current baseline data on the levels and amounts of heavy metals in Hawaiian nearshore waters are lacking. Studies conducted by the Water Resources Research Center (WRRC) and the State of Hawaii in 1973 found elevated levels of chromium, copper, nickel, zinc, chlorinated pesticides, PCBs and extreme levels of lead in the Ala Wai Canal near Waikiki. Levels of lead, arsenic and other heavy metals in Hilo Bay on the island of Hawaii have increased significantly in the 20 years since the WRRC study (De Carlo, 1993). Most of the studies on heavy metals have been area specific and baseline data with which to compare current concentrations of heavy metals are lacking.

4.2 PCBs and chlorinated hydrocarbons

Organic substances such as PCBs, chlorinated hydrocarbons, pesticides and herbicides have been used extensively in recent years, however, their impact on the Hawaiian marine environment remains poorly understood (De Carlo, 1993). Past use of pesticides such as chlordane, which do not decompose in the environment, may result in future problems. The use of the banned pesticide heptachlor, for example, resulted in tainted milk supplies on the island of Oahu in the early 1980s. The number of golf courses being proposed and developed in the Hawaiian Islands has focussed the attention of the public on the impacts of pesticides and herbicides.

4.3 Petroleum hydrocarbons

Petroleum contamination does not appear to be a major problem in Hawaii. Most petroleum spills have been small with most occurring in the south and southwestern coastline of the island of Oahu. Honolulu Harbor and Pearl Harbor are the sites of about 30 percent of all spills reported in Hawaii. Another major oil spill area is the off-loading sites for Hawaii's two oil refineries at Barbers Point on Oahu.

4.4 Radioactivity

Radioactivity is not known to be a problem in the marine environment of Hawaii.

5. Use of Living Marine Resources

5.1 Use levels and patterns

Reported commercial landings for inshore species between 1980 and 1990 averaged 1,300 tons per year. Total landings may be significantly greater, since fishing is a popular pastime of residents and non-commercial landings are not reported. The bulk of the commercial inshore fish catch is concentrated in the main Hawaiian Islands. Although inshore fish species may be relatively abundant in the northwestern Hawaiian Islands, the considerable distance to the fishing grounds and prohibitions on fishing within the 20 fathom isobath around these islands make the resources of this area inaccessible to most fishermen.

Within the main Hawaiian islands, the inshore fish catch makes up a relatively small fraction of the total weight of commercial landings. However, the inshore stocks may be far less abundant than pelagic species such as skipjack tuna and marlin. In all, 47 species of fish comprise 91% (by weight) of all inshore fish catch reported. While overall catch rates remain constant, a decline in the nearshore fishery since 1900 was noted by Shomura (1987). The island of Oahu has also shown a decline in the catch per unit effort in the last decade although environmental factors may contribute to the decline (Smith, in press).

Hawaii is one of the few states that doesn't require a saltwater fishing license and without licensing and reporting requirements, it is difficult to estimate the total fish catch from recreational sources. Recreational fishermen outnumber commercial fishermen significantly, but their per trip landings is probably considerably lower. Surveys indicate that there may be as many as 187,000 recreational anglers in Hawaii while there are about 4,000 licensed commercial fishermen. Despite the fact that commercial fishermen are required to report all catch, there may be considerable underreporting. In the past, actual commercial landings may have been as much as double the amount reported for some species. Lacking reliable catch records, it is difficult to determine the health of the inshore fisheries.

5.2 Overharvested species

It is possible that the inshore reef fishery of Hawaii is being overharvested due to an increased number of people engaged in the fishery (Dr. R. Brock, University of Hawaii Sea Grant, pers. comm.; Dr. B. Carlson, Waikiki Aquarium, pers. comm.). The Western Pacific Regional Fishery Management Council has recently placed controls on the harvesting of *opakapaka* (*Pristipomoides filamentosus*), due to overfishing.

5.3 Destructive fishing practices

The use of chlorine or other poisons to capture fish has been a recurring problem in the Hawaiian islands. No data exists on the extent of the problem.

5.4 Exploitation of endangered species

The taking of any endangered species for any reason is prohibited by law and strictly enforced by state and federal enforcement officials.

5.5 Introduction of exotic species

The introduction of alien species to the marine environment of Hawaii has adverse impacts, however, these impacts have not been well documented. The best documented introduction is the *taape* (*Lujanus kasmira*) or blueline snapper. This reef fish is not desired by local fisherman and thus not heavily fished. The species is thought to be competitively superior relative to a number of native species has taken over numerous habitats (Dr. R. Brock, University of Hawaii Sea Grant, pers. comm.).

Echeuma seaweed was brought into Hawaii as a potential marine aquaculture species. It has become established here and has out competed some of the local species of seaweed on the windward side of Oahu. Recent algal blooms on Maui may be due to recent introductions or increased nutrient loading (Dr. R. Brock, University of Hawaii Sea Grant, pers. comm.). The larvae of new species of marine organisms are introduced to Hawaiian waters by way of bilge water or the bottoms of ships, although there is little data on this.

6. Use of Non-living Resources

6.1 Beach and sand extraction

Beach sand extraction for commercial purposes is prohibited from all sandy beaches. Individuals may take sand for personal use subject to regulation by the Department of Land and Natural Resources.

6.2 Coral reef dredging

Coral reefs are not dredged in Hawaii for use as a building material as it is on other Pacific islands. Coral dredging does take place on a limited basis for harbor maintenance and development.

6.3 Marine sand mining

The Department of Land and Natural Resources, Department of Transportation and the County Department of Recreation conduct limited sand mining for beach replenishment.

6.4 Deep seabed mining

Deep seabed mining for strategic minerals such as cobalt and manganese remains in the research stage.

7. Ecosystem Effects

7.1 Water quality degradation

The influx of nutrients from point source and non-point source pollution has changed the quality of coastal waters in Hawaii with uncertain impacts on marine ecosystems. The influx of nutrients from land-based sources may have little or no impact where the volume of the receiving waters around Hawaii is great and the mixing characteristics rapidly disperse the nutrients into low concentrations. In areas around Hawaii where the receiving waters are shallow and the mixing characteristics poor, nutrification and follow-on changes to the ecosystem may be a problem. More damaging impacts to the nearshore marine ecosystem of Hawaii seem to occur from the amount of particulate material in sewage effluent as well as the presence or absence of heavy metals in the sewage.

7.2 Habitat damage and destruction

Sewage effluent and sedimentation have extensive damaged habitats at Kaneohe Bay and Sand Island, both of which are sites of sewage effluent outfalls and heavy sedimentation due to land development (Maragos et al., 1985). Dramatic recovery in the ecosystems of both these areas were observed after the effluent outfalls were removed and land use management implemented.

7.3 Species depletion/extinction

No information was available on the depletion on extinction of particular species in Hawaiian waters.

8. Public Health Effects

8.1 Marine food pathogens

In recent years there has been at least one small outbreak of cholera in Hawaii which is possibly attributed to the ingestion of contaminated seafood taken from Hawaiian waters. While evidence in support of this attribution is anecdotal, there is concern among state health officials that seafood taken from Hawaiian waters is susceptible to contamination by *Vibrio cholera* and other bacterial or viral pathogens.

8.2 Contaminated recreational waters

Contaminated recreational waters is an issue of considerable controversy in Hawaii. There is an abundance of anecdotal evidence claiming a variety of health impacts from supposedly contaminated

swimming beaches but little hard evidence exists. The relationship between levels of pollution (as measured in terms of indicator organisms) and human and environmental health impacts is poorly defined in Hawaii and other tropical regions in comparison to temperate areas where most of the research on this issue has been undertaken.

8.3 Paralytic shellfish poisoning

There is no evidence that paralytic shellfish poisoning is a problem in Hawaii.

8.4 Ciguatera

A number of cases of ciguatera poisoning are reported annually in Hawaii. Although the reasons for the spread of ciguatera are still being investigated it has been suggested that cases of the disease are more frequently seen in areas where the reef has been damaged. However, there has also been a number of reports of ciguatera from the island of Hawaii in areas where there is little or no development.

9. Water Quality Control and Ecosystem Management

9.1 Land-based pollution control

Wastewater outfalls are generally situated in deep waters where dilution and ocean currents effectively remove the effluent. Outfalls in shallower waters are a matter of concern to many, as are the possible impacts of wastewater injection wells on nearshore waters. Non-point source pollution generated by storm run-off, illegal dumping, agriculture, development activities, private cesspools and septic tanks continues to pose control difficulties. There are a number of agencies and programs (federal, state, and local) in Hawaii that are concerned with reducing, preventing and regulating both point and non-point sources of land-based pollution.

9.2 Ship-based pollution control

The pollution generated by ships and boats is a problem focused mainly in the harbors around the state. Hundreds of minor oil spills are reported to the U.S. Coast Guard every year. Enforcement of regulations prohibiting ocean dumping is difficult, at best. As the number of craft in the state increases, the pollution they cause is expected to become a more pressing problem. The U.S. Coast Guard, the State Department of Land and Natural Resources and the Harbors Division of the State Department of Transportation regulate the activities of vessels in the waters around Hawaii.

9.3 Fisheries management

Fisheries management in Hawaii is the responsibility of the state Department of Land and Natural Resources and the Western Pacific Regional Fishery Management Council. The fishing industry in Hawaii has changed in recent years with the influx of longline fishing vessels from the U.S. mainland. Greater numbers of commercial vessels from

Asia are also fishing in waters near Hawaii and enforcement of the 200 mile exclusive economic zone around the Hawaiian islands is difficult to perform effectively.

9.4 Non-living resources management

Sand mining is regulated by statute 205A Hawaii Revised Statutes which prohibits the removal of beach sand. Marine sand mining is generally prohibited within 1,000 feet of the shoreline and in depths less than 30 feet.

9.5 Protected areas

There are a number of protected marine areas in the state where fishing is prohibited or managed. These areas are administered by the state Department of Land and Natural Resources. In 1967 the state initiated the first of nine Marine Life Conservation Districts (MLCD) at Hanauma Bay, Oahu. The purpose of the MLCDs is to protect unique marine areas of special interest. MLCDs have also been created at Pupukea and Waikiki on Oahu; Kealakekua Bay, Lapakahi, Waialea Bay, and Old Kona Airport on Hawaii; Manele-Hulopoe on Lanai; and Molokini Shoal on Maui.

In addition to the MLCDs, the State has created the Waikiki-Diamond Head Shoreline Fisheries Management Area which requires the closure of this heavily fished area every other year to allow fish stocks to recover. Fisheries Management Areas have also been established at Puako and four areas along the Kona coast of Hawaii.

9.6 Traditional management

Traditional marine resource conservation and management is no longer practiced in Hawaii.

10. Recovery and Rehabilitation

10.1 Water quality recovery

There have been a few efforts made to rehabilitate degraded water quality in areas around the Hawaiian islands. Notable among these is the rerouting of wastewater disposal from relatively nearshore waters to deep outfalls. This was done at Kaneohe Bay and Honouliuli and Sand Island treatment plants on Oahu, with documentation of improved water quality (Smith et al., 1981).

10.2 Ecosystem recovery

The removal of wastewater disposal from shallow water sites to deeper areas has resulted in the recovery of reef ecosystems in those shallow areas, as has been documented in Kaneohe Bay (Maragos et al., 1985). The extension of the outfalls into deep water has resulted in the establishment of communities of marine organisms around the pipes and associated structures.

10.3 Ecosystem rehabilitation

The state has created three artificial reefs on Oahu at Maunalua Bay, Ewa and Waianae to enhance as well as rehabilitate the local marine ecosystem.

11. Ecosystem Perturbations and Catastrophic Events

11.1 Marine pollution emergencies

There have been 13 oil spills of 5,000 gallons or more reported in the Hawaiian islands since 1983, 7 of which occurred in Pearl Harbor. The largest, 120,000 gallons in Pearl Harbor, 1987, is classified as a medium size spill. It has been estimated that a large oil spill on the order of 10-11 million gallons, will occur once every 135 years and smaller spills on the order of 40-50 thousand gallons will occur every 4.5 years. In 1980, a Greek tanker ran aground in French Frigate Shoals in the Northwestern Hawaiian Islands spilling 2,200 tons of powered kaolin clay. Studies indicated that the environmental impact of this spill was localized and thought to be minor.

11.2 Large storms and cyclones

Hawaii is not located in an area of frequent cyclonic storms. However, there have been two major hurricanes which have impacted the Hawaiian Islands. In 1982 and 1992, hurricanes caused extensive damage to the western coast of Oahu and the Islands of Kauai and Niihau. Rainstorms periodically release large amounts of rain on the islands with rapid run-off and extensive erosion which impact nearshore marine ecosystems.

11.3 El Nino

No specific information was available on the effects of El Nino events on the coastal and marine areas of the Hawaiian Islands.

11.4 Global climate change

Sea level rise, increased water temperature and the increased frequency and intensity of tropical storms would have serious impacts on the coastal and nearshore marine ecosystems of the Hawaiian Islands. The steep cliffed coastal areas of some of the islands make sea level rise and storm waves less of a concern in those areas. There was no specific information on the effects of global climate change on marine ecosystems in Hawaii.

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Appendix III.1 List of Agencies, Organizations and Individuals Contacted

A. Hawaii

1. State Agencies/Organizations

Coastal Zone Management Program, Office of State Planning
D. Tom, Program Manager
V. McMillan, Program Specialist

Division of Aquatic Resources, Department of Land and Natural Resources
H. Sakuda, Director
P. Kawamoto, Program Manager
E. Onizuka, Program Manager

Environmental Planning Office, Department of Health
J. Harrigan, Planner

Harbors Division, Department of Transportation
C. Tsuda, Deputy Director for Harbors

Ocean Resources Branch, Department of Business, Economic Development & Tourism
C. MacDonald, Manager

2. University of Hawaii

Environmental Center
J. Miller, Assistant Coordinator

Hawaii Cooperative Fishery Research Unit
J. Parrish, Leader

Hawaii Institute of Marine Biology
M. Atkinson, Associate Researcher

Oceanography Department
E. Laws, Chairman

Sea Grant College Program
P. Rappa, Extension Agent

Sea Grant Extension
R. Brock, Extension Agent

Waikiki Aquarium
B. Carlson, Director

Pacific Biomedical Research Center (PBRC)
S. Palumbi, Researcher

Water Resources Research Center
P. Moravcik, Technology Transfer Specialist

Hawaii Institute of Geophysics (HIG), SOEST
C. Helsley, Director

Department of Botany
C. Smith, Researcher

3. City and County Agencies/Organizations

Parks and Recreation
R. Bond, Maintenance Administrative Assistant

Public Works
A. Ho, Environmental Engineer
D. Nagamine, Water Quality Head

4. Non-Government Agencies/Organizations

AECOS, Inc.
E. Guinther, President

Bishop Museum
A. Allison, Chairman

Conservation Council for Hawaii
W. Sager, President

Envirosearch
N. Convard, Pacific Regional Manager

Hawaiian Electric Co.
D. Fukuda, Environmental Scientist

Oceanic Institute
D. Ziemann, Program Manager

Pacific Science Association
L. Eldridge, Executive Secretary

Sea Life Park - Hawaii
T. Gild, Ops Manager

Sierra Club Legal Defense Fund
M. Smaalders, Resource Analyst

The Nature Conservancy (TNC)
P. Holthus, Consultant

Surfrider Foundation
T. Schulz, Development Director

Hawaii Golf Course Action Alliance
M. Protheroe, Director

B. Guam

1. Territorial Agencies

Guam Environmental Protection Agency
M. Borja, Chief of Surveillance
G. Stillberger, Chief Planner - Environmental Review

Guam Division of Aquatic and Wildlife Resources
G. Davis, Fisheries Supervisor

Bureau of Planning, Coastal Zone Management Office
M. Ham, Administrator

Territorial Planning Council
M. Gawel, Environmental Planner

Guam Department of Public Health - Epidemiology
R. Haddock, Epidemiologist

2. University of Guam

Marine Laboratory
S. Amesbury, Professor C. Birkeland, Professor
J. Lacson, Assistant Professor
E. Matson, Associate Professor
S. Nelson, Professor
V. Paul, Associate Professor
G. Paulay, Assistant Professor
R. Richmond, Professor
B. Smith, Extension Faculty
T. Donaldson, Research Affiliate

Water and Energy Research Institute of the Western Pacific
G. Denton, Assistant Professor
H. Wood, Associate Professor

C. Commonwealth of the Northern Mariana Islands

1. Commonwealth Agencies

Division of Fish and Wildlife
J. Gourley, Fisheries Supervisor
D. Stinson, Wildlife Supervisor
S. Snow-Cotter, Natural Resource Planner

Division of Environmental Quality
J. Sarcone, Environmental Scientist

Coastal Resources Management Office
J. Villagomez, Administrator
J. Furey, Coastal Coordinator

Commonwealth Utilities Corporation
M. Breen, EPA Construction Grants Manager
L. Babauta, Water Quality Laboratory Supervisor
J. Hoffman, Water Resources Planner (USGS-IPA)

Department of Public Works
R. Meecham, Special Assistant on Landfill Relocation

D. American Samoa

1. Territorial Agencies

Department of Marine and Wildlife Resources
R. Tulafono, Director

American Samoa Environmental Protection Agency
S. Weigman, Environmental Coordinator

American Samoa Coastal Management Program
L. Peau, Director

Department of Marine and Wildlife Resources
P. Craig, Chief Biologist
American Samoa Power Authority
M. Dworsky, Wastewater Manager

2. Non-Government Agencies/Organizations

Star Kist, Inc.
W. Adams, Managing Engineer

E. Federal Agencies/ Organizations

Hawaii-based

National Marine Fisheries Service
G. Boehlert, Director

NOAA Pacific Islands Network
S. Ziegler, PIN Coordinator

NOAA Sanctuaries Program
C. Evans, Hawaii Liaison (Program Specialist)

U.S. Army Corps of Engineers
W. Lennan II, Ecologist
M. Stahl, Ecologist
P. Galloway, Ecologist
R. Moncrief, Ecologist

Western Pacific Regional Fishery Management Council
R. Schroeder, Senior Scientist

U.S. Fish and Wildlife Service
M. Molina, Fish and Wildlife Biologist

U.S. Geological Service
J. Eychaner, Assistant District Chief

U.S. Coast Guard
R. Seebald, Chief

U.S. Forest Service, Institute of Pacific Island Forestry
G. Conrad, Director
C. Whitesell, Project Leader
L. Newell, Pacific Islands Forester

U.S. Soil Conservation Service
L. Yamamoto, Water Quality Specialist Guam-based

Guam-based

U.S. Navy Public Works Center - Fena Water Laboratory
H. Dorsey, Supervisor
J. Heininger, Scientist

U.S. Air Force, Anderson Air Force Base, Office of the Civil Engineer
H. Hirsh, Natural Resource Planner

American Samoa-based

U.S. Soil Conservation Service
R. Hansen

U.S. Mainland-based

U.S. NOAA, International Liaison Office
T. Laughlin, Chief, PIN

U.S. EPA Region IX
N. Lovelace, Director
B. Melzian, Regional Oceanographer

F. Regional Organizations

1. Pacific Basin Development Council
   J. Norris, Director
   M. Hamnett, Senior Policy Analyst
2. East-West Center, Program on Environment
   J. Maragos, Senior Fellow
3. South Pacific Commission
   T. Adams, Senior Inshore Fisheries Scientist
4. South Pacific Regional Environment Programme
   A. Smith, Coastal Management Officer
5. South Pacific Applied Geoscience Commission
   J. Eades, Deputy Director

Appendix III.2 Inventory of Research - American Samoa

1. Program Name

American Samoa Environmental Protection Agency (ASEPA)

2. Responsible Official(s)

Togipa Tausaga, Program Director
Sheila Weigman, Environmental Coordinator

3. General Purposes of Research Sponsored by the Program

The ASEPA program includes research to define and address problems concerning water quality, air quality, drinking water, pesticides, hazardous materials, hazardous waste and public education.

4. Administrative Character of the Program

The program is modelled after USEPA programs. The Environmental Quality Commission is the decision making board with ASEPA as secretariat.

5. Technical Character/Funding Levels of the Current Research Programs

5.1 Water Quality Monitoring

ASEPA assesses water quality in Pago Pago Harbor and other bays in American Samoa to determine compliance with American Samoa Water Quality Standards and determine long term trends. Eighteen stations in Pago Pago Harbor are monitored monthly and the major bays are monitored annually for basic water quality parameters such as dissolved oxygen, turbidity and nutrients. Data are used to determine if the cannery discharge is in compliance with NPDES permit conditions and for the annual Water Quality Report.

Funding level: $75,000 FY93

5.2 American Samoa Toxicity Study

ASEPA and DMWR are cooperating to verify the findings of the 1991 Pago Pago Harbor Pilot Toxicity Study (high levels of metals found) and to determine whether and where fish are safe for consumption on Tutuila Island. Samples of four to six species of fish were collected from 11 sites around Tutuila Island to be tested for a range of parameters including heavy metals. Sediment and soil samples will also be tested for these parameters. A risk assessment evaluation of the test results will be completed by a contractor.

Time frame: June, 1992 to September, 1993

Funding level: $46,500 FY93 (does not include in-kind labor and sample analysis by USEPA Las Vegas lab)

5.3 Toxicity Source Assessment and Remediation

To determine the possible sources of toxic components (e.g., stormwater, soil) to Pago Pago Harbor and design and implement

remediation for sources as feasible. Twenty-five to 35 samples of stormwater streambeds and soils will be obtained and tested for toxicity parameters. Archival research on past harbor uses will also be conducted. After toxicity testing, design for remediation of high priority and feasible sites will be completed and installed.

Time frame: October, 1992 to September, 1993

Funding level: $39,500 FY93

5.4 Malaeimi Valley Ground Water Recharge and Flood Control Study

To determine the impact of development in the Malaeimi Valley on ground water recharge to the Tafuna-Leone Plain and flooding in the lower reaches of the watershed. All data on hydrology in the watershed were collected, on-site investigation was to be completed, technical assessment of the potential impacts to the aquifer recharge and downstream flooding along with recommendations for mitigation are to be provided. A computer model of the groundwater system will be provided for future planning purposes.

Time frame: July, 1992 to September, 1993

Funding level: $50,000 FY93

5.5 Non-point Source Management Planning

To review and evaluate the effectiveness and appropriateness of non-point source management measures for non-point source pollution problems and priorities in American Samoa. ASEPA is working with the American Samoa Coastal Management Program to determine whether management measures contained in the document "Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters" are appropriate for American Samoa.

Time frame: October, 1992 to September, 1993 Funding level: $20,000 FY93

5.6 Village Watershed Demonstration Project

To remediate major non-point source pollution problems in a village watershed which fronts a reef. All major non-point source problems will be assessed and practical remediation schemes will be applied. Water quality testing and visual observations will be made before and after the project is implemented to determine project success.

Time frame: October, 1992 to September, 1993

Funding level: $65,000

6. Technical Character/Funding Levels of Projected Research

6.1 Water Quality Monitoring

Time frame: To be completed through 1997, as specified in the cannery discharge permits and for the ASEPA program.

Funding level: $75,000 per fiscal year

6.2 Investigation of Alternative Microbiological Water Quality Standards for American Samoa

Time frame: Not yet planned, targeted for FY94

Funding level: Likely be $35,000

6.3 Stormwater Quality and Management

Assessment of stormwater quality in densely populated, highly polluted, vital watersheds and impact on habitats (reef, woodlands, etc.) within the watershed.

Time frame: Not yet planned, no target date

Funding level: $50,000

6.4 Fate of the Leachate from Futiga Landfill

Time frame: Not yet planned, targeted for FY94

Funding level: $40,000

1. Program Name

Department of Marine and Wildlife Resources (DMWR)

2. Responsible Official(s)

Ray Tulafono, Director Dr. Peter Craig, Chief Biologist

3. General Purposes of Research Sponsored by the Program

The program monitors and manages fishery resources of American Samoa and develops appropriate fisheries and mariculture programs.

4. Administrative Character of the Program

DMWR is a territorial department under the Governor's Office. It operates under funding primarily from the U.S. Fish and Wildlife Service's Sport Fish Restoration Funds.

5. Technical Character/Funding Levels of the Current Research Program

5.1 Offshore Fisheries Documentation

To document use of offshore fishery resources to enable DMWR to better manage these resources.

Time frame: Ongoing

Funding level: $124,000 FY93

5.2 Inshore Fisheries Documentation

To document use of inshore fisheries resources to enable DMWR to better manage this important subsistence fishery resource.

Time frame: Ongoing

Funding level: $114,000 FY93

5.3 Biology of Reef Fishes

To obtain biological information on key reef fishes in an effort to determine distribution, abundance and life histories. The basic biological information will enable DMWR to develop management strategies to prevent overfishing and depletion of this subsistence fishery.

Time frame: Ongoing

Funding level: $49,000 FY93

5.4 Monitor and Replace Fish Aggregation Devices (FADs)

In an effort to promote sport fishing opportunities to the territory, DMWR deploys and monitors FADs.

Time frame: Ongoing

Funding level: $109,000 FY93

5.5 Mariculture - Giant Clam Hatchery

DMWR successfully cultures and raises two species of giant clam, Tridacna derasa and Hippopus hippopus.

Time frame: Ongoing

Funding Level: $20,000 FY93

6. Technical Character/Funding Levels of Projected Research

The current projects will continue at similar funding levels. In addition, the following projects are under consideration.

6.1 Research Workshop

DMWR will begin the next 5-year cycle of research with a workshop designed to produce a 5-year research plan. At this workshop both local and off-island experts will set research priorities and develop an action plan to carry the department through the next 5 years.

Funding level: $5,000

1. Program Name

Fagatele Bay National Marine Sanctuary (FBNMS)

2. Responsible Official (s)

Alfonso P. Galeai, Director, Economic Development Planning Office
Nancy Daschbach, Coordinator, FBNMS

3. General Purposes of Research Sponsored by the Program

To increase the knowledge of the marine environment, provide information to enable the management to make decisions about the natural resources of the site and to enhance the marine education of the public.

4. Administrative Character of the Program

FBNMS operates under a cooperative agreement between the American Samoa Government and NOAA. The NOAA Sanctuaries and Reserves Division provides administrative support and the America Samoa Economic Development Planning Office serves as the lead agency.

5. Technical Character/Funding Levels of the Current Research Program

Although FBNMS has a mandate to perform or support research at the site, funding has not been available.

6. Technical Character/Funding Levels of Projected Research

6.1 Water Quality Monitoring

To set up and manage a water quality monitoring program with ASEPA and DMWR providing technical support.

Time frame: To begin late 1993 or early 1994

Funding level: $2,000

1. Program Name

Star-Kist, Inc.

2. Responsible Official(s)

Maurice Callahan, General Manager
William Adams, Engineering Supervisor

3. General Purposes of Research Sponsored by the Program

The cannery is responsible for monitoring its outfalls and wastewater and ensuring that they meet the National Pollution Discharge Elimination Standards.

4. Administrative Character of the Program

Although the canneries perform their own monitoring, their outfalls are also monitored by ASEPA. Their discharges must comply with NPDES. The two canneries in American Samoa share many of the monitoring tasks.

5. Technical Character/Funding Levels of the Current Research Program

5.1 Pipeline Discharge Monitoring

Routine monitoring of the pipeline effluent is conducted at three depths.

Time frame: Ongoing

5.2 Wastewater Monitoring

Wastewater is treated with separation and tested before it is discharged into the pipeline.

Time frame: Ongoing

5.3 Deep Ocean Site Monitoring

Separated sludge is shipped to a deep ocean disposal site seven miles from the canneries and the site is tested monthly both pre- and post-dumping at three depth by a contractor.

Time frame: Ongoing

5.4 Annual Pipeline Inspection

The pipeline is inspected visually, with dye studies and by water quality monitoring of the effluent by a contractor.

Time frame: Ongoing

1. Program Name

VCS Samoa Packing Company

2. Responsible Official(s)

Michael P. McCready, General Manager

3. General Purposes of Research Sponsored by the Program

The cannery is responsible for monitoring its outfalls and wastewater and ensuring that they meet the National Pollution Discharge Elimination Standards.

4. Administrative Character of the Program

Although the canneries perform their own monitoring, their outfalls are also monitored by ASEPA. Their discharges must comply with NPDES.

5. Technical Character/Funding Levels of the Current Research Program

5.1 Pipeline Discharge Monitoring

Routine monitoring of the pipeline effluent is conducted at three depths.

Time frame: Ongoing

5.2 Wastewater Monitoring

Wastewater is treated with separation and tested before it is discharged into the pipeline.

Time frame: Ongoing

5.3 Deep Ocean Site Monitoring

Separated sludge is shipped to a deep ocean disposal site 7 miles from the canneries and the site is tested monthly both pre- and post-dumping at three depths by a contractor.

5.4 Annual Pipeline Inspection

The pipeline is inspected visually, with dye studies and by water quality monitoring of the effluent by a contractor.

Time frame: Ongoing

Appendix III.3 Inventory of Research - Guam

1. Program Name

University of Guam Marine Laboratory

2. Responsible Official(s)

V. Paul, Director
S. Wilkins, Laboratory Manager Faculty members

3. General Purposes of Research Sponsored by the Program

The UOG Marine Laboratory conducts pure and applied research into marine and aquatic systems. Areas of research include the ecology, evolution, behavior, taxonomy, systematics, zoogeography, physiology, chemistry and geology. The Laboratory also supports post-doctoral research fellows, and provides additional support to pre-doctoral candidates from other institutions.

4. Administrative Character of the Program

The Laboratory is a unit of the University of Guam and is affiliated with a number of departments and units.

5. Technical Character/Funding Levels of the Current Research Programs

5.1 Causes of variation in secondary metabolite production by tropical seaweeds. (V. Paul)

Secondary metabolites are utilized by tropical seaweeds to deter grazing and browsing species, especially fishes. This project will determine causes for the variation in production of these substances within and between seaweed species.

Funding level: $250,000/five years; National Science Foundation

5.2 Biological monitoring of cooling water effluent from the Tanguisson and Cabras Power Plants on Guam. Guam Power Authority. (S.G. Nelson)

This study monitors the effects of cooling water effluent upon selected marine organisms, to determine possible impacts.

Funding level: $75,000 FY93 5.3 Tumon Bay: Comprehensive environmental study. Guam Department of Parks and Recreation. (S. Amesbury) This is a comparative study of changes in the composition of algae, invertebrates and fishes in Tumon Bay, Guam's leading tourist resort area. Data will be compared against a previous survey conducted in the late 1970's. Funding level: $90,000 FY93

5.4 Interagency agreement for biological and bioassay monitoring. Public Utility Agency of Guam. (R. Richmond)

This provides for biological monitoring and assays in communities likely to be impacted by utilities operations.

Funding level: $25,000 FY93

5.5 Age and growth analyses of collected otoliths to provide information on the biology of yellowfin tuna stocks fished by long-liners in the Western Pacific waters. Guam Department of Commerce. (S. Amesbury)

This project will utilize otoliths and other data collected at Guam's commercial port, where commercial longlining operations are supported, to obtain age and growth information.

Funding level: $3,600 FY93

5.6 Establish an in-stream program for the Ugum River Water Supply Facility. Public Utility Agency of Guam. (B. Smith and S. Nelson)

This project provides a baseline study of the Ugum River system, which has been designated a water supply source. The project will attempt to characterize the biology and ecology of the system's aquatic organisms, and establish and implement baseline and monitoring procedures. Some of the organisms, particularly fishes and crustaceans, have partially marine life cycles.

Funding level: $51,000 FY93

5.7 Minority Biomedical Research Support-Project #4: The reproductive biology and population genetics of corals. National Institutes of Health. (R. Richmond)

This project will attempt to describe the reproductive biology of corals in the Marianas, principally on Guam, investigate genetic relationships between populations, and identify likely impacts that may inhibit or reduce coral reproduction.

Funding level: $55,156 FY93

5.8 Minority Biomedical Research Support- Project #2: Relationships of Ciguatera producing dinoflagellates to seaweeds. National Institutes of Health. (C. Lobban)

Ciguatera is a problem common to the Mariana Islands. This project will examine the relationship between toxin-producing dinoflagellates and benthic algae on Guam's reefs.

Funding level: $33,015 FY93

5.9 Regional management plan for sustainable sea cucumber fishery for Micronesia. National Marine Fisheries Service. (R. Richmond)

This project will attempt to establish and provide the basis for maintenance of a sea cucumber fishery at various islands of Micronesia. Research will include the identification of likely species and an investigation their biology includes baseline data on the distribution and relative abundance of organisms, potential measurement of impacts to the marine environment as they affect the fishery and identification of likely indicator species for monitoring environmental health.

Funding level: $58,190

5.10 Baseline marine biological study of Guam's Taragüe Marine Refuge at Anderson Air Force Base. Department of the Air Force, contracted to The Nature Conservancy (Pacific Region). (S. Amesbury)

The study will assess the algal, invertebrate and vertebrate fauna for Guam's first marine reserve.

Funding level: FY93-94, amount not indicated

Additional Marine Laboratory projects and interests for which funding was not specified:

5.11 Transport of fecal coliform bacteria into Tumon Bay: drinking water well changes in response to rainfall and tidal cycles. (E. Matson)

Potable water will increasingly become an issue on Guam, because of recent population increases and economic growth. This project will characterize the effects of rainfall and tidal cycles upon well water output.

5.12 Larval responses to temperature effluent: Responses of rabbitfish larvae (Siganidae) to different levels of power plant thermal discharges. (S. Nelson)

Thermal effluent may be an important impact upon recruitment and early growth of marine organisms. This project will characterize effects of thermal effluent upon a commercially important species. 5.13 Cave-dwelling marine invertebrates. (G. Paulay) A survey of marine cave specialized invertebrate fauna occurring in the Mariana Islands. These may be threatened by terrestrial development and groundwater pollution.

5.14 Informal surveys of introduced marine species. (G. Paulay)

The introduction of exotic marine invertebrate species may have serious impact upon local communities. Effort been concentrated at Apra Harbor, where shipping activities and the repositioning of naval equipment have resulted in introductions.

5.15 Corals of the Northern Mariana Islands. (R. Randall and T. Donaldson)

Descriptions of species collected during the CNMI-Chiba Natural History Museum and Institute Northern Mariana Islands Expedition (1992). The reef fauna of the volcanic Northern Mariana Islands is still poorly known. This study will provide geographic range extensions for a number of coral species collected during the expedition.

5.16 Patterns of species richness, species diversity, distribution, diet and habitat utilization of shallow water groupers (Serranidae: Epinephelinae) of the Northern Mariana Islands. (T. Donaldson)

Results of the CNMI- Chiba Natural History Museum and Institute Northern Mariana Islands Expedition, and projects funded previously by NOAA under the Interjurisdictional Fisheries Act (Mariana Islands Fish

Biology and Mariana Islands Grouper Biology), and the U.S. Fish and Wildlife Service Sportsfish Restoration program (Shallow water epinepheline grouper biology).

Various aspects of the habitat and reproductive ecology, reproductive behavior, feeding ecology and zoogeography of important grouper species.

5.17 Ecology and behavior of obligate and facultative coral-dwelling fishes. Results of studies previously funded by the Coypu Foundation and the U.S. Fish and Wildlife Service Sportsfish Restoration program Reef fish projects. (T. Donaldson)

The studies examined the relationship between various reef fish species and corals of the genus *Pocillipora*, with emphasis on the utility of this relationship as an indicator of ecological health.

5.18 Aspects of sex change and reproductive biology of groupers (Serranidae: Epinephelinae) of the Northern Mariana Islands (in conjunction with the Department of Fisheries, Kyushu University). (T. Donaldson and A. Nakazono)

An examination of gonad structure, spawning cycles and reproductive ecology of groupers common and important to the Northern Mariana Islands. Some support has come from the Marianas Fish Biology and Marianas Grouper Biology projects under the NOAA Interjurisdictional Fisheries Act program.

5.19 New records of fishes from the Mariana Islands. (R. Myers and T. Donaldson)

This project is a continuation of efforts to assemble a comprehensive list of fish species occurring in the archipelago. Previous efforts have concentrated on nearshore species. This project will also include deepwater and species exclusive of mesopelagics. Funding sources have included the U.S. Fish and Wildlife Service Sportsfish Restoration program and the Coypu Foundation. A zoogeographic analysis will follow. 6. Technical Character/Funding Levels of Projected Research

No information provided.

1. Program Name

University of Guam Water and Energy Institute

2. Responsible Official(s)

G. Denton, Assoc. Professor
H. Wood, Assoc. Professor

3. General Purposes of Research Sponsored by the Program

WERI conducts basic and applied research into various aspects of marine and groundwater resources, including chemistry, biology,

hydrology, toxic contamination, geology and sedimentology. WERI also conducts research into alternative energy matters.

4. Administrative Character of the Program

WERI is a unit of the University of Guam.

5. Technical Character/Funding Levels of the Current Research Programs

No information provided.

6. Technical Character/Funding Levels of Projected Research Programs

6.1 A toxic contaminant assessment of Guam's coastal water resources. (G. Denton, H. Wood and G. Davis)

This project will attempt to characterize levels of toxic contamination in a variety of coastal resources and habitats. The outcome will include a baseline for future monitoring comparisons.

Funding level: Year 1 - $433,966; Year 2 - $109,574; Year 3 - $115,039

1. Program Name

Guam Division of Aquatic and Wildlife Resources (DAWR)

2. Responsible Official(s)

R. Lujan, Chief
G. Davis, Fisheries Supervisor

3. General Purposes of Research Sponsored by the Program

The DAWR is the lead agency for research and management of marine and freshwater fisheries and fisheries habitats in the territory.

4. Administrative Character of the Program

The program is largely modelled upon project agreements between the Division and the U.S. Fish and Wildlife Service's Sportsfish Restoration Program, which are administered over a five year period. Additional support and interaction comes from other federal agencies, especially the Western Pacific Regional Marine Fisheries Council and the National Marine Fisheries Service.

5. Technical Character/Funding Levels of the Current Research Programs

5.1 Guam Fish and Wildlife Investigations: Management of Guam's Marine Fisheries Resources

5.1a Study 1: Fisheries participation,effort and harvest surveys

Subsistence, recreational and commercial fishing have always been important on Guam. This project monitors activity in inshore and offshore fisheries. The project seeks to provide baseline catch and effort data on reef fish, bottom fish and pelagic fish resources and provide and historical data base for management purposes.

Funding level: FY92 - $52,500; FY93 - $55,250; FY94 - $58,250

5.1b Study 2: Computerized data manipulation of Guam's fisheries data

This project will attempt to computerize marine fisheries data, analyze fisheries data for the development of a marine fisheries plan and provide technical assistance to staff biologists for the analysis of other fisheries data.

Funding level: FY92 - $20,250; FY93 - $21,500; FY94 - $22,500

5.1c Study 3: Studies of Guam's recreationally important fish

This project is attempting to provide an analysis of fish responses to fishing pressure, determine life cycles and basic biology, investigate behavior and ecology in habitat preferences and seasonality and evaluate the need for and development of a management plan. Target species include: Mulloidichthys flavolineatus (FY90-92), and Lethrinus harak (FY90-93). Additional species have yet to be named for study.

Funding level: FY92 - $29,956; FY93 - $30,250; FY94 - $32,000

5.1d Study 4: Establishment of a marine sanctuary

This project seeks to establish a marine conservation area and provide a basis for stock replenishment.

Funding level: FY92 - $22,000; FY93 - $23,250; FY94 - $24,500

5.1e Study 5: Fish population densities and distribution

This project will attempt to estimate population densities and distribution patterns of recreationally important species, and attempt to forecast their abundance by correlating stock assessments with fisheries survey data over time.

Funding level: FY92 - $26,750; FY93 - $28,250; FY94 - $29,750

5.2 Marine Fish Habitat Improvement and Aggregating Devices

A five-year project to: 1) improve the quality of fish habitats, including protection of corals from destruction by fishing operations

through the development of a shallow water mooring system; and 2) to enhance pelagic fisheries by the deployment of a functional fish aggregation device (FAD) network, which will be monitored for effectiveness.

Funding level: $129,600 FY92; other years not indicated

6. Technical Character/Funding Levels of Projected Research Programs

No information provided.

Appendix III.4 Inventory of Research - CNMI

1. Program Name

CNMI Division of Fish and Wildlife

2. Responsible Official(s)

A. Palacios, Chief
J. Gourley, Fisheries Supervisor
D. Stinson, Wildlife Supervisor

3. General Purposes of Research Sponsored by the Program

The Division conducts basic and applied research on the biology and management of fish, fisheries resources and habitats. Wildlife programs in marine systems are also supported. The Wildlife Section has three projects related to marine environments. Projects are funded annually with five year project agreements with the U.S. Fish and Wildlife Service under the Pittman-Robertson Act.

4. Administrative Character of the Program

The Division is part of the CNMI Department of Natural Resources. Projects are modelled after five year agreements made with the U.S. Fish and Wildlife Service Sportsfish Restoration Program. Additional funding and interaction comes from a variety of sources, especially the National Marine Fisheries Service, NOAA and the Western Pacific Regional Fishery Management Council.

5. Technical Character/Funding Levels of the Current Research Programs

5.1 Checklist of CNMI Fishes

A project to assess and maintain a comprehensive species checklist of marine and freshwater species occurring in Commonwealth waters, and to collect and maintain a reference collection. Two color posters, with fish names in six languages plus the scientific name, will eventually be produced with Guam's DAWR.

Funding level: $13,092 FY93

5.2 Inshore Reef Fish Research and Management

To characterize the reef fishery through determination of basic life history characteristics of various species; to determine catch per unit effort and assess potential for overfishing; to assess accuracy of current size restrictions.

Funding level: Creel Survey - $34,357 FY93
Biological Analysis- $19,480 FY93

5.3 Shallow and Deepwater Bottomfish Research and Management

To characterize current status of bottomfish stocks on offshore banks and seamounts; to examine basic life history characters; to develop management guidelines.

Funding level: $45,168 FY93

5.4 Pelagic Fish Research and Management - Offshore Creel Survey

To characterize the pelagic fishery with respect to length frequency analysis and seasonality; to obtain basis life history data; to collect catch per unit effort data for analysis of fishery; to organism and maintain a computer data base.

Funding level: $50,148 FY93

5.5 Pelagic Fish Research and Management: Performance Assessment of Fish Aggregation Device

To estimate the level of use of FADs by fishermen; to determine catch per unit effort and compare with non-use of FADs.

Funding level: $12,244 FY93

5.6 Resource Protection and Management

To develop appropriate mitigation plans and marine impact assessment plans for development projects; to coordinate environmental activities with local and federal agencies with respect to marine and freshwater environments.

Funding level: $28,218 FY93

5.7 Oceania Wetland Inventory: Puerto Rico Mudflats

Surveys of species richness and population sizes are made at a principal mudflat on Saipan.

Funding level: No funding information provided

5.8 Migrant Shorebirds: Patterns of Migration

Surveys to assess species richness and population sizes are annual and usually limited to Saipan and Rota. Survey data includes that obtained from Audubon Society Christmas counts.

Funding level: No funding information provided

5.9 Seabird Surveys

An investigation of annual nesting populations at both the northern (isolated volcanic) and southern islands of the archipelago. The most recent survey was during the joint CNMI-Chiba Natural History Museum and Institute (Japan) expedition (1992). Southern island surveys include data from annual Audubon Society Christmas counts.

Funding level: No funding information provided

6. Technical Character/Funding Level of Projected Research

No information provided

1. Program Name

CNMI Coastal Resources Management Office

2. Responsible Official(s)

J. Villagomez, Administrator
J. Furey, Coastal Coordinator

3. General Purposes of Research Sponsored by the Program

To characterize marine and coastal habitats in relation to potential and actual impacts and to coordinate and enforce coastal environmental regulations.

4. Administrative Character of the Program

CRM was originally patterned after the federal CZM program. CRM currently operates as an agency of the Governor's Office and maintains a Coastal Resources Management Board for decisions regarding development projects.

5. Technical Character/Funding Levels of the Current Research Programs

None

6. Technical Character/Funding Levels of Projected Research

6.1 CNMI Marine Monitoring Program for Non-point Source Pollution

Funding level: Grant 306 request: $487,333
Grant 6217 request: $42,000
Program income: $218,902
GIS system request: $17,500
(submitted to the U.S. Environmental Protection Agency)

6.2 Multi-year Strategy Plan to Assess Coastal Hazards, Cumulative and Secondary Impacts, Wetlands, Marine Debris, Ocean Resources, Public Access, Special Area Management Plans and Energy and Government Facility Siting.

Funding level: No funding information provided

6.3 Development and Implementation of a Watershed and Wetland Protection Plan for the Magpo Valley, Tinian (with DEQ)

While largely a freshwater project, there are also implications for coastal impacts and management.

Funding level: No funding information provided

Appendix III.5 Inventory of Research - Hawaii

1. Program Name

Environmental Health Administration, Department of Health (DOH)

2. Responsible Official(s)

Bruce Anderson, Deputy Director for Environmental Health

3. General Purpose of Research Sponsored by the Program

Through the Water Quality Standards Program, the U.S. EPA and the State of Hawaii fund contracts for applied research projects designed to provided DOH with data necessary to support revisions to the Hawaii Water Quality Standards and other water pollution control activities. Bacterial and chemical monitoring of coastal waters is carried out by the staff of the Monitoring Section of the Clean Water Branch.

4. Administrative Character of the Program

The Environmental Health Administration is the State's primary environmental protection agency. Within this division of DOH is the Water Quality Standards Program, managed by the Environmental Planning Office (EPO) and the Monitoring Section of the Clean Water Branch (CWB). These programs primarily enforce federal and state water quality standards and policies.

5. Technical Character/Funding Level of the Current Research Program

Within the Water Quality Standards Program, major marine research initiatives which may continue into 1997 include projects to elicit more information on seasonal macroalgal blooms observed in shallow coastal waters along the west coast of Maui (see Maui Algal Bloom Task Force) and projects designed to collect data in support of area-specific water quality standards. Area-specific standards are being developed for parts of the Kona coast on the Island of Hawaii (see West Hawaii Task Force). Annual funding levels vary, but a minimum level of federal funding is available each year for applied research contracts awarded through the Water Quality Standards Program. Levels may be much higher, if there is public perception of a serious problem in the marine environment which deserves special funding. Funding levels for laboratory analyses (Monitoring Program) are determined by the legislative appropriation to the state "Blue Water Monitoring Program" which is largely state funded.

6. Technical Character/Funding Level of Projected Research

No information provided.

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