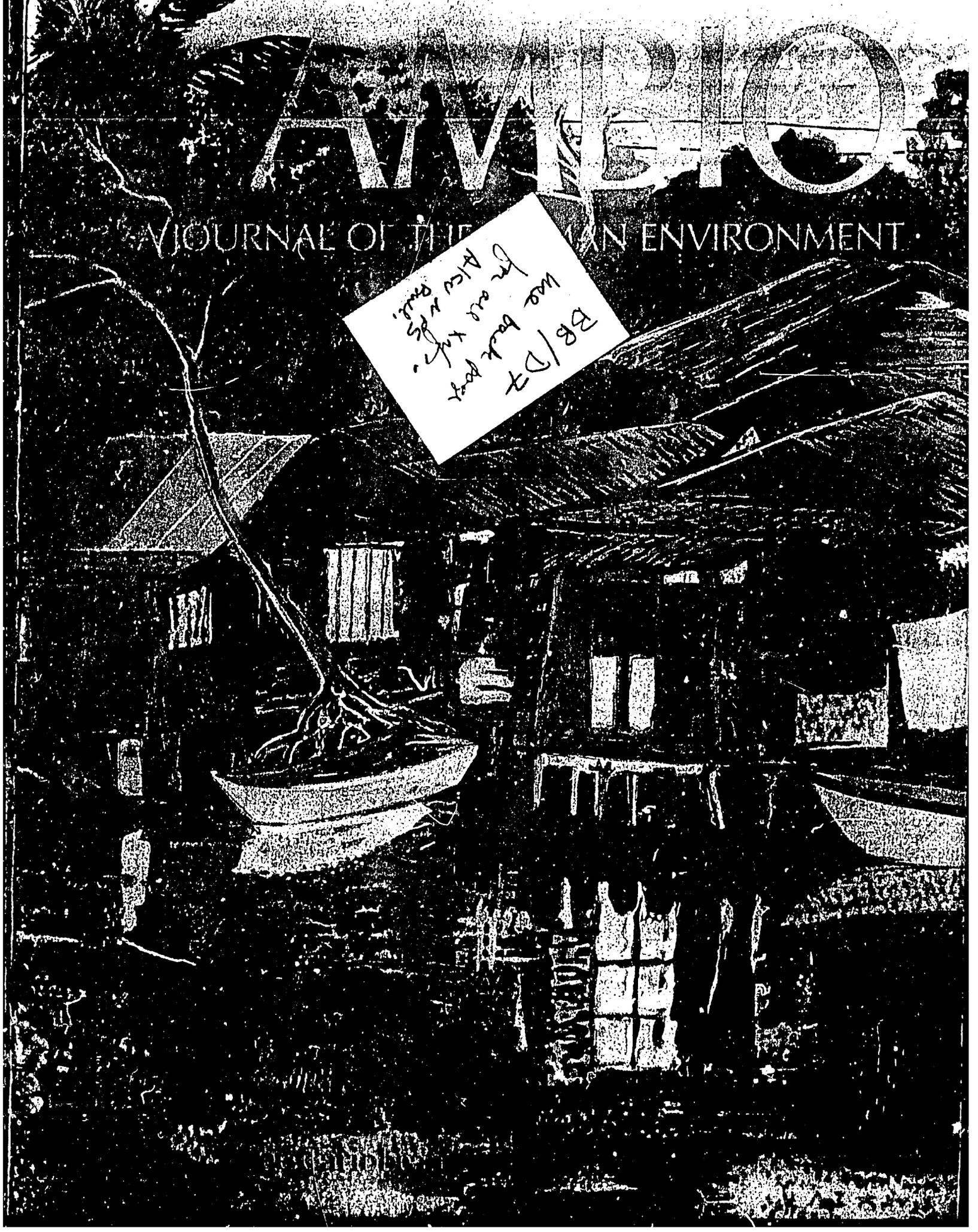
SWEDISH ACADEMY OF SCIENCES/PERGAMON PRESS VOLUME X NUMBER 6 1981

# AMBIO

## A JOURNAL OF THE HUMAN ENVIRONMENT



# Marine and Coastal Environmental Stress in the Wider Caribbean Region

BY ARSENIO RODRIGUEZ

*The Caribbean Sea is not as polluted as the Mediterranean or the Baltic, but accelerating coastal pollution around urban and industrial areas is causing increasing stress to the coastal and marine resources of the region. The author presents an overview of the environmental problems afflicting the Wider Caribbean.*

BEST AVAILABLE DOCUMENT

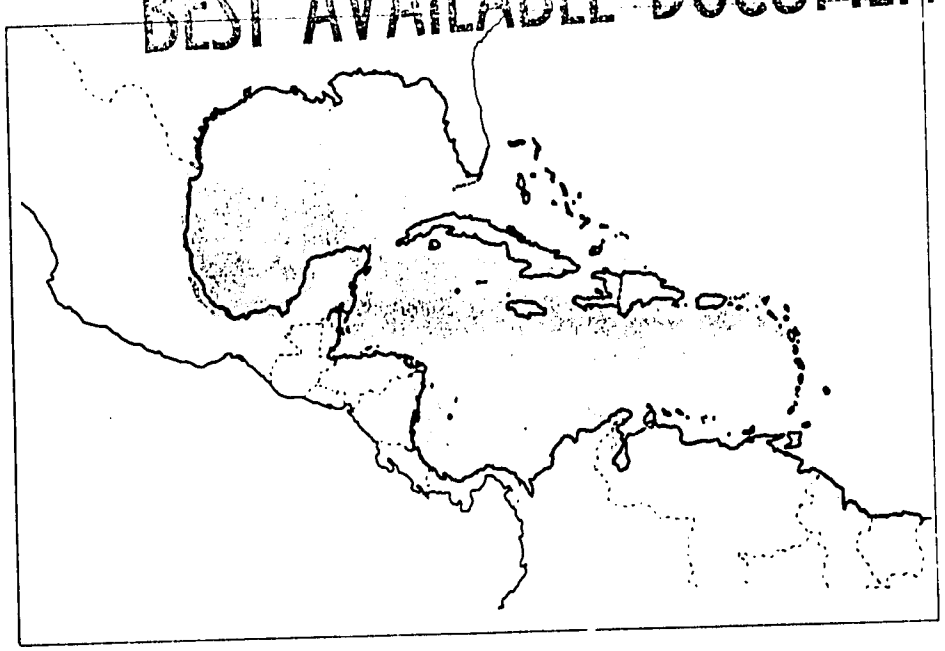
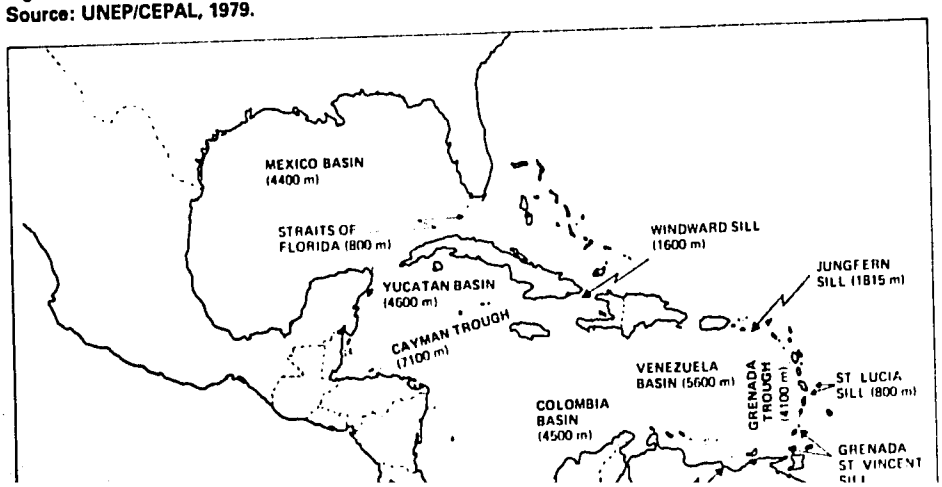


**Figure 1. The Wider Caribbean Region as defined by UNEP. Source: UNEP.**

**Figure 2. Average depth of major basins and sills in the Wider Caribbean. Source: UNEP/CEPAL, 1979.**

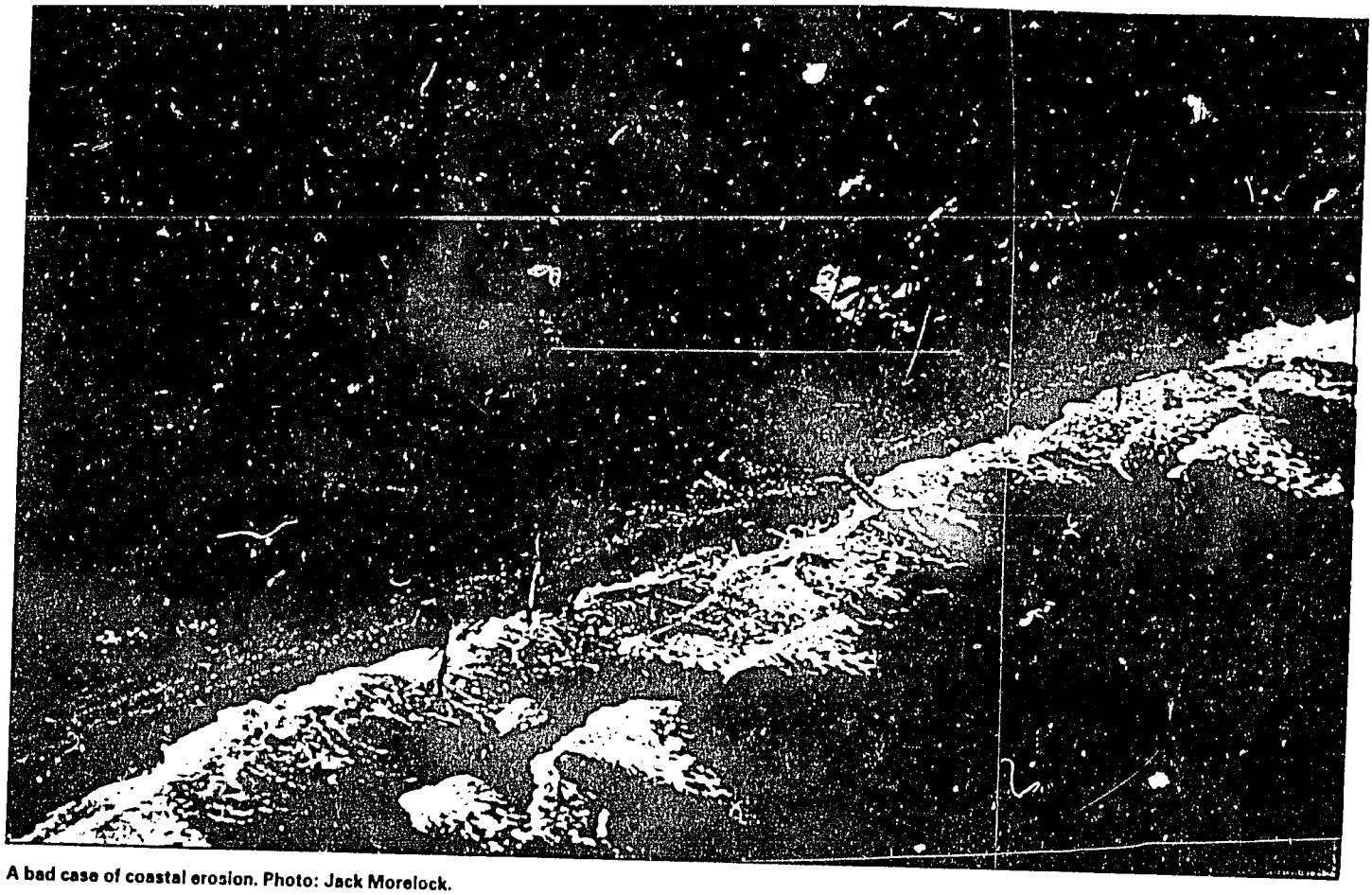



For the purposes of this article, the Wider Caribbean is defined as the coastal and open waters of the Caribbean Sea proper, the Gulf of Mexico and adjacent waters of the Atlantic Ocean. The coastal areas included are those of East Mexico, the Atlantic coasts of Central America and Panama, the Bahamas and the Antillean Archipelago, the northern tier countries of South America from Colombia to French Guiana and the Gulf areas of the United States (Figure 1).

## HYDROGRAPHIC CHARACTERISTICS

The Wider Caribbean is a semi-enclosed body of water consisting of several deep basins separated by major sills (Figure 2). The average depth is approximately 2200 meters with the deepest point being 7100 meters, in the Cayman Trench. The two major basins are the Caribbean Sea and the Gulf of Mexico. Jointly these two basins have been called the "American Mediterranean" (1). The total surface area of the Caribbean is approximately $4.31 \times 10^6$ km$^2$ (2).

The general movement of the surface waters is stable all year round, although some seasonal changes can be found in the velocities. The prevailing currents are shown schematically in Figure 3. The current systems shown in this figure are only yearly averages. Smaller currents or eddies develop seasonally such as the Gulf of Panama and the Gulf of Mexico loop currents (3). Therefore, a general estimate of the mass transport of material, including pollutants, by currents should be made only cautiously, because the large spatial and temporal variability which has been observed in the Caribbean may lead to serious errors if only prevailing current systems are taken into



A bad case of coastal erosion. Photo: Jack Morelock.

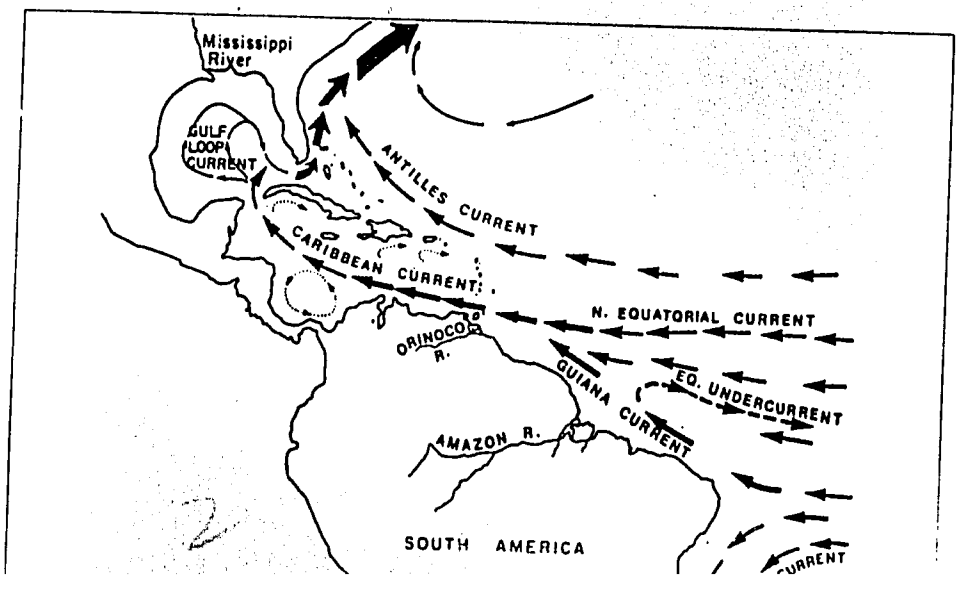
account. As an example, the westerly inflow of water through the island passages of the Lesser Antilles barrier is disturbed in its passage. This results in the generation of large turbulent wakes and eddies which could concentrate nutrients because of the associated current patterns (4). The same concentration effect could apply to pollutants.

The surface temperature in the tropical parts of the region averages about 27°C and does not vary much during the year. The seasonal fluctuations do not exceed 3°C. The same holds true for the southernmost part of the Gulf of Mexico. However, its northern part shows extreme seasonal changes in temperature, from about 16°C in winter to 28°C in summer, so that during the winter months there is a strong latitudinal temperature gradient. The cooling of surface waters in the northern and central part of the Gulf of Mexico during winter months also affects the vertical temperature distribution. A surface mixed layer is formed during the winter in parts of the Gulf of Mexico extending to the permanent thermocline normally established at about 100 m (3). In the Greater Caribbean area and adjacent seas the temperature decreases by 10–15°C during the first 200 m, beyond which depth there is only very slow further decrease.

relatively high salinities between January and May (with maxima >36.5 percent in February and March) are regularly followed by lower salinities between June and December (with minima <34.5 percent in October and November). The cause of these variations is the inflow of low salinity water from the south-east in late autumn which arises from the inflow of equatorial Atlantic waters containing water discharged by the Orinoco and Amazon rivers or by water from the equatorial convergence (5, 3).

The drainage area of the Wider Caribbean Region is about $7.5 \times 10^6$ km$^2$ (6) (see Figure 4). This includes the drainage

Figure 3. Prevailing currents in the Wider Caribbean and adjacent areas. Source: UNESCO, 1977.



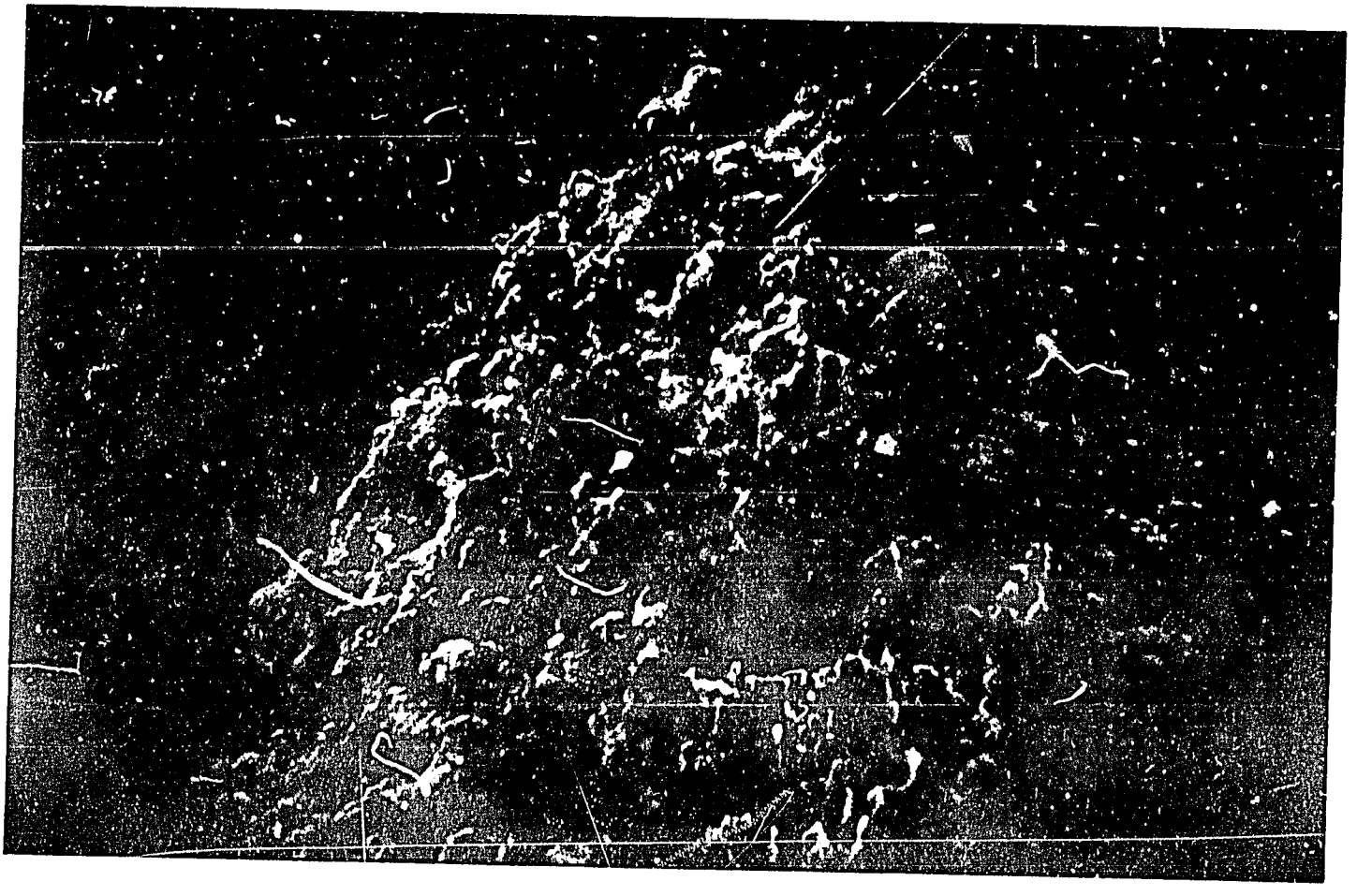


Figure 4. The watershed of the Wider Caribbean Region showing major rivers. Source: Caribbean Data Atlas/IUCN.

Statute Miles
Kilometres

Regionally Important Rivers

1 Apalachicola
2 Mississippi
3 Rio Grande
4 Urumacinta
5 San Juan
6 Atrato
7 Magdalena
8 Orinoco
9 Amazonas

Relative Volume of Flow

Large
Medium
Small

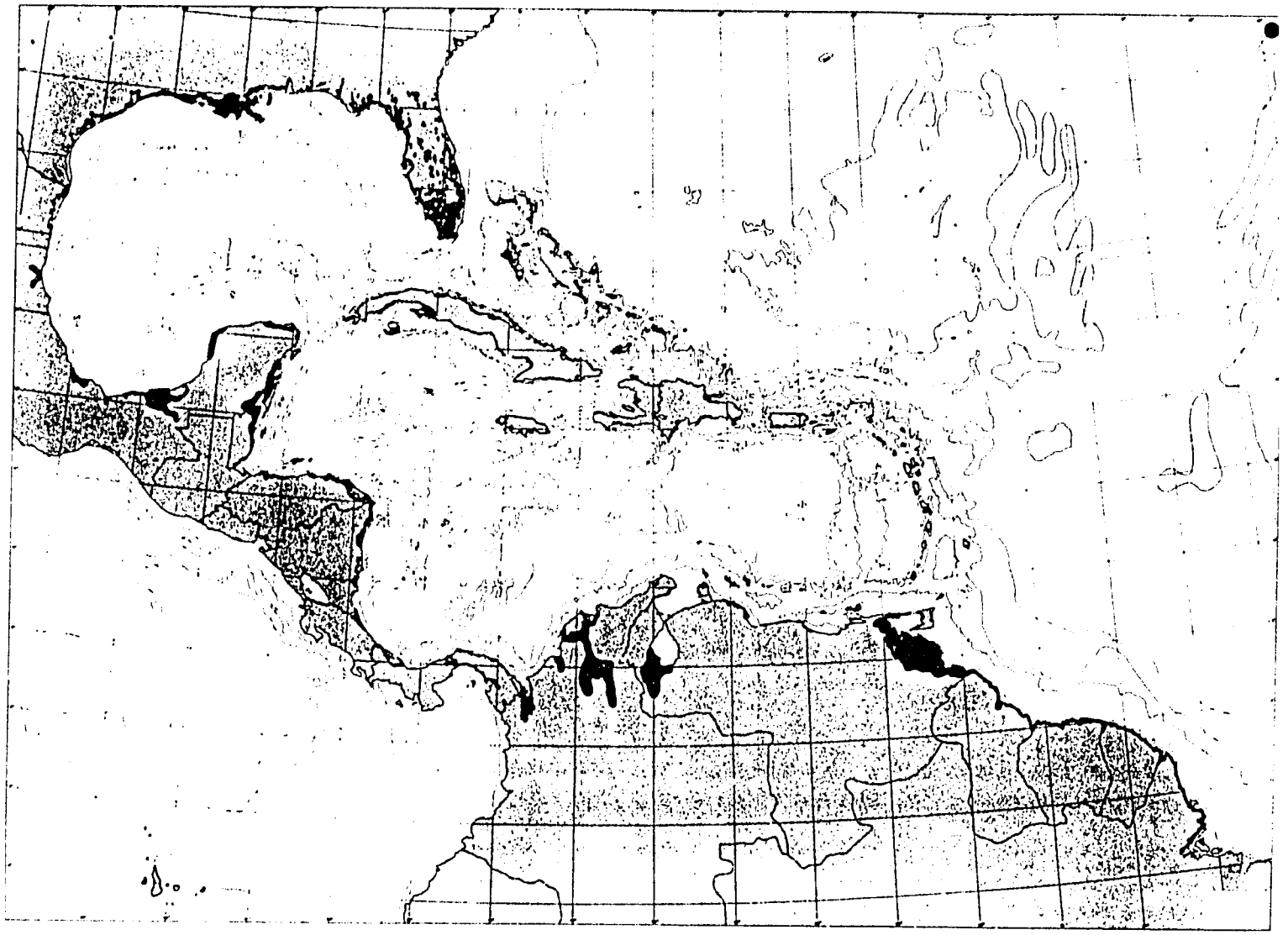


**Figure 5. Wetlands in the Wider Caribbean, showing mangroves as well as herbaceous and palm wetlands.**
**Source: Caribbean Data Atlas/IUCN.**

Statute Miles
Kilometres
Mangroves, Herbaceous & Palm Wetlands

basins of two of the world's largest rivers, the Mississippi and the Orinoco. The largest is the Mississippi basin, $3.25 \times 10^6$ km$^2$, with an inflow of about $1.8 \times 10^4$ m$^3$/sec while the Orinoco basin discharges about $3.0 \times 10^4$ m$^3$/sec from an area of $0.95 \times 10^6$ km$^2$. Although the Orinoco is geographically outside the Caribbean proper, it is included in this discussion because the major current flowing northwest along the Venezuelan coast carries most of the Orinoco outflow into the Caribbean Sea. On the other hand, because their influence has not been quantified, outflow from rivers south of the Orinoco (*eg* the Amazon discharges 4–5 times more than the Orinoco) have not been included, although their contribution to the Caribbean hydrography must be very significant (5).

Data on water discharges of major rivers into the Caribbean basin are summarized in Table 1.

**Table 1. List of major rivers affecting the Greater Caribbean Region.**[1]

| River | Area (km²) | Water discharge (m³/sec) |
|---|---|---|
| **USA** | | |
| Apalachicola (Fla) | 44 000 | 820 |
| Mobile (Ala) | 97 000 | 1 500 |
| Mississippi (La) | 3 268 000 | 18 400 |
| Brazos (Tex) | 114 000 | 160 |
| Colorado (Tex) | 107 000 | 19 |
| **USA – MEXICO** | | |
| Rio Grande (Tex) | 467 000 | 23 |
| **MEXICO** | | |
| Panuco | 66 300 | 549 |
| Grijalva | 36 300 | 723 |
| Usumacinta | 47 700 | 1 763 |
| **GUATEMALA – HONDURAS** | | |
| Motagua | 16 600 | 262 |
| **HONDURAS** | | |
| Ulua | 22 500 | 528 |
| Patuca | 25 600 | 825 |
| **HONDURAS – NICARAGUA** | | |
| Coco | 28 700 | 950 |
| **NICARAGUA** | | |
| Rio Grande de Matagalpa | 19 700 | 762 |
| **NICARAGUA – COSTA RICA** | | |
| San Juan | 38 900 | 1 620 |
| **PANAMA** | | |
| Changuinola | 2 745 | 204 |
| **COLOMBIA** | | |
| Magdalena | 235 000 | 7 500 |
| **VENEZUELA** | | |
| Orinoco | 950 000 | 30 000 |

[1] Criteria of choice: water discharge more than 200 m³/sec or drainage area more than 100 000 km²
SOURCE: Reference 6.

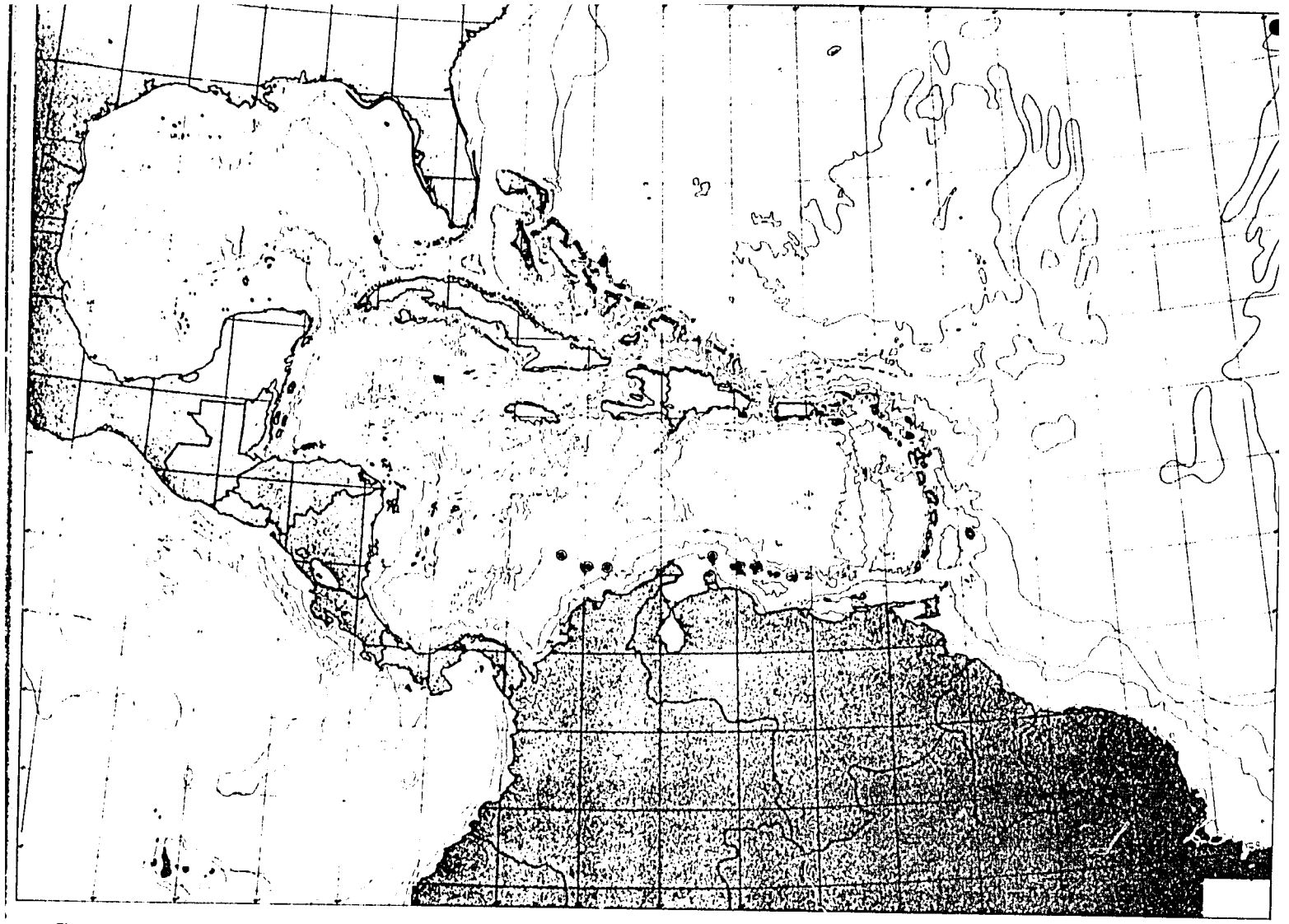



**Figure 6. Living reefs in the Wider Caribbean.**
**Source: Caribbean Data Atlas/IUCN.**

## LIVING RESOURCES

There are factors which limit the ecology of the offshore seas and, as a result, the fisheries potential of the Caribbean Region, in comparison with temperate seas such as the North Atlantic or the Norwegian Sea. First, the Caribbean region lacks an extensive, shallow continental shelf except in the Yucatan Gulf and parts of the South American Shelf. Four-fifths of the waters of the Wider Caribbean Region are deeper than 1800 m and half are deeper than 3600 m. Second, water temperatures do not fluctuate over a wide range so that there is a relatively stable thermocline which prevents mixing of surface and deep waters. Although there are significant upwelling areas, they are not a dominant feature. The result is a restricted nutrient supply which is reflected in the limited fishery in offshore areas. Nevertheless, certain areas namely the Gulf Coast of the United States, the Bahia de Campeche, the Jamaican Ridge area and the North Coast of South America, have important commercial shrimp fisheries. These fishing grounds are often associated with shallow areas where a premium is placed on the role of highly productive coastal ecosystems such as mangroves, coral reefs, sea grasses, estuaries and coastal lagoons because of the vital life support systems that they provide the fisheries. Figures 5 and 6 illustrate respectively the general distribution of mangroves and coral reefs in the Wider Caribbean region.

## SOURCES OF ENVIRONMENTAL STRESS ON COASTAL AND MARINE RESOURCES

Twenty-seven countries plus a number of territories and dependencies share the waters of the Wider Caribbean Region. These states are marked by a striking diversity of cultural and historic backgrounds, natural resource endowments, political organization and degrees of socio-economic development.

The Caribbean in general is a developing region where the level of industrialization and urbanization is still relatively modest. Consequently, general pollution of the marine environment caused by wastes from land-based sources has not reached the severe levels found in more industrialized regions. Nevertheless, for some years there have been localized problems of marine pollution and there are planned activities which are potentially damaging.

The riparian countries and States of the USA which border the Wider Caribbean have an estimated population of 168 million. However, only a fraction of this population is concentrated along the coasts of the Region. In the case of some islands the entire population could be considered as coastal (see Figure 3, p. 278).

The level of the socio-economic development in the Region is tremendously diverse, with per capita incomes ranging from $170 to $13 000 per year (7).

Export-oriented single-crop agriculture has been the principal economic activity of most of the Caribbean states during the past century or so, with the exception of the few mineral-rich territories which export raw ores. With post-war increases of capital investment and technology transfer, many countries have shifted towards other sectors such as manufacturing and tourism. In general however, most of the countries of the region still have monocultural, export-oriented economies devoted to the production of basic commodities; either agricultural, mineral or both. Although shifts to industrialization have sometimes resulted in a reduction of agricultural output, in general they have encouraged energy-intensive agricultural practices. With this has come increased use of fertilizers and chemical pesticides in some countries of the region. As modernization proceeds it is expected that the application of agricultural chemicals, especially pesticides will increase. The environmental impact of these chemicals on the tropical ecosystems of the Wider Caribbean Region still needs to be determined.

Although there is not widespread industrialization in the region, certain local areas are being intensively industrialized as processing centers for indigenous or imported raw materials. In fact, the expansion of processing indigenous raw materials, especially oil (in the case of resource-endowed countries) or the development of trans-shipment and processing facilities for imported raw materials (by countries lacking natural resources) seems to be a major strategy of the developing countries of the region. Recently, a number of large trans-national corporations have tried to move into the Caribbean to capitalize on the region's inexpensive labor and in some cases on legal concessions not available elsewhere.

Parallel to industrialization and intensification of agriculture, other sectors of the economy, such as tourism and fisheries, are being developed with varying degrees of intensity by different countries. In fact in some of the smaller islands of the eastern Caribbean, marine-resource-oriented tourism is a major source of badly needed foreign exchange.

Because of its diversity, it is not easy to generalize on the socio-economic situation of the region except to stress that raw materials production, intensification of agriculture and industrialization are steadily increasing. In many countries, especially the smaller eastern islands, with limited exploitable natural resources, tourism is the main dollar earner. In most cases all these activities are being superimposed on economies that have been tensive agriculture, limited natural resource exploitation or self-sustaining agrarian activities and fishing. As many of the activities are taking place in the coastal zone they threaten the marine environment through direct injection of wastes, alterations in coastal morphology and ecology, poor land-use practices, and runoff pollution.

### Industrial waste

Apart from contamination by petroleum hydrocarbons there is no widespread marine pollution in the Wider Caribbean Region, although severe, localized environmental problems do occur mainly in the vicinity of large urban or industrial areas (see Box 1). These problems threaten the development of certain economic activities, such as coastal tourism and fisheries, which depend on a healthy marine environment. The increasing pace of industrial development of the region will inevitably increase the risk of environmental disruption unless adequate and timely measures are taken, including careful selection of sites for future industrial activities, application of appropriate waste treatment and disposal practices and selection of appropriate technologies.

The largest industrial concentrations can be found 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 (8).

Removal of sand from beaches and coastal areas for use in the construction industry is widespread in the Caribbean. This is not a polluting activity *per se*, but it may be the single most destructive coastal industrial activity, producing severe and irreparable beach erosion in many places (9). Furthermore, destruction of beaches increases the amounts of particulate material in the water column, resulting in high turbidity in coastal waters which in turn adversely affects sensitive and productive benthic communities such as coral reefs (see photos).

### Domestic waste

Marine pollution caused by domestic wastes, mainly from urban areas, is generally known to be a problem common to the whole region and is associated with all major cities in the area. In some locations, direct discharge of raw sewage into coastal waters has already resulted in potentially hazardous conditions for human health and the marine environment (10). Although [illegible] coastal communities appears to have been carried out, data from 1974 indicate that less than 10 percent of the sewage systems surveyed had adequate treatment facilities, and it seems that this percentage has not changed (11). Data on sewage systems in urban areas, as furnished by countries of the region, are presented in Table 2.

Since the sewage generated by 30 million people is dumped more or less untreated into the Caribbean (11), it is doubtful that the development of sewage treatment facilities will keep pace with population and industrial growth in the short term. As a result, the assimilative capacities of natural waters—particularly coastal lagoons and estuaries—will continue to be exceeded.

The domestic sewage load from urban centers is compounded by the numerous resort hotels throughout the region, particularly in the insular Caribbean which discharge untreated sewage close to bathing beaches (12). Many of these hotels have "package" sewage treatment plants which are often overloaded or inadequately maintained [illegible]

**Box 1. Anitra Thorhaug, a marine biologist at Florida International University, in Miami lists the following hot spots in the Wider Caribbean.**

**Cartagena, Columbia—mercury; Colon, Panama—oil; Veracruz, Mexico—thermal effluent; Galveston, Texas—oil; New Orleans, La—industrial waste; Tampa Bay, Florida—sewage; Kingston, Jamaica—bauxite waste; Port-au-Prince, Haiti—sewage; Santo Domingo, Dominican Republic—urban runoff; San Juan, Puerto Rico—sewage; Port of Spain, Trinidad/Tobago—oil; Cumana, Venezuela—sewage; and Havana Bay, Cuba—all of the above.**

Table 2. Population served by sewage systems in the Greater Caribbean Region.

| Country | Urban Population served (in 1000s) | % | Total Population (in 1000s) | % Total Population |
|---|---|---|---|---|
| Antigua | [illegible] | [illegible] | [illegible] | 0 |
| Barbados | [illegible] | [illegible] | [illegible] | 0 |
| Belize | [illegible] | [illegible] | [illegible] | 3 |
| Colombia | [illegible] | 68 | [illegible] | 41 |
| Costa Rica | 404 | 43 | [illegible] | 21 |
| Cuba | [illegible] | [illegible] | [illegible] | 31 |
| Dominica | [illegible] | 0 | [illegible] | 0 |
| Dominican Republic | [illegible] | 27 | [illegible] | 21 |
| El Salvador | [illegible] | 36 | [illegible] | 15 |
| Grenada | 10 | 36 | 10 | 13 |
| Guatemala | 725 | 31 | 725 | 11 |
| Guyana | 118 | 43 | 118 | 14 |
| Haiti | 0 | 0 | 0 | 0 |
| Honduras | 444 | 48 | 445 | 16 |
| Jamaica | 133 | 21 | 153 | 7 |
| Mexico | 15 390 | 41 | 18 463 | 27 |
| Montserrat | 0 | 0 | 0 | 0 |
| Nicaragua | 403 | 31 | 403 | 17 |
| Panama | 874 | 67 | 1 134 | 58 |
| Surinam | 85 | 58 | 85 | 21 |
| St Kitts | 0 | 0 | 0 | 0 |
| St Lucia | 0 | 0 | 0 | 0 |
| St Vincent | 0 | 0 | 0 | 0 |
| Trinidad | [illegible] | 69 | 232 | 27 |
| Venezuela | 5 000 | 5 | 5 267 | 40 |

SOURCE: Reference 30.

Another aggravating problem is contamination of the marine environment from human wastes and garbage discharged from boats (13).

### Agricultural waste

Marine pollution from agricultural activities can be categorized broadly in terms of 1) inorganic fertilizers; 2) pesticides; 3) liquid effluents containing high organic loads from industries such as sugar refineries and rum distilleries and 4) high silt content run-off resulting from poor soil management practices. Although data on the importance of these sources are fairly scarce there are indications that pollution stemming from agricultural activities is increasing and may already be serious.

The inorganic fertilizers utilized in the Wider Caribbean Region are mainly nitrogen, phosphorus-based compounds, or potash. Consumption figures for two representative periods are presented in Table 3. Rainfall leaches these into rivers and coastal marine ecosystems, which in turn leads to eutrophication of rivers and estuaries when the elevated nutrient levels cause rapid proliferation of "algal blooms" followed by high biological oxygen demand (BOD) when the bloom dies and decay processes occur. Although not substantiated by analytical measurements, there is evidence that such problems exist in some areas of the region (14).

Analysis for DDT and DDE in the tissues of reef-dwelling groupers in the Gulf of Mexico and Grand Bahamas showed that these compounds are present (15). Of the three reef systems analyzed, those in the Gulf of Mexico had a higher level of these residues. Another study of plankton and a variety of shrimp and fish from the Gulf of Mexico and the Northern Caribbean showed that DDTs were widely distributed, although the levels were generally low (16). Samples with the highest concentrations were found along coastal areas. In addition, these toxic compounds may be carried into the Caribbean from outside the region. For example, evidence has been presented that the Atlantic trade winds deposit chlorinated hydrocarbons in amounts comparable to those transported to the Caribbean by major rivers (17, 18).

Since an increase in the use of pesticides is expected in the Wider Caribbean region, steps should be taken to develop pilot monitoring programs in areas of potential contamination in order to assess the concentration levels and their bioaccumulation in the trophic chains in marine and coastal communities.

### River inputs

The total amount of river water discharged to the Wider Caribbean is approximately $2.8 \times 10^3$ km$^3$/year ($2.8 \times 10^{15}$ liters per year) (6) (see page 285). This includes two of the world's largest rivers, the Mississippi and the Orinoco. Some rivers in Colombia, Mexico, Guatemala and the United States are currently being monitored for various pollutants or pollutant-related parameters. However, the number involved to date is still quite limited (19).

Monitoring and control of pollution from rivers flowing into coastal mangroves, lagoons, estuaries and coral reefs are of particular importance because these areas are the primary source of biological productivity for the Wider Caribbean Region, and they are vulnerable to damage from run-off. For example, the increased sediment loads from many small rivers (resulting from soil erosion) have proved fatal to coral reefs and other communities (20).

Table 3. Fertilizer consumption in the Wider Caribbean Region in 1976/1977 (Thousand's of metric tons).

| Country | Potash ($K_2O$) | Phosphate ($P_2O_5$) | Nitrogenous (N) |
|---|---|---|---|
| Bahamas | 0.6 | 0.4 | – |
| Barbados | 1.5 | 1.9 | 0.4 |
| Belize | – | 1.2 | 0.6 |
| Colombia | 34.6 | 54.3 | 63.8 |
| Costa Rica | 16.8 | 40.0 | 10.4 |
| Cuba | 116.0 | 175.6 | 207.5 |
| Dominican Republic | 19.4 | 15.0 | 21.4 |
| El Salvador | 8.7 | – | – |
| Guadeloupe | 3.2 | 1.8 | 3.0 |
| Guatemala | 19.0 | 19.4 | 26.3 |
| Haiti | 0.1 | 0.2 | – |
| Honduras | 5.4 | 13.0 | 9.0 |
| Jamaica | 5.7 | 10.0 | 1.3 |
| Martinique | 4.1 | 5.3 | 6.4 |
| Mexico | 50.0 | 392.2 | 223.8 |
| Nicaragua | 8.8 | 17.0 | 14.0 |
| Panama | 7.5 | 14.3 | 4.2 |
| St Kitts-Nevis-Anguilla | 1.2 | 0.2 | 0.5 |
| St Lucia | 1.2 | 1.0 | 1.3 |
| St Vincent | 1.0 | 1.2 | 0.4 |
| Trinidad and Tobago | 7.4 | 6.0 | 0.2 |
| US Virgin Islands | – | 0.2 | 0.2 |
| Venezuela | 40.0 | 22.1 | 46.8 |

SOURCE: Reference 7.

Table 4 presents sediment discharge data from rivers into the Gulf of Mexico and the Caribbean Sea.

Table 4. Partial List of sediments discharged by rivers into the Gulf of Mexico and the Caribbean Sea.

| River | Sediment discharge (10⁶ tons/year) | Sediment yield (tons/km²/year) |
|---|---|---|
| USA | | |
| Mississippi | [illegible] | [illegible] |
| Apalachicola | [illegible] | [illegible] |
| Mobile | [illegible] | [illegible] |
| Brazos (Tex) | [illegible] | [illegible] |
| Colorado (Tex) | [illegible] | [illegible] |
| Rio Grande | [illegible] | [illegible] |
| COLOMBIA | | |
| Magdalena | [illegible] | [illegible] |
| VENEZUELA | [illegible] | [illegible] |
| Orinoco | 960 | [illegible] |
| EL SALVADOR | [illegible] | [illegible] |
| Rio Grande at Moscoco | 2350 | [illegible] |
| HONDURAS | | |
| Choluteca | 1510 | [illegible] |
| COSTA RICA | | |
| Reventazon | 1387 | [illegible] |
| Grande | 838 | [illegible] |
| NICARAGUA | | |
| Viejo | 854 | [illegible] |
| PANAMA | | |
| Bonjano | 3213 | 811 |

* Low values due to Dams
SOURCE: Reference 6.

## Oil Pollution

The Wider Caribbean Region is potentially one of the largest oil producing areas in the world. Existing and projected production areas onshore and offshore are located along the coasts of Venezuela, Trinidad and Tobago and in the Gulf of Mexico. For the entire region nearly one-third of the total oil production or $3.1 \times 10^6$ barrels per day (in 1978) was from offshore wells (21). Significant expansion is expected; as of 1979 just two countries—USA and Mexico—had planned or were beginning to construct no less than 38 offshore platforms (22b).

Based on past experience, approximately 6.7 percent of the total offshore production can be expected to spill into the marine environment as a consequence of pipeline accidents, blow-outs, platform fires, overflows, malfunctions and other less serious occurrences. These sources accounted for the release into the Wider Caribbean waters of an estimated 76.6 million barrels of oil during 1978 (21). Figure 7 illustrates oil spill high-risk zones associated with offshore production.

Besides the offshore production areas, another source of oil pollution in the region is associated with oil refineries and related facilities. The present refining capacity in the Wider Caribbean is estimated to be $12.2 \times 10^6$ barrels per day distributed among 73 refineries (21). Although there are no estimates for the Caribbean on the amount of waste oil reaching the marine environment from coastal refineries, an extrapolation of data from other regions suggests that operational spillages resulting from refineries are of minor significance (22a).

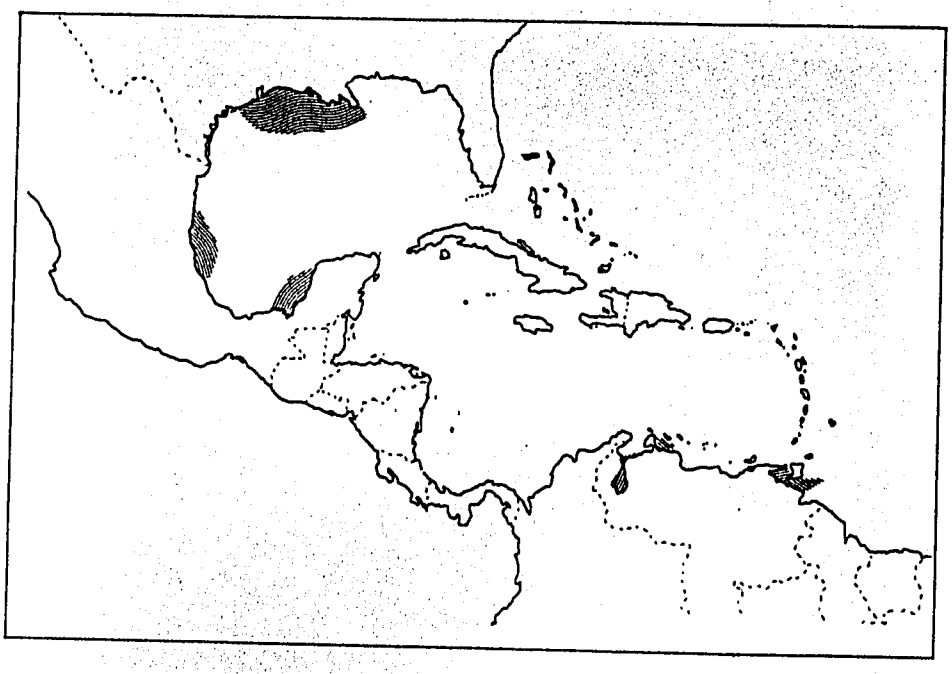


Figure 7. High risk zones for oil spills in off-shore areas in the Wider Caribbean.
Source: IMCO, 1979.

## Oil Transport

About 5 million barrels of oil are transported through the Wider Caribbean every day, which generates a relatively intensive tanker traffic (see also p 277). Tanker movements through restricted channels and in the vicinity of some ports increase the possibility of shipping accidents in those areas. Figures 8 and 9 illustrate these high-risk zones, and Table 5 shows the likely points of impact of oil spills resulting from accidents within the high-risk zones.

As can be seen there are three major pathways for oil transportation in the Wider Caribbean:

- The pathway for the transportation of Middle Eastern, West African, and North African crude oil to the United States usually by supertanker with a stop for refining, trans-shipping or lightering and subsequent transport by smaller vessels to the US coast.

- The pathway for shipping either crude or refined products from Venezuela and/or Aruba, Curaçao and others to various world markets.
- The shipping of Alaskan crude oil through the Panama Canal to the US Gulf Coast, the Virgin Islands or US east coast refineries.

In the future the transport of crude oil or refined products from Mexico and Guatemala may create another major pathway.

In addition to major oil spills resulting from tanker accidents, significant discharges of oil into local Caribbean ports occur as a consequence of ballasting, ship cleaning, tank washings and docking and undocking operations. Discharges of tank washings are the greatest continual source of oil pollution to the marine environment from tankers, and are believed to be responsible for the tar balls which often appear on Caribbean and Gulf of Mexico beaches. It has been estimated that oil discharges from tank washings within the Wider Caribbean waters could be as high as 7 million barrels a year (21).

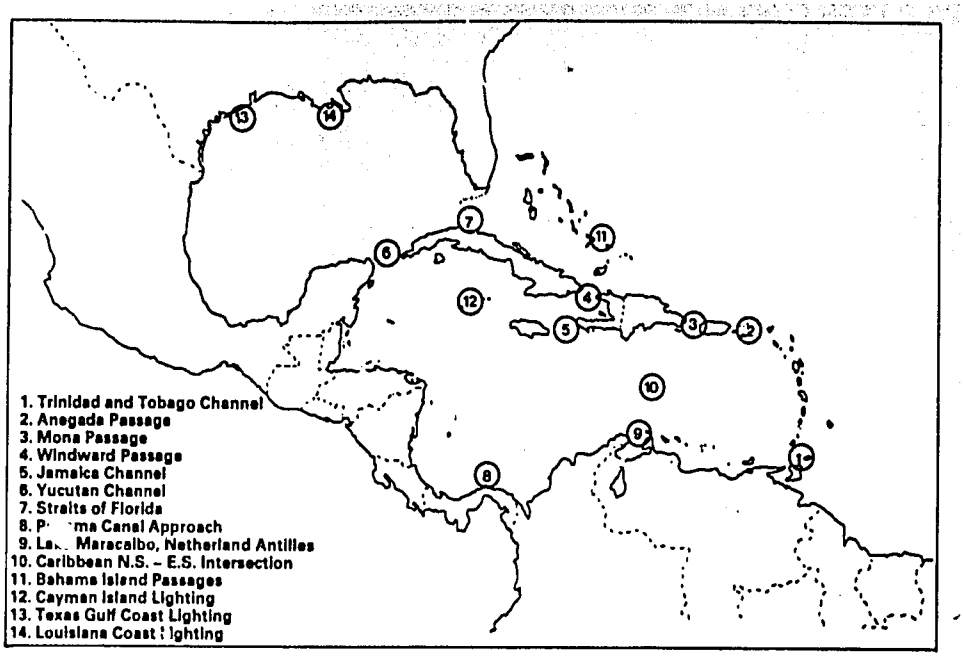



**Figure 8. Oil spill high risk zones associated with through shipping. Source: IMCO, 1979.**

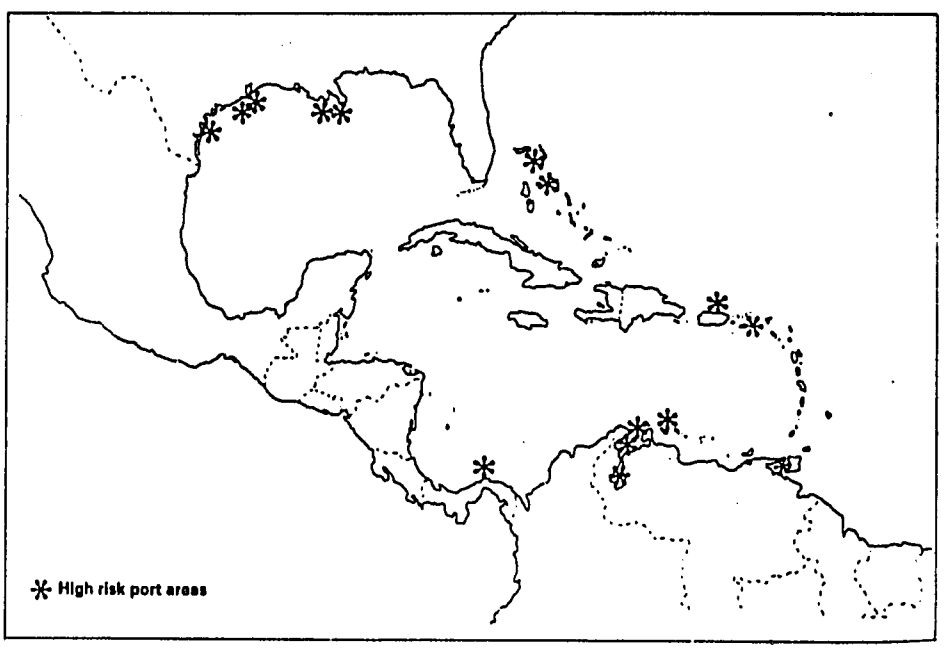



**Figure 9. Oil spill high risk zones associated with port approaches. Source: IMCO, 1979.**

## EFFECTS OF ENVIRONMENTAL STRESS ON THE MARINE AND COASTAL RESOURCES

Developmental activities will continue to take place in the region, in some instances at a very accelerated pace. Countries with extensive petroleum resources plan to develop energy-intensive heavy industries such as petrochemical processing, iron, steel and aluminum smelting, caustic soda and chlorine production. On the other hand countries without natural resources are attracting non-resource-based industries such as refineries, pharmaceutical plants, as well as light industries and tourism. For a variety of reasons such as ease of trans-shipment, easy waste disposal and availability of cooling water, most of these developments will take place in the coastal zones. And naturally all tourist development in most of the Wider Caribbean has been, and will continue to be, oriented towards the coast. Concomitant with coastal development is coastal urbanization.

These trends carry with them the risk of increased environmental impacts which threaten the delicate coastal marine ecosystems upon which most of the marine biological productivity of the region depends. The importance of the various coastal ecosystems in providing nutrients for the region's limited fishery has already been stressed. At present there is a marked paucity of data concerning the environmental impact of the existing and planned development processes on the marine environment of the region. Without this information it is not possible to verify the environmental consequences of developmental activities and the effects on the different economic sectors which depend on coastal and marine resources. For example, an island endowed with extensive mangrove swamps may, as a consequence, have a shrimp fishery. Without knowing that the shrimp fishery depends on the existence of healthy mangroves, a decision may be made to destroy them in order to construct harbors, tourist centers, or even to harvest the mangrove for its most like material for fuel. It has been proposed in some countries. The consequence may be a ruined shrimp fishery.

### Effects on Human health

Information concerning the extent of coastal pollution from sewage outfalls in the Caribbean is very limited. A few reports have been published connecting sewage pollution to human illness in the region. For example, in Kingston harbor, high bacterial levels were found along the entire northern shore of the harbor, and

fish kills have been associated with high bacteria concentrations (23). Epidemiological data suggesting a relationship between quality of bathing waters and health of bathers in the Caribbean are entirely lacking, although active studies are under way in some countries.

Other harmful pollutants such as heavy metals, PCBs and chlorinated hydrocarbons might be present in the marine environment, particularly near coastal industrial concentrations. Information on the levels of these pollutants, on their potential bio-accumulation in organisms consumed by man, and on the incidence of actual public health impairment is not generally available, although there is one report of high mercury levels in Cartagena Bay, Colombia (24) and there have been general reports on shellfish and fish poisoning within the region, some of which have been associated with pesticide runoff (25).

**Effects on marine and coastal ecosystems**

High organic load effluents from primary-treated sewage and industrial waste discharges are responsible for increasing abiotic conditions and the general deterioration of Kingston Harbor (10). Inadequate secondary-treated sewage discharges coupled with dredging resulted in severe environmental degradation of a coastal lagoon system near San Juan, Puerto Rico (26).

Oil pollution from a major spill in 1973 resulted in extensive mortality to marine organisms and general disruption of the marine environment in communities associated with mangroves and *Thalassia* in Cabo Rojo, Puerto Rico (27). Chronic deterioration of the surrounding mangrove forests was observed long after this incident had been reported (28). Likewise an oil spill in Florida Bay in 1975 caused extensive damage to marine communities. In 1976 another spill involving several thousand gallons of diesel and black oil took place (29). Although damage to marine communities by the oil and the chemicals used to disperse it in clean-up operations was not estimated, the incident was associated with massive fish kills.

The information available on the effects of pollutants on marine organisms and ecosystems in the Wider Caribbean Region is limited. However, there are indications that stress conditions do exist in coastal areas adjacent to several urban and industrial sites in the region. The degree of this stress has to be assessed and the effects on public health and marine resources need to be quantified in order to provide a substantive case for managing developmental activities in an environmentally-sound fashion.

**Effects on socio-economic activities**

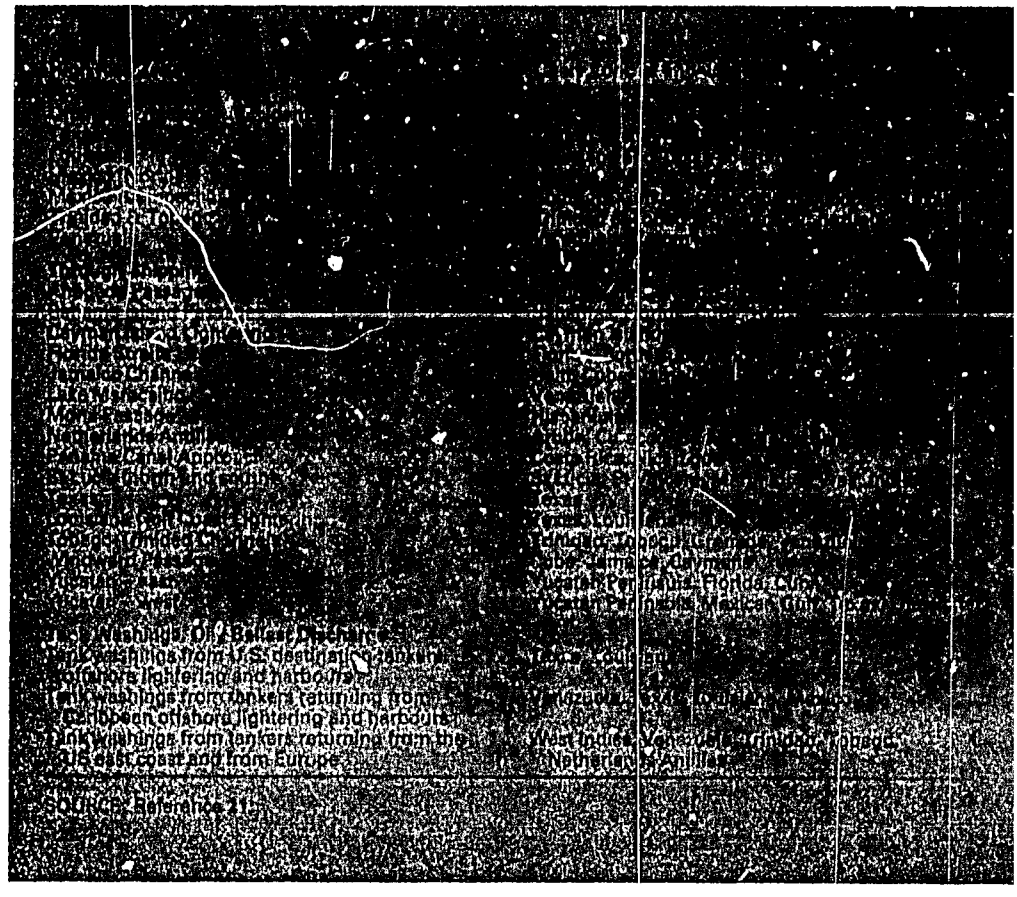
The two most important socio-economic activities in the Wider Caribbean Region that rely on a healthy marine environment are fisheries and tourism.

There is a fairly high dependence on fish protein sources, which is likely to be maintained and increased. This is especially true for smaller islands which lack livestock production. Although, for mainly historical reasons, much of the fish requirement is imported, Caribbean fisheries have been developing and expanding.

As already mentioned, the Caribbean fisheries are closely linked to coastal ecosystem productivity due to the limited upwellings and shallows in the region. No statistics connecting reduced fish landings to mangrove destruction exist, although it has been implied that a dwindling of the mangroves in Puerto Rico might be responsible for a slump in coastal fisheries. On the other hand, there is substantial evidence that mangrove swamps, coral reefs, *Thallasia* beds and coastal lagoons contribute to the life cycle of a great majority of the commercial species of fish and shellfish captured in the region. Thus, degradation of these ecosystems resulting from pollution, or from physical disruption of coastal areas, has a far more severe effect than if the fishery was linked to productivity in open waters.

Marine-oriented tourism is particularly important for the insular Caribbean, much of which has no other source of foreign exchange. Deteriorating conditions of beaches by domestic sewage or industrial waste reduce their desirability for tourists. Of major concern in this respect is oil pollution, directly in the form of tar on beaches and indirectly for the effects it has on the coastal ecosystems which constitute the major tourist attraction. Both the increased oil tanker traffic through the region—including very large crude carriers—and extensive production activities increase the probability of spills. A massive oil spill that hits tourist beaches could cause economic chaos, especially in the case of small tourist-oriented islands. Definitely these types of pollution are a major threat to the fragile economies of the small island states of the region.

**Table 5. Zones of high risk from oil spills and likely points of impact.**



## THE NEED FOR MARINE AND COASTAL ZONE MANAGEMENT POLICIES

Most Caribbean countries have not fully developed the managerial and custodial ethics or the policies needed to adequately protect and use their coastal and marine assets. The most important reasons for this situation are as follows: a) national economic problems often overshadow environmental considerations so that costs or, alternatively, loss of potential revenue are perceived as outweighing benefits; b) there is a general lack of awareness of the role marine and coastal resources could play in the process of socio-economic development and the improvement of the

quality of life; and c) there is a paucity of data relevant to the potential damage to marine ecosystems by coastal development activities and marine pollution.

Because policies concerning coastal and marine resource management are seldom articulated at the highest level of decision-making in many of the Caribbean countries, environmental considerations are not incorporated, as a rule, into development planning. This situation however has been changing gradually in recent years. The Barbados delegation to the January 1978 Commonwealth Caribbean meeting on the Law of the Sea summarized, in an excellent way, the region's growing concern about the protection of its marine resources:

"The pollution problems of the Caribbean Sea may not have reached the magnitude of those in the Baltic and the Mediterranean ... but the similarity of land-locked configuration of the Caribbean with the potential for retention of pollutants from a developing region warrants early preventive action. If the countries of these regions are to benefit from the exploitation and sharing of the resources of the Caribbean Sea it becomes imperative that immediate action is taken to arrest the trend towards destruction of marine life which is so essential to the maintenance of the marine ecological balance and to the sustenance of our people."

## CONCLUSION

The following major findings of a recent study undertaken by the United Nations Environment Program and the Economic Commission for Latin America support the need for such action (22b):

- There is a lack of data on the major sources of marine pollution in the Wider Caribbean Region, on the amounts of pollutants entering the marine environment, on the present levels of pollutants in the various components of this environment and on the effects of pollutants and coastal development activities on marine ecosystems, human health and coastal amenities;
- There is a general lack of adequate treatment and marine disposal of industrial and domestic wastes that can damage human health and highly productive marine ecosystems, such as mangroves and coral reefs;
- Oil pollution from operational and accidental sources is a growing threat to the region's ecological and economic resources;
- In most instances there are no water quality or seafood standards for toxic materials which are suitable for tropical warm waters;
- The region's national policies on marine pollution control and coastal and marine resource protection are either of very recent creation or non-existent;
- There is no effective regional co-ordination for data gathering, and exchange and no integrated marine pollution monitoring and research programs.

In an effort to protect and develop their marine and coastal resources the Governments of the Wider Caribbean Region adopted an Action Plan at a meeting in Montego Bay, Jamaica on April 8, 1981. The principal objective of this plan is to assist the Governments of the region in minimizing environmental problems through a comprehensive assessment of the state of the Caribbean environment and the development of managerial guidelines for the rational utilization of marine and coastal resources. This Action Plan is intended to provide a framework for cooperative action at the regional level, leading to the incorporation of environmental guidelines into the development process of the Caribbean countries.

### References and Notes


1. R Hodgson, *Gulf and Caribbean Marine Papers* 7, 12 (1973).
2. UNESCO Report of the IOC/FAO/UNEP International Workshop on Pollution in the Caribbean and Adjacent Regions, IOC Workshop Report No. 11 Port of Spain, Trinidad (Paris, UNESCO, 1977).
3. D K Atwood, *Regional Oceanography as it Relates to Present and Future Pollution Problems and Living Resources – Caribbean*. In Collected Contributions of Invited Lecturers and Authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, IOC Workshop Report No. 11, Supplement (Paris, UNESCO, 1977).
4. I D Leming, *Eddies West of the Southern Lesser Antilles*, in Symposium on Investigation and Resources of the Caribbean Sea and Adjacent Regions (Paris, UNESCO, 1971).
5. G Wust, *Stratification and Circulation in the Antillean-Caribbean Basins*, Colombia University Press, New York (1964).
6. J M Martin and M Meybeck, *Review of River Discharges in the Caribbean and Adjacent Regions;* in Collected Contributions of Invited Lecturers and Authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, IOC Workshop Report No. 11, Supplement (Paris, UNESCO, 1977)
7. *United Nations Statistical Year Book 1977*, New York, United Nations (1978).
8. UN/DIESA, *Marine and Coastal Area Development in the Wider Caribbean Region: An Overview* (New York, UN/DIESA, 1979).
9. C Deane, M Thom, and H Edmunds, *Eastern Caribbean Coastal Investigations (1970–1973)*. Caribbean and Regional Beach Control Program, (University of West Indies, Kingston, Jamaica, 1973).
10. B A Wade, I. Antonio and R Mahon, *Marine Pollution Bulletin* 3, 106 (1972).
11. F Butrico, Unpublished PAHO report communicated to UNEP-RS/PAC, February 8, 1979.
12. E W Mood, *Health Aspects of Coastal Water Pollution*, in Collected Contributions of Invited Lecturers and Authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, IOC, Workshop Report No. 11, Supplement (Paris, UNESCO, 1977).
13. E W Mood, *Beach Pollution in the Caribbean: an Environmental Health Assessment and Suggested Environmental Health Strategy*, Proceedings of a Conference/Workshop on Environmental Health Strategy, Grenada (Pan American Health Organization, Washington DC, 1978).
14. A M Gajraj, *The Environmental Consequences of the Industrialization of the Commonwealth Caribbean*, Caribbean Technology Policy Studies Project, (Department of Chemical Engineering, University of the West Indies, St Augustine, Trinidad and Tobago 197[illegible]).
15. C S Giam, *Bulletin of Environmental Contamination and Toxicology*, 11, 189 (1974).
16. C S Giam, M K Wong, A R Hanks, W M Sackett, and R L Rochardson, *Bulletin of Environmental Contamination and Toxicology* 9, 376 (1973).
17. R F Bidleman, and C Olney, *Science* 183, 56 (1973).
18. H L Windom, and R A Duce, *Marine Pollution Transfer* (Chapter 13). (Lexington Books, D. C. Heath and Company, Lexington, Massachusetts, 1976).
19. WHO/UNEP Draft Project (ETS/79.1) on the GEMS/WATER Operational Network, Geneva, World Health Organization (1979).
20. R E Johannes, *Marine Pollution Bulletin* 1, 186 (1970).
21. *The Status of Oil Pollution and Oil Pollution Control in the Wider Caribbean Region* (London, IMCO, 1979).
22. a Survey of Offshore Drilling Platforms in *Ocean Industry*, 14, 35 (1979).
22. b UNEP/CEPAL, *The Status of Marine Pollution in the Wider Caribbean*, UNEP – Regional Seas Program Activity Centre, Geneva (1979).
23. B A Wade, The Pollution Ecology of Kingston Harbor Jamaica, Research Report from the Zoology Department (3 Vols.), University of West Indies, Mona, Jamaica (1972–1975).
24. *Study concerning mercury pollution in Cartagena Bay* (TCP/COL/6701) (Food and Agriculture Organization of the United Nations, Rome, Italy) (1979).
25. A Ali, *Use of Pesticides in Agriculture and their Effects on Various Water Supplies*, proceedings of a Conference Workshop on Environmental Health Strategy, Grenada, Pan American Health Organization (Washington DC, 1978).
26. C Cintron, and A Rodriguez, *A Mangrove Lagoon System; Results of Modification by Man*, Paper presented at the First Conference on Oceanography of the Caribbean (Puerto Rico, 1972).
27. E T Bergquist, and R J Nadeav, *Effects of the March 18, 1975 Oil Spill near Cabo Rojo, Puerto Rico, in Tropical Marine Communities*, in Proceedings of the 1977 Oil Spill Conference, New Orleans, Louisiana, March 8–10, 1977 (American Petroleum Institute, Washington DC).
28. A Lugo, Paper presented at the IMCO/OAS/UNEP Meeting of the Smaller Caribbean Islands on Oil Spill Contingency Planning (San Juan, Puerto Rico, June 16–20 1980).
29. A M Gajraj, The Development Process in the Commonwealth Caribbean and its Environmental Impact, *West Indian Journal of Engineering*, 1978.
30. PAHO/WHO, Overview on Environmental Health in the Wider Caribbean Region, Division of Environmental Health (Pan American Health Organization, Washington DC, 1979).



**Arsenio Rodriguez Mercado from Puerto Rico is the Program Officer responsible for the UNEP-sponsored Caribbean Action Plan. His involvement with the Caribbean Environment Program started in 1977 in Port of Spain, Trinidad where he served as senior scientific officer in charge of developing the technical and scientific components of the Caribbean Action Plan, a joint effort of UNEP and the Economic Commission for Latin America (ECLA). From 1973 to 1975 he was the senior scientific and technical advisor to the Secretary of the Natural Resources Department in Puerto Rico. From 1975 to 1977, he directed the Puerto Rico Coastal Zone Management Program. He is the author of several articles in specialized journals. His main field of interest is coastal zone management and marine biology. His address: United Nations Environment Program, Palais des Nations, CH-1211 Geneva 10, Switzerland.**