Bol. Inst. Oceanogr. Venezuela, Univ. Oriente 27 (1 & 2): 25-36 (1988).

THE STATE OF CORAL REEFS IN THE WIDER CARIBBEAN[1]

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I.- BACKGROUND

Coral reefs are tropical and subtropical ecosystems that flourish at temperatures between 25 and 29° centigrade in insular and continental platforms. Living coral cover and species diversity is highest where waters are clear due to low input of nutrients and fine sediments. Recent Caribbean coral reefs are about 5,000-12,000, years old and started developing when insular and continental shelves drowned after the last glacial period (ADEY, 1978). They are spread throughout the Wider Caribbean from the Gulf of Mexico south to Panamá and Tobago and north to Bahamas and represent 9% (1,000 Km2) of the total area covered by these ecosystems in the world (SMITH, 1978). Bermuda and northern Brazil (Recife) contain the northernmost and southernmost coral reefs, respectively, in the Atlantic Ocean. These are biogeographically related to Caribbean reefs but are impoverished in terms of reef related species. Those off Brazil exhibit relatively high endemicity (MARGARIDA, 1982).

The susceptibility of coral reefs to disturbance in relation to other nearshore ecosystems, such as mangrove forests and seagrass beds, has been recently illustrated by OGDEN and GLADFELTER (1983). This report should be viewed in the context of an extensive coral bleaching event that occured throughout the Caribbean in 1987 (WILLIAMS *et al.*, 1987). Bleaching has been related to the expulsion of endodermal symbionts, known as zooxanthellae (GOREAU, 1964) which, under normal conditions, contribute to the nutrition and calcification of corals (MUSCATINE and CERNICHIARI, 1969). Corals bleach when subject to environmental stresses. Although this event may not be directly linked to human activities (given its extension) it is reasonable to think that the probability of recovery is diminished where coral reefs are already subject to local stresses (2). Sediment removal by reef corals, for example, is highly dependent on the production of mucus in some coral species (HUBBARD and POCKOCK, 1972). Mucus production has been shown to be intimately related to the activity of zooxanthellae (CROSSLAND *et al.*, 1980). Reef coral are alreday stressed by increased sediment load due to intense upland deforestation in many Caribbean islands (e.g., JOHANNES, 1975).

Coral reef degradation (in terms of observable changes in the relative abundance of major benthic components) resulting from human activities is well known to be underway in the Caribbean. It has been documented near Kingson, Jamaica (HEAD and HENDRY, 1985), in Veracruz, Mexico (TUNNELL, 1985), in Venezuela (WEIIS and GODDARD, 1977), in Parque Nacional Cahuita, Costa Rica (CORTES and RISK, 1985), in the Puerto Rican southern and western coast (C. GOENAGA, V. VICENTE, R. ACEVEDO, J. MORELOCK, *personal observations*), in Lindberg Bay, St. Thomas (VAN EEPOEL and GRIGG, 1970; VAN EEPOEL *et al*, 1971; GRINGG and VAN EEPOEL, 1970), in Boca Chica, República Dominicana (GERALDES and BONNELLY DE CALVENTI, 1977) and elsewhere as mentioned below. Significant small spatial scale (i.e., 1 m^2) changes in the community structure of nearshore, Puerto Rican coral reefs have occurred within the last decade and are associated with massive mortalities of *Diadema antillarum* (VICENTE, 1987) although the ultimate causative agent remains unknown. The main objective of this report is to summarize the available published and non published information of the effects of pollution on coral reefs of the Wider Caribbean and adjacent waters. Examples from elsewhere are included whenever information from the region under consideration are not available.

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1 Based on a report to the United Nations Environment Programme and the Intergovernmental Oceanographic Commission.

2 This phenomenon may be related to human activities. Preliminary observations suggest that bleaching is related to higher than normal penetration of solar radiation into the sea (R. Armstrong, C. Goenaga and V. Vicente, personal observations). This is consistent with the known fact that the thinning of the ozone layer, particularly in the poles but also in the tropics, results from the usage of chlorofluorocarbons and halons. This subject, however, is outside of the scope of this report.

II.- SOCIOECONOMIC IMPORTANCE OF CORAL REEFS

Although coral reefs are mainly known for their natural beauty and high biotic diversity, this is only a minor portion of what they represent to nations that possess them. Recently it has been suggested that their importance for the maintenance of life on Earth transcends national barriers as explained below. Following is a list of the socioeconomic importance of coral reefs:

PRODUCTION OF PHARMACOLOGICAL COMPOUNDS

A large diversity of chemical compounds have resulted possibly as a consequence of complex interactions between species in the coral reef. Some of these substances are highly active biocompounds whose applications in medical research are just now being discovered. These include antimicrobial, antileukemic, anticoagulant and cardioactive properties (SALM and CLARK, 1982). Coral reef organisms have been used as tools in the elucidation of physiological mechanisms (e.g., sea hare), fertilization (e.g., sea urchin), regeneration and cell association (e.g., sponges) and mechanisms of drug action (e.g., squids) (ANGELES, 1981).

PREVENTION OF COASTAL EROSION AND STORM DAMAGE

This is particularly important for regions with low lying coastal plains. Coral reefs also contribute to the formation of sandy beaches and sheltered harbors.

NUTRITION

Fisheries in the Caribbean can be defined, with few although significant exceptions (e.g., upwelling zones and shrimp fisheries), as coral reef fisheries (MUNRO, 1983). Reef fishery products are often the primary source of dietary protein for coastal and island people. According to the Caribbean Fisheries Management Council (National Ocean and Atmospheric Administration, U.S. Department of Commerce) 59% of the total fisheries consumed in Puerto Rico and the Virgin Islands come from coral reefs. The fisheries potential of many Caribbean reefs has been impaired in the last decades partially due to overfishing (e.g., APPELDORN, 1985) and, possibly, to habitat degradation (e.g., BOUCHON-NAVARRO *et al.*, 1985).

RECREATION

Tourism on many Caribbean islands is based on reef related activities and on the aesthetic and recreational value of reefs. Submarine trails in Trunk Bay, St. John, are utilized daily by hundreds of tourists. This type of development, however, requires close supervision and a parallel educational process about the fragility of component reef organisms.

EXTRACTION OF ATMOSPHERIC CARBON DIOXIDE

Coral reef constitute about 0.17% of the world ocean area and about 15% of the shallow sea floor within the 0-30 m depth range (SMITH, 1978). These ecosystems play an important role in the marine carbon budget primarily through the deposition of aragonitic calcium carbonate. Surface tropical waters, which are stratified by a permanent thermocline, are supersaturated with respect to calcium carbonate. The inorganic transfer of atmospheric CO_2 across the air-sea interface is, therefore, limited. By extracting $CaCO_3$, coral reef organisms provide a way of bringing more CO_2 into the ocean system. Reported rates of $CaCO_3$ deposition by coral reefs demonstrate that these ecosystems are an important buffer in the Earth's CO_2 cycle (BARNES *et al.*, 1986).

III.- HUMAN ACTIVITIES AFFECTING CORAL REEFS

In general, coral reefs within the Wider Caribbean are threatened by pollution related to industry, domestic wastes and upland vegetation clearing. RODRIGUEZ (1981), in a review of environmental stress in coastal waters of the Wider Caribbean, pointed that there is no widespread industrial pollution there, apart from contamination by petroleum hidrocarbons. He added, however, that severe, localized problems do occur and stressed that these problems threaten the development of economic activities which depend on a healthy marine environment. The largest industrial concentrations occur along the coasts of Venezuela, Colombia, Mexico, Cuba, the US Gulf states, Puerto Rico, Trinidad and Tobago, the Netherlands Antilles, the US Virgin Islands and Jamaica. Industrial development in the Central American states, with the exception of the San Pedro Sula area on the north coast of Honduras, is mainly along or oriented towards the Pacific coast rather than the Caribbean (RODRIGUEZ, 1981).

Marine pollution caused by dumping domestic

wastes into the ocean (RODRIGUEZ, 1981), and upland vegetation clearing (i.e., be it for industry, urbanization or agriculture) without concern towards appropriate land conservation practices (JOHANNES, 1975) are two other activities, common to the whole region, that have a negative impact upon coral reefs. These are associated with all major cities in the area.

Other activities that are spatially and temporally restricted, although not necessarily insignificant, are: mining of coral reefs, military activities, standing and walking over coral, ship grounding, anchoring, coral collecting, fishing with explosives and with bleach, dredging and thermal pollution. Of these, the first seven destroy reef structure directly while the last three modify the relative abundance of the living components. The effect of most of these have been documented for the wider Caribbean and examples are given next.

A. OIL POLLUTION

Many coral reef scientists have expressed their apprehension concerning the harmful effects of oil spills (e.g., BAK and ELGERSHUIZEN, 1976). Degradation of some Caribbean coral reefs have already been attributed to chronic oil pollution. CHAVEZ *et al.* (1985), for example, noted that the reef biota a Cayo Arcas, a group of islands off Yucatán (Mexico) that hold and oil pumping station, has been subjected to considerable environmental stress. Specifically, they attributed the disappearance of dense *Acropora cervicornis* thickets at this site to "activities related to the oil industry".

BAK and ELGERSHUIZEN (1976) have suggested that the water soluble fraction of oils in seawater is more harmful to corals than their direct contact with oil. RUETZLER and STERRER (1970) suggested that corals escaped observable damage from and oil spill in Panamá because they were continuously submerged. Detergents, however, can disperse oil and its toxic fractions into deeper waters affecting the biota that otherwise would not come in contact (CERAME-VIVAS, 1969; CINTRON, 1981). Nevertheless, direct field evidence of these effects are generally wanting.

Data from laboratory experiments show that colonies of the scleractinian *Madracis mirabilis* were more affected by mixtures of various crude oils and Shell dispersant (LTX type) than by either the crude oils or the dispersant separately (ELGERSHUIZEN and DE KRUIJF, 1976). These investigators hypothesized that the observed non additive effects were related to a higher solubility of the toxic oil fraction in sea water after emulsification by the dispersant. Active ingestion of oil drops by corals do not occur and it is unlikely that oil is adsorbed to living coral tissue (BAK and ELGERSHUIZEN, 1976). Mucus produced by corals, however, can trap drops of oil that may be incorporated into the reef food web via the mucus-eating fish and crustaceans (ELGERSHUIZEN *et al*, 1975). Zooxanthellae from the Caribbean scleractinian *Diploria strigosa* exhibit reduced photosynthesis after light hour exposure to dispersed oil in concentrations of 19 pm (COOK and KNAP, 1983). Although recovery was rapid, long term effects were not looked at. Also, most of these experiments simulate the effect of episodic, acute oil spills. The effect of chronic, long term oil pollution remains unassessed to my knowledge.

SHINN (1972) observed that the scleractinian *Montastrea annularis* can survive two hours total immersion in Louisiana crude oil and that *Acropora cervicornis*, exposed for two hours to a mixture of seawater containing one part crude to 6-12 parts seawater, caused inmediate retraction of polyps although recovery was complete after 24 hours. Based on these observations he remarked that "it would seem safe to conclude then that crude oil spills do not pose a significant threat to Atlantic reef corals". However, as JOHANNES (1975) has noted, this statement is premature since Shinn reported no subsequent observations on these corals. DODGE *et al.* (1985) determined experimentally that corals treated with chemically dispersed oil at concentrations of 20 ppm showed no depression in calcification. Once again, it is unknown whether long term impairment of vital functions, such as reproduction or maintenance, had occurred in individuals of these species. Also, Shinn's own experiments illustrate the importance of interspecific response to oil. Evidence of pathological responses, includin impaired development of reproductive tissues, atrophy of mucous secretory cells and muscle bundles, has been observed in colonies of the shallow water Caribbean coral *Manicina areolata* during exposure to water accommodated fractions of Nº 2 fuel oil (PETERS, *et al.*, 1981). This atrophy may help explain the decreased capacity of coral to recover from injuries after subject to oil pollution reported in Panamá by GUZMAN ana JACKSON (1989). GOODING (1971) also documented an extensive destruction of reef associated biota, other than corals, by an oil spill in Wake Island.

Other effects of oil and the use of dispersants on coral reefs are the alteration of the physical properties of the reef surface (which inhibits larval settlement), the impairment of oxygen exchange across the air-water interface (BLUMER, 1971; KINSEY, 1973) and the interruption of light penetration by surface oil films

(MERGNER, 1981). These have not been documented in the Caribbean.

B. OIL DRILLING MUDS

In addition to the danger of oil spills, potentially detrimental effects of drilling near coral reefs include the actual physical disturbances caused by anchoring, pipeline and drill rig construction, the resuspensin of bottom sediment created by such activities, shadowing by the rig platform and the discharge of drilling effluent which include sewage, deck drainage, produced formation water, produced sand, materials for treating wells, drill cuttings and drilling muds (DODGE and SZMANT, *in press*; THOMPSON and BRIGHT, 1977). The effects of drilling muds are discussed below.

Drilling muds are introduced in the marine environment during offshore drilling operations. These are discharged at low levels and occasionally in bulk (up to 2.000 barrels or 148 tons in a few hours) then the muds require renewal or on termination of drilling activities (THOMPSON *et al.*, 1980).

Drilling muds are varied in composition and those containing ferrochrome lignosulphonates and other additives such as diesel fuel, appear to be more toxic. Their effect on reef corals have been recently reviewed by DODGE and SZMANT (*in press*). Their major conclusion is that more research is urgently on this subject.

Exposure to chrome lignosuphate drilling muds leads to the production of mucus as a "stress" response in Porites *divaricata, P. furcata, P. astreoideos, Montastrea annularis, Acropora cervicornis* and *Agaricia agaricites* (THOMPSON *et al*, 1980) and may be responsible for decreased growth rates, after short term exposure, by *M. annularis* (HUDSON and ROBBIN, 1980). DODGE (1982) suggested that lower calical relief in clorals exposed to used drilling muds can result in decreased sediment-shedding capabilities which may remain effective for some time after the period of exposure in *M. annularis*.

SZMANT *et al.* (1981) have further investigated the response of *M. annularis* to drilling muds. They found that the rates of calcification and respiration of this species decreased by 53% and 25%, respectively, after four weeks of exposure to 100 ppm drilling mud and 84% and 40% after six weeks of exposure. Gross photosyinthesis was reduce by 36% after five weeks. Nitrate uptake rates decreased by 42% and 48% after four and six weeks while ammonium uptake decreased by 32% and 49% after five and six weeks of exposure. Colonies exposed to 100 ppm were not able to feed on zooplankton and several of the experimental colonies died before completion of the experiment.

C. SILTATION FROM UPLAND VEGETATION CLEARING

Siltation of coral reefs results from upland vegetation clearing and is generally considered an important factor controlling reef coral. It can limit reef corals by: 1) increasing water turbidity (JERLOV, 1968) and, thus, affecting the photosynthetic output of zooxanthellae, 2) causing energy expedinture in particle rejection (LASKER, 1980), 3) increasing the potential for bacterial infection (DUCKLOW and MITCHELL, 1979; PETERS, 1984), 4) abrasion (WEIN, 1962; STORR, 1964), 5) creating conditions unsuitable for larval settlement (MARAGOS, 1972), 6) reducing feeding periods (personal observations) and/or altering heterotrophic and autotrophic feeding efficiencies (DODGE and SZMANT, *in press*), 7) affecting planktonic food supply (BAK, 1978), and, 8) shifting the relative abundance of fish and promoting the survival of those that graze on the benthos (GALZIN, 1981). The removal of mangrove stands, generally accompanying upland deforestation on developed coastal areas, magnifies the problem of siltation. These stands act as natural barriers for runoff due to precipitation. In the Puerto Rican southwestern coast it is not uncommon to observe large sediment plumes after heavy rains where the mangroves have been removed and replaced with "casetas" (*personal observations*).

Although coral reefs are known to occur under silt laden and/or eutrophic waters (GOENAGA, 1988), it is unknown whether these are in the process of disappearing or whether the component biota is or will be capable of adapting to these conditions. The available evidence suggests that at least some of the biotic components which depend more upon sunlight die in deeper, although are able to persist in shallower, portions of reefs (MORELOCK *et al.*, 1979); ACEVEDO, 1986); GOENAGA, 1988).

D. SEWAGE DISCHARGE

Sewage discharge into coastal waters may affect coral reef communities by 1) causing nutrient enrichment and enhancing the growth of algae at the expense of corals (MARSZALEK, 1981), 2) depressing oxygen levels (WADE *et al*, 1972), and 3) by introducing toxic substances such as chlorine (cf. MUCHMORE and EPEL, 1973). Coral morbidity and mortality under experimental conditions is apparently the result of competition for space with algae and light and not

directly related to effluent toxicity (MARSZALEK, 1981). Sewage is known to stress reefs in Barbados, Curaçao, Florida Keys, Guadeloupe, Jamaica, Martinique, St. Kitts and British and U.S. Virgin Islands (ROGERS, 1985).

The classical example of the effects of eutrophication on coral reefs is Kaneohe Bay in Hawaii. Twenty six to ninety nine percent of the local coral reefs here were destroyed by overgrowth of corals with the green alga *Dictyosphaeria cavernosa* due to cultural eutrophication (MARAGOS, 1972). Partial regeneration of the reef habitat has occurred six years after diversion of sewer discharges from the ocean (MARAGOS *et al.*, 1985). In Puerto Rico, coral reefs growing close to sanitary discharges also show proliferations of green algae, namely, *Ulva* sp., *Enteromorpha* sp. and *Dictyosphaeria* sp. (V. VICENTE and C. GOENAGA, *personal observations*). These tend to colonize corals from their bases eventually overgrowing them. Recent mass mortalities of the black sea urchin, *Diadema antillarum*, in the Caribbean make the situation worse. This urchin is a voracious omnivore that continually grazes on fleshy and filamentous algae covering the substrate.

E. DREDGING AND MINING

The impact of dredging on coral reef communities are of three basic types: 1) mechanical damage (resulting in breakage of coral and octocoral colonies many of which subsequently die), 2) sediments loading or siltation (i.e., rapid deposition of coarse silt and sand size sediments resulting from sediment laden water leaking from the dredge pumps) resulting in burial and death of colonies, and, 3) increased turbidity resulting in loss of color, excessive mucus secretion of death in scleractinians. Also, waters over dredged areas have significantly more bacteria than neighboring seawater (GALZIN, 1981). This seems related to the suspension of fine sand particles that are utilized as a substratum by the bacteria and may result in the elimination of certain benthic faunal and floral species and the proliferation of tolerant species. GALZIN (1981) also found that sand dredging in Guadaloupe, French West Indies, resulted in a decline of the abundance of the fish fauna and a reduction of species equitability.

One effect of dredging that is usually ignored is the resuspension of toxic materials, such as heavy metals, into the water column. Metals may be detrimental to corals by impairing their physiological processes and possibly by weakening the structure of the aragonite skeleton (HOWARD and BROWN, 1984).

Associated with dredging operations are mining and smelting processes. Fifty six large scale mining operations are reported in the Caribbean, all discharging effluent, with little regulation, into waters showing incomplete and slow mixing characteristics (HOWARD and BROWN, 1984). BROWN and HOLLEY 1981) found slightly elevated levels of copper and zinc and relatively high concentrations of tin in the silt fraction of reef sediment near to a tin smelter at Ko Phuket, Thailand. It is not unreasonable to think that the same is occurring in the Caribbean.

F. THERMAL POLLUTION

Activities generating thermal pollution, mainly related to the energy industry, are known to be maintained in the vicinity of Caribbean coral reefs,. Although the effect of this type of pollution has not been documented for the Caribbean it is known that thermal effluent retard growth or cause mortality in scleractinians and also prevent larval recruitment into thermally enriched areas of reefs of Guam (NEUDECKER, 1981). Maximum ambient temperatures were found to be close to lethal temperatures for corals in Guam (MAYOR, 1918). Mayor noted that the temperature at which the feeding reactions and normal metabolic processes cease are more significant that death temperatures. For example, three species of coral ceased to feed at temperatures 1.5-3.0°C lower than their lethal temperatures.

G. ANCHORING

Anchoring on top of coral reefs can represent considerable disruption to coral reef communities. DAVIS (1977), for example, estimated that this activity has demaged nearly 20% of staghorn communities in the fort Jefferson National Monument, Florida. TILMANT and SCHMAHL (1981) found a significant linear correlation of reef use and incidence of physical damage. Standing and walking over coral and coral collecting can also ruin large portions of reefs (GOENAGA, *personal observations*). Although this damage appears to be localized and inconsequential in the long run it may not be so, especially where usage is intense.

However, touristic sightseeing of coral reefs, if well planned and with adequate supervision, seems to be highly compatible with the preservation of these ecosystems and can be highly productive in terms of education and in terms of the employments generated. The economy of many Caribbean islands depend to a large extent on external tourism. The promotion of this activity for internal tourism seems equally important

since it is likely to create an awareness of this important natural resource on islanders.

H. MILITARY ACTIVITIES

Although military maneuvers near coral reefs are possibly not widely practiced in the Caribbean, an example from Vieques, off eastern Puerto Rico, will illustrate the result from this activity. It seems particularly important to discuss this activity given that several authors (see below) have stated that military activities are inoffensive to coral reefs and this notion may be utilized to justify further maneuvers elsewhere.

In 1982, ANTONIUS an WEINER concluded that the "military impact of the Viequen reefs was negligible when compared to natural damage caused by storm-generated wave action".

These conclusions are based on comparisons made between the reefs from Vieques and those in the eastern coast of St. Croix (presumably not subject to military activities) with which they found no differences. A close look at their section on Materials and Methods, however, reveals that, in their work, "the emphasis was on shallow water communities". It is widey known and has been extensivelly documented (e.g., WOODLEY *et al*, 1981; GRAUS *et al.*, 1984; among many others) that damage to coral reefs by storms occurs mainly in shallow waters. It is at these depths that corals with the highest growth rates predominate (e.g., *Acropora palmata* and *A. cervicornis*). This is one reason why hurricanes have minimal long term effects on coral reefs (GRAUS *et al.*, 1984). Deeper portions of coral reefs, where slower growing, massive corals predominate, are not affected as heavily by storms. However, military activities do not discriminate between shallow and deeper portions of the reef and bombs drop in shallow and in deep substrates affecting them equally. Is seems reasonable, therefore, to question why did Antonius, a consultant for the U.S. Navy, did not investigate the deeper portions of the reefs in Vieques. The same critique applies to the work by RAYMOND and DODGE (1980).

In another work, DODGE (1981) also concluded that "... a general similarity between (bombing) range and control stations..." in Vieques, together with "... quantitative coral abundance and diversity data of others (namely, data by Antonius and Weiner, 1982) indicate a lack of anomalous and adverse sedimentation/turbidity conditions affecting coral on reefs near the range area". However, several comments must be made. Reef corals, as well as other organisms, need energy for processes other than growth, namely reproduction and maintenance. The effects of the presence of the range on these two other processes were not assessed. Coral colony fragmentation, a process acknowledged by ANTONIUS and WEINER (1982) and DODGE (1982) to occur in Vieques, is, in fact, known to severely limit the reproductive potential of some species (SZMANT-FROELICH, 1985). An example of one of this species is *Montastrea annularis*, the very same species utilized by DODGE (1981) in his study.

Aerial photographs of eastern Vieques do show extensive cratering resulting from bombing activities on land as well as in the sea. Craters range in diameter from 5 to 13 m and its effects extend beyond the extent of direct disruption (ROGERS *et al.*, 1978). These reefs are littered with artillery and airdelivered exploded and unexploded ordnance (metal fragments, frare casings, parachutes) which have sustained extensive damage. Damage to reefs in Vieques has been categorized by ROGERS *et al.* (1978) as follows: 1) damage by direct hits and by shock waves which shear colonies near the site of impact, 2) damage due to abrasion by steel and rock fragments generated by the blasts, 3) damage by fragments that come to rest on top of living coral tissue, 4) fracturing and weakening of reef structure by blasts and direct hits, 5) dislodgement of colonies which can be transported by heavy seas causing greater damage, 6) deposition of coarse sediments on top of living corals, 7) damage by flare parachutes which drape around soft and stony coral, and others.

Large numbers of unexploded ordnance in these reefs limit their future utilization as fishing and/or touristic centers. It is hard to estimate the cost involved in their restoration. We can barely hope that leaching substances from oxidizing and degenerating ordenance do not pollute marine life in these areas.

I. SHIP GROUNDING

Ship grounding in coral reefs can abrade, fracture or overturn reef biota and hull breakage can result in the spill of hazardous substances. Also, alteration of the hydrodynamic regime while the ship is emplaced over the reef can generate sediment plumes that increase water turbidity and smother corals downcurrent. Direct damage by ship grounding is more localized than that of storms but may alter the reef contour and relief to a much greater extent (SMITH, 1985).

CURTIS (1985) describes how portions of Molasses

Reef, Florida, was crushed and resembled a "graded roadbed covered with a veneer of coralline debris" when the M/V WELLWOOD grounded. He foud that the damage was significant but that it depended on depth, location and afflicted taxa. Additional consequences of this grounding included damage by cable drag, propeller wash scour and shading. In Bermuda, ship groundings have obliterated topographical features of coral reefs creating flat, barren areas with deposits of boulders and rubble and sparse surviving corals (SMITH, 1985). Damage to coral reefss by ship grounding has also occurred on other important marine reserves such as Mona Island, Puerto Rico (H. FERRER, G. CINTRON and R. MARTINEZ, Department of Natural Resources, Commonwealth of Puerto Rico, personal communication).

J. FISHING WITH BLEACH AND EXPLOSIVES

Fishing with bleach and with explosives occurs in the Caribbean although it is more generalized in the Indopacific. In the Caribbean fishing with bleach occurs in the islands of Antigua (ROGERS, 1985) and Bahamas (CAMPBELL, 1977). Explosives are used in Antigua, Bahamas, Barbados, Dominican Republic, Grenada, Jamaica and St. Lucia (ROGERS, 1985).

Bleach (sodium hypochlorite) is applied to coral heads to drive commercially valuable species into range of spears and granges. CAMPBELL (1977) correlated the use of this chemical with infection of coral by blue-green algae (*Oscillatoria submembranacea*), anaerobic (*Desulfovibrio* sp.) and the aerobic bacterium *Beggiatoa* sp. He further suggested that most fish and many crustaceans, annelids and mollusks become scarce in bleached coral reefs although the evidence in mostly circumstantial.

K. OVERFISHING

The manner in which overfishing may affect coral reefs is uncertain but it is likely that community structure is modified. For example, overfishing of predator species in St. Croix was suggested to be the cause of unusual abundances of the echinoid *Diadema antillarum* in 1973 (OGDEN *et al*, 1973. Diadema antillarum can locally overgraze bottom vegetation and corals and its abundance has been directly linked to the frequency of recruitment of reef corals (SAMMARCO, 1980).

IV. CAPACITY FOR RECOVERY

Denuded coral reef communities can recover by regeneration of partially damaged colonies or fragments or through recolonization by larval settlement. Factors which can influence coral. recolonization include the extent of damage and its location, the availability of coral larvae, the requirement for a "conditioning" period of the substratum before corals can settle, the availability and diversity of microhabitats for settlements and survival, the role of grazers, and competition with other organisms such as algae and soft corals (PEARSON, 1981).

The available evidence suggests that coral communities may recover from major natural disturbance after several decades but are likely to suffer irreversible changes from man-made disturbances (WEISS and GODDARD,1977). Full recovery from man-made disturbances may be prolonged or prevented altogether because of permanent change to the environment or a continuation of chronic, low level disturbances (PEARSON, 1981).

In 1975 JOHANNES reviewed the known effects of pollution on coral reef communities. He pointed out that reef corals are central to the integrity of the reef community and when these selectively killed, migration or death of the other reef fauna ensues. Accordingly, the environmental tolerance of the reef community as a whole cannot exceed that of its corals.

At this point it is necessary to mention that non-structural coral communities have the same practical importance as coral reefs in terms of coastal protection, nutritional importance, and others. Coral communities differ from coral reefs essentially in the thickness of the biogenic framework. The former form thin veneers over preexisting structures, such as cemented sand dunes, that drowned after sea level rose during the last glacial period. Coral reefs, in contrast, have a thicker framework which, to a larger extent, have been the product of biogenic (i.e., versus physicochemical) activity. Non-structural coral communities give integrity to the underlying structure and prevent its physical or chemical erosion and eventual destruction.

The importance of habitats neighboring coral reefs, such as seagrass beds and mangrove forests, has been stressed by OGDEN and ZIEMAN (1977). Seagrass beds are important feeding grounds for nocturnal feeding fishes, such as gruts and snappers, which shelter on reefs by day. When they return to the reef these fishes deposit organic compounds in the form of feces that become available to detritivores and are introduced to the reef food web. Mangroves provide nurseries for juveniles of

certain reef fish (chaetodontids, scarids, lutjanids) and are also feeding grounds for fish that shelter on reefs; mangroves also introduce fixed nitrogen and organic into the trophic system of reefs as do reef flats and seagrass beds.

Consequently, damage to these neighboring communities can potentially have an effect on nearby coral reefs.

Based on this review some recommendations seem logical:

1) Construct a detailed bibliography on the factors that contribute to the degeneration of coral reefs on a world basis and analize situations on the basis of these experiences.

2) Monitor polluted and non polluted reef habitats to be able to differentiate between natural and man-induced sources of ecological variation.

3) Establish marine parks in close coordination with fishing communities; fishing communities must have an active and principal role in the management of the park.

VIII.- CONCLUSIONS

Although in many cases a causal nexus have not been shown conclusively, the correlation between unplanned development and coral reef degradation makes it hard to attribute the latter effect to causes other than the former. Stressed reef communities show drastic reduction in live coral cover, overgrowth by filamentous green algae, erosion of physical framework and reduction of diversity of associated fish and invertebrates. Reef degradation has already been shown to result in an increase in wave energy at beaches, beach erosion and massive sediment movements (HEAD and HENDRY, 1985) not to mention the decline in the catch of edible species. Touristic development, of primordial importance to many Caribbean nations and in principle highly compatible with the preservation of coral reefs, rests upon the amenity value of the coast, and this, in turn, depends upon maintaining the natural ecology of the reefs and related environments. In turn, we observe repeatedly that developers are able to respond only to the short term advantage of lower economic cost by land clearing extensive coastal areas without concern for land conservation practices and in detriment of natural littoral and sublittoral marine communities. Recent findings that coral reefs play a significant role in the carbon dioxide cycle magnifies the importance of these ecosystems and puts them in a global perspective. The destruction of coral reefs, therefore, is no longer of national but of international interest.

It is perhaps sad that statements related to the preservation of coral reefs more than a decade ago by Johannes (1975) are as timely as ever and acquire more significance today. Johannes stated that:

"... the allocation of money for coral reef research and management is... very small in relation to the importance of these communities to man and... their vulnerability to pollution."

"... environmental crises (related to the destruction of coral reefs) develop faster than they can be completely assessed. In this context it is more important to make interim decisions in time than to make more scientifically satisfying decisions later" (i.e., after the ecosystem is irreversibly damaged).

And also more timely than ever, he adds about scientists that comfortably and cowardly sit over their data, knowledge and/or insights that "those who remain silent when their observations point to environmental decay are the undertakers of the environment; environmental post mortems become their stock and trade".

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(Manuscrito recibido el 30 de Junio de 1989).