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LAND-BASED POLLUTION AND ITS IMPACT

ON CORAL REEFS AND RELATED ECOSYSTEMS

THE CARIBBEAN EXPERIENCE

IMPLICATIONS FOR EAST AFRICAN COASTAL TOURISM

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ABBREVIATIONS

BOD	Biological Oxygen Demand
CIDA	Canadian International Development Agency
ROCAP	Regional Office For Central America and Panama, USAID
TCAM	Tropical Coastal Area Management, newsletter for the Asian Region
TSS	Total Suspended Solids
UNEP	United Nations Environment Program
UNECLAC	United Nations Economic Commission For Latin America and the Caribbean
USAID	U.S. Agency For International Development
USEPA	U.S. Environmental Protection Agency

1.0 ABSTRACT

Over the last 15 years, the Caribbean has experienced major changes both culturally and economically. Most of the Caribbean island nations, as well as Belize, are turning to tourism as the mainstay of their economies. Tourism depends on coastal zones which are environmentally healthy. However, these changes are resulting in degradation of coral reefs and their related ecosystems, mangroves and seagrasses. The coral reefs throughout the Caribbean are rapidly dying, being smothered in algae and slowly collapsing. Although there are a number of complex interrelated causes for this phenomenon, land-based pollution is believed to be the major cause. This is primarily from nutrient enrichment of nearshore marine waters associated with improperly or untreated domestic sewage originating from major urban areas and from tourism developments. The world's tropical waters are nutrient poor and ecologically thrown out of balance by this enrichment. Second in importance in causing coastal degradation is believed to be pollutants associated with agricultural runoff including sediment, pesticides and fertilizers. The solutions are obvious. Some, such as appropriate sewage treatment and disposal, will be capital intensive. Others will require changing traditional practices (e.g. small farmers) and will be slow in coming. Although, donors and decision makers are beginning to become sensitized to these issues, no one to date has put forth the level of effort or finances necessary to have a positive impact in helping to conserve the Caribbean's coastal zone. If immediate and large scale efforts are not put forward, not only does the world risk to see the collapse of an entire ecosystem, the Western Atlantic's coral reefs, but the collapse of the tourist industry on which most of the Caribbean is counting on for its economic future.

African coastal countries and Indian Ocean nations who wish to develop long term sustainable coastal tourism, have many lessons to be learned from the shortsightedness of the Caribbean in this arena including:

*The Need For An Immediate Assessment To Determine The Location Of Pristine Coral Reefs Along The East And Southern African Coasts As Well As Around The Indian Ocean Island Nations And To Begin Efforts To Conserve These Areas.

*The Need To Develop Coastal Zone Management Plans For Tourism Areas. Consideration must be given as to whether these activities are best handled by existing institutions or by creation of coastal zone management authorities.

*The Need To Develop Prefeasibility Studies To Address Sewage And Solid Waste In Established Coastal Tourism Areas. Donor Support And Taxation Of Tourism Developments Must Be Searched Out Immediately To Begin Financing These Studies And Ultimately The Construction Of Facilities.

*The Need To Take A Systems/Watershed Approach, Linking Land-based Development Activities Into Watersheds That Drain Into Coastal Areas In Need Of Protection.

*The Need To Develop A Regional Coral Reef Monitoring Program Which Includes Both Water Quality As Well As Biological Monitoring.

*The Need To Involve Artisanal Fishermen In Development Of Marine Management Plans And For Fishermen To Reap Economical Benefits From Associated Tourism.

*The Need To Require Holding Tanks On Boats (Commercial and Recreational) So That Domestic Sewage Is Not Dumped Into Nearshore Coastal Waters.

Many of the above needs can be initially dealt with through negotiated policy reform between donors and national governments to assure that donor support will be made in an investment climate that maximizes the potential for long term sustainable economic returns in the coastal tourism sector.

There will be many who will respond that today this area of the world is not developed enough along its coast line to worry significantly about many of the above issues. Fifteen years ago, the same was said by people in the Florida Keys and throughout the Caribbean. It happened to them and it could happen to you!! Now is the time to begin addressing these issues while development of your coastal areas is in its infancy.

2.0 INTRODUCTION

Millions of tourists from North America and Europe have flocked annually to the tropical coastal zones of the Caribbean. They are attracted to these areas because of the:

*Beautiful White Beaches

*Pristine Aqua Blue Waters

*Bountiful Seafood

*SCUBA Diving and Snorkeling

*Sportfishing

*Mild Climate.

From 1968-80, the author dived on the coral reefs along the Central American coast from Belize to Nicaragua, the Florida Keys, the Sea of Cortez in old Mexico, and Grand Cayman Island (Figure 1). During this period of time, these tropical coastal zones were for the most part sleepy backwater areas unknown by most of the Developed World. Their tropical waters and associated coral reefs, seagrasses, mangrove swamps and salt ponds were for the most part pristine and environmentally in balance with their surroundings, including with man.

Over the last 15 years, increasing affluence in Europe and North America and the accompanying increase in leisure time has resulted in a massive influx of tourists to the Caribbean. This has brought about major changes in the economy, the culture and is increasingly resulting in an unbalancing of the Caribbean's coastal ecosystems where the majority of the tourism is situated. Other social, cultural and economic factors are also resulting in adverse impacts on the coastal zone.

2.1 <u>The Colonial Legacy</u>. Most of the Caribbean countries suffer from the legacy of their colonial past; monoculture economies. For instance Barbados, St. Kitts and the Dominican Republic have traditionally depended on sugar cane as the backbone of their economies. The Windward Islands of Grenada, St. Vincents, St. Lucia and Dominica depend on banana production. As a result, the economies of most of these countries are very fragile, being at the mercy of world market prices.

FIGURE: MAP OF THE CARIBBEAN BASIN

2.1.2 Sugar Quotas. On the sugar cane islands, quotas have been drastically reduced by the United States in recent years in order to protect the powerful lobby of sugar cane and sugar beet farmers. Similarly, many of the European nations have greatly reduced their demand for Caribbean sugar due to increased production of sugar from sugar beets. Artificial sweeteners have also diminished the demand for sugar.

Antigua has already abandoned sugar cane production in favor of tourism. The Dominican Republic is promoting agricultural diversification into alternative cash crops such as pineapple. Barbados continues sugar cane production because it is labor intensive. However tourism has become the backbone of its economy. St. Kitts is struggling to continue with sugar through ethanol production, however increasingly, it is turning towards tourism in hopes of developing the Southeast Peninsula.

Changes in landuse practices in an attempt to modernize this sector are resulting in increased erosion into the coastal zone.

2.1.3 Banana Subsidies. The Windward Islands, better known as the "Banana Islands" have their banana prices subsidized by the British. The advantage of bananas is that they can be harvested nine months from planting and yield bananas on a weekly basis, providing the small farmer with a regular and steady source of income while most other crops are seasonal.

Current practices of farming on steep slopes, and dependency on large inputs of pesticides and fertilizers are resulting in degradation of the coastal zone on these islands as sediment, nutrients and pesticides find their way from the land to the sea.

Britain will join the European Common Market in 1992 and will likely no longer be able to continue paying higher than world market prices for this product. Furthermore, most of the bananas produced on these islands are of lower quality than those produced by Central America and Africa and will not successfully be able to compete in a free market.

2.2 Agricultural Diversification. As a result of the difficulties in traditional agriculture, everyone in the Caribbean is talking of agricultural diversification. Unfortunately, as one sugarcane plantation owner in Barbados explained, "we've been trying to diversify for over two hundred years and have not determined what to diversify into."

*In many cases the soils are not rich enough to support commercial outputs of other crops.

*The prevalence of the fruit fly throughout the Caribbean makes it difficult for most countries to freely export crops to the United States.

*Most countries are also confronted with increasingly stricter standards by their northern neighbors with regard to pesticide residue levels and aflatoxin levels which are often resulting in the rejection of these products at the port of entry. They not only do not have the information to properly select appropriate pesticides, they do not have farmers who are adequately trained in their use nor do they have the sophisticated instrumentation operational to test for the levels of these toxic substances on their export products, on local food and in their drinking water.

*Pests such as the bont tick lower the quality of meat from livestock and make it impossible to import live animals into the United States.

*There is also the problem of economies of scale. Most farmers are small plot holders of only a few hectares or less. Trying to obtain quality and quantity control for an export market is next to impossible.

Where feasible, diversification into horticulture and exotic fruits, which require high inputs of pesticides, could have grave implications for the island ecology if these inputs are not properly managed.

2.3 Out Migration. At the same time out migration to North America and Europe, the traditional savior of the Caribbean from over-population, is becoming increasingly more difficult. This is because North America and Europe are tightening their immigration policies in order to keep their own countries from suffering the same fate as their tropical neighbors; over-population, economic and political instability, high unemployment. This is forcing island governments to look for quick but often shortsighted solutions to resolve this problem.

2.4 Changing Socio-cultural Make-up Of Caribbean Societies. All of this is further complicated by changes in the socio-cultural makeup of the Caribbean societies. Modern day communications have come to the Caribbean. Most countries have from 5-10 United States television stations. Most people have families in the United States, Canada or England. As a result, the youth of the Caribbean have increasing desires, both materialistically and professionally. They are no longer content to "cut cane" like their parents, this being associated with slavery and culturally unacceptable to the youth of these countries. Fishing, another important traditional employer of islanders, is becoming an old man's profession. Other than the independence which this lifestyle brings, the work is tedious, dangerous, physically demanding and the rewards are very few. Ninety nine percent of the fishing in the Caribbean is artisanal in nature. For the most part, fishermen use motorized canoes or small open hauled

runabouts, and fish with seines, hook and line, gill nets or Z-traps. More and more the sons of fishermen are turning into beach boys, escorting the tourists, running SCUBA diving operations, or offering rides on jet boats and water skies.

2.5 Tourism As The Panacea To The Caribbean's Economic Future. With increasing difficulty in these more traditional sectors of the economy, more and more the Caribbean islands and Belize are turning towards tourism as their mainstay and hope for the future. Developers from North America and Europe are falling over each other trying to find the next piece of "Paradise" on which to put their hotels. Unfortunately, neither the developers nor the leaders of these countries are sensitive to the fragility of the tropical coastal zone and what it will require to make tourism not only a mainstay of the economy today but a sustainable part of the economy for the next generation.

The mentality of the developers and decision makers is "Let's get on with development today in order to stimulate the economy and provide employment. Tomorrow we'll worry about the environment." As a result of this shortsightedness, the trained technicians of these island nations, most of whom understand the issues, are not involved in the planning process to assure that tourism development will not only provide short term gains but will be sustainable for future generations.

2.6 The Demise Of The Caribbean's Coastal Zone Ecosystem. The attraction of tourists to the Caribbean and other tropical coastal paradises depends on maintaining clean clear blue waters safe for swimming, white sandy beaches, abundant seafood, and beautiful coral reefs for snorkeling, SCUBA Diving and sportfishing. The author of this report returned to the Caribbean two years ago as the Regional Environmental Management Specialist to the Caribbean for the U.S. Agency For International Development (USAID). He expected to spend the next two years plying the waters of the Caribbean diving, amassing a collection of slides depicting the beautiful underwater world of the Caribbean and helping to establish marine parks. What the author observed was both shocking and frightening, the degradation of an entire ecosystem regionally, the coral reefs and their associated coastal zone.

The causes of this problem and possible solutions are presented in this paper. Although data is limited, the two major causes resulting in the decline of the Caribbean's coastal ecosystems are believed to be domestic sewage and run-off from agricultural areas (Hunte February 1989). In some cases the solutions are simple (e.g. appropriate sewage technology) but will require tremendous capital inputs from the international development banks if this is to be addressed on a scale large enough to have a positive impact. In other instances, the change may be more difficult, since it means changing the practices and attitudes of

people (the shortsightedness of decision makers and the traditional but often destructive practices of small farmers).

3.0 THE IMPORTANCE OF CORAL REEFS TO THE ISLAND ECOLOGY.

The importance of coral reefs to the beaches of the Caribbean can not be overstated. The gradual but natural degradation of coral reefs and coralline algae by the physical action of waves and by bioeroders (e.g. parrotfish) provides the sands on a continual basis that nourish the beaches. More importantly, coral reefs provide a barrier to protect the coastline and coastal property from wave and storm action. Once coral barriers are lost (e.g. from pollution, dynamiting to open channels for boats) there is a tendency for increased loss of beach as sand is carried away and not replaced.

Beaches are important not only for tourism but also as marine turtle nesting habitat including but not limited to the endangered hawksbill (Eretmochelys imbricata), the green (Chelonia mydas) and the leatherback (Dermochelys coriacea).

Although beaches are dynamic rather than static in nature (e.g. beaches may change their physical shape depending on the tidal cycle or become temporarily modified after a storm event), once the protective coral barrier is lost (e.g. loss of fringing reef on Barbados's west and south coasts from pollution), this erosion often accelerates and becomes permanent. Because of inappropriate coastal zone planning, it is common for resorts to be built right to the edge of the beach. Once a beach begins to erode, there is a tendency by the developer to put up breakwalls, groins and jetties to stop this erosion. While locally this may be successful, it usually compounds the problem by stopping the littoral movement of sand, often magnifying beach erosion for several miles up current from the modified site (Cambers 1988 and CIDA 1988). "Peter" is robbed to pay "Paul".

Coral reefs are also important to the nearshore artisanal trap and hook and line fisheries. The reef provides habitat to important commercial/sport reef fish such as snapper, grouper. It also provides an important source of protein to local communities in the many small reef fish that are caught. Semi-pelagic Barracuda, species of jack and bonito ply these coral reefs in search of small bait fish on which they feed. These semi-pelagic fish are also important to the commercial and sportfisheries of the Caribbean. In turn, these fish and invertebrates such as lobster, king crab and conch are important sources of seafood to the tourist industry.

4.0 THE BASIC ECOLOGY OF CORAL REEFS.

4.1 Geographical Location. Worldwide, hermatypic or true colonial corals are found roughly within a belt bounded by the Tropics of Cancer and Capricorn, that is 23 & 1/2 degrees north and south of the equator (Smith 1971).

4.2 Water Quality And Coral Reefs.

4.2.1 Temperature. Colonial coral reefs are found in tropical waters in which seawater temperatures range from 16-36 degrees Centigrade (61-97 degrees Fahrenheit). The areas where coral reefs are best able to flourish have seawater temperatures at an optimum of between 23-25 degrees Centigrade (73-77 Fahrenheit), (Smith 1971).

4.2.2 Salinity. The average salinity of seawater is 35 parts per thousand (ppt.). Corals can survive in salinity ranges between 25-40 ppt (Smith 1971).

4.2.3 Light and Depth. Because of a symbiotic relationship between corals and a brown algae, zooxanthellae, coral reefs are restricted to depths less than 150 feet, the maximum depth at which there is adequate light for photosynthesis. The most vigorous growth of corals is at depths shallower than 90 feet where there is sufficient wave action and current to provide oxygen and food to the coral polyps (Smith 1971). The most vigorous reef growth tends to occur in high energy zones including the windward side of shorelines and the seaward side of the reef where there is heavy surf action and strong currents.

4.2.4 Nutrients. Coral reefs have evolved to thrive in a nutrient poor system in which nutrients are recycled rapidly through the food chain. In the Eastern Caribbean, the following nutrient concentrations are typical of "non-polluted marine waters (Bellairs Research Institute, May 1989):

Parameter	Background Concentration In Unpolluted Eastern Caribbean Waters ug-at/l & mg/l	
	Coastal	Oceanic
Nitrate (NO3 + NO2) as N:	0.70 & 0.01	0.35 & 0.05
Total Phosphate Phosphorous as P :	0.10 & 0.003	0.06 & 0.002

Waters which exceed these concentrations due to pollution can result in a number of deleterious effects that can cause a demise in the coral reef community (Shinn 1989). These effects include increased blooms of phytoplankton that decrease light penetration in the surface waters and thus decrease the photosynthetic rate of the zooxanthellae, ultimately reducing coral productivity (Hunte 1989 and 1987, Tomascik and Sander 1987, Woodley Sept. 1987, Woodley et al April 1987), USAID 1987 and UNEP 1988).

Probably the most observable deleterious effect has been the smothering of the coral reef by epiphytic (Benthic) algae that cuts off the light needed by zooxanthellae to photosynthesize and prevents the coral polyps from filtering food out of the surface waters (DeGeorges 1989b, DeGeorges 1988a and 1988b, DeGeorges and Ford 1988, Hunte 1989 and 1987, Johnson et al Dec. 1988, MAB Aug. 1989, O'Callaghan et al 1988, Ward 1990, Woodley Sept. 1987 and Woodley et al April 1987, WWF 1986). With all sources of nutrition cutoff, the coral reef dies.

From personal observations by the author, the most susceptible corals to algal overgrowth are the staghorn (Acropora cervicornis), the elkhorn coral (Acropora palmata) and finger coral (Porites spp.). The least susceptible are the gorgonians and fire coral (Millepora spp.). Eventually, all of the hard corals and the gorgonian fan corals (e.g. Gorgonia ventalina and G. flabellum) begin to succumb to this phenomenon as the pollution progresses.

Where this has been observed by the author as a problem, the most common genera of benthic algae that turn coral reefs into algal reefs include:

*Turbinaria sp., a brown algae, family Cystoseiraceae
*Lobophora variegata, a brown algae, family Dictyotacae
*Dictyota spp., a brown algae, family Dictyotacae
*Halimeda spp., a green algae, family Halimedaceae
*Amphiroa sp., a red algae, family Corallinaceae.

Although there is limited quantitative data, these are common algae found on the coral reef which in nutrient enriched conditions appear to take up this new man induced niche, out competing corals for space.

4.2.5 Sedimentation. For similar reasons as increased algal growth, increases in sedimentation can result in either decreased photosynthesis of the zooxanthellae and/or smothering of the coral reefs (DeGeorges 1989b, Wood and Johannes, 1975, Johnson et al 1988).

4.3 <u>The Relationship Between Coral Reefs and Zooxanthellae</u>. The survival of hermatypic or colonial corals depends on a symbiotic relationship between coral polyps and a unicellular brown algae called zooxanthellae (Note ahermatypic or non-colonial corals do not have this relationship). This is a dinoflagellate which lives inside the coral polyp. This is unlike most of its group which is planktonic (including the infamous red tide which can result in massive fish kills) and important to the aquatic food chain. It is the zooxanthellae that give many of the corals their color.

Approximately 94-98 percent of all organic carbon produced by the zooxanthellae during photosynthesis leaks out of the algal cells to be used as a food source by the coral polyp (Vernon 1986). The production of carbon greatly increases the rate of reef building by increasing the rate of deposition of the corals' limestone skeleton ($CaCO_3$). This light enhanced rate of calcification enables the coral reefs to grow faster than they are eroded by the action of the sea and eroding organisms (e.g. parrotfishes). It is the major reason why light and thus depth are limiting factors to colonial coral (Ahermatypic corals are not limited by light, growing at great depths, and obtaining all of their nutrition from the capture of plankton). Zooxanthellae provide the colonial corals 98 percent of their total food requirements, the rest being filtered from the water column.

In turn, the zooxanthellae extract phosphates and nitrates from the corals waste products, thus enabling an entire ecosystem to develop in what would appear to be an unproductive nutrient poor system. The efficient and rapid recycling of these nutrients results in the tropical world's coral reefs being one of the most productive natural and diverse communities, marine or terrestrial (Wood and Johannes 1975).

4.4 <u>The Dependency of Coral Reef Communities On Other Aquatic Ecosystems In The Caribbean</u>. The survival of coral reef communities are strongly tied to a number of aquatic ecosystems and their environmental health. These ecosystems include seagrasses, mangroves and salt ponds. Coral reefs can not be seen to exist in isolation of other marine ecosystems. The protection of coral reef communities will require not only a systems approach, but will require a watershed approach if they are to have a future. "We cannot interfer in one area of the ecosystem without paying due attention in other areas and to the well-being of future generations," (John Paul II 1989).

4.4.1 Seagrasses. Seagrasses are normally found on the shallow inland side of coral reefs. In the Caribbean the most common seagrasses are Turtle grass (*Thalassia testudinum*) and Manatee grass (*Cymodocea filiforme*). Seagrasses not only help to stabilize the movement of sand, important to protecting the reefs from sedimentation, but are also extremely important as grazing grounds for herbivorous fish and as nursery grounds (Gilmore 1987 and Zieman 1982). Among others, fishes from the families of Pomadasyidae, Lutjanidae and Holocentridae find shelter on the reef during the day and move into the adjacent grass beds at night to feed. The seagrasses also serve as an important food source for marine turtles including the green turtle and the loggerhead turtle (W.A.T.S. 1983).

Increased sedimentation from land-based activities (e.g. farming on steep slopes) or dredging for tourism development can cut off the light necessary for photosynthetic activity by the seagrasses, thus resulting in their deterioration or death. Likewise, nutrient enrichment from improperly treated sewage can result in epiphytic algae growing over the seagrasses, significantly decreasing their ability to photosynthesize (Wood and Johannes, 1975).

4.4.2 Mangrove Swamp. The mangrove ecosystems of the Caribbean consist of four major species, the Red mangrove (*Rhizophora mangle*), the Black mangrove (*Avicennia germinans*), the White mangrove (*Laguncularia racemosa*) and Buttonwood (*Conocarpus erecta*). The Red mangrove is the primary colonizer and is typically found along the river's edge or on the flooded edge of shallow cays. It is the most common species observed in the Caribbean. The more salt tolerant species are found progressively further inland and are respectively the Black mangrove, the White mangrove and the farthest inland being Buttonwood.

The Red mangrove ecosystem serves as a nursery ground for many commercially valuable species of fishes, shrimps, lobsters, crabs and oysters, as well as assorted fauna of birds, reptiles and mammals. This includes the endangered manatee (*Trichechus manatus*). The two major functions for fish provided by the red mangroves are refuge from predation provided by the physical structure of the prop roots, and a rich and varied food resource based on mangrove detritus. Both adult and juvenile fishes associated with coral reef ecosystems have been commonly collected from Red mangrove ecosystems of Southern Florida including gray snapper (*Lutjanus griseus*), great barracuda (*Sphyraena barracuda*), and white grunt (*Haemulon plumieri*) (Thayer, Colby and Hettler, 1987). Surveys in mangroves at Punta del Este on Isla de la Juventud of Cuba recorded adults and juveniles of over 55 coral reef fish species. The dominant species included the bluestriped grunt (*Haemulon sciurus*), the schoolmaster (*Lutjanus apodus*), gray snapper, sergeant major

(Abudefduf saxatilus), the beaugregory (Stegastes leucostictus), the foureye butterflyfish (Chaetodon capistratus) and juveniles of the great barracuda (Valdes-Munoz, 1981). Approximately 15 species of common reef fish were taken from mangrove systems on the island of Guadeloupe (Louis and Lasserre, 1981). About 68% of the reef fish species collected off Guadeloupe spend their juvenile stages in the mangrove system.

Unfortunately human disturbances have taken a heavy toll on mangrove ecosystems including cutting and filling for expansion of towns, disposal of garbage and sewage (Rutzler and Feller 1988), and cutting for firewood and building material (Johnson et al Dec. 1988).

4.4.3 Salt Ponds. Salt ponds tend to consist of hypersaline ponds, cut off from the sea except during exceptionally high tides associated with storms or hurricanes. They are often fringed with mangroves and serve as important habitat for migratory water birds. They play a major role in trapping sediment coming off of the land, protecting seagrasses and coral reefs from the deleterious effects of erosion (Towle et al 1986).

Unfortunately, like many wetlands in the world, they are generally seen as worthless by the island communities. They are often used as garbage dumps, or opened up to the sea in order to make marinas for tourism developments.

5.0 THE IMPACTS OF DEVELOPMENT ON CORAL REEFS AND THEIR RELATED ECOSYSTEMS.

5.1 The Impacts Of Sewage Associated With Tourism And Major Urban Areas On Coral Reefs. By all indications, point source pollution from untreated or inappropriately treated domestic sewage appears to be the major reason for coral reef degradation in the Caribbean. Typically, sewage disposal in the Caribbean has been designed to address the public health issue of bacterial pollution, suspended solids and the diminution of organic matter which can starve surface waters of their life giving oxygen. It has not addressed the issue of coastal eutrophication and marine habitat deterioration (Bellairs Research Institute May 1989).

5.1.1 Inappropriateness Of Septic Tanks, Secondary and Tertiary Treatment Of Human Wastes In Tropical Waters. Where they exist in the Caribbean, sewage treatment plants have been designed by North American and European engineers who are insensitive to the ecology of tropical waters. Their design (e.g. trickling filter and activated sludge) has typically been undertaken to meet secondary treatment levels. Money is usually put into construction of an expensive plant and sewering. What little money remains is put into a short outfall under the assumption that public health risks have been minimized (Archer 1988 and UNECLAC Dec. 1985).

In the case of tourist resorts, most developers use prefabricated sewage treatment plants, also designed to attain secondary levels of treatment, or they use septic tank systems. In both instances effluent is discharged close to shore and/or enters into the nearshore waters indirectly through drainage ditches or through groundwater percolation (Ward July 1990 and Archer 1988).

Septic tanks in coastal areas with high groundwater tables often malfunction during heavy rain events, flushing huge quantities of effluent into coastal waters. There are even reported instances of "Honey Dippers" (trucks that haul septic tank sludge) dumping septic tank sludge, a major solidwaste disposal problem, into coastal waters as a disposal method. Likewise, many private homes in the Caribbean dispose of domestic sewage through "sump holes." Basically, raw sewage is discharged directly into the karst or igneous geology, without any regard for the potential to contaminate ground water and potentially coastal marine waters.

In the Caribbean, it has been clearly demonstrated that even secondary sewage treatment plants do not achieve designed treatment levels due to the difficulty in attracting skilled technicians to operate these plants, operational expenses and spare part supplies (Archer, 1988 and UNECLAC 1986). Even if they functioned properly, secondary treatment plants do not adequately remove viruses (Table 1). While it takes ingestion of many bacteria to make a person ill, it takes the ingestion of only one viral unit to cause illness. In the United States, where tourism is important, regardless of treatment, outfalls are generally designed to assure a minimum of three days before any of the discharge returns to coastal waters in order to maximize the likelihood of viral dieoff from the sun's ultraviolet rays.

Likewise, secondary treatment does not adequately remove the nutrients (nitrogen and phosphorous) that are ecologically damaging to coral reefs and grass beds (Table 1).

Tertiary treatment would be the solution if high tech were to be used in order to solve both ecological and public health problems in the tropical waters of the Caribbean. Even then a long outfall would be desirable in order to minimize public health risks to bathers where tourism is an important sector of the economy. Unfortunately, this is very expensive, highly sophisticated and inappropriate technology for most of the developing world. If secondary treatment systems can not be maintained then tertiary systems would pose that much more of a problem and expense.

As a result, the nearshore discharge of effluent from sewage treatment plants throughout the Caribbean continues to pose both public health and ecological risks, both of these factors being vital to the sustainability of tourism.

It should be noted that the ecological risks are not only due to nutrient enrichment. If chlorination to kill bacteria/viruses is undertaken improperly, high residual chlorine levels in the effluent can be extremely toxic to aquatic life.

The author has assessed the inadequacy of treatment throughout much of the Caribbean (Table 2). The degraded coral reef noted in this table is very likely due to a number of causes, not just from inappropriate sewage technology (e.g. sedimentation, pesticide and fertilizer runoff from agriculture, dredging for tourism development). However, where quantitative data exists, coral reef degradation has been closely linked to inappropriate sewage disposal (Bellairs Research Institute May 1989 and Hunte Sept. 1987).

5.1.2 <u>The Solution To Pollution Is Dilution For Human Waste Disposal In The Caribbean And Most Tropical Waters</u>. USAID has spent the last two years working with the Bellairs Research Institute which is associated with the University of the West Indies. Using local Caribbean ecologists, sanitary engineers and oceanographers, it was determined that in most cases, the old adage "the solution to pollution is dilution" holds true for the tropical areas of the world. The pollution problem, both public health and ecologically, is a nearshore coastal phenomenon. Modern day technology solves neither of these issues without going to extreme expense and sophistication, both of which are not appropriate to the developing world.

It has been determined that in most cases in the Caribbean the solution to wastewater treatment and disposal is preliminary treatment with a long outfall which will go beyond the coral reefs, into the open ocean and be quickly diluted out by offshore currents. This is the solution being chosen by both Barbados and Grand Anse in Grenada. The first reaction of many ecologists from the Northern Hemisphere will be that this is unsound.

First of all, this is a nearshore problem. Secondly, if one takes all of the Windward and Leeward Islands, there are only about 700,000 residents plus temporary tourists, not even the size of a large metroploitan area in the United States or Europe which may contain 10 million or more residents plus significant quantities of industrial wastes. In the Caribbean, with few exceptions (e.g. rum distilleries and sugar cane refineries) most sewage is human and contains only conventional pollutants (organic matter, suspended solids, nutrients and bacteria/viruses). Furthermore, the Caribbean Sea is vast relative to the amount of human, pollution. It is not a closed

system with a long detention time (e.g. Chesapeake Bay, Great Lakes, Mediterranean Sea) or of limited carrying capacity to absorb such pollutants, as with many rivers. In the case of the Grand Anse Outfall in Grenada, it is estimated that within two hundred meters of the outfall diffuser, conventional pollutants will be brought to background levels and carried further offshore.

Finally, it comes down to economics; that is land costs, construction costs, operation and maintenance costs including collection and disposal of sludge which can become a solid waste problem, and finally the cost of a highly skilled technician to run the facility. The following is a comparison of these factors for the 600,000 gallon per day (0.6 MGD) facility being planned for Grand Anse Beach, Grenada:

Parameter	Secondary Treatement			Preliminary Treatement
	Facultative	Aerated	Extended	
Construction Cost ($US)	1.5 million (Note:Does not include cost of outfall)	1.5 million	1 million	300,000
Annual Operation & Maintenance Cost ($US)	35,000	150,000	150,000	35,000
Sludge	Medium	Low	High	Minimal
Skill Required To Operate	Low	Medium	High	Low
Land Area Required (Acres)	8-10	5	1	0.5
Hurricane Vulnerability	Low	High	High	Low
Seismic Vulnerability	High	High	High	Low

Source: Bellairs Research Institute. May 1989.

In this case, construction costs alone are from 3-5 times the cost of preliminary treatment and they do not solve the ecological or public health problems without an extended outfall. The solution for Grenada will consist of a collection system for both domestic sewage and gray water (wash water), preliminary treatment to remove grease, grit and large particulate matter (25-75 mm screens producing 100 kg dry weight of solids per day

under maximum operation), followed by a 350 meter (1,148) outfall with a 100/1 diffuser. The length of the outfall was determined by conducting long term oceanographic current studies to locate the best site in the area that has the strongest offshore currents on a year round basis.

Although land disposal (e.g. spray irrigation and deep well injection) should be considered as an option, this normally requires at least secondary treatment, and sophisticated technology and timing (usually at night) to spray the effluent. Operation and maintenance thus return as a problem, although this could be resolved if the hotelier were willing to pay the cost of a highly skilled technician, for instance, to spray irrigate the golf course. However, in general this has not proven successful. It appears that often more effluent is produced than needed for irrigation.

5.1.4 Nutrient Pollution From Untreated Gray Water. In most tropical sewage treatment systems, gray water is ignored. In most tropical countries, soaps used in washing dishes and laundry are rich in phosphates (MAB Aug. 1989). They are often piped right to the beach. Any sewage treatment and disposal works in coastal areas must take into account gray water in designing the size of the treatment and disposal works if the ecological integrity of the tropic's coastal zones are to be preserved.

5.1.5 The Need For Coastal Zone Planning And Regulations. What all of this means to the tropical coastal planner and developer is that regulations need to be adopted that require money to be invested in selecting an appropriate outfall sight and length, and not in the design and construction of expensive and inappropriate treatment technologies. This will require the development of coastal development plans that may require hotels to cluster in certain areas of the coast so that developers can pool their money in order to collectively pay for appropriate sewage treatment and disposal design, construction, operation and maintenance.

This will require teaming up tropical ecologists and oceanographers with sanitary engineers to first locate the best offshore currents and then the most appropriate length and route for an ocean outfall. If these steps are not taken, one can be assured that the future of the coastal zone in the vicinity of major tourist and urban areas will be only one of decline.

5.2 The Impacts Of Non-Point Source Pollution From Agricultural And Urban Activities On Caribbean Coral Reefs. The last 15-25 years has seen major changes take place in the Caribbean, both in the area of agriculture and urbanization.

5.2.1 Sedimentation Associated With Sugar Cane. On islands traditionally dominated by sugarcane such as Barbados and St. Kitts, the youth are turning away from manually cutting cane and large scale mechanization is taking over. As in most parts of the world this results in a change in how the land is managed to handle large combines. Fields are enlarged and many traditional practices that would have minimized soil loss are abandoned (Personal Communication Hazel A. Oxenford, Marine Ecologist, Bellairs Research Institute).

5.2.2 Sedimentation Associated With Banana Production. On the Windward Islands of Grenada, St. Vincents, St. Lucia and Dominica, "Bananas are King." Britain has been subsidizing bananas on these islands for about 25 years. High quality bananas are produced by a few plantations located on suitable flatlands. The amount of land suitable for bananas is quite limited. As a result the small farmer is pushed onto land that is steep sloped and should not be farmed. Squatting on Crown lands is a problem on many of these islands and is resulting in a loss of tropical forests which are important from the standpoint of biological diversity and as watersheds for the islands' drinking water supplies (Miller et al 1988).

Bananas do not adequately hold soils on these steep slopes. Additionally, herbicides such as paraquat, are used to keep the understorage vegetation around banana trees to a minimum, leaving the ground for the most part bare and exposed. When rain events occur, often severe and short in duration, huge quantities of sediment are washed into the coastal zone creating a brown ring around these islands. This not only reduces light penetration in the water column, but eventually this sediment settles out, smothering the corals and sea grasses.

The once beautiful El Cahuita coral reef off of Costa Rica is reputedly dead from heavy sedimentation associated with small farmers producing bananas on steep slopes in the watershed that drains this reef (Personal Communication Frank Zadroga, USAID Regional Environmental Management Specialist for Central America)

5.2.3 Coastal Sedimentation Affecting The Coral Reefs Of Belize. In a recent fishing survey in Belize, the fishermen explained how the rivers were "running dirty" since the conversion of southern coastal Belize into citrus production. Refugees from Guatemala and El Salvador squatting along the Hummingbird Highway also appear to be increasing runoff from slash and burn agriculture. Furthermore, fishermen have noted "dirty water" coming from the Gulf of Honduras over the coral reefs during the peak September

rainy season. Honduras is also being heavily degraded in its watersheds draining into the Gulf from slash and burn agriculture. This land-based pollution may be crossing international Boundaries and affecting the second largest barrier reef in the world (220 miles long). (DeGeorges 1989b).

5.2.4 Coastal Sedimentation and Solid Waste Pollution Associated With Urbanization In The Caribbean. The problem of solid waste and the impacts resulting from inadequate disposal methods is a regional problem in the Caribbean and not a direct result of tourism (UNECLAC 1986), although addressing this issue becomes that much more critical if tourism is to become a major economic force in the region. As affluence has reached the Caribbean islands a growing middle class and second homes for North American/Europeans have resulted in conversion of prime farmlands into suburbia. Little attention has been paid to solid waste (Often dumped into guts-perennial stream beds), or to appropriate landscaping. In may urban areas garbage is collected and dumped into coastal wetlands (Johnson et al Dec. 1988, Cambers 1988 and UNEP 1988):

*Directly into the sea at Choc Bay, Castries and into Soufriere Bay, Anse Chastinet in St. Lucia,

*Into a mangrove wetlands near St. Georges in Grenada

*Into Great Heed salt pond/mangrove system in St. Kitts

*Into the sea at Port Elizabeth, Bequea,

*Into the Flashes mangrove system in Barbuda

*Into a mangrove swamp on Ambergris Cay.

This physically destroys these wetlands. Leachates from the sites also contaminate coastal waters with toxic pollutants (MAB Aug. 1989). In most cases these dumps are eye sores, within easy viewing of major tourist routes.

The net result is that when major rain events occur heavy sediment loads and other associated contaminants are flushed into the sea on most Caribbean islands. One has to only visit a coastal area after a rain event to observe the brown ring and floating garbage encircling these islands. Not only is there a major public health risk from this runoff, but nearshore corals are being smothered by such pollutants. The author has personally come down with stomach problems on a number of occasions after swimming in coastal areas muddied after a major rain event. On a number of the islands, the U.S. Embassy warns against swimming at such times.

Plastic pollution is a major problem in the Caribbean and after most rain events is commonly found in coastal tourism waters. Not only is this bad for tourism, but certain species of sea turtles (e.g. the loggerhead) are known to mistakenly ingest plastic as a jellyfish and die. Plastics pollution has gotten to be such a problem that in September 1988, the Texas Land Commissioner made a special trip to attend the Regional Seas Conference sponsored by UNEP in Mexico City. He pleaded with the Caribbean nations to help control plastics pollution. Given the clockwise movement of currents in the Gulf Of Mexico, these plastic wastes are washing up on the shores of Padre Island, destroying the aesthetic value of its beaches for tourism.

5.3 The Impacts Of Pesticides And Fertilizer Use On Coral Reefs. Very little is known about the degree to which pesticides and fertilizers are a problem in the Caribbean. This, like sedimentation and nutrient pollution from sewage, is not monitored on most islands. Pesticides require sophisticated instrumentation and trained technicians to operate them. A number of the islands have skilled technicians and inoperable gas chromatographs. This is due to a failure by decision makers to perceive the need for such analyses. However, this is changing rapidly, as the need to monitor residual pesticide levels on export crops is becoming an economical necessity and because of an increasing awareness by the island communities that pesticide contamination, both direct (Contamination of farm workers) and indirect (contamination of islanders from consumption of contaminated drinking water, vegetables, meat and seafood), is a major public health risk to the future of islands' residents. Pesticide control boards are becoming more active in controlling what pesticides are coming into the country. There is an increasing desire to assure that farm workers are properly trained in safe pesticide handling and disposal (There are a number of instances reported from St. Vincent and Dominica where farm workers have washed down contaminated pickup trucks or pesticide containers in local streams resulting in fish kills).

On many of the banana islands tremendous amounts of pesticides are used, primarily in banana production (DeGeorges 1989a):

Island	Annual Use Of Pesticides (Active and Inert Ingredients)	Number Of USEPA Restricted Pesticides
Grenada	224,488 lb (1988)	20
St Vincents	906,679 lb (1988)	10
St. Lucia	759,182 lb (Jan.-Oct. 1989)	13
Dominica	2,345,712 lb (1988)	11

This comes out to 5.2 to 7.2 pounds of active ingredients per acre in production per year compared to 23 pounds of active ingredients/acre in production/year in San Joaquin County California, known as one of the most intense areas for pesticide use in the world. The most commonly used USEPA Restricted Pesticides include the nematocides Furadan (Carbofuran), Mocap (Ethoprop) and Vydate (Oxamyl); and the herbicide Gramoxone (Paraquat).

The Caribbean Environmental Health Institute conducted a study of pesticides and other toxic contaminants in St. Lucia's coastal waters. The findings were so shocking that the report has never been released. The Bellairs Research Institute recently found high levels of chlordane and other pesticides in coastal sediment, seagrass and in sea egg eggs (A local urchin, or "Sea Egg," (Tripneustes ventricosus) whose eggs are considered a local delicacy) (Hunt 1989). Fish flesh was not analyzed. This pesticide has been banned from use on Barbados for about 10 years. It is a chlorinated hydrocarbon and very persistent in the environment. It is believed that this is only the tip of the iceberg. As there is an increasing awareness of the danger from agrochemicals, and monitoring becomes more routine, it is likely that the severity of this problem will become better understood, both from a human and ecological prospective.

With regard to the impacts of fertilizer use on the coastal environment, this has not been quantitatively studied. On the Windward Islands, tremendous quantities of fertilizer are used in producing bananas. For instance on St. Lucia, it is estimated that 1,000 metric tons of N/P/K fertilizer are imported each month (DeGeorges 1989a). Monitoring of streams and rivers draining agricultural lands into coastal waters will ultimately be required if the degree of nutrient and pesticide pollution in the coastal environment is to be ascertained. Coastal marine sediment, coral, seagrass and fish flesh also need to be monitored to determine if pesticides are bioaccumulating through the food chain.

6.0 OTHER POSSIBLE CAUSES FOR CORAL REEF DEGRADATION

One of the major problems with much of the concern about what is happening to the coral reefs of the world is that there is insufficient quantitative data to scientifically and categorically state for each reef the exact cause of degradation. There is a major need to establish long term coastal monitoring programs so that this need can be met. Never-the-less, other causes of coral reef degradation in the Caribbean that have been put forth include:

*Global warming that is raising the temperature of the Caribbean's surface waters by a about 2 degrees Fahrenheit, resulting in extrusion of zooxanthellae observed as white patches on coral, or "Bleaching". Once this symbiotic relationship is destroyed (Rensberger 1987, Roberts 1988 and 1987), ultimately the coral becomes more vulnerable to disease (e.g. White band and Black Band Diseases that kill off corals, especially staghorn and elkhorn coral).

*Increased ultraviolet radiation from depletion of the ozone layer.

*Pollution in the Southern Caribbean carried by waters from the Orinoco River of Venesuela.

*Regional dieback of the Black Sea Urchin, Diadema antillarum in the mid-1980's resulting in increased algal overgrowth due to the loss of this algal grazer.

*Overfishing of algal grazers, such as parrotfish, contributing to increased algal growth covering the reefs.

*Boat Anchor and Diver Damage.

*Damage of Coral From Souvenir Collectors, or to supply the aquarium industry.

Although global and regional issues must be addressed, for many other reasons than just coral reef dieback, there is a danger that they will obscure the more immediate and pressing issue of land-based pollution associated with each island nation. Furthermore, they do not lend themselves to immediate actions in which positive benefits may be observed. These issues also make it too easy for decision makers to ignore doing anything about land-based pollution, by using factors that are out of their control as the major reason for the coral reef's demise.

Although there is little evidence, many scientists feel the regional dieback of sea urchins from a viral disease or the whiteband/blackband diseases attacking corals in the Caribbean are symptoms of a highly disturbed and pollution stressed ecosystem rather than the causes of the degradation (Ward July 1990 and Shinn 1989)

As for the fishermen, although he is a part of the problem and needs to be helped in better managing his marine resources, he is not believed to be the major culprit in the demise of the Caribbean's coral reefs.

With the establishment of management plans for marine parks, the impacts of tourism (e.g. anchor/diver damage, souvenir collecting, commercial exploitation) should be minimized.

Although important to address, it is the author's belief, based upon what he has observed and based upon a minimal amount of quantitative data, that these issues can not compare to the pressing need to address the damage caused to the Caribbean's coral reefs associated with land-based pollution.

7.0 TROPICAL COASTAL DEGRADATION WORLD WIDE.

Unfortunately, what has been described in this paper is not unique to the Caribbean. Coral reefs and their related habitats (mangroves and seagrasses) may be disappearing at a faster rate than the world's tropical forests. Unfortunately, their demise is not as visually evident to the public nor as easily quantifiable as are the changes affecting the world's forests. A minimal review of the literature indicates the following:

* The Florida Keys have gone from virgin untouched coral reefs in the 1960's to dead algal covered reefs in the 1980's, primarily from human sewage and runoff (Ward July 1990).

*Coastal Mangroves are being destroyed for aquaculture and charcoal production while coral reefs are being destroyed from excessive sedimentation and pollution associated with tourism in South Johore, Malaysia (TCAM Dec. 1988).

*Land clearing for logging is smothering the coral reefs of Palawan, Philippines with sediment, resulting in their death and in reduced reef fish catches (TCAM 1988).

*Land-based pollution in Upper South Thailand associated with sewage discharge, mine tailings and agricultural runoff is destroying the coral reefs and mangrove swamps in the area (TCAM 1988).

*Coral Reefs in the Gulf of Aqaba (Red Sea) are being kille and covered by epiphytic algae in the vicinity of phosphate loading terminal. It is believed that phosphat dust is eutrophying local waters. Especially sensitive t algal overgrowth is Acropora sp., Seriatopora sp. an Stylophora sp., all species of branching micropolypal cora (Fishelson 1973).

*Fringing reefs along the west and south coasts of K Phuket, Thailand are being threatened by land-base pollution, siltation from tin dredging, and nutrient loadin from domestic effluents (Lemay and Chansang 1989).

*Sedimentation and pollution, from the Athi River Watershe in Kenya, have significantly increased since 1961 destroying large areas of coral reef around the Malindi Ree complex (Dubois et al 1985).

*Approximately 99% of the corals over an area of 88 hectares in Hawaii's Kaneohe Bay were destroyed by domesti sewage and shoreline erosion covering the corals with sil and algae. With construction of a long ocean outfall, the corals are beginning to recover (Kuhlmann 1988).

*Siltation and agrochemicals are being washed fro watersheds on Ishigaki Island, Japan, greatly deteriorating the coral reefs. The corals most sensitive to environmental deterioration are the important reef builders of the genera: Acropora, Stylophora, Pocillopora, Leptoseris, Pavona, and Pectina (Kuhlmann 1988).

However, to the author's knowledge, much of this coral degradation is localized. In the case of the Caribbean, the entire coral reef ecosystem appears on the verge of collapse. The Florida Keys might also be considered a part of this phenomenon.

8.0 THE ATTEMPTS OF DONORS AND INTERNATIONAL CONSERVATION AGENCIES TO DEAL WITH CORAL REEF PROTECTION IN THE CARIBBEAN

8.1 Sewage Treatment and Disposal. The author is aware of only two ongoing donor activities in which sewage treatment and disposal will be dealt with in the near future. USAID is funding the Grand Anse sewage treatment and disposal works in Grenada. The Inter-American Development Bank is funding the South Coast Sewerage Project on Barbados. Both of these efforts were in conjunction with Bellairs Research Institute and will consist of preliminary treatment and an outfall that will reach past the coral reefs into strong offshore currents as described above. On the Island of Jamaica, USAID has conducted prefeasibility studies for similar outfalls for the tourist centers of Ocho Rios, Negril and Port Antonio. The Canadians are conducting an assessment of

the sewage needs for Montego Bay where currently a trickling filter plant designed for 0.75 MGD is completely broken down and discharging an estimated 3 MGD just 200 meters upstream from where the confluence with the Montego River and Bay takes place.

Who will pay for the final design and construction costs for this sewage treatment and disposal. Furthermore, every island and mainland area draining into the Caribbean with any sizeable coastal towns and/or tourist resorts has this need. Will it be undertaken on a scale large enough to have an impact and keep the entire coral reef ecosystem of the Caribbean from being destroyed? Donor agencies such as USAID just do not have this kind of financing. Financing must come from the private sector (e.g the tourism developers) and/or the multilateral banks. The solution is available. The only question that arises is are decision makers willing to make the resource users who are benefitting from the coastal zone pay the price it will require to assure that coastal tourism and related activities such as fishing have a future in the Caribbean. The same can be said for the remainder of the tropical world.

8.2 Control Of Soil Erosion. Soil erosion and agroforestry are two areas where the donors have had some experience over the last 10 years in the Caribbean. Probably the most important lessor learned from this experience is that projects dealing with small farmers and traditional practices will take more than just the classical two year donor funding. In some cases changing attitudes could take a generation. More and more projects are being designed with five and ten year horizons. More and more these projects are being turned over to non-governmental organizations who tend to have closer contact with the target communities than the national governments.

Land tenure is also an issue. USAID has had little success with soil conservation in Jamaica because many of the farmers are tenants and have no vested interest in investing in long term agricultural productivity (Personal Communication, Mark Nolan USAID/Kingston). Donors wishing to initiate watershed management soil conservation programs may first have to address the question of land ownership as part of a policy reform program.

USAID will attempt to link erosion control in watersheds that drain into important marine areas in projects being undertaken by the Belize and Barbados (Regional covering the Windward and Leeward Islands) Missions. These will likely be five year projects with options for a second five years.

The regional USAID office for Central America, ROCAP, has a ten year plan in which erosion control, agroforestry, reforestation and natural forest management are priorities (USAID 1989). To the author's knowledge there has been no attempt to date to systematically link these activities to critical watersheds that drain into marine areas targeted for protection.

The UNEP Regional Seas Program considers land-based pollution to be the number one problem in the Caribbean (UNEP July 1988). It is very likely that the 1990's will see a major emphasis placed on addressing this issue.

8.3 Control Over Agrochemicals. Until recently, there was little or no control over agrochemicals in the Caribbean. Out of growing economical assessment, a number of the islands, especially the Windwards, have reactivated their pesticide control boards, especially the islands of Dominica, St. Lucia and Grenada. The rest of the Windwards and the Leewards are showing strong interest in revitalizing their pesticide control boards and updating their pesticide legislation. Belize has also recently adopted stringent pesticide importation legislation which permits only USEPA approved pesticides. Barbados also appears to have adequate control. In the southern Caribbean, the islands seem to have gotten control over banned or cancelled pesticides from North America and Europe being dumped by unscrupulous exporters (DeGeorges 1989a).

However, what they badly need is to develop monitoring capabilities to assure that residual pesticide levels on produce are safe for export as well as local use, and that drinking water, food in general, farm workers and the environment are not contaminated. It appears that there may be a move in the near future to link the USEPA to the Caribbean Environmental Health Institute which in turn will help develop the regional capability to monitor and control pesticides.

There is also a major need for farmer training. This may be addressed in the regional environmental project being undertaken out of the Barbados Mission.

Like many other issues training farmers in safe pesticide use, controlling importations and monitoring to assure human and environmental safety can not happen too quickly.

8.4 Establishment of Marine Parks, A Failure To Understand The Problem. Within the last few years, the word biodiversity has become a buzz word. Sustainable natural resources management is another word that is thrown about. The international conservation agencies, with donor support, are just now beginning to address these issues. Unfortunately, in many cases, as with the tropical coastal zone, these conservation activities are being undertaken with an inadequate understanding of the ecosystem to be conserved nor of the linkages to other ecosystems.

In the case of the Caribbean's tropical coastal zone, a number of marine parks have been established. The general agenda has been to buoy off the park, keep off the fisherman, provide visitor centers and brochures to educate sport divers about not touching or harvesting the corals for souvenirs.

The author has personally dived on the Holchan Marine Park in Belize. Fifteen years ago as a Peace Corps Volunteer, the author dived this reef when Ambergris Cay was a sleepy fishing village. Today this island is built out from tourism, has a serious water supply shortage, and a serious sewage problem. While the fish life in the park is impressive, most of the coral is dead and algal covered as of July 1989. It is estimated that if all the nutrients produced by human waste from Ambergris Cay and Cay Caulker reach the reefs, it would be the equivalent of annually dumping 6,500 fifty pound sacks of 20/10/10 (NPK) fertilizer onto the coral reefs of these two nearby island. Put in these terms it is no wonder that these reefs are mostly dead (DeGeorges 1989b).

The author dived Montego Bay Marine Park in 1988. Fifteen years ago the author was told by one of the original owners of the Chalet Caribe, the first dive operation on the Bay, "You want to see good diving, go to Montego Bay" (Personal Communication Andrew Baynes, First Class Diver British Subaqua Club). Today Montego Bay contains mostly dead coral smothered in algae and sediment (DeGeorges 1988b and O'Callaghan February 1989). Among other causes this is believed due to a minimum of 3.0 MGD raw sewage discharged into the Bay plus tremendous sediment loading from the Montego and Great Rivers that drain major urban and agricultural areas.

In 1988, the author dived Les Arcadins Marine Park, in Haiti. The coral is being smothered in Dictyota sp. algae in such large quantities that it appears like underwater bushes (DeGeorges and Ford 1988). It is believed that pollution originating from Port-au-Prince and other coastal towns is the key to this degradation, although no water quality information is available.

What this indicates is that there has been a failure by most of the international conservation agencies undertaking these activities to acknowledge the linkages of the coral reef to land-based pollution, as described in this paper, and therefore there has been no attempt to link activities in the watershed (e.g agriculture and tourism) that could produce pollutants which will deteriorate the coral reef.

In most instances, the response has been, it is the fishermen that are causing the problem. It is said that they are overfishing the reefs and the coral reef grazers (e.g. parrotfish-Scarids and surgeonfish-Acanthurids) are disappearing that control algal cover (Lapointe 1989, Woodley Sept. 1987, Woodley et al April 1987, and Wilcox and McClanahan Dec. 1988). The author's experience in the Caribbean is that fishing is an artisanal canoe fishery on most islands. The efficiency of the gear has not increased, except for the outboard motor. Fishing is still conducted by traditional methods such as Z-traps, gill nets, seines and handlines. The number of fishermen if any thing is stable or decreasing. It is mostly an old man's job that the youth of today refuse to enter into due to the physical adversities and the low pay. Yes, the fisherman is a part of the problem and to some degree may be contributing to an imbalance in the Caribbean's coastal ecosystem. He certainly needs help in managing these fishery resources. However, he is a small part of the problem and since he tends to be unimportant in the grand scheme of modern island development, the finger is easily pointed at him as the culprit. No one seems to be willing to push the biggest income generators on the islands (Tourism and Agricultural Sectors) to deal with the real cause of coastal degradation at a scale that will result in a recovery of this ecosystem. It is often said that the average colonial coral grows two centimeters a year. Given the degree of degradation observed in the Caribbean, regulating land-based polluters can not happen to quickly.

Things are beginning to improve. USAID missions in both Barbados and Belize are looking at a systems approach to protecting the coral reefs and will begin linking activities in watersheds that drain into touristically important marine parks. Water quality monitoring may take place to determine to what degree land-based pollution is being decreased. Programs will also involve local fishermen in developing marine management plans. No longer will the coral reef be looked upon as an isolated ecosystem but will be linked to conserving all systems in the watershed on which it depends including grass beds, mangrove swamps and appropriate landuse practices along with waste disposal on the mainland.

9.0 LESSONS TO BE LEARNED FOR EAST AND SOUTHERN AFRICA FROM THE CARIBBEAN EXPERIENCE.

Tourism associated with East and Southern Africa's natural resources is becoming more and more the corner stone to the future economies of the region. In Kenya gross foreign exchange earnings from tourism exceeded those from coffee and tea for the first time in 1987. In 1977 tourism generated 48 million Kenya pounds. By 1987 it rose to KP 292 million and KP 432 million in 1989. It is estimated that over 50 % of this tourism takes place along Kenya's coast. Zanzibar and Madagascar are just beginning to recover economically and are looking closely at tourism as a key sector of their economies. Already a major Italian developer is opening a hotel on Zanzibar. Mozambique is said to have similar potential if it can ever attain political stability. The Seychelles already depend mostly on tourism for foreign exchange.

If the coastal zones are to become important and sustainable components of the tourism economies there are a number of actions that will need to be taken:

9.1 <u>The Need For An Immediate Assessment To Determine The Location Of Pristine Coral Reefs Along The East And Southern African Coasts As Well As Around The Indian Ocean Island Nations</u>. Surveys should be undertaken to locate where pristine coral reefs exist that are of economical importance. Immediate steps should be taken to conserve these reefs by carefully controlling activities in the watersheds draining into these areas so that land-based pollution is minimized.

9.2 <u>The Need To Develop Coastal Zone Management Plans For Tourism Areas</u>. Coastal Zone Management Plans need to be developed for all tourism developments. Strict requirements should be developed to control sewage and solidwaste disposal, dredging, and architectural design/landscaping so that development occurs in harmony with the natural surroundings and not in direct opposition. This will also require the adoption of tropical water quality standards, effluent guidelines and environmental assessment requirements (MAB 1989).

Consideration must be given as to whether these activities are best handled by existing institutions or by creation of coastal zone management authorities. The coastal zone management authority would coordinate development activities with river basin authorities on control of watershed pollution that affects the coast. What ever route is selected, consideration must be given to finding innovative ways of generating income so that the authority can be as financially autonomous as possible.

The role of the authority would be to mobilize and harness technical and financial resources for the purpose of planning and regulating development of the coastal zone in collaboration with appropriate management and development institutions such as fisheries and parks departments, sewage and health authorities, hotel associations, fishermen's cooperatives, government tourism boards and local governments.

9.3 The Need To Develop Prefeasibility Studies To Address Sewage And Solid Waste In Established Coastal Tourism Areas. In already developed tourism areas, prefeasibility studies should be requested from the donors to plan for proper sewage and solid waste disposal. Plans should be drawn up on who will be required to pay the construction costs. Taxation of the tourism industry should be considered in order to cover recurring costs of operating sewage and solid waste disposal facilities and paying qualified technicians to operate them.

9.4 The Need To Take A Systems/Watershed Approach Linking Land-Based Development Activities Into Watersheds That Drain Into Coastal Areas In Need Of Protection. Where possible, there should be coordinated attempts to link terrestrial development activities in the areas of range management, agricultural development and forestry to critical watersheds that drain into coastal areas that are deemed worthy of protection.

9.5 The Need To Develop A Regional Coral Reef Monitoring Program Which Includes Water Quality, As Well As Biological Monitoring. The exact cause for the demise of any one coral reef may be complex and varied. In most cases there is little or no quantitative data to determine why one reef is healthy and another is deteriorating. Water quality can be an important source of information to help undertand what is happening, when combined with biological surveys of the coral reef (Live versus dead coral, coral diversity), of fish diversity and of fishermens' catches.

The main reason why long term trend data does not exist is because it is expensive and time consuming and not a priority for most developing countries who have other more pressing problems such as improving their economies and employing their people. What this implies is that innovative ways will have to be found to support such a program. One thought is to have a special coastal conservation tax for all tourists staying in coastal hotels. Donors might also consider using local currency to establish an endowment fund for such activities. This money

could then go to support the following type of monitoring program:

*Water quality and hydrological monitoring of discharges from important rivers in order to calculate the loading of pollutants from their watersheds such as nitrogen, phosphorous, sediment, organic matter and pesticides.

*Water quality monitoring in coastal waters around hotels on septic tanks especially after rain events when coastal septic systems often fail. This would include monitoring nutrients, suspended solids, organic matter, bacteria and light penetration. The bacteria would be monitored for public health reasons.

*Water quality monitoring around sewage outfalls to determine how quickly pollutants return to background levels.

*Water quality monitoring and biological surveys (fish and coral) on both healthy and degraded coral reef to better understand the reasons for this degradation so that remedial measures may be taken. In the case of healthy coral it would be to monitor the quality of its waters in order to take remedial measures, if the need arises, prior to the coral community reaching a crisis state with regard to environmental health.

If this is to be undertaken at a regional level, The UNEP Regional Seas Program would be the likely coordinating body as it is in the Caribbean.

9.6 <u>The Need To Involve Artisanal Fishermen In Development Of Marine Management Plans And To Reap Economical Benefits From Associated Tourism</u>. Like many resource users, the artisanal fishermen often are pushed out by and do not reap the benefits of tourism. In fact in many cases they suffer the consequences that a degraded marine environment brings to nearshore reef fisheries. For instance, it is said that dynamiting by outsiders is destroying much of Kenya's coral reefs. If programs are initiated to involve the fishermen in the development of tourism management plans and then to benefit economically from their enactment (Both as a community, and more importantly as individuals), they will likely become proponents of natural resources management of the marine environment and help to control poaching and other misuse of the area similar to what is happening around the big game parks, especially in Southern Africa.

As an example on the island of Ambergris Cay off of Belize, the sons of fishermen are becoming heavily involved in the diving and sportfishing sectors. While at first against the idea of a park and the closure of traditional fishing grounds, the fishing community has become one of the biggest supporters of the Holchan Marine Park. After seeing the economical benefits from the international renown that such a park brings, other fishing communities are asking to establish similar parks. Many of the fishermen seem to be open and willing to deal with the coastal pollution issues as their families become a part of this sector since they now have a long term vested interest in the region.

9.7 The Need To Require Holding Tanks On Boats (Commercial And Recreational). Consideration must be given to requiring the installation of holding tanks on boats and to requiring that sewage be dumped in open waters beyond the coral reefs rather than in protected nearshore waters when they are at anchor. This may be very difficult to implement.

Many of the above needs can be initially dealt with through negotiated policy reform between donors and national governments to assure that donor support will be made in an investment climate that maximizes the potential for long term sustainable economic returns in the coastal tourism sector.

There will be many who will respond that today this area of the world is not developed enough along its coast line to worry significantly about many of the above issues. Fifteen years ago, the same was said by people in the Florida Keys and throughout the Caribbean. It happened to them and it could happen to you!! Now is the time to begin addressing these issues while development of your coastal areas is in its infancy!!

TABLE 1

COMPARISON OF POLLUTION REMOVAL BY

WASTEWATER TREATMENT AND DISPOSAL OPTIONS

Parameter	Raw Sewage(a)	Treatment Level		
		Primary(b)	Secondary(a)	Tertiary(a)
Total Dissolved Solids (TSS)	100-350 mg/l	35-123 mg/l	25-40 mg/l	5-16 mg/l
Biological Oxygen Demand (BOD)	100-300 mg/l	65-195 mg/l	25-35 mg/l	5-15 mg/l
Total Phosphorous as P	6-20 mg/l	10 % Reduction(c) or less	8 mg/l (10% Reduction(b) to 30% Reduction(c)	0.5-8 mg/l 99% (b) Reduction
Total Nitrogen as N	20-85 mg/l	20% Reduction(c) or less	30 mg/l (10% Reduction(b) to 50% Reduction(c)	3-30mg/l(e) 90% (b) Reduction
Viral Reduction	10,000 units/l Max. Conc., 1,000 units/l typical(f)	0-3 % (f)	90% prior to Disinfection (g)	90-99.999% (h) Metallic or Polyelectrolyte Coagulation + pH Adjustment
Total Coliforms million org. per 100ml	Average 30(i)	Average 2(i)	Average 0.001(i)	-
Fecal Coliforms million org. per 100ml	Average 4(i)			

TABLE 1 (Cont)
COMPARISON OF POLLUTION REMOVAL BY
WASTEWATER TREATMENT AND DISPOSAL OPTIONS

Parameter	Treatment Level, Preliminary(j)
Total Dissolved Solids (TSS)	200 mg/l
Biological Oxygen Demand (BOD)	190 mg/l
Nutrients	Insignificant
Total Coliform million org per 100 ml	40,000
Viral Reduction	Insignificant

(a) Source: USEPA. 1977. Note: Low value weak sewage, high value strong sewage.
(b) Source: USEPA. 1976. Note: Indicates that for primary treatment there is a 65% reduction in TSS and 35% reduction in BOD. Values shown computed from raw sewage data shown in above table.
(c) Source: Clark, John. 1977.
(d) Low value based on Two-stage lime coagulation and filtration
(e) Low value based on Two-stage lime coagulation, filtration and selective ion exchange or biological nitrification-denitrification.
(f) Source: USEPA. 1972.
(g) Source: USEPA. December 1978.
(h) Source: USEPA. June 1980.
(i) Source: Zison, Stanley W., K.F. Haven and W.B. Mills. August 1977.
(j) Source: Bellairs Research Institute. May 1989.
TSS = Total Suspended Solids in a water column = Suspended Particulate Matter

BOD = Biological Oxygen Demand = Change in oxygen concentration in a water sample incubated over a 5 day period as an indirect means of measuring respiration. That is to say the demand on an aquatic ecosystem by aerobic bacteria to decompose organic matter. Thus this is an indirect way of measuring the organic load on a system.

Nitrogen and Phosphorous are nutrients associated with waste water. The more nutrients dumped into an aquatic ecosystem the more likely it is to experience such phenomena as algal blooms and oxygen depletion. This "Aging" process in an aquatic system is known as eutrophication. Note: Nutrients can originate from other sources, naturally from weathering processes of geological strata (Phosphorous), the decomposition of terrestrial vegetation, and from agricultural fertilizers.

TABLE 2

YPICAL SEWAGE TREATMENT SYSTEMS

OBSERVED BY THE AUTHOR

IN THE CARIBBEAN (1989-1990)

LOCATION	TREATMENT	OBSERVED ECOLOGICAL IMPACTS
Barbados		
*Bridgetown	Activated Sludge	1. Major odor problems 2. Short outfall degrading surrounding marine env.
*West And South Coast (Major Tourism)	Hotels On Septic Systems or Package Plants With Short Outfalls, Untreated Effluent From Rum Distillery Discharged Nearshore	1. Fringing Reefs 99% Dead 2. Outer Bank Reefs beginning To Show Signs of Algal Overgrowth 3. Nearshore Fishing On A Decline 4. Beach Erosion Accelerating
South Coast	Sump Holes or Septic Tanks	1. Reef Mostly Dead Apparently High Sedimentation Associated Steep Sloped Agriculture
Grenada		
*St. Georges	Raw Sewage Outfall	1. Have not dived area but outfall appears to be to short in relation to currents risking to contaminate nearshore waters.
*Grand Anse Bay	1. Three Tourist Hotels On Septic Systems 2. Medical School On Septic System 3. Private Homes?	1. High Incidence of Eye, Ear And Skin Infections. 2. High Percentage Of the *Porites* sp. coral dead and overgrown with *Dictyota* sp. algae.

TABLE 2 (Cont.)

TYPICAL SEWAGE TREATMENT SYSTEMS

OBSERVED BY THE AUTHOR

IN THE CARIBBEAN (1988-1989)

LOCATION	TREATMENT	OBSERVED ECOLOGICAL IMPACTS
Tobago Keys, The Grenadines *Horseshoe Reef *World's End Reef	1.Up to 140 boats a day anchor in the vicinity of these reefs during the winter months, none of which have holding tanks 2.Additional pollution is believed to come from inappropriate sewage disposal on islands of Petite St. Vincent, Petite Martinique, Union, Mayreau, Canouan and Palm	1.Approximately 99% of the Elkhorn Coral (Acropora palmata) dead but still standing. 2.Approximately 30-40 % of Porites sp. dead 3.Overall state of reef degraded, much of dead coral covered in light purple/violet coralline algae
St. Vincent		
*Young Island & Bay between Young Is.& Dike Island	1.Hotels in area on septic systems 2.Large number of Sail Boats in the area with no holding tanks.	1. Coral Reef Around Young Island and mainland Hotels Mostly Dead. 2. Large areas of dead elkhorn and Porites sp. Elkhorn alive in early 1980's
*Kingstown *Camden Industrial Park	Central collection system pumping raw sewage into Kingstown Harbor Septic Tanks ?	1. Between Harbor and Industrial Park: a.Old Woman Pt..Shallow star coral signs of bleaching of star coral,deeper portion of reef star and other corals OK b.Turtle Bay most of reef algal covered

TABLE 2 (Cont.)

TYPICAL SEWAGE TREATMENT SYSTEMS

OBSERVED BY THE AUTHOR

IN THE CARIBBEAN (1988-1989)

LOCATION	TREATMENT	OBSERVED ECOLOGICAL IMPACTS
Antigua	Becoming heavily built out for tourism, hotels on septic systems or package plants	1. British Armed Forces Divers as part of Reef Watch warn Antigua that its reefs are rapidly degrading from sewage and sedimentation, 1989 2. Shallow offshore reefs in high energy zone at Ariadne Shoals and Soft Willie appear degraded.
St. Kitts		
*Basseterre	No sewage or collection system. Sewage flushed into Basseterre harbor during rain events	USAID sponsored Southeast Peninsula environmental study found that most of of the reefs south of Bassterre were degraded and algal covered.
*Sugar Cane Refinery	Dumps untreated waste into the harbor	
*Frigate Bay Hotels	Package Treatment Plants into lagoons, one discharging to Atlantic and other to Caribbean side. Newer hotels treatment discharge unknown	
U.S Virgin Islands	Secondary Treatment and Septic Systems ??	Personal Communication by author with Natural Resources Planner from islands leads him to believe that there is heavy coral reef degradation.

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TABLE 2 (Cont.)

TYPICAL SEWAGE TREATMENT SYSTEMS

OBSERVED BY THE AUTHOR

IN THE CARIBBEAN (1988-1989)

LOCATION	TREATMENT	OBSERVED ECOLOGICAL IMPACTS
Dominican Republic		
*La Caleta By Airport	??	Coral Reef appears healthy
Haiti		
*Port Au Prince and environs	No known treatment systems	Les Arcadins Marine Park contains severely degraded coral smothered by Dictyota sp. algae
Jamaica		
*Montego Bay	1.A Trickling Filter Plant is being bypassed dumping 3.0 MGD of raw sewage into Montego River 200 meters upstream from where it enters into Montego Bay. 2.Some hotels on septic/ package plants	1. The coral reef over the entire bay is mostly dead and algal/silt covered.

TABLE 2 (Cont.)

TYPICAL SEWAGE TREATMENT SYSTEMS

OBSERVED BY THE AUTHOR

IN THE CARIBBEAN (1988-1989)

LOCATION	TREATMENT	OBSERVED ECOLOGICAL IMPACTS
Belize		
*Belize City	Oxidation Ponds with nearshore Outfall	1. Coral Reefs dived by author along Belize's 220 mile barrier reef appear to be highly degraded and have high algal cover. This includes the outer atolls including the Turneffes, Lighthouse and the Blue Hole. although less degraded than the barrier reef in vicinity of the two Cays
*Ambergris Cay	Septic Tanks on most hotels	
*Cay Caulker	Four Inch Raw Sewage Outfalls	
		2. It is obvious that there are other factors coming into play but sewage is believed to be a major cause.
	3. In the vicinity of Ambergris Cay and Cay Caulker, the annual production of sewage is equivalent of dumping 6,500 50 pound sacks of 20/10/10 N/P/K fertilizer on to the barrier reef.	4. Fishermen claim that in the late 1970's a hurricane hit, a fertilizer ship ran aground on Lighthouse Reef and a freak Red Tide killed off many of the fish that are algal grazers, especially parrotfish which never recovered. These events could be linked and need further investigation.

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September 27, 1990

MEMORANDUM

To : Bob Rose, REDSO/ENG
From : Andre ~~Wagenhoffer, REDSO~~/ENG
Concerning : USAID/National Academy of Science Funded Conference On Mangroves, Coral Reefs And Related Ecosystems Held In Mombasa From September 24-29, 1990.

A first of its kind conference on coastal issues in East Africa was recently held in Mombasa. This conference was sponsored by USAID/S&T and the National Academy Of Science. About 100 scientists attended from all over the world including Mexico, Jamaica, Belize, Sri Lanka, India and Australia. East African and nearby Indian Ocean States which attended included Kenya, Tanzania/Zanzibar, Madagascar and Mozambique.

The REA presented a paper and slides on "Land-Based Pollution And Its Impact On Coral Reefs And Related Ecosystems, The Caribbean Experience, Implications For East African Coastal Tourism. Interestingly enough, there was a paper presented from a researcher experiencing similar problems in Australia. The REA was approached by concerned persons from Zanzibar, Mozambique and Madagascar.

USAID Missions in Kenya, Tanzania, Mozambique, Madagascar, and the Indian Ocean States should look very closely at the issues presented in this paper (Attached) if coastal tourism (e.g. over 50% of Kenya's tourism) is to become or continue to remain sustainable. Countries like Zanzibar, Madagascar and Mozambique are being inundated with requests to build major tourist resorts along their coasts. They are currently not capable of dealing with this scale of development and all of the complex interrelated issues. The REA is available if the Missions should wish to look into this matter.

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