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2.2 MARINE ENVIRONMENT IMPACT OF LAND-BASED ACTIVITIES IN THE TRUST TERRITORY OF THE PACIFIC ISLANDS

by

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INTRODUCTION

Our knowledge of the adverse effects of land-based activities on the environment is more limited for tropical than for temperate marine areas. Yet in the increased rates of metabolism, decreased oxygen levels, and lower levels of dissolved nutrients in warm tropical waters (Johannes and Betzer 1975), there is greater cause for concern about the tropical marine environment, especially in shallow restricted coastal areas.

Increasing development of the Pacific Islands is resulting in many activities that affect the coastal marine environment. This paper deals with the impact of land-based activities on the marine environment in the U.S. Trust Territory of the Pacific Islands (TTPI), an ocean area of some 7.77 million km^2. Within this area are 2141 islands with a total land area of 1800 km^2. Most of the examples cited are from Yap Island, the smallest (101 km^2) of the six original districts of the Trust Territory.

SILTATION

Probably the most serious and widespread impact of land-based activities on the marine environment today is siltation.

GENERAL EFFECTS

Creation of an oxygen demand - Sediment traps organic matter on the bottom and creates an oxygen demand which may result in gas ebullition and an objectionable anaerobic condition (Bartsch 1954, and Ellis 1940, cited by Hollis et al. 1964). Brown and Clark (1968) monitored dredging operations in a waterway in New York and noted that dissolved oxygen was reduced 16 to 83 percent during dredging operations when Secci disc readings showed a turbidity of 1.0 to 0.5 m. Because the level of dissolved oxygen normally decreases with increases in water temperature, this effect is especially important in warm waters such as those of the TTPI.

Reduction of light penetration - Turbidity brought about by siltation decreases light penetration and interferes with photosynthesis. Phinney (1959) reported that sediments from a highway construction resulted in a reduction of 61 percent in primary production in a period of heavy sedimentation. A reduction in the amount of primary production decreases the source of support for a food chain and also the amount of dissolved oxygen in the water.

Flocculation of planktonic algae - Jackson (1963) reported that silt flocculates planktonic algae and carries such organisms to the botom to die. This effect lowers primary productivity and oxygen levels in an aquatic habitat.

Increase in nutrient load - If sediment contains organic nutrients, this combined with other effects described above may result in eutrophic conditions. A University of Maryland (1970) study of spoil disposal showed that the levels of phosphates and nitrogen in the vicinity of the discharge increased by factors of 50 and 1000, respectively, over ambient levels.

Adsorption and absorption by small particles - Silt is thought to provide added surface area for the growth of microorganisms. An increase in the concentration of bacteria, fungi, and other microorganisms alters the oxygen level, pH, and other characteristics of water and may result in anaerobic conditions producing noxious gases.

The adsorption and absorption of chemicals is particularly important if it leads to a buildup of toxic substances in a limited area with the possibility of sudden release (Clairns 1968). In this regard, Brunge and Bailey (1966) report that the availability of endrin in an aquatic environment is influenced by the suspended solids load. The presence of silt in the water is said to precipitate oil as well.

Delay of self-purification of water - The ability of water to cleanse itself is hampered by a decrease in the level of dissolved oxygen, and by increases in the nutrient and bacterial levels.

Mechanical abrasive action - Some authorities believe that the presence of mineral particles in moving water results in a damaging abrasive action on aquatic organisms, including corals.

Smothering of the bottom - The most direct effect of siltation is the deposition of sediments on a stream or ocean floor. Much of this sediment will settle into the crevices of a coral reef, making the habitat of innumerable tiny organisms inaccessible. Though poorly understood, this varied biota probably plays a significant role in the functioning of a coral reef community (Johannes 1970). Other bottom dwelling creatures may be smothered by the layer of material deposited upon them. Shifting of the unstable bottom created by sedimentaiton may interfere with the attachment of many sessile benthic species and act as a physical barrier, preventing free exchange of gases on the leaves of higher aquatic plants (Phinney 1959).

Changes in the species composition of the community - Although the literature contains contradictory reports on the effects described above, largely because these are different types of siltation, it is clear that siltation does affect the species composition of particular aquatic community, sometimes from the beginning of the food chain all the way to the end products harvested by man. The University of Maryland (1970) study of spoil disposal showed that at the site of discharge, "an erratic series of species fluctuations occurred. After 1 year, the channel had about the same number of individuals as during the pre-dredging period, but not as many species were present". A contrasting situation is presented by Griggs and Kulm (1969) from a study of turbidity current deposition in the nutrient poor Cascadia Channel in the northeast Pacific Ocean. Here, the benthic organisms in the channel were four times as abundant as those of the adjacent plain.

EFFECTS OF SILTATION ON CORAL

Tropical coral reefs are made up mostly of hermatypic corals and coralline algae. Hermatypic corals exist to depths of about 90 m, but thrive best at shallower depths of 25 m or less. Zooxanthellal, symbiotic algae, live within the coral endoderm and skeleton. It is believed that these algae obtain their inorganic nutrients and carbon dioxide from the coral, and provide oxygen and some carbohydrates for the coral (Clarke 1954; Newell 1959). These symbiotic algae require sunlight for photosynthesis. In addition, sunlight is needed for the deposition of calcium carbonate (Goreau 1963). The living part of the coral itself is a soft pulp which filters nutrients from surrounding waters.

Coral reefs are among the most biologically productive and taxonomically diverse of any ecological community (Johannes 1970). As such, they represent a great resource at the present time, with possibly even greater potential for the future. In addition, their beauty represents one of our greatest tourist attractions. Although corals do not account for the major fraction of the total reef biomass or metabolism, they seem to be the most essential organism for the maintenance of the coral reef ecosystem, and the resistance of a reef community to environmental stresses cannot exceed that of its coral component (Johannes 1970). Thus it is important that siltation standards be set to prevent siltation levels from exceeding the tolerance levels of corals.

Siltation results in turbid waters and the deposition of a blanket of sediment on corals. The light reaching corals is thus reduced; the zooxanthella cannot photosynthesize and their benefit to the coral is lost. In addition, light reduction may interfere with deposition of calcium carbonate. Edmonson (1928) studied the effect of darkness on 17 species of Hawaiian coarls and found that after 18 days of darkness, more than 50 percent died, especially species of <u>Pocillipora</u> and <u>Porites</u>, common genera in Micronesia.

The tiny coral polyps normally filter the water for nutrients. Many can remove excess sediment from their surface by ciliary action However, when the amount of sediment in the water increases, this ciliary action is inadequate and the corals are smothered. The vulnerability of corals to smothering varies with species. It is thought that those species adapted to living in clear waters such as the outer reef margin are less able to remove sediments from their surfaces and are therefore more easily damaged by siltation.

Planulae, the free swimming larvae of corals, need a hard surface to settle on. A soft, unstable shifting bottom produced by siltation would hinder their settling and thereby present the recolonization of silt-damaged areas by corals.

Damage to corals may contribute to population explosions of crown-of-thorns starfish (<u>Acathaster plancii</u>). Chesher cited by Levin 1970) cites instances on Guam, Rota, and Ponape where populations of this starfish increased sharply following blasting and dredging operations. The increased populations of crown-of-thorns starfish then destroyed more living corals.

The most direct evidence on siltation damage to corals is reported by Brock et al. (1965, 1966) following dredging activities on Johnston Island. About 28 million m^2 of reef and lagoon were seriously affected by sediment-laden waters and 4 million m^2 of reef were totally destroyed by dredging. There was also a reduction in the numbers of enchinoderms and fish species present.

The effects of sediments on corals in Kaneohe Bay, Oahu, Hawaii, is being studied. Large amounts of sediment enter this bay as a result of erosion caused by land-use practices. According to Maragos (cited by Levin 1970), 10 to 15 years ago coral growth existed to 10 m in depth. It is now limited to 4 m or less.

Corals live within a salinity range of 21 to 40 percent (Newell 1959; Shepard 1963; Wells 1957). The addition of large amounts of freshwater runoff is damaging to them. If lowered salinity does not kill them outright, it probably causes stress and makes them vulnerable to damage and death from other causes.

SOURCES OF SILTATION

Major sources of siltation in the TTPI are surface runoff, shoreline landfill operations, and dredging operations.

<u>Surface runoff</u> - Natural siltation in Micronesia is greatest around the high islands. Elevated watershed areas provide for the collection and acceleration of flowing water from the land to the sea. This water picks up loose soil and humus and carries all out to sea. Around the high islands of Micronesia however, filtering zones remove sediments before runoff reaches the clear waters of the lagoon and reef. The coasts of many Micronesian high islands have mangrove forests, where sediments from the land are filtered out and chemically buffered. Large amounts of organic material accumulate and decay in mangroves. Another filtering zone often found near the mangroves are expanses of seagrass meadows. The bottom of these areas varies from mostly silt on the inner margin to mostly sand on the outer margin. These seagrass meadows contribute a great deal to the filtering and settling of siltation which gets through the mangrove.

It appears that these elaborate filtering and silt-adjusted biotic communities that have evolved around high islands serve to stabilize much of the natural runoff from the land, if left intact. Unfortunately, little is known about the operation and carrying capacity of this system, its relation to nutritional levels of lagoon and reef waters, and their relation to fish nurseries and the coral reef community.

The activities of early inhabitants of the high islands no doubt increased levels of siltation above natural levels; however, whether by design, necessity, or both, major land-based activities (largely agricultural systems) seem to have made minimal increases in sediment production.

On many islands, there are low areas just inland of the coastal strand of mangrove. These areas, probably swamp or marshland originally, can function as a sediment trap, allowing the sediment from higher areas to settle before flowing into the ocean. Island people have largely converted such areas into taro patches. In doing so, they have modified the species composition of the area to one which utilizes the natural system for food production, but does not change the area's function as a sediment trap.

Traditional agricultural activities further inland also made only minimal increases in soil erosion, and the islands of Truk, Ponape, and Yap present three strategies of food production with built-in measures for maintaining the vegetative cover on the soil.

On Truk, the steep, lower slopes have usually been converted into cocounut-breadfruit agroforest. This produces food, while maintaining a cover of trees to protect and stabilize the soil. The native forests on the top of Truk's higher islands have, in some places, such as Fefen, Dublon, and Tol, been left to prevent soil erosion. The steepness of the open slopes below these forests indicates their effectiveness, and also their vulnerability, for if these slopes are not stabilized, the forested areas will be undercut and more devastating erosion will result. The seriousness of removing tree cover on such steep islands was tragically demonstrated in recent years when heavy rains resulted in a mudslide which took six lives.

The island of Ponape is high enough to create considerable orographic rainfall and more than 10,000 mm of rain per year estimated to fall on upper slopes. Removal of vegetaion cover under such conditions results in severe erosion. The Ponapean agricultural specialty, the growing of huge yams (Dioscerea spp.) however, provides for a continued vegetation cover. This activity is carried on in a diffuse pattern by men who plant yams below trees which they climb, to train the vines up the tree. Depending upon the tree species and the amount of sunlight filtering through its leaves, the tree may be injured so that it drops some or all of its leaves as the yam grows. Eventually, the yam vine covers the tree. After the yams are harvested, the tree may recover; if not, the open space is rapidly covered over by surrounding vegetation and erosion is minimal.

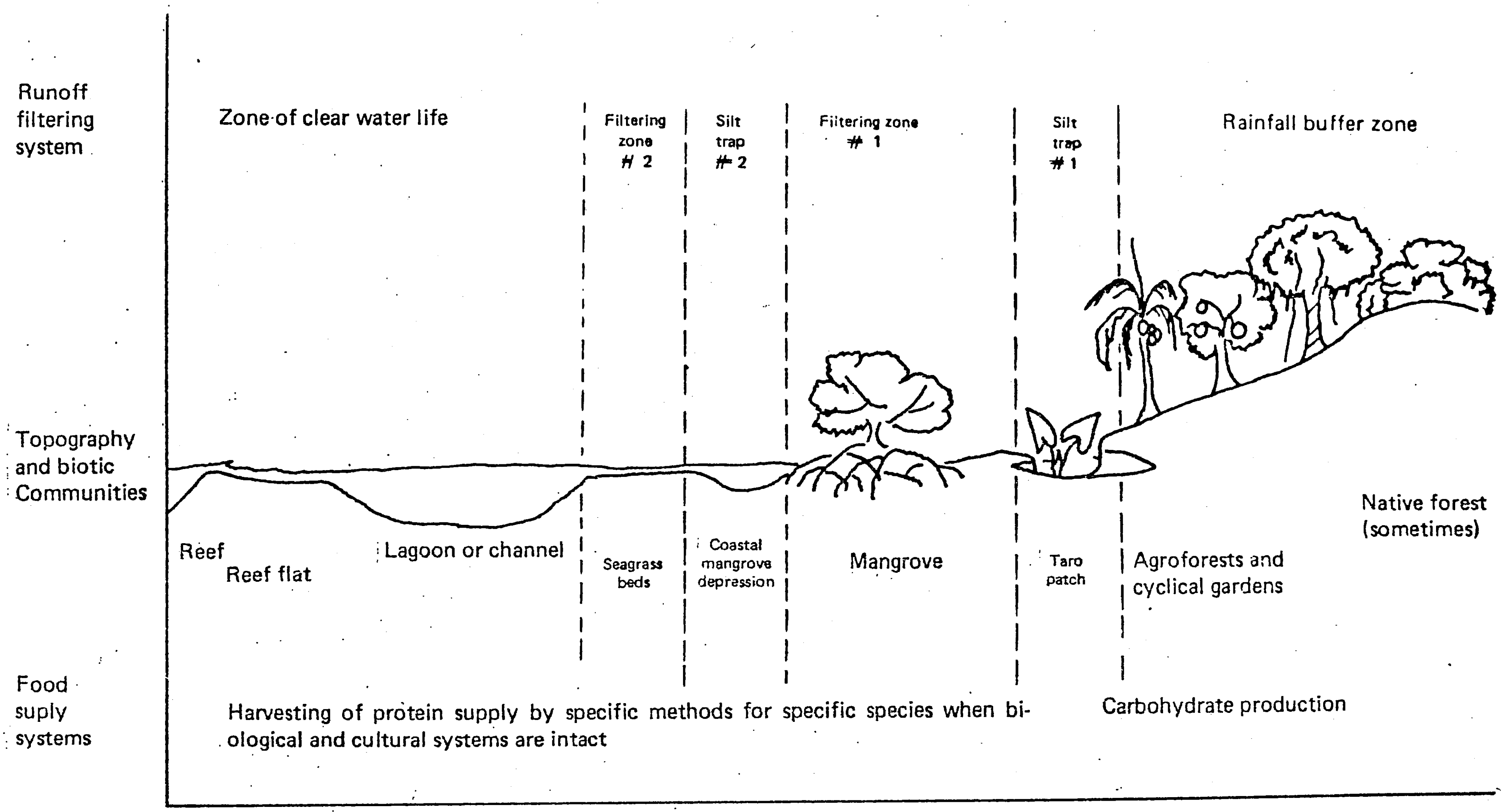

Figure 1 — The relationship between island topography, biotic communities, and traditional food production systems on high islands of the Trust Territory of the Pacific Islands.

Yap Island is subjected to frequent storms and unpredictable rainfall. The forests have been "customized" for the production of a variety of foods. Many species of food trees are allowed to grow and their harvest alternated with produce from taro patches and yam gardens. Burning is used to open up small garden areas and to produce ash fertilizer under trees and bamboo patches. Curcubits generally grow rapidly and cover the ground as the leaves of the burnt trees or bamboo fall, opening a "skylight" in the forest canopy. Yam vines climb up the trees and bamboo poles, producing a higher cover as the curcubits are harvested and die back. These are replaced by slower growing crops. The result is multilayered protective and food producing vegetation, which after some years is allowed to go fallow so that the 'skylight" in the forest canopy gradually closes.

The relationship between these food producing systems, island topography, and the filtering of coastal runoff is diagrammed in figure 1. In many areas, the natural or modified erosion has now been accelerated. Plumes of eroded soils are often seen near the mouth of many streams and drains in Micronesia. This runoff represents a lost resource, and becomes a problem of marine pollution by siltation. Activities which aggravate this soil erosion include burning, which removes the vegetative cover from hills; cultivation practices; and construction and bulldozing operations such as roadbuilding.

Bulldozing operations are probably the biggest cause of soil erosion. When the vegetation of savanna lands is removed by fires, and the exposed soil degraded, the root systems of these fire-adapted species are left to hold the soil. A bulldozer removes not only ground cover but also the root structure.

<u>Shoreline landfill operations</u> - It is a general practice throughout Micronesia to produce additional land area by filling in the coastline with trash and other materials. On Yap, at least in the past, a retaining wall was constructed, and then the area inside the wall was filled with trash and other materials, including sod from seagrass beds. Large areas of land were thus built. Following a decrease in population, much of this land is now being reclaimed by the mangrove and sea. The practice of depositing trash at the water's edge however, continues--too often without benefit of a retaining wall. When soil is part of the deposit, there is considerable siltation, often beyond the mangrove filter zone, so that sediments are carried into hitherto protected waters.

<u>Dredging operations</u> - Dredging operations are often carried on beyond the filtering systems of mangroves and seagrass beds. Siltation produced by these operations may be especially damaging as it reaches the clear waters of natural communities normally protected by the silt traps, and filtering systems of mangrove and seagrass beds.

EFFORTS TO REDUCE SILTATION

In 1974, the Trust Territory Environmental Protection Board (TTEPB) addressed the problem of siltation by passing "Regulations Concerning the Control of Earthmoving and Sedimentation in the TTPI.". This has now become Title 63, Chapter 13, Subchapter III of the Trust Territory Code.

This regulation requires that anyone doing any earthmoving activity, except agricultural or for the construction of a one- or two-family residence, apply for a permit from the TTEPB. The application must contain an erosion and sedimentation control plan which must be implemented; and upon completion of the work, soils must be stabilized.

At first, these regulations were neither widely known nor enforced, at least on Yap, as evidenced by projects such as the construction of the hospital, when large amounts of soil were bulldozed directly into the water. Since about 1975, however, projects done in the TTPI by outside contractors have been monitored by the Office in Charge of Construction (OICC) of the U.S. Navy, which enforces existing laws. The main evidence of compliance with the regulations today is the use of silt booms about landfill and dredging operations, and the construction of stabilized seawalls. Some monitoring of turbidity is done by OICC and environmental health personnel. The U.S. Army Corps of Engineers also cooperates with environmental health workers in enforcing regulations in coastal areas.

Since the OICC began enforcing regulations on the large projects under its administration, siltation problems have been somewhat alleviated. Regulations are not as strictly enforced against TTPI government agencies or private operations as against construction firms. This is because environmental health workers are put in the awkward position of bringing charges against their own government, neighbours, or kin. Especially when budgets are stretched, the philosophy that "environmental protection is fine as long as it doesn't impede progress' prevails.

There are also problems of evaluating permit applications. Current environmental health personnel are too few to conduct surveys to adequately evaluate various permit applications, especially underwater surveys. The alternatives are to hire expensive outside consultants, or to issue permits so that activities can be carried out on a provisional basis. Given budget limitations and the push for economic development, this latter alternative is the most attractive. Once provisional permits are listed, they are unlikely to be revoked unless damage is very obvious or there are public complaints.

The problem of local enforcement would be made easier if public support existed for the enforcement of siltation regulations. In the Trust Territory of the Pacific Islands however, the public is only now beginning to become aware of potential siltation problems. This limited awareness, combined with a natural hesitancy to complain, especially when otherwise desirable projects are underway, makes the work of local enforcers of environmental regulations difficult.

Ideally, a biological monitoring and assessment program would include a trained scientist working with a group of environmental health workers and local youth in such programs as Youth Conservation Corps, Young Adult Conservation Corps, and Comprehensive Employee Training Act. This could result in better resource management and increased public awareness, and at least complement other Young Adult Conservation Corps activities such as the training of local youth by Navy Sea-Bee construction teams.

The omission of agricultural activities from earthmoving permit requirements is a cause for concern. Traditional subsistence agricultural practices such as taro patch culture and cyclical forest gardening, where the canopy is gradually removed and later allowed to grow back, conserve soil resources. But newer practices, such as the burning of large areas, breaking of soil on steep slopes, and clearing with bulldozers, result in soil degradation and aggravated soil erosion.

The final report of the International Reference Group at Great Lakes Pollution from Land Use Activities reports that "pollutent contributions per unit area are generally one or two orders of magnitude higher for agricultural and urban land compared to forested and idle land." (Sonzogni et al., 1980).

The TTPI Five Year Indicative Development Plan places priority on agricultural development, and there is a tendency for neoagricultural projects to be preceded by the clearing of large areas with bulldozers, leaving the soil easily degraded and eroded.

The Forest Service, U.S. Department of Agriculture, is currently beginning a project to evaluate traditional agroforestry in Micronesia. Agroforests consist largely of multiple use food trees and represent a well adapted system of "permanent agriculture" (Douglas and Hart, 1968). A current vegetation mapping project of the TTPI by the Forest Service has demarcated considerable acreage devoted to this traditional agricultural specialty. It is a most effective system of land use, especially on slopes where openland bare soil type of agriculture would otherwise result in erosion and subsequent siltation.

There is also need to define and protect watershed areas in Micronesia, and to control wildfires so that soils will not continue to be degraded, and nutrients lost to erosion.

CHANGES IN CURRENT AND NUTRIENT FLOW PATTERNS

The building of roads and causeways is a major source of siltation, both directly and indirectly. These roads are generally made of coral fill, which is often obtained through dredging operations. Also, new roads often provide access to forested slopes, where soils are more fertile than those degraded by repeated burning. Without regulatory controls on earthmoving for agricultural purposes on sloping land, the tree cover is destroyed and erosion generally follows.

Another serious problem is that many roads are being built along the perimeter of high islands, either between the land and mangrove or through the mangrove forests. Unlike old paths in such areas, which had many passages for water and bridges, these roads are created with heavy machinery so that the soil is compacted. Bridges and culverts, being expensive, are limited to only what is necessary to meet engineering requirements. There is a need to evaluate the impact of these roads on nutrient cycling between land and sea. The contribution of nutrient-rich runoff from the land to mangroves, and the function of mangroves in settling sediments and regulating nutrient flow to the lagoon, is becoming well known. In a number of instances, water circulation to mangroves has been cut off, causing mangrove trees to die. The effect on mangrove trees can be seen, whereas the effect on seagrass communities and lagoon and reef communities beyond is not yet apparent. If we consider the mangrove as a physical and biochemical filter, then the situation is analogous to clogging the pores of the filter and punching a few big holes. Major roadbuilding projects are now being carried out on many high islands and there are no provisions for environmental impact assessment and no appraisals of the damage being done.

One of the most common interferences with natural flow patterns is the construction of causeways. Often, too few culverts or bridges are allowed for providing normal water circulation. As a result, silt depostis build up. One striking example of this is the Tuanmokot channel area between Takatik Island and Sokehs Island on Ponape. A causeway was built from the shore of mainland Ponape to Takatik Islet with only one bridge to allow for water circulation. Another causeway with one set of culverts connects mainland Ponape with Sokehs Island at the other end of the bay. As a result of the restriction of currents, and dredging operations in the area, the bay is very heavily silted. One resident reported that the water depth below the Nintu River and decreased about 0.5 m over a 2- to 3-year period after the causeway was built, preventing larger boats from passing through the area at low tide.

More recently, this bay was chosen as a site for the Ponape sewer outfall. Bottom silt in the area of the outfall is nearly 1 m deep and water extremely turbid. Current studies done in the area after the decision to site the outfall there indicate that the main body of the effluent from the sewage treatment plant "will drift alternately in a north and southwest direction in the channel.

The distance effluent will travel depends greatly on the tidal range and wind conditions. During neap tides, the effluent will generally stay in the vicinity of the outfall site. However, during spring tides, the effluent may exit past the Commercial Port on its way to Jokaj Passage" (Tsuda et al., 1978).

There appear to be no regulations specifically relating to the construction of causeways or provision for nutrient flow in mangrove areas. There is a need to develop an understanding of the water and nutrient flow requirements of mangroves, and the effect of the road construction on mangroves and the coastal and reef community beyond. Guidelines are needed for the provision of adequate water and nutrient circulation when roads are built in mangrove areas.

A recent vegetation mapping project carried out by the Forest Service, U.S. Department of Agriculture, in Palau, Yap, and Ponape demarcates relatively large areas of apparently stunted mangroves. These generally lie to the interior of extensive mangroves where limited water circulation might be suspected. Studies of current and nutrient flow in these areas may be useful in future mangrove resource management.

OIL SPILLS

Understanding of the destructive effects of oil pollution on marine ecosystems is increasing. Loya and Rinkevich (in press) summarize damage to coral reefs--that is lack of colonization by corals in reef areas chronically polluted by oil; decrease in coral viability; damage to reproductive systems, including abortion of planulae; and abnormal responses of planulae and adult coral. Other effects include lower growth rates, death of tissues, disruption of feeding, excessive mucus secretion leading to enhanced growth of bacteria, and eventual coral destruction.

Damage to mangroves from oil has been reported by Gilmore et al. (1970) in Guayanilla Harbour, Diaz-Pferrer (1962) in Puerto Rico, Davis (in Ferguson Wood and Johannes 1975) in the Dry Tortugas, Rutzler and Sterrer (1970) in Panama, and Spooner (1970) in Saudia Arabia, among others.

There have been many oil spills, mostly small, in the TTPI. Their most spectacular effect has been the death of mangrove trees. Effects on corals have not been assessed. These spills were lamented and "prohibited" by local legislation, but little action was taken until about 1973. In response to the U.S. Federal Water Quality Act of 1970, the TTEPB in conjunction with the U.S. Coast Guard coordinator for oil spills, held a training session for TTPI environmental health workers. Within weeks of this session, oil spill reports began coming in. In the year following the training session, 18 reports were submitted from the Yap District alone. One of these reports was against a private firm, three against the local Department of Public Works power plant, five against TTPI Government field trip ships, and six against the U.S. Coast Guard LORAN station installation. The source of the remaining spills was not legally determined.

The most striking effect of these and other oil spills in Yap and other Districts was the dieback of mangrove trees. In Yap, most mangrove trees surrounding Chamorro Bay died as a result of earlier stresses and an oil spill just after Mobil Oil began operations. Other adverse effects are not known, though large *Porites* coral heads and seagrass beds reported in this bay (Sugiyama, 1942) are no longer present. Some mangrove trees have grown up in the area since the spill.

The mangroves lining the downwind shore of a peninsula near Yap's main harbor died back about 1967, but are now being reestablished. During and after the dieback period, a tarlike substance was washed up on shore. Parasites were reported to be infesting land crabs at this time, so that meat and eggs were sparse. It is unknown if the two circumstances were related, but the crabs came from the affected area. Recently, there has been less oil in the area and the crab population appears to be abundant and healthy again.

A series of spills occurred on three sides of the Coast Guard LORAN station. One flowed into a freshwater stream and then into the ocean. A fisherman from the area reported that an oil spill had been in the area for about a month. When he fished in the area about 3 months after the spill, his catch was smaller than was usual. When the area was investigated about a year after the spill, water in the upper part of the stream was mostly clear, surrounding vegetation seemed normal, and the algae *Chara* and *Spirogyra* were abundant in the stream. Further downstream, there was some dieback of the mangrove *Bruguiera conjugata*, and more seaward, of *Rhizophora* sp.

Another series of spills occurred where the oil pipeline to the LORAN station comes to shore. Here also was mangrove dieback, and a number of betelnut (*Areca cathecu*) and coconut (*Cocos nucifera*) trees uphill from the shore, near a leak in the pipe, died or lost vigor. Clams collected in the area, and the area itself, had a strong odor of diesel oil. A hole dug adjacent to the mangrove area revealed a black, foul smelling layer of mud at about 0.5 m depth. Children in the area complained of itchy skin after swimming in the water.

For about 10 years, limited amounts of waste oil and some larger accidental spills (a spill of 15,000 to 30,000 liters is recorded), went downhill into a freshwater marsh area below the LORAN station. Some of the vegetation in the marsh died. After a series of larger spills, taro patches fed from the marsh were reportedly not growing well, and observations by an agriculturist confirmed this. Taro, when cooked, tasted like oil and could not be eaten. On at least one occasion, a bloom which appeared to be chrysophyte algae occurred, and the floating brown masses traveled downstream and into the ocean. A fish kill was reported in this area during extremely low tides, but it could not definitely be connected to the oil spill.

Other spills of diesel oil into taro patches in Truk and Yap have demonstrated that the application of enough oil can kill taro outright in a short period. Oil spills from shipwrecks on outer islands have been a matter of concern, especially since some of these atolls are nesting sites for sea turtles. One of the more publicized spills resulted from the wreck of the Solar Trader on the reef of West Fayu, on December 24, 1971. The ship contained more than 700 tons of fuel and lubricating oil. After salvage attempts failed, the ship was abandoned and the oil leaked out of the punctured hull and into the lagoon and surrounding waters. Oil continued to leak slowly from the tanks for more than 6 months. During spring and summer low tides, the exposed portions of the reef within 550 m of the vessel were coated with oil. A thin film covered the lagoon, in patches measuring 15 to 24 m in diameter.

An investigation in March and April 1972 found that oil was still leaking out of ruptured tanks, but the tides were exposing only a portion of the reef to the oil. In July 1972, the ship was pumped dry of the remaining 180 tons of oil, and major damage was said to be limited to the exposed portions of the reef. Some 520 tons of oil had spilt into the water.

During July and August 1972, Mike McCoy, TTPI Marine Resources Staff, observed the reef portions affected by the oil. Many dead lobsters were spotted in the area and clams were either dead or inedible. During the weeks following the oil spill, a large algal growth was observed on the coral in the affected area. Algal growth was also stimulated on reef outcroppings near the island where a thin film of oil had coated the dead coral.

Recently, Palau experienced a spill of 1500 tons of coconut oil from a reefed tanker. The oil was carried by prevailing currents down the southeast coast of Palau and the Rock Islands, where it remained in coves and pockets without much natural flushing action. About 2 weeks later, a marine Environmental Protection Officer investigating the spill found that a cove off Eilmalk (a large rock island) "reeked of copra oil. The water was choked with algae and dead sea life was evident. Residents of Pelileu Island reported that seagrass flats, reefs and beaches along the north and east sides of the island had been seriously affected by the spill." *)

Palau was also a proposed site for a superport and oil transshipment facility which would have been the largest such facility in the world. It was designed to handle crude oil tankers larger than any now in commercial operation. The facility was to have been constructed by a consortium of Japanese and Iranian industrial firms and U.S. financiers. This facility would require the dredging of some 8 million cubic meters of ocean bottom, and the coversion of

*) Pacific Daily News, May 7, 1980.

the pristine islands of Kayangel into a nuclear power station, following an influx of construction workers equal in numbers to the entire indigenous population. Much concern was expressed over this threat to a showplace of marine variety and beauty, and the proposal has since become dormant.

Section 311 of the U.S. Clean Water Act regarding oil and hazardous substance spills is administered by the U.S. Coast Guard. An Oil Spill Contingency Plan has been developed for the TTPI. This plan includes procedures for immediate action in case of spills of oil or other hazardous substances in the TTPI; procedures for requesting outside assistance in cases beyond local capabilities; and reporting procedures. It also includes a list of individuals in each state and entity who are responsible for organizing immediate action in case of oil spills. The responsible person is usually the Chief Sanitarian for each state and entity. *)

PESTICIDE SPILLS

Little is known about the distribution of chlorinated hydrocarbons in reef organisms and less about their specific effects (Ferguson Wood and Johannes 1975). Instances of damage from pesticide spills, however, are reported by a number of authors. Marschall (1976) reports that after the use of the chlorinated hydrocarbon lindane to control the coconut rhinoceros beetle (*Xyloryctes jamaicensis* Drury) and the accidental spill of one bag into the lagoon of Nukunono Atoll in the Tokelaus, all corals in a 2 km section of the lagoon along the Motu Te Kakai were dead, with the exception of *Porites*. Alcyonarian corals, and algae typical of waste polluted waters were absent; and *Acanthaster* were uncommon in the area. No similar damage was noted in other parts of Nukunono Lagoon where lindane had not been used.

The use of lindane and other chlorinated hydrocarbons was not very effective in controlling the beetle and was abandoned in favor of biological controls between 1967 and 1970. In 1975, 6 years after the initial survey following the lindane contamination, the lagoon of the Motu Te Kakai was again surveyed and much of the area was still dead. The only corals in recovered areas were species of *Pocillopora*.

Marschall (1976) reported that a bag of DDT, accidentally thrown into the lagoon on the atoll of Fakaofo in the Tokelaus, in May 1975, resulted in the death of thousands of fish in the days that followed. His laboratory tests showed that DDT in extremely small quantities could kill corals.

In the past, large amounts of pesticides were shipped to the TTPI. Some of these substances have spilled into the water, as in the following examples:

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*) Draft environmental report of the TTPI prepared by the TTEPB, Office of the High Commissioner, May 16, 1980, Saipan, N.M.I.

On April 17, 1970, 15 to 25 tons of fish suddenly died in the Truk Lagoon. Six people who ate them were hospitalized (Bourns, 1970). Samples of these fish were sent for analysis and found to contain the pesticide Endrin in the highest concentrations recorded in fish up to that time.

On Yap, during April 1973, approximately 132 liters of Endrin which had become mixed with spilled crystals of sodium arsenite went through two septic tanks and into a freshwater stream, and then into an estuarine bay. This spill resulted in the death of everything in the stream and a fish kill in the bay beyond, as well as some dead seabirds and rats, and some sick chickens along the stream and bay. Water samples taken along the river on May 5, after heavy rains had flushed the river, indicated decreasing levels of arsenic from 22.6 mg/l to 0.015 mg/l with increasing distance from the spill. Observations of the contaminated bay, and of a nearby control bay that was not in the path of the flow, were made 2 weeks after the spill. No fish were seen, and no live plankton were collected in the contaminated bay, while both were abundant in the uncontaminated bay. Forty-five days after the spill, three observers travelling up the contaminated bay for 50 minutes saw no marine life. In contrast, a period of 8 minutes spent in the uncontaminated bay resulted in the sighting of seven fish and three schools of belonid and/or hemiramphid fish. Plankton tows made in the bays showed that by this time at least planktonic life was returning to the contaminated bay.

Another spill of approximately 19 liters of pesticide into the waters of Yap Harbour resulted in dead fish being seen from the Donguch to the Madrich side of the harbour.

Following the Yap spill, action by the TTEPB and U.S. Environmental Protection Agency resulted in the removal of banned pesticides from Yap Island. Also eventually removed from Yap were about 2900 kg of 10 percent DDT; about 3860 of 52 percent sodium arsenite from Truk, 370 kg of 75 percent DDT from Majuro; and 680 and 340 of DDT from Woleai and Ulithi atolls respectively.

Pesticides in the TTPI are now regulated by Trust Territory Pesticide Regulations, Chapter 13, subchapter IV, Title 63, Trust Territory Code. This regulation is intended to control the importation, use, and disposal of all peticides in the TTPI. It requires that all pesticides sold be registered by the U.S. Environmental Protection Agency, and that importers of restricted pesticides (those determined by EPA or TTEPB to be especially dangerous), be licensed by the TTEPB, and that they inform the TTEPB of any orders placed, or arrivals of such pesticides. In addition, users of restricted pesticides must be certified and pass an examintation, and be recertified from time to time. Such applicators are monitored from time to time. Stockpiling of pesticide supplies in the TTPI is now kept to a minimum.

Table 1 - Comparison of two lists of the most common species in the coral portion of the reef off southern Okeefe's Island, Yap

Sugiyama (1942)	Neudecker (1978)[1]
"Dominant" corals	"Predominant" corals
Acropora spp.	*Acropora formosa*
(8 species and 11	*Clavarina scrabicula*[2]
taxa listed)	*Porites andrewsi*
Porites spp.	"Abundant" corals
(6 species listed)	*Fungia fungites*
"Comparatively abundant"	*Fungia echinata*
Favia rotumana	*Montipora* spp.
Favites vierens	"Common" corals
Goniastrea pectinata	*Psysogyra lichtensteini*
Cyphastrea chalcidium	*Favia* spp.
Fungia spp.	*Pocillopora* spp.[3]
Astreopora spp.	*Pavona* spp.
Montipora foliosa	*Alveopora allingi*[2]
Millepora tortuosa	

[1] In Tsuda et al., 1978.

[2] Not listed by Sugiyama for Yap.

[3] Not listed by Sugiyama for this area, but listed for Yap.

SOME RESULTS OF LONG-TERM MARINE IMPACTS ON YAP

The condition and productivity of fishing grounds are of great interest and concern to traditional fishermen of Yap, and of direct importance to the nutritional wellbeing of the people of the island. However, monitoring of the condition and productivity of the marine environment has not been an official function of any of the authorities during the decades of succession from Spanish to German to Japanese to American administration. Some studies for the advancement of science have been made, however, and a comparison of two of these provides some record of changes occurring in a limited area over a 36-year period.

In 1942, Sugiyama surveyed part of Yap Island and the coral reefs within Yap Harbor. He provided a map of Yap Harbor showing the marine communities present and described three major zones (Sugiyama, 1942). Thirty-six years later, Neudecker made a quantitative assessment of coral species composition of reef communities in the Yap Lagoon, as part of a survey which resulted in a rough map of major marine communities around Yap (Tsuda et al., 1978). Nine of the sites studied by Neudecker and mapped by the University of Guam Marine Laboratory team are included on the map provided by Sugiyama. One of Neudecker's sites in this area is described. "This lagoon fringing reef was off the southern end of O'Keefe Island. The reef is horseshoe-shaped with coral development on the margin and a reef flat in the center about 200 m at its widest" (Neudecker in Tsuda et al., 1978). A comparison of the lists by Sugiyama and Neudecker of the most common species in the coral portion of this area (table 1) shows some differences.

A comparison of the maps made by Sugiyama (1942) and Tsuda et al. (1978) identifies some further differences:

(i) The coral zone was formerly more extensive.

(ii) The area about Donguch is now largely a silted seagrass bed with limited coral, probably as a result of dredging, landfills, and causeways built to connect a series of islets.

(iii) The Donguch area and perimeter of Chamorro Bay are now largely devoid of mangroves except for small patches of mangroves on the north shore of Chamorro Bay. Photographs taken of this bay in early Japanese times show it ringed with mangroves. Some of these mangrove trees were killed as a result of an oil spill about 1967.

(iv) Chamorro Bay no longer has the extensive seagrass beds shown on Sugiyama's map.

(v) The "massive porites" reported by Sugiyama to be growing in the "unfavourable waters" at the head of bays, including Chamorro Bay, are no longer to be found. This bay has been subjected to considerable sedimentation as a result of the building of a causeway at its western end, and to restriction of water flow through the main connection with the lagoon as a result of various types of bridges and causeways at the eastern end. In addition the bay has received considerable nutrients from raw sewage outfalls, and as a result of being previously ringed with outhouses over the water.

(vi) There is less coral about Dugor Bay now, especially on its southern perimeter where Sugiyama indicates "porites dominant" and Tsuda shows no corals.

(vii) The mangroves about Tahugino and the hospital point are now much less extensive. Some of this is the result of recent oil spills and dredging.

(viii) The coral zone off Bii Island is narrower now.

(ix) The southern portion of the area indicated as seagrass by Sugiyama on the north side of Tomil Harbor, south of the mangroves fringing Tomil, is indicated as now being an area of algae and sand on Tsuda's map.

(x) The area southeast of Balebat shown to be "Halimeda dominant bottom material sands" on Sugiyama's map is shown as seagrass beds by Tsuda.

Discussions with resident fishermen in this last area produced more details on changes in the abundance of coral growth, population composition of fish, and other life in the area. Other information on local activites, such as the removal of coral from the "lupuu" fishing area (Falanruw et al, 1968) affecting the composition of the marine community, were recorded.

It is worth noting that changes reported by local residents are corroborated in this instance by the results of scientific investigations, and that additional interesting and useful information could be forthcoming with support for the translation of local knowledge into scientific language. Inasmuch as some of the impacts of current land activities on the marine environment are beyond the experience and control of local fishermen, but of concern to both scientists and islanders, such cooperative exercises would bring about better communication and better understanding.

EVALUATION OF ENVIRONMENTAL PROTECTION ACTIVITIES

The examples that have been described, though neither devastating nor very large in scale serve to show that marine impacts exist, and in some cases could have been more serious.

A look at the TTPI example shows several things: first, most environmental legislation is either an extension of Federal environmental legislation, or modeled on it, or is locally developed or complied with in order to obtain Federal funds, and the most effective enforcement is by Federal agencies. However, the local Trust Territories Environmental Protection Board (TTEPB) is progressively developing the capacity to perform these functions. Secondly, western concepts and methods of formal environmental protection are relatively new and in the process of being developed, as is shown by the five amendments to the basic law creating the TTEPB between 1972 and 1978. Especially notable is the most recent change in the definition of the Board's work. The first version of Public Law 4-C-78, passed in 1972, charged the Board:

> ... to achieve and maintain such levels of air, land and water quality as will protect human health, welfare and safety and to the greatest degree practicable prevent injury to plant and animal life and property, as will foster the comfort and convenience of its people and their enjoyment of health, life and property and will promote the economic and social development of the Trust Territory of the Pacific Islands and facilitate enjoyment of its attractions.
>
> In 1978 this portion of the law was changed to:
>
> The Board shall balance the needs of economic and social development against those of environmental quality and shall adopt regulations and pursue policies which, to the maximum extent possible, promote these twin needs."

Although this version is subject to fewer different legal interpretations, it contains the assumption that there is a conflict between economic and social development and environmental quality. This assumption is unfortunate. It may be partly due to the failure of some scientists to relate their assessments of environmental impact to the needs of administrators. It is not sufficient to provide long lists of species in an area, with tables of numbers, and expect that somehow this will enable administrators to make wise decisions. The priority which some scientists have placed on collecting scientific data, without reference to the short and long term prospects of meeting human needs, has probably contributed to the concept of a conflict between environmental quality and human welfare.

If this misconception is not corrected, there is danger of future exploitation and degradation of the resources of the TTPI. In response to the reduction in funding expected to accompany changes in the Trusteeship status in 1981, increasing emphasis on economic development may result in a "boom and bust" that will leave the Islands poorer than they were.

USE OF LOCAL NATURALISTS

The need to support and organize a considerable number of scientists pursuing many specialities in developed countries has generated many organizations relating to resource management at local, national, and especially international levels. This leads to some overlap even in big countries. When this multiplicity of scientific specialties and organizations coverges upon small island countries, there is even more overlap and confusion, with disproportionate application of effort. One cannot help but notice the large ratio of specialized outside "helpers" to small generalized local staffs.

In an effort to be fair and spread their budgets, there is a tendency for organizations dealing with the Pacific Region to sprinkle some help here and some there. Specialists are sent cirsscrossing the Pacific, spending a few days here, a few there. Often they cannot get to these different areas when they are needed. When they do arrive, they find that there are no data on the problems for which they have been consulted; the problem is not well formulated or is outside their specialty, or is on too small a scale. Again, they find that knowledgeable people already on the island have not been consulted; that there is no one to work with them, especially on weekends; and that there is no one available to follow-up on their work. Sometimes communications are poor, so that when they arrive, no one knows why they came. There are overlapping studies and contradictory opinions about research needs.

Many of these problems of inefficient use of manpower could be avoided if there existed a corps of local naturalists specializing geographically rather than by discipline. While few organizations could afford to locate even one staff scientist on a small island, collective contributions from a number of organizations might suffice to support one or more local persons. Given the small land area in the vast Pacific, the numbers of such local naturalists would not have to be great to be effective.

Such a corps of local naturalists would be provided with good general training and access to the findings of "pure" scientists, as well as to a network of specialists supported by large countries with whom they could communicate about specific problems. In the TTPI, much of the present environmental legislation generates a need for environmental impact studies. Thus far, this has resulted in the employment of outside scientists exclusively. Funding for such studies, whether from local or international sources, could be used to provide employment for local scientists and naturalists, initially perhaps on a counterpart basis. Such a policy must inlcude specific budgeting lest these local people merely be invited to, somehow, take part, "for free".

Inasmuch as "resource management" requires the control of people using these resources (Johannes, 1980), it is misplaced sophistication to suppose that resource problems can be solved by the employment of outside experts to the exclusion of local people. The new environmental ethic which has arisen in developed countries is in response to problems of misapplication of money, energy, strong chemicals, nonbiodegradable materials, nucleotides and powerful technology. This ethic is nourished by exchanges between citizens and scientists who communicate with their fellow citizens. Without support for local naturalists in the Pacific, and the communication of information by such locally available and credible people, we cannot expect a similar neotraditional environmental ethic to emerge and flourish in the Pacific.

Many scientific meetings end with recommendations about the need to survey traditional conservation practices and about the need for environmental education. The involvement of local personnel in environmental impact assessment would go a long way towards addressing both of these needs. A corps of "barefoot scientists;" i.e. local naturalists, could also make valuable contributions to local planning and development efforts and help to define problems so that when outside expertise is needed, it will be effectively used. They would also advance the science and resource management in general, in concert with both "pure" scientists and the wealth of traditional knowledge of peoples with a history of living with limited resources. Further, the support of such local naturalists would be consistent with ecological principles of applying nutrients at the "grass roots" trophic level.

Most Pacific Nations cannot afford the "luxury necessity" of pure scientists. Most would need assistance in developing and supporting a cadre of naturalists. This is an area where outside aid would be well invested.

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