CLIMATE CHANGE IMPACTS ON CARIBBEAN COASTAL AREAS AND TOURISM

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ABSTRACT

Tourism in the Caribbean is the most important source of external revenue; effectively all tourism development has occurred in the coastal areas, where the beaches are the principal attraction. Relatively few of the most intensively developed resorts have beaches broader than about 30 meters at high tide, and both qualitative and quantitative assessments illustrate that most of the world's sandy shorelines are in retreat, which includes the Caribbean. This situation is likely to get worse, in part, because sea-level rise has amounted to about 18 cm (1/2 foot) during the past century. Both the accumulating warming (about 0.5ºC in the past 100 years), possibly due in part to the buildup of anthropogenic trace gases in the atmosphere, and the rising level of the seas are projected to increase over the next several decades. With this prognosis, Caribbean areas will suffer increasingly adverse effects, both to the environment and to the economy.

Additional Index Words: Caribbean, environmental stresses, sea-level rise, coastal and marine tourism.

INTRODUCTION

Tourism is a big business. The U.S. Department of Commerce reports that tourism is the fastest growing industry worldwide. They also state that by the turn of the century, tourism will likely be the world's number one industry. Already, coastal and marine tourism in many parts of the Caribbean is a significant source of revenue and is the leading economic sector in the Caribbean as a whole (UNIDO, 1987). In the late 1980's, annual revenues from tourism were $7.3 billion (CTO, 1989). For 1994, this figure had increased by almost 60% to $11.67 billion (CTO, 1995). Throughout the Greater and Lesser Antilles as well as other Caribbean islands, tourism development has occurred in coastal nearshore areas, where the beaches are the principal attraction (Gable and Aubrey, 1990).

Research assessments indicate that about 70% of the world's sandy beaches are experiencing erosion (Bird, 1985; Bird, 1987; Warrick and Farmer, 1990); this is particularly a problem for the Caribbean region where relatively few of the most intensively developed resorts (tourist facilities) have beaches broader than about 30 meters at high tide. This is important because of global climate change, a premise that presents far-reaching multidisciplinary scientific challenges (Houghton, et al., 1992; Warrick, et al., 1993; Broecker, 1995). While changes in climate are the norm; increasingly, humans have become an agent of that change. Consequently, environmental problems associated with the potential impact of climate change are an important concern for governments and planners in the Caribbean region.

Governments appear to be increasingly aware of the risks associated with contemporary climate change that may occur during the coming decades. This is particularly true for low-lying island nation-states. Coastal development should therefore be cautiously planned and positioned in locales that will be least disturbed from such environmental stress. Perhaps adequate understanding of global change cannot be garnered without analysis of the causes and consequences of anthropogenic changes in specific regions (e.g., Gable et al., 1990, 1991; Maul, 1993a). This understanding can be achieved by detailed site studies, some of which have already begun (Turner et al., 1990; Schmandt and Clarkson, 1992; Titus, 1993), and a fresh analysis of the scope of environmental stress arising from global change.

This paper reviews selected tourism-oriented economies, highlights some coastal areas in the Caribbean already experiencing the cumulative effects of environmental degradation, addresses the ramifications of anticipated climate changes on these and other areas in the Caribbean and proposes strategies (planning) that ought to be taken, considering the magnitude of uncertainty that exists in the projections of global climate change.

CLIMATIC CHANGES

Global change is defined as alterations in climate, land productivity, oceans and other water resources, atmospheric chemistry, or ecological systems, including global warming, which are significant enough to influence the future hospitality of the Earth, whether such changes are caused by natural cycles or by human activity, or a combination of both. Forecasts of global climate change are typically projected with general circulation models (GCM's) using mathematical calculations and relationships (e.g., Weaver and Hughes, 1994). According to these models, tropical regions during the next century may experience increases in mean temperatures between 0.3° to 3.0°C, (Jaeger, 1988; Maul, 1993b; Wigley and Santer, 1993); however, the geographical distribution, magnitude and timing of the increases remain uncertain. Studies of the Barbados coral reefs indicate that the western tropical Atlantic (wider Caribbean) is sensitive to climate change and is capable of changing rapidly in a geologic sense. The lack of resolution of climate changes on a regional scale (even for surface hydrology, precipitation, cloudiness, and contemporary warming) precludes policy actions that would favor draconian measures at present (Guilderson, et al., 1994).

Within the next century, as a result of anthropogenic activities, average global temperatures are projected to be warmer than any experienced during recorded history (Schneider, 1994). And generally, instability in the climate of the North Atlantic region through the millennia is the rule rather than the exception (Dansgaard, *et al.*, 1993). Even a small increase in the average global temperature would likely cause dramatic shifts in world agriculture production (Rosenzweig and Parry, 1994), disrupt national economies, and raise sea levels flooding coastal cities, wetlands, and other areas (Titus, 1993; Woodworth, 1993). Human activities are already producing changes unprecedented in recorded history, such as global air quality, patterns of deforestation, and abundance and distribution of plant and animal species.

Global change research transcends the boundaries of traditional scientific disciplines and requires an interdisciplinary approach to studying the entire Earth system and its history, including the atmosphere, oceans, ice, soil and solid earth, biota, and solar influences. An important goal of global change studies is to develop the capability to project significant global changes, both natural and human-induced (and the synergy that exists between the two).

Associated with the global warming aspect of climate change are the secondary responses, altered precipitation patterns and increases in sea surface temperature that lead to changes in storminess, cloudiness, and changes in *relative* sea levels (Maul, 1989). Regarding the latter, Aubrey et al. (1988) ascertained historical rates of relative sea level in the Caribbean. Their results indicate that the rates of change have not been uniform over the past half century, varying from an emergence of the land 5.3 mm/yr to a submergence of the land at 9.3 mm/yr (see Table 1). The recent global rate of sea-level rise, determined from the few available long period tide gauge stations, may exceed 2.5 mm/yr (Peltier and Tushingham, 1989), though for the past century, worldwide tide gauges show a rise of 1.8 mm/yr (Douglas, 1991). Sahagian, et al. (1994) note, however, that the reported rise in sea level would have been even larger if human factors such as storing water in reservoirs or channelling it into groundwater aquifers by irrigation works had not been undertaken.

Eustatic change in sea level is the worldwide change in the volume of ocean water as contrasted with local oceanographic effects (currents) or uplift or subsidence of the land. In the Caribbean region, tectonism causes movement of lithospheric plates. These movements exert significant influence on tide-gauge records. Known vertical movements along Caribbean coasts are dominantly subsiding (Haq, 1994). Despite these geophysical tendencies in the wider Caribbean, at least 30% of the twentieth-century sea-level rise is directly attributable to human factors (Sahagian, et al., 1994). Accurate interpretation of past sea level oscillations is necessary both to calibrate and to assess GCM output as well as observations of historical climate change and forecasts of future climate change.

Other impacts of climate change include coastal erosion, land submergence, increased storm flooding and saltwater intrusion further inland. In general, drought conditions, followed by fire and entomological infestations are believed to be the most likely processes to mediate bio-geographical ecotone diversity change under a rapidly changing climate (Neilson, 1993). Moreover, tropical biodiversity and global change are topics of considerable study (e.g., Pimm and Sugden, 1994; Peters and Lovejoy, 1992) and remain important variables in the wider Caribbean region. In addition, alterations in coastal ocean upwelling intensity will effect marine living resources (Bakun, 1990). Achieving a sustainable use of these marine living resources is made difficult but not impossible under all the present stress conditions in the Caribbean basin (e.g., Rosenberg, et al., 1993).

TABLE 1. Relative Land-Level/Sea-Level Changes for Selected Wider Caribbean Locations. (Negative represents land submergence, positive means emergence)

Locality	*Emergence/Submergence mm/yr*	*Length of Tide Gauge Record (years)*
Port-Au-Prince, Haiti	-9.3	13
Puerto Cortes, Honduras	-8.9	21
Progreso, Mexico	-5.2	30
Puerto Plata, Dominican Republic	-4.4	16
Cartagena, Colombia	-3.6	21
Puerto Castilla, Honduras	-3.2	14
Key West, Florida	-2.2	20+
Riohacha, Colombia	-2.0	17
Magueyes Island, Puerto Rico	-1.9	23
Guantanamo Bay, Cuba	-1.8	31
Puerto Limon, Costa Rica	-1.6	21
Cristobal, Panama	-1.1	61
Veracruz, Mexico	-0.8	29
Port Royal, Jamaica	-0.5	16
Barahona, Dominican Republic	+2.3	11
Carmen, Mexico	+2.6	11
Alvarado, Mexico	+5.3	12

Adapted and modified from Aubrey et al., 1988; Maul, 1989; and Gable et al., 1990.

Other indicators of stresses on marine resources include the occurrence of ciguatera and red tides, both caused by toxic algae. These toxic organisms are known to cause illness and even death in humans (Anderson and White, 1992). Apparent increases in red tides and toxic algal blooms may be linked to global change (Anderson, 1989). An increase in the occurrence of ciguatera or red tide as a possible secondary effect of climate change in coastal zones and could have an economic impact especially through shellfish aquaculture and fisheries that are important in providing provisions for residents and tourists alike (Shumway, 1989).

While increased temperatures may have ramifications for biological organisms, it is the associated effects of rising sea level and possible increased storminess that are especially important to tourism activities in the Caribbean (Hendry, 1993). Recently, some unusually powerful hurricanes and an increased number of tropical storms have been felt in the region (Lawrence and Gross, 1989; Case, 1990). For the Atlantic region in 1995, there were more tropical storms than for any year since 1933, causing several billion dollars in damages in their wake (Le Comte, 1996).

Another effect accompanying climate change is the possible alteration of the magnitude and duration of storms. Storm patterns are responsive to perturbations in weather and climate in the short- and long-term. As climate warms, geographical gradients in atmospheric and oceanic temperatures will intensify. Storms (both tropical and extra-tropical) in response to ocean and atmosphere interactions may change in intensity (magnitude) and track, with some areas experiencing increased incidence of severe storms (Gray, 1993; Mayfield and Lawrence, 1996). Areas within the Caribbean are likely to be affected, as the western Atlantic Ocean on average presently accounts for between 12 to 15 percent of the yearly global total of tropical storms, including hurricanes.

Recently, several Lesser Antilles islands were wracked by Hurricane Luis. In St. Maarten, Luis caused an estimated $500 million in damage, including three of the island's major hotels being closed for the 1996 winter-spring season (Kurkjian, 1996). According to Swiss Re, a reinsurance firm, of all natural disasters the "bill" for Hurricane Andrew in 1992 (at $16 billion in claims) surpasses all other single natural catastrophes of any kind to date. For the Pacific region, El Niño/Southern Oscillation causes dramatic shifts in storms, reflected by more storms of greater intensity during part of the ENSO cycle.

PHYSICAL AND CULTURAL ATTRIBUTES

The Caribbean region is the largest concentration of small developing countries in the world; it is comprised of about 33 countries (plus additional territories) within and around the Caribbean Sea (UNIDO, 1987). The Caribbean countries display diversity of character and form, though they collectively face similar climate change and interrelated (climate change and the nearshore environmental stress) problems. Their resource base, particularly for the island entities, is limited in scale and scope, yet some of the most biologically productive and complex ecosystems found in the world exist in the Caribbean coastal zone (UNIDO, 1987; USAID, 1987).

The economic importance of coral reefs, beaches, seagrass beds, mangrove forests, and coastal estuarine ecosystems derives mostly from their linkage to other resources, especially coastal tourism and fisheries (USAID, 1987). These coastal and marine habitats contribute a large percentage of income, especially to the Greater and Lesser Antilles economies. Recent economic performance of many Caribbean countries depicts tourism, construction, and agricultural production (e.g., bananas) as the leading sectors in gross domestic product (GDP), particularly in the smaller, less-developed economies in the region (UNIDO, 1987).

Culturally, the peoples of the Caribbean are a mix of African, Asian, European, and native American. Table 2 provides socioeconomic, demographic, and environmental data concerning selected island countries and territories in the Caribbean Basin. Most of the smaller island states have economies that are based on tourism, including the distinctive micro-states of the British Virgin Islands, Cayman Islands, Anguilla, Montserrat, and the Turks and Caicos. In addition, Antigua and Barbuda, Aruba, the Bahamas, Barbados, the Netherlands Antilles, and the United States Virgin Islands (USVI) among others (including Cuba) rely heavily upon income from tourists. As a consequence, in some cases, the influx of tourists during the northern hemisphere winter season is large enough so that when averaged, tourists outnumber the year-round residents. This situation could lead to a loss of indigenous cultural identity (Bastin, 1984). Nevertheless, tourism and the needs of tourists have already led to the modification of the coastal and marine habitats and when coupled with anticipated changes in climate could present unfamiliar and costly problems.

Table 2. Selected statistics for the wider Caribbean island countries and territories.

	GDP Dollars (millions)	Population (est.)	Per Capita Income ($)	Land Area km^2	Land Area mi^2	Length of Shoreline km	Length of Shoreline miles	Forest Coverage: % Total Land Area	Forest Coverage: Avg. change 1980-1989
Anguilla	55.80	9,540	1,914	91	35	102	63	N/A	N/A
Antigua and Barbuda	422.45	67,000	6,390	442	171	153	95	22	-0.2
Aruba	1,026.31	78,900	2,786-8,625	193	74	364	226*	13	-1.9
Bahamas	3,065.10	273,000	11,500	13,942	4,400	3,542	2,201	19	-2.1
Barbados	1,462.00	264,100	6,240	431	166	97	60	23	0.0
Bonaire	N/A	11,400	6,390*	288	111	364	226*	N/A	N/A
British Virgin Islands	142.77	18,000	6,246	153	59	304	189	N/A	N/A
Cayman Islands	639.13	30,000	8,626	260	100	214	133	N/A	N/A
Cuba	N/A	10,896,000	696-2,785	114,524	44,218	3,735	2,321	16	-1.0
Curacao	1,534.08	147,000	6,390*	444	171	364	226*	N/A	N/A
Dominica	146.70	73,000	2,680	751	290	148	92	59	-0.7
Dominican Republic	9,738.72	7,157,000	1,080	48,442	18,699	1,288	800	22	-2.8
Grenada	169.44	96,500	2,410	345	133	121	75	16	4.3
Guadeloupe, St. Martin, and St. Barthelemy	N/A	405,000	2,786-8,625	1,780	687	306	190	55	-0.3
Haiti	896.84	7,041,500	695	27,713	10,700	1,771	1,101	1	-4.8
Jamaica	3,289.75	2,480,000	1,390	11,422	4,410	1,022	635	22	-7.2
Martinique	2,852.63	360,000	2,786-8,625	1,080	416	290	180	40	-0.5
Montserrat	58.19	13,000	4,030	102	39	46	29	N/A	N/A
Puerto Rico	39,264.80	3,685,000	7,020	8,897	3,435	700	435	34	0.0
St. Christopher and Nevis	152.80	42,000	4,470	262	101	135	84	37	0.2
St. Lucia	384.25	158,000	3,040	616	238	158	98	7	-5.2
St. Maarten, Saba, and St. Eustatius	N/A	35,266	6,600	68	26	364	226*	N/A	N/A
St. Vincent and the Grenadines	219.83	110,500	2,130	389	150	84	52	27	-2.1
Trinidad and Tobago	4,637.23	1,282,000	3,730	5,128	1,980	362	225	37	2.2
Turks and Caicos	78.70	13,000	1,680	430	166	546	339	N/A	N/A
U.S. Virgin Islands	1,343.90	109,000	8,626+	342	132	175	109	6	0.0

Source: Adapted and modified from: UNIDO, 1987; Gable and Aubrey, 1990; Gable, 1991; The World Bank Atlas: 1995, 1994; and the Caribbean Tourism Organization, 1995.

* Netherlands Antilles (includes Aruba, now considered independent)

NATURE OF ENVIRONMENTAL PROBLEMS

Virtually all of the independent nations bordering the Caribbean Basin are developing countries. For many Caribbean countries and territories the major source of revenue is coastal tourism. As a consequence of human economic activities (including tourism), degradation of the marine and coastal environment is being felt basin-wide (Rodriguez, 1981; Goudie, 1987; Simmons and Associates, 1994). Although problems associated with environmental degradation may be confined primarily to the coastal areas of most countries, their effects are more widespread due to patterns of water circulation, prevailing wind systems, nearshore bathymetry, and terrestrial topography. Limits to how quickly natural ecosystems can respond to the combination of climatic changes when juxtaposed upon present environmental degradation is of special concern (Gleick, 1989).

Mangroves are an important resource throughout the Caribbean because they aid in nutrient removal, control local mean water levels and flow direction, and act as sediment baffles, spawning grounds, nurseries, and feeding habitats for traditional and commercially important finfish and crustaceans. The prevalent practice of mangrove "clear cutting" and filling for land and fuel results in increased siltation and eliminates the shoreline stabilization these swampy forests provide particularly during severe storms.

Other current environmental problems, particularly in the eastern Caribbean, include the use of coral reefs as a raw material for the making of cement and aggregate (Pernetta, 1994). Dredging for the construction of engineering works such as jetties, for example, as well as other developmental works has led to the destruction of some coral reefs. Moreover, the recent discovery of mass bleachings on Caribbean coral reefs may be related to global warming trends through higher seawater temperatures (Porter, et al., 1989) and may be an early indicator of climate change (Goreau, 1990). The general decaying of most of the coral reefs in the Caribbean Basin from overfishing, pollution, sedimentation from nearshore erosion, and physical destruction, due in part to the dragging of ship anchors and plundering for souvenirs, may have reduced the capacity of coral reefs to endure temperature changes (Bunkley-Williams and Williams, 1990). The additional stress of climate change presents a new dilemma for researchers and coastal zone managers.

Additional localized problems include the use of fertilizers, pesticides, and insecticides. The runoff from these chemicals into the marine environment poses serious threats. Organotins used in paints for yachts and other vessels present a serious environmental threat to shellfish populations in coastal areas and may make their way into the food web through zooplankton and finfish posing a threat to humans (Champ and Lowenstein, 1987).

Plastic debris in the Caribbean has been a relatively recent environmental contributor to aesthetic degradation. Wilber (1987) has found oceanically-derived plastic to be a common occurrence, particularly on the beaches in the Bahamas and the Antilles. Much of the plastic present in the marine environment is likely to be deposited on sandy shores (Wilber, 1987). In addition, floating tar and oil slicks, notably the 1989 spill into Christiansted Harbor on St. Croix, fouled some Caribbean beaches and had a negative impact on tourism (Aubrey, et al., 1991).

Urbanization and industrialization are causing an increase in domestic sewage and industrial effluents, resulting in both direct and indirect impacts to adjacent marine waters (Gesamp, 1990; Simmons and Associates, 1994). Because of poor or no sewage treatment plants, high counts of fecal coliform bacteria are often found on the beaches and adjacent waters, which of course has a negative impact on tourism. The continued promotion of tourism and the construction of large hotels behind the beaches exacerbates this problem. The carrying capacity for a particular area can be exceeded by untreated wastes from these hotels which creates serious and recurring health problems. Therein lies the quandary; the undoing by tourism and the tourist industry of the environmental quality that attracted visitors to a location (Murphy, 1986). Therefore, proper planning for these facilities is critically important, particularly if development is to be sustainable (Ruchelshaus, 1989; Aubrey, et al., 1991).

The majority of Caribbean coastal lowlands and their adjacent coastlines presently experience extensive damage from erosion and inundation during storms. Most beaches exhibit signs of erosion mainly because of human activities such as the construction of jetties, groins, and breakwaters that interfere with littoral processes. In addition, the removal of sand from beaches and streams for use as aggregate has caused considerable coastal erosion (Gable and Aubrey, 1990). Because of human activities, such as draining and reclamation, many natural coastal wetlands, marshes, lagoons, and salinas have been permanently altered and adversely impacted (Vicente, et al., 1993). Add to these problems the present and potential rise in sea level, and it becomes imperative to alter policies for sustainable tourism.

Enhanced relative sea-level changes (land subsidence) caused by underground fluid extraction, salinization of ground waters, and deforestation are other basin-wide problems. Deforestation is especially problematic in the wider Caribbean islands (Hedges and Woods, 1993; Table 2). While several of these environmental problems occur to varying degrees in some countries, they may not exist in detrimental form in others. In this review, however, differentiation has not been ventured. Environmental deterioration in developing countries in general continues at an ominous rate (Gleick, 1989). Moreover, because of present environmental stresses, the addition of another in the nature of climate change is an unwelcome prospect.

CARIBBEAN PERTURBATIONS

Concern about potential climate change accelerated by human actions has spurred policy analysis and assessment of effects for various regions of the globe. Although some may question the need for policy analysis when the scientific basis for human (anthropogenic) induced climate change is so controversial, it seems prudent, however, to identify in advance sensitive locations and issues arising from such change. Through such a sensitivity analysis, available resources can be focused on those issues and areas most demanding of attention. Such focusing is particularly necessary for sovereign archipelagic states lacking adequate resources to complete comprehensive analyses of potential climate change impacts. Here, a vast and interconnected region, the wider Caribbean is examined for its sensitivity to potential climate change impacts.

The Caribbean, much like the Pacific region, is particularly susceptible to changing climate and an associated acceleration of sea-level rise because within the Caribbean lie many islands that are low in height, some less than six meters above mean sea level. Of particular importance in controlling local sea-level rise is subsidence, which includes both regional and local tectonics as well as sediment consolidation. For example, if an area is rising geologically as fast as sea level, the net effect will be no apparent local rise of sea level, whereas an area subsiding as fast as sea level is rising will appear to have twice the eustatic rise. There are many places, especially low-lying deltas, in which the rate of subsidence is as great or greater than the projected rates of sea- level rise for the next 50 plus years; in some localities excessive subsidence rates will outstrip even the most pessimistic scenarios for sea-level rise. Consequently, rising sea levels and increasingly landward-penetrating storm surges may render some islands uninhabitable. For other inhabited islands, the option to move inland to higher ground is limited. In addition, many of these archipelagoes, which contain far more coastal zone per unit of land area than do continental nations, recently became independent; most rely heavily upon coastal aesthetics and marine resources both for local consumption and revenue.

Coastal areas that are already out of equilibrium from either natural or anthropogenic disturbances, or a combination of both, can be found throughout the Caribbean Basin (Gable and Aubrey, 1989; Gable, et al., 1990), as well as in other parts of the world (Leatherman and Nicholls, 1995). Erosion modifies these shores considerably, depending upon their age, composition (volcanic, coralline, combination of both), geologic history, exposure to erosive forces (storm swell, wave runup), and anthropogenic impacts (sand mining, reef dynamiting, and dredging).

The geography, demography, and historical record provide insights into the potential environmental issues of the Caribbean Basin. Extensive riverine runoff drains both agricultural and urban sources of pollution that directly affect the nearshore environment. The deltaic coasts for many of the larger island states are particularly vulnerable to the indirect effects of global warming (e.g., sea-level rise, storms, etc.). Shipping activities support the extensive coastal commerce, making this region particularly vulnerable to marine accidents that would likely affect large areas of the coastal zone. The diverse political and economic structures of all the countries constituting the Caribbean Basin will require cooperation in order to develop the types of comprehensive scientific and technical plans, as well as the necessary international (legal) agreements and conventions, to address the regional and global environmental impacts in this area.

One noteworthy localized Caribbean coralline island is Anguilla. It provides a representative setting where impacts of projected relative sea level will have a major impact. In one recently completed study of a handful of beaches, the average erosion rate was measured at 0.3 m/yr (Cambers, 1988). While the causes of this erosion were not adequately ascertained, the increasing amounts of tourism make it a matter of immediate concern. Like most other tourism-related activities in the Antilles, these activities are centered on the coast (ECLAC, 1986). For Anguilla the number of hotel rooms over a ten-year period showed a 112% increase in capacity (Table 3). Other islands exhibited similar double to triple digit percent changes in accommodation capacity for the same time period. As yet, no specific planning guidelines or requirements have gone into force concerning the care for all coastal resources.

IMPACTS OF POTENTIAL CLIMATE CHANGES ON TOURISM

One of the fastest growing sectors of international trade, especially for small Caribbean countries and territories with limited alternative development opportunities, is tourism. Tourism in the Caribbean has been growing both in size and complexity in an attempt to satisfy both the sophisticated international travelers and the mass marketing of the region (ECLAC, 1986; Waters, 1994; CTO, 1995; Table 3).

More importantly, the link between environmental quality and tourism is evident, especially in the wider Caribbean, where the environment is the significant part of the product. The predominant product for tourism in this region is the attraction of beaches and the appealing climate (ECLAC, 1986; Gable, et al., 1990; Maul, 1993a). Moreover, while "beach tourism" has predominated in most Caribbean countries since the 1960's, the Caribbean Basin now competes worldwide for these types of tourists, with parts of the Mediterranean coast, Africa and other exotic locations such as the Maldives and Seychelles in the Indian Ocean and the archaepelagic islands of the South Pacific (ECLAC, 1986). A calculation or analysis of the recreational demand by international and domestic tourists for saltwater beach days in the islands is needed, much like what has been accomplished in Florida (See: e.g., Bell and Leeworthy, 1990). They have calculated a recreational value to just the tourist of the saltwater beach in Florida at roughly $8.8 million per acre per year. Beach nourishment projects and their costs in relation to the value of Caribbean beach recreation ought to be assessed (Edwards and Gable, 1991). Because of the global tourism market and its important contribution to the Caribbean economy, the effects of anticipated climate changes on Caribbean coastal zones should not be taken lightly.

Beach tourism itself has significant impacts on coastal zones. For example, construction of seaside hotels accentuates erosion by eliminating plant life which anchors sand dunes (ECLAC, 1986). In addition, coastal engineering works (e.g., groins and jetties) that once were envisioned as shoreline stabilizers, are now known to accelerate erosion downdrift as a result of improper planning (Walker, 1984; Walker, 1990).

Caribbean tourism with its large dependence on sandy beach front locations is especially susceptible to the consequences of a rising sea level, including inundation, erosion, increased flooding and saltwater intrusion into aquifers (Blommestein and Singh, 1987). As beaches are the prominent attraction for tourists, the loss of sandy beaches from any cause will diminish carrying capacities and ultimately tourism earnings. Several locations throughout the Caribbean are already experiencing this problem (see: Kohsiek, et al., 1987; Cambers, 1988; Gable, et al., 1990).

Table 3. Selected Caribbean islands: tourism data.

	Visitor Accommodations			Percent Change	Visitor Stayover Arrivals (Thousands)			Percent Change	Visitor Expenditures in U.S. $ (millions)			Percent Change
	1985	1990	1994	1985-1994	1985	1990	1995	1985-1995	1985	1990	1994	1985-1994
Anguilla	461	751	978	112.1	15.4	31.2	38.5	150.0	11.3	34.6	51.0	351.3
Antigua and Barbuda	1,931	2,752	3,317	71.8	156.0	205.7	191.4	22.7	132.5	298.2	394.0	197.4
Aruba	2,064	5,736	6,150	198.0	206.7	432.8	614.2	197.1	126.5	353.4	450.7	256.3
Bahamas	13,166	13,475	13,398	1.8	1368.3	1561.1	1598.1	16.8	995.0	1332.9	1332.6	33.9
Barbados	6,852	6,709	5,685	-17.0	359.1	432.1	442.1	23.1	309.0	493.5	597.6	93.4
British Virgin Islands	848	1,043	1,224	44.3	129.9	160.6	240.4 *	85.1	67.8	132.1	188.2	177.6
Cayman Islands	2,061	3,064	3,453	67.5	145.1	253.2	361.4	149.1	85.5	235.7	328.3	284.0
Cuba	N/A	12,868	23,254	80.7 *	240.5	340.3	519.4	116.0	116.4	243.4	850.0	630.2
Dominica	405	531	757	86.9	21.5	45.1	60.5	181.4	8.7	25.0	30.6	251.7
Grenada	597	1,105	1,428	139.2	52.0	82.0	108.0	107.7	32.4	37.5	59.3	83.0
Guadeloupe	3,605	5,072	7,798	116.3	216.4	288.4	475.0 *	119.5	95.0	197.1	389.3	309.8
Jamaica	12,218	16,103	19,760	61.7	571.7	840.8	1018.9	78.2	406.8	740.0	919.0	125.9
Martinique	2,914	5,802	7,220	147.8	193.5	281.5	457.2	136.3	92.8	240.0	378.9	308.3
St. Christopher and Nevis	780	1,402	1,593	104.2	46.1	75.7	95.9	108.0	31.0	57.7	76.2	145.8
St. Lucia	1,735	2,370	2,954	70.3	94.5	138.4	230.8	144.2	90.0	153.8	224.1	149.0
St. Maarten	2,300	3,400	3,710	61.3	356.5	564.7	479.6	34.5	128.5	315.5	408.2	217.7
St. Vincent & the Grenadines	987	1,058	1,215	23.1	42.1	53.9	48.5	15.2	23.0	56.0	50.5	119.6
Trinidad and Tobago	1,710	2,121	2,700	57.9	197.1	194.0	265.6	34.8	197.3	94.7	80.2	-59.4
Turks and Caicos Islands	750	1,014	1,068	42.4	29.2	41.9	77.8 *	166.4	12.2	36.5	56.5	363.1
U.S. Virgin Islands	4,784	4,520	5,461	14.2	411.5	462.5	562	36.6	507.4	704.9	918.5	81.0

Source: Adapted and modified from the Caribbean Tourism Organiazation, 1995.

*1990-1994 data.

Factors such as habitat destruction, coastal pollution and shoreline alteration when coupled with relative sea-level rise exacerbate beach loss (Blommestein and Singh, 1987). Besides the aforementioned problems with beach loss, tourism may be impaired by climatic changes through impacts on hotels and similar facilities, marinas and infrastructure for cruiseship dockings, sewage outfalls and waste disposal sites, and the alteration or loss of natural ecosystem attractions such as coral reefs (Blommestein and Singh, 1987).

Socioeconomic impacts at both the local level (microeconomic) and the national level (macroeconomic) will result from human-induced climate change (Maul, 1989; ALM, et al, 1993). Modelling of these impacts in the Caribbean has recently been attempted (Engelen, et al., 1993). With one of the major economic activities in the wider Caribbean being tourism, negative impacts upon this sector will have detrimental reverberations for the prospect of sustainable development and economic growth, and perhaps for political stability. For some time now, this sector has provided over two million jobs basin-wide and has accounted for over half the Gross National Product (GNP) for some of the smaller nations (Beekhuis, 1981).

By the mid 1980's, the tourism sector accounted for about 33% of GNP and directly or indirectly for half the employment in the Bahamas (UNIDO, 1987). In the Netherlands Antilles, tourism is the second largest sector for employment and foreign exchange earnings. For Antigua and Barbuda, tourism is directly or indirectly responsible for over 40% of GNP (the highest in the region) and employs greater than 50% of the labor force. This has resulted in the expansion of the construction industry for hotels and other tourism-associated conveniences and industries. Tourism in Barbados has contributed to GNP by about the same amount that the manufacturing sector has, which is roughly 10% over the decade of the mid-1970's to the mid-1980's (UNIDO, 1987).

In the British Virgin Islands, the tourist sector depends primarily on the charter and maintenance of yachts, contributing more than 50% of GNP while providing employment for roughly 30% of the populace. The yachting activity has an associated focus of snorkeling around coral reefs, a habitat already adversely impacted from environmental stress (Milliman, 1993). Similarly, other Caribbean micro-states rely heavily on tourism and its associated infrastructure developments (water desalination, roads, electricity, airport improvement and waste treatment). For example in the Cayman Islands, hotel accommodations have recently increased by 67% (CTO, 1995). In Montserrat, the economy is primarily dominated by tourism and related activities in real estate and construction.

CUMULATIVE IMPACTS

The variable effects of global climate change, coupled with present environmental stresses from human activities upon landscapes (ecosystems) mentioned above, illustrate the need for a proactive and less reactive cumulative impact assessment (Cocklin, et al., 1992). Further, Cocklin, et al. (1992) stress the need that these cumulative environmental impact assessments be performed on a regional approach as opposed to project-based assessments. For our purposes, this means that island-wide assessments and/or even basin-wide evaluations are necessary to illustrate proper accountable cumulative links of individual tourism development projects and environmental quality problems, among others. Moreover, the greenhouse effect, believed a triggering mechanism, is considered to provide disruptions to ecological processes that can change system behavior in the region (Cocklin, et al., 1992).

An attempt to evaluate the exposure, response, risk and vulnerability of cultural, economic, social, biological, and physiographical implications of global change and their local, basin-wide, regional and inter-regional manifestations can be described as a cumulative impact assessment (Bedford and Preston, 1988; Kotlyakov, et al., 1988). Cumulative impacts can be defined further as the impact on the local, regional or global environment which is a consequence of the incremental impact of the action (e.g., climate change). The cumulative effects of environmental variability (including climate change) on many scales, determines the mean state of an ecosystem (McGowan, 1990). Minor but collectively significant actions taking place over a period of time can result in cumulative impacts (Preston and Bedford, 1988). In addition, while greenhouse gases normally occur in unification, synergistic effects of interacting combinations superimposed upon direct effects are also important (Parsons, 1990). A paradigm of the cumulative impacts describing interactions of anthropogenic forcings upon regional coastal landscapes was attempted for part of the western Indian Ocean (Gable, et al., 1991). A similar example extrapolated for the Caribbean Basin ought to include an assessment of both anthropogenic land use and hydrological practices modified by global climate change perturbations. The consequent cumulative effects will probably have pronounced combined impacts upon the coastal landscapes (e.g., coral reefs and beaches) as well as upon the human socioeconomic environment (e.g., commerce and tourism) that utilize those habitats.

While further study (particularly through case examples) is necessary for analysis of climate changes and their direct and indirect cumulative effects on Caribbean coastal and marine tourism, governments have some management and policy options to consider. Blommestein and Singh (1987) offered these policy options:

- promoting alternative styles of tourism, thus reducing the primary dependence of Caribbean tourism on the beaches
- restoring beaches (sand replenishment)
- protecting and providing shoreline space for diverse ecobiomes such as mangroves, lagoons, coral reefs, seagrass beds, shrub vegetation
- promoting changes in insurance legislation wherein requiring building setback lines to be promulgated and properly placed depending on terrain and marine conditions
- employing climate change scenarios (e.g., sea-level rise) in the design of structures and engineering drawings
- leaving high risk areas fallow.

Other ways to address the human and scientific aspects of global environmental change when coupled with present environmental stress can be considered. The adoption of comprehensive coastal zone management/planning schemes is one noteworthy example, especially in how one attempts to manage changes from sea-level rise (Pernetta and Elder, 1992). A few of these planning texts have been implemented in the wider Caribbean (Gable, 1987; Sorensen and

Brandani, 1987; Maul, 1993b); however, they were promulgated because of crises that existed. Planning texts that foresee problems for a given locale and then providing mechanisms for mitigation specifically for those distressed areas would be a better approach (Sorensen, 1993). Because of the ramifications of potential climate change, environmental impact assessments should be performed when site analysis for tourism facilities are being planned, modified, or modernized.

Based on knowledge of local response to the direct and indirect changes in climate along with the best available scientific findings on the magnitude and timing of human-altered climatic conditions, appropriate decisions can be arrived at concerning policy implementation. Though the uncertainties concerning the human-altered global climate change do not warrant draconian developmental and environmental regulations, global climate change demands increased consideration as part of the matrix of both environmental and economic issues (Gable and Aubrey, 1990).

CONCLUSIONS AND RECOMMENDATIONS

The impacts of contemporary climate change and the ancillary effect of sea level rise may affect the lives of many citizens throughout the Caribbean Basin, which is now viewed as one large ecosystem especially as it relates to marine resources management (Alexander, 1993). These effects may include ecological (e.g., decreased biological productivity), economic, environmental and social parameters and also may have ramifications on jurisdictional boundaries, for example, exclusive economic zones of up to 200 nautical miles and public health considerations (Maul, 1993a).

While it is convenient to separate and categorize the impacts from these activities individually, all categories of stress, be they local, regional and/or global, will be operating simultaneously on the same ecosystem components (e.g. coral reefs, coastal fisheries, mangroves, beaches, etc.). Because the interaction of these stresses often covers a large area and crosses political jurisdictions, they represent regional and basin-scale risks (Ayres, 1992). It is imperative, therefore, to follow through to develop and/or enhance local, national, and international programs and policies to address these and similar environmental issues. Such a program ought to among others:

- Determine the scale and scope of existing (marine) pollution or problems (e.g., Jickells, et al., 1990)
- Understand the human dimensions of global environmental change (NRC, 1992; Stern, 1993)
- Identify the critical marine habitats/ecosystems or their components at risk (e.g., Gable, 1993)
- Ensure that data and information produced as a result of global change research and assessment activities is in a form that can be readily used by policymakers (Viles, 1989)

- Assess how much risk is acceptable (including a vulnerability analysis; e.g., Leatherman, et al., 1995; Nicholls and Leatherman, 1995)

- Establish concepts and methods of wider Caribbean coastal zone economics and the management of enclosed bays and lagoons (Edwards, 1987; Sorensen, et al., 1993)

- Construct necessary legislative and regulatory statutes for monitoring and controlling pollution activities

- Establish an institutional and financial framework to support a plan of action that is amenable and agreed upon by all countries for reducing or mitigating the environmental stress on this vast regional sea (e.g., Ahuja, 1993)

- Commence environmental auditing for tourism specifically wherein a documented, objective periodic, and systematic evaluation will be performed with the aim designed to protect the environment (Goodall, 1995). This would help ensure or safeguard that tourism activities and operations are as environmentally-compatible as possible

- Work with UNEP, the World Bank, Interamerican Development Bank, and with academic, state, industry, and other groups conducting research and assessments of global change and its effects, in order to provide for periodic public and peer review of the program.

The UNEP Regional Seas Programme in Kingston, Jamaica ought to coordinate a continuous multi-decade, basin-wide program that would incorporate the above mentioned issues as well as acting as a liaison with interested donor agencies (e.g., World Bank) and scientific organizations and researchers.

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