Mangrove Forests: One of the World's Threatened Major Tropical Environments

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The mass media and scientific press have widely reported losses of tropical environments, such as felling of rain forests and bleaching of coral reefs. This well-merited attention has created a worldwide constituency that supports conservation and restoration efforts in both of these threatened ecosystems. The remarkable degree of public awareness and support has been manifested in benefit rock concerts at Carnegie Hall and in the designation of ice cream flavors after rain forest products. Mangrove forests are another important tropical environment, but these have received much less publicity. Concern about the magnitude of losses of mangrove forests has been voiced mainly in the specialized literature (Saenger et al. 1983, Spalding et al. 1997).

AT LEAST 35% OF THE AREA OF MANGROVE FORESTS HAS BEEN LOST IN THE PAST TWO DECADES, LOSSES THAT EXCEED THOSE FOR TROPICAL RAIN FORESTS AND CORAL REEFS, TWO OTHER WELL-KNOWN THREATENED ENVIRONMENTS

Mangrove trees grow ubiquitously as a relatively narrow fringe between land and sea, between latitudes 25°N and 30°S. They form forests of salt-tolerant species, with complex food webs and ecosystem dynamics (Macnae 1968, Lugo and Snedaker 1974, Tomlinson 1986).

Destruction of mangrove forests is occurring globally. Global changes such as an increased sea level may affect mangroves (Ellison 1993, Field 1995), although accretion rates in mangrove forests may be large enough to compensate for the present-day rise in sea level (Field 1995). More important, it is human alterations created by conversion of mangroves to mariculture, agriculture, and urbanization, as well as forestry uses and the effects of warfare, that have led to the remarkable recent losses of mangrove habitats (Saenger et al. 1983, Fortes 1988, Marshall 1994, Primavera 1995, Twilley 1998).

New data on the magnitude of mangrove area and changes in it have become more readily available, especially with the advent of satellite imagery and the Internet. Moreover, information about the function of mangrove swamps, their importance in the sustainability of the coastal zone, and the effects of human uses of mangrove forests is growing. Some published regional assessments have viewed anthropogenic threats to mangrove forests with alarm (Ong 1982, Fortes 1988, Ellison and Farnsworth 1996), but reviews at the global scale are dated (Linden and Jernelov 1980, Saenger et al. 1983).

We collated and revised published information to review the status of mangrove swamps worldwide. To assess the status of this major coastal environment, we compiled and examined available data to quantify the extent of mangrove forest areas in different parts of the world, the losses of mangrove forest area recorded during recent decades, and the relative contributions by various human activities to these losses.

We first assessed current mangrove forest area in tropical countries of the world. It is difficult to judge the quality of these data in the published literature, because in many cases the methods used to obtain them were insufficiently described and the associated uncertainty was not indicated. Much information based on satellite imagery is summarized in the *World Mangrove Atlas* (Spalding et al. 1997). We compared and

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Table 1. Mangrove areas in all the countries for which multiyear data are available.

Country	Early estimate		Late estimate	
	Year	Area (km^2)	Year	Area (km^2)
Americas				
Anguilla	1980	1.0[1]	1990	0.3[1]
Antigua-Barbuda	1980	9.0[1]	1990	1.5[1]
Bahamas	1980	3086[1]	1990	1419[1]
Belize	1980	730[1]	1990	783[1]
Brazil	1983	25,000[2]	1997	13,400[3]
Cayman Islands	1980	114[1]	1990	72[1]
Colombia	1983	4400[2]	1993	3580[4]
Cuba	1980	4000[1]	1990	5297[1]
Ecuador	1979	2037[5]	1991	1620[5]
El Salvador	1983	450[2]	1994	268[6]
Grenada	1980	2[1]	1990	1.5[1]
Guadaloupe	1980	80[1]	1990	31[1]
Guatemala	1983	500[2]	1997	161[7]
Honduras	1982	288[8]	1992	239[8]
Jamaica	1980	70[1]	1990	106[1]
Mexico	1983	6600[2]	1992	5246[9]
Panama	1983	4860[2]	1988	1679[10]
Peru	1980	280[2]	1997	51[3]
St. Kitts/Nevis	1980	0.5[1]	1990	0.2[1]
St. Lucia	1980	3.0[1]	1990	1.8[1]
St. Vincent	1980	1.0[1]	1990	0.6[1]
Turks and Caicos	1990	236[1]	1997	111[3]
United States	1958	2749[11]	1982	1900[12]
Venezuela	1983	6736[2]	1993	2500[13]
US Virgin Islands	1980	9.4[1]	1990	3.1[1]
Africa				
Benin	1983	30[2]	1997	17[3]
Cameroon	1983	2720[2]	1997	2494[3]
Guinea	1983	2600[2]	1999	2963[14]
Guinea-Bissau	1953	4760[15]	1995	2484[15]
Liberia	1983	400[2]	1995	190[14]
Madagascar	1921	4000[16]	1997	3403[14]
Senegal and Gambia	1982	5000[2]	1995	2352[14]
Sierra Leone	1979	2337[17]	1995	1000[18]
Asia and Australia				
Australia	1983	11,617[2]	1990	10,000[19]
Brunei Darussalam	1983	70[2]	1997	171[3]
Bangladesh	1980	6400[20]	1997	5767[3]
China and Taiwan	1980	670[2]	1995	178[21]
India	1963	6820[22]	1992	3565[23]
Malaysia	1980	7300[3]	1990	6424[3]
Myanmar	1965	5171[2]	1994	3786[24]
Pakistan	1983	2495[2]	1997	1683[3]
Philippines	1920	4500[25]	1990	1325[25]
Singapore	1983	18[2]	1990	6[26]
Thailand	1961	3724[27]	1993	1687[27]
Vietnam	1945	4000[28]	1995	1520[28]
Yemen	1980	40[29]	1997	81[3]

(1) Ellison and Farnsworth 1996; (2) Saenger et al. 1993; (3) Spalding et al. 1997; (4) Alvarez-Leon 1993; (5) Parks and Bonifaz 1994; (6) Funes 1994; (7) Jimenez 1993; (8) Stonich et al. 1999; (9) Yañez-Arancibia et al. 1993; (10) D'Croz 1993; (11) Lugo and Snedaker 1974; (12) Odum et al. 1982; (13) Conde and Alarcon 1993; (14) Saenger and Bellan 1995; (15) Simao 1993; (16) Marguerite 1993; (17) Johnson and Johnson 1993; (18) Diop 1993; (19) Robertson and Duke 1990; (20) Linden and Jernelov 1980; (21) Li and Lee 1997; (22) Sidhu 1963; (23) Azariah et al. 1992; (24) Htay 1994; (25) Primavera 1995; (26) Chou 1990; (27) Menesveta 1997; (28) Turner et al. 1998; (29) Sheppard et al. 1992.

supplemented data from the atlas with data from local or regional publications, where available, to update estimates of the area covered by mangrove forests for as many countries as possible.

We then estimated long-term changes in mangrove habitat areas by compiling information on time courses of areas of mangrove forests. These data too were compiled for as many countries as published sources allowed. Few papers reported multiyear data; most of our compilation consists of data for a given country, published in different years (Table 1).

To examine linkages between human activities and losses of mangrove habitats, we compared overall economic activity by compiling data on per capita gross national product (GNP; data from the Central Intelligence Agency's *World Factbook* are available at Web site *www.cia.gov*). We also compared loss of mangrove habitat with absolute coastal population density (calculated as the length of coastline per country and estimating that 37% of the population lives within 100 km of the shore [Cohen et al. 1997]). Then, to identify the relative contribution of specific human activities responsible for losses of mangroves, we compiled published data on areas of mangrove that were lost or converted to other land covers through diverse human uses.

Area of current mangrove forest

We estimate, from our compilation of the most recent data for all countries where mangroves have been reported, that there are roughly 1.7 x 10^5 km^2 of mangrove habitats along the shorelines of the world (Table 2). Our estimate of total mangrove area is similar to previous calculations of total mangrove area, 1.7 x 10^5 km^2 (Saenger et al. 1983), and 1.8 x 10^5 km^2 (Spalding et al. 1997). These compilations are based on near-complete coverage of current mangrove areas in countries

Table 2. Current area of mangrove forests, total known losses, and percentage loss compared with initial value of acreage for Asia, Africa, Australia, and the Americas, as well as totals for the world.

Region	Present mangrove area (km^2)	Area of mangroves for countries with available multiyear data: Present area (km^2)	Original area (km^2)	Percentage of total present mangrove area represented in loss estimates	Percentage loss of mangrove forest area	Annual rate of loss (km^2 y^{-1})[1]	Percentage of original area lost per year
Asia	77,169	26,193	41,208	34	36	628	1.52
Africa	36,259	14,903	21,847	41	32	274	1.25
Australia	10,287	10,000	11,617	97	14	231	1.99
Americas	43,161	38,472	62,242	89	38	2251	3.62
World total	166,876	89,568	136,914	54	35	2834	2.07

Source: Data are compiled from the references in Table 1.

1. Annual loss rates are calculated from the mean number of years between original area and present area for each region: 24, 25, 7, 11, and 17 years for Asia, Africa, Australia, the Americas, and the world, respectively.

around the world, but they include data collected across widely different times (1980s to present) through different methods, and there is large uncertainty in most of the numbers (Spalding et al. 1997). Even when the methods include modern remote sensing, uncertainty in remotely sensed data is greater for mangrove forests than terrestrial forests, because the translation of imagery to area is difficult in land parcels with the elongated linear shapes of mangrove forests (Muchoney et al. 2000).

To gain a notion of the uncertainty in estimates of mangrove area, for each country we compared two estimates from Spalding and colleagues (1997), who include both their estimate from vegetation maps and remote sensing and a recent estimate drawn from the literature. From these presumably independent estimates, we calculated that the mean difference between independent estimates of mangrove area per country was 36%; estimates of area are therefore relatively uncertain when considered for each country. We also calculated that, for the entire data set, the mean differences had an associated coefficient of variation of only 2.5%. This low value suggested that aggregating the data would yield more reliable results. For this calculation, we aggregated the country data on the basis of continents.

By far the largest proportions of mangroves occur in Asia and the Americas (Table 2). Countries with the largest area of mangroves are Indonesia (4.25×10^4 km^2; Spalding et al. 1997), followed by Brazil (1.34×10^4 km^2; Spalding et al. 1997), Nigeria (1.05×10^4 km^2; Saenger and Bellan 1995), and Australia (1.00×10^4 km^2; Robertson and Duke 1990).

Rates of mangrove forest loss

Mangrove acreage decreased during recent decades in most countries for which we found multiyear data in the literature (Figure 1). The rates of decline differ from country to country (Table 1), but the striking feature in Figure 1 is the dominant pattern of reduced acreage for nearly all countries, particularly those with large mangrove forest areas.

To evaluate losses of mangrove acreage within each continent, we pooled the country data from those countries with plausible multiyear records (Figure 1) and calculated losses per continent. We excluded data from some countries, however, because reported changes in area could reflect actual changes in area stemming from the combined effects of destruction, restoration efforts, and natural expansion of mangrove forests, as well as apparent increases derived from the improved quality of surveys. In practice, rates of increase from restoration and natural re-growth are slow (Roth 1992, Sherman et al. 2000), so that significant short-term (a few years) increases were most likely due to survey improvements. We did include data from Belize, Brunei, Cuba, Jamaica, Sierra Leone, and Yemen, where there were modest multiyear increases in area of mangroves (Table 1, Figure 1). In Cuba, for instance, there was a reported 257 km^2 of planted mangroves (Spalding et al. 1997); this does not match the increases in Figure 1, but it shows that some increases were real rather than a result of better surveys.

To determine the change in mangrove area for each country with good multiyear data, we calculated the difference between the current and the "original" area of mangroves (by "original" we mean the earliest recorded area of mangrove forests in the literature). We then compiled the results by continent (Table 2). To obtain rates of change, we divided the change in area by the number of years spanned by the records. The span of years varied. For example, we found data for the Philippines and Madagascar beginning in the 1920s; for Vietnam, 1945; and for Thailand and India, 1965; the bulk of the data, however, were from the late 1970s to the early 1980s (Figure 1).

For all continents, present-day mangrove forest area is substantially smaller than the original area, with a world average loss of 35% (Table 2). On a worldwide scale, just under

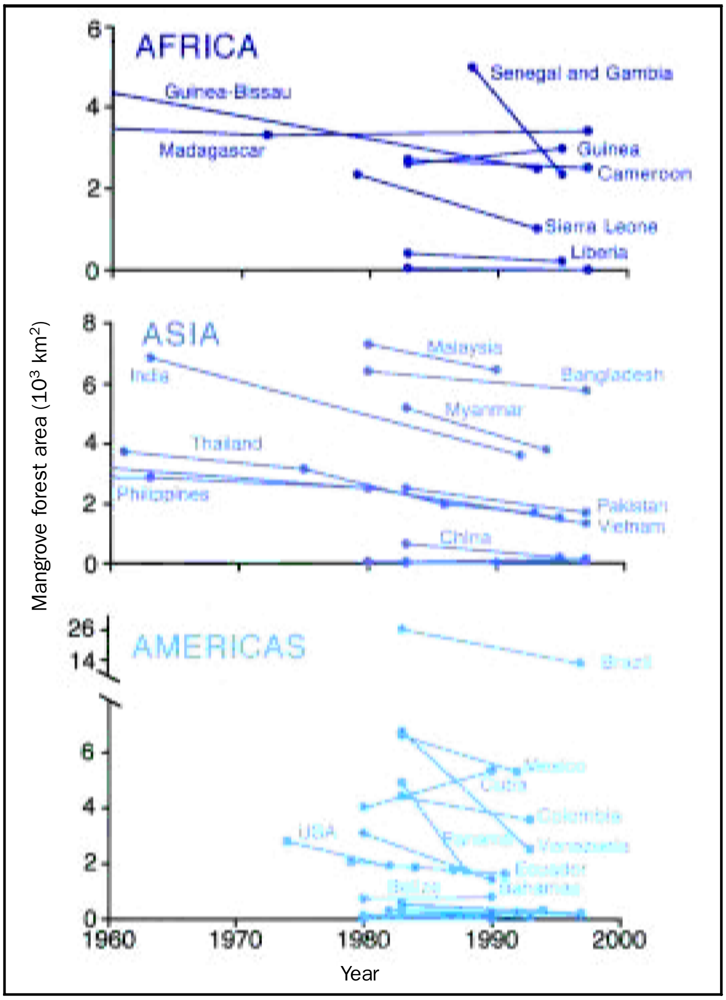

Figure 1. Change in area of mangrove forest for countries in Africa, Asia, and the Americas (data sources are listed in Table 1). Data from Angola, Cambodia, Dominican Republic, Fiji, French Guyana, Gabon, Indonesia, Iran, Nicaragua, and Papua New Guinea were not used because there were unrealistic changes in mangrove area across only a few years. Such large changes in short time periods must result from different mapping techniques rather than from real areal changes. Data from Guinea Bissau (4760 km² in 1953), Madagascar (4000 km² in 1921), Philippines (5000 km² in 1920), and Vietnam (4000 km² in 1945) extend to the left of the y-axis. Unlabeled countries have less than 500 km², and include Benin in Africa, Brunei, Singapore, and Yemen in Asia, and Anguilla, Antigua-Barbuda, Cayman Islands, El Salvador, Grenada, Guadaloupe, Guatemala, Honduras, Jamaica, Peru, St. Kitts, St. Lucia, St. Vincent, and Turks and Caicos in the Americas. All other countries with mangroves had insufficient data to calculate a time course.

3×10^3 km² of mangroves have been lost each year since the early 1980s, which translates into an overall areal loss rate of 2.1% per year. On a continental basis, losses can be larger, as in the Americas, for example (Table 2). Published regional-scale surveys confirm high loss rates. For example, mangrove loss rates in Southeast Asia have been greater than 1% per year (Ong 1982). It is therefore evident that both the magnitude of mangrove loss and annual loss rates are considerable.

The estimates of losses of mangrove area shown in Table 2 are based on information from countries that in aggregate hold 54% of the world's mangrove acreage (Table 2). We can surmise that the remaining 46% of the world's mangroves are exposed to similar losses. Two countries with large areas of mangrove were not included in our calculations. We found no plausible multiyear record of mangrove areas for Indonesia (26% of the world total), where losses in some regions are said to reach 50% to 80% (Wolanski et al. 2000). Estimates of Nigerian mangrove areas (6.3% of the world total) from the 1980s to 1997 exist (Saenger et al. 1983, Adegbehin and Nwaigbo 1990, Diop 1993, Saenger and Bellan 1995), but differences in the estimates make it difficult to find a convincing time course. Research and surveys to assess destruction of Indonesian and Nigerian mangroves should be a priority. We expect that, given the many published citations of damage in parts of the world for which we could find no documented losses, the reductions in total mangrove areas that we report are underestimates.

Do losses of mangrove forests matter? Mangrove ecosystems support essential ecological functions, so significant losses of mangrove forests will have important consequences. Mangrove forests intercept land-derived nutrients, pollutants, and suspended matter before these contaminants reach deeper water (Marshall 1994, Rivera-Monroy and Twilley 1996, Tam and Wong 1999), and they export materials that support near-shore food webs, including shrimp and prawns (Rodelli et al. 1984, Twilley 1988, Sasekumar et al. 1992). These natural subsidies are provided in addition to various extractive benefits, including wood, lumber, honey, tannins, mariculture crops, salt, and so on (Saenger et al. 1983, Spalding et al. 1997).

Because mangroves are strategically located between land and sea and are biogeochemically important, the effects of losses of their area are magnified. Nutrient transport from land to estuaries is the principal agent of ecological change in many coastal areas (GESAMP 1990, Goldberg 1995); land-derived nutrients thus have to traverse fringing coastal wetlands—including mangrove forests—on their way to receiving estuaries. In fact, nutrient processing down-estuary from mariculture facilities might mitigate eutrophication caused by effluent from the mariculture ponds (Wolanski et al. 2000). Burial and denitrification within mangrove forests significantly lower the export of terrigenous nutrients to the estuaries (Rivera-Monroy et al. 1995, Robertson and Phillips 1995, Rivera-Monroy and Twilley 1996). This fortuitous location means that the role of mangrove forests is far more important biogeochemically than their relatively small area (compared with terrestrial tropical forests, for example) might suggest.

Mangroves also perform other important services, such as preventing coastal erosion by stabilizing sediments (Marshall 1994, Tam and Wong 1999), furnishing nursery and spawning areas for commercially important coastal fish and shellfish species (Rodelli et al. 1984, Sasekumar et al. 1992), and providing stopover sites for migratory birds, fish, and mammals (Saenger et al. 1983). Mangrove forests are also habitats for a diversity of species that have considerable importance, both economically and ecologically. The fauna of mangroves includes fish and shellfish taxa that support subsistence fishing, as well as rare endemic proboscis monkeys in Borneo, scarlet ibis, the vulnerable straight-billed woodcreeper in Trinidad, threatened Bengal tigers in India and Bangladesh, rare *Bulbophyllum* and other orchids in Singapore, endangered manatees in Florida, and many other key species (Saenger et al. 1983). Any loss of mangrove forest therefore means a loss of important subsidies to subsistence uses and ecological, economic, and conservation functions.

Mangrove habitat losses relative to human activity

To identify the general anthropogenic effects on mangrove losses, we first stratified the loss data into countries with losses (filled circles in Figure 2) and countries with no losses or with gains (open circles in Figure 2). In countries with reductions in area of mangrove forests, the percentage loss of mangrove forests increased as per capita GNP increased (Figure 2a). The scatter of the data was considerable, so the relationship, although significant, is not particularly predictive (Prairie 1996). This scatter may be attributable in part to foreign rather than national investment, reflecting substantial international monetary subsidies in industrial-level maricultural and wood-chip exploitation (Wolanski et al. 2000). There was no evident relationship between human population density and percentage change in mangrove area (Figure 2b). We conclude that the relative wealth of a country, more than the concentration of humans, may establish the potential for loss of this coastal environment, but this effect may be broadly altered by foreign financial involvement.

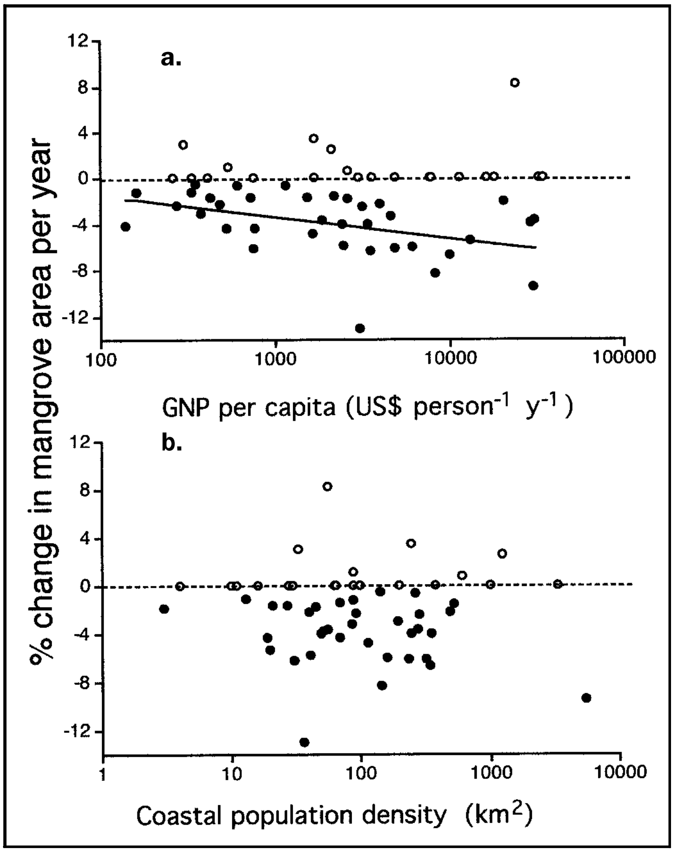

Figure 2. Annual percentage change in mangrove area for each country, as a function of the per capita GNP (a) and the coastal population density (b).

Many specific human activities at various levels (subsistence, artisanal, and industrial) reduce the area of mangroves (Wolanski et al. 2000). Humans harvest fish, crabs, shellfish, reptile skins, and honey at subsistence and artisanal levels from most of the world's mangroves (Nurkin 1994). People also harvest forest products for local consumption of wood, charcoal, and tannins; at industrial levels, they harvest wood chips and lumber (Ong 1982). They cut and fill mangroves for agricultural, industrial, and urban development (Linden and Jernelov 1980); they convert mangroves to salt flats for salt production, and to shallow diked ponds for maricultural purposes (Nurkin 1994, Primavera 1995). In addition, other activities on land diminish the area of mangroves, including interception of freshwater in Bangladesh, Thailand, and Taiwan and wartime use of herbicides in Vietnam and "mangrove control" in Africa (Linden and Jernelov 1980).

As Table 3 shows, mariculture plays a major role in the reduction of mangrove forest area. Shrimp culture is, by a considerable margin, the greatest cause of mangrove loss; including losses attributable to fish culture, maricultural endeavors are responsible for more than half (52%) of the losses of mangroves.

Although fish culture is ancient, with records of tambak fish culture in Java and bangos culture in the Philippines going back to 1400 (Herre and Mendoza 1929), the practice has proliferated recently, supported by national and international subsidies (Wolanski et al. 2000). Diverse forest uses (mainly industrial-level lumber and wood-chip production, with minor effects from artisanal making of charcoal and extraction of tannin) also lead to significant losses of mangroves (Table 3). Other activities, such as salt production, cause losses of lesser magnitude, but these are nonetheless important locally.

We estimated the mangrove loss due to mariculture by compiling data on the areas of maricultural ponds reported in each country (Jory 1997, Primavera 1995). We assumed that the entire area of the ponds was built on land previously occupied by mangroves. Therefore, if ponds were built on upland areas, our assumption would overestimate mangrove losses. However, for intensive maricultural practices, it is important to be as close to water as possible because flushing is important to maintain high water quality (Primavera 1991). Moreover, dry land can be used for agriculture and is thus considered more valuable than mangroves.

In addition, the area of mariculture ponds is most likely underreported, and the industry is growing quickly. For example, the percentage of commercial shrimp yield that was farm raised increased from 3% to almost 30% between 1981 and 1995 (Lucien-Brun 1997). Our estimates, based largely on data reported in the mid-1990s, almost certainly underestimate the area of coastal habitat converted to mariculture. Because of these considerations, and lacking any more concrete data, we simply assumed that culture ponds were built on mangrove habitats.

The sum of losses from all the various human activities, across all continents, reached 36 x 10^3 km^2 (Table 3). This sum was obtained from data from countries that hold 66% of the area of mangrove forests. The prorated, aggregate loss from various human uses amounts to 64% of the total loss of mangrove forest area that we report (Table 2, the difference between the original 136,914 km^2 and the present 89,568 km^2). Losses estimated by summing areas altered by specific activities (Table 3) were smaller than total world mangrove loss (Table 2) because losses have increased in many countries in recent years, and, unfortunately, the data on uses tend to be older than the data on total area. The 64% accounted for by summing the effects of various activities, however, seems to be a sufficiently large portion of losses of mangrove forests to warrant evaluating the relative importance of the various human activities.

The importance of mariculture for mangrove habitat losses

It is apparent that maricultural practices are responsible for the bulk of the increasing losses of mangrove swamps worldwide. This mirrors, at a larger, global scale, what has been said for specific sites. For example, pond culture has been reported to be responsible for 50% of the loss of mangrove environments in the Philippines (Primavera 1991), and 50%–80% in Southeast Asia (Wolanski et al. 2000). Most of the damage is attributable to the direct loss of habitat from conversion of “cheap” mangrove land to valuable shrimp, prawn, and fish ponds (Figure 3).

Intensive mariculture has many other, indirect ecological effects. Shrimp culture demands supplies of juveniles, a demand that has decimated natural stocks (Sasekumar et al. 1992, DeWalt et al. 1996). Intensive shrimp farming demands intensive use of fish meal as shrimp food, which puts pressure on offshore stocks (Primavera 1991). Because the conversion of food to shrimp is incomplete, considerable amounts of organic matter and nutrients pass through the ponds, and the effluent may cause or exacerbate the eutrophication of downstream estuaries and mangrove forests (Wolanski et al. 2000). There is too little substantive information on the intensity or extensiveness of these critical effects, but flow rates and concentrations in the effluents suggest that there must be significant impacts.

The problems associated with maricultural practices in ponds established in areas previously occupied by mangroves are exacerbated by the short life span of such ponds. Attendant problems of eutrophication, accumulation of toxins, sulfide-related acidification, and crop diseases limit use of a pond to a 5–10-year span, after which growers move on to a new area of mangrove (DeSilva 1998, Wolanski et al. 2000). This shifting cultivation pattern accelerates loss of mangrove environments, because the rate of recovery from spent ponds to mangrove forests is much slower than the rate of habitat loss (Primavera 1991). Fuller assessment of the combined effects of direct losses of habitat and the potentially major consequences of indirect effects of maricultural practices should therefore be a high priority for understanding what is taking place in one of the world’s major coastal habitats.

Table 3. Human use of mangrove area leading to loss of habitat, by continent.

	Area affected by each activity (10^3 km^2)					
Activity	Asia	Americas	Africa	Australia	World total	Percentage of total[1]
Shrimp culture	12	2.3	–	0.005	14	38
Forest use	4.6	4.9	–	–	9.5	26
Fish culture	4.9	–	–	–	4.9	14
Diversion of freshwater	4.0	–	0.09	–	4.1	11
Land reclamation	1.9	–	–	–	1.9	5
Herbicides	1.0	–	–	–	1	3
Agriculture	0.8	–	–	–	0.8	1
Salt ponds	0.02	–	0.03	–	0.05	–
Coastal development	0.05	–	–	–	0.05	–
Total area	29	7	0.12	0.005	36	
Percentage of mangrove area represented	85	75	2	100	66	

Source: Data from Linden and Jernelov 1980, Saenger et al. 1983, Ong 1995, Fortes 1988, Jory 1997, Stonich et al. 1999.

1. Does not total 100% because of rounding.

Figure 3. Oblique aerial view of a mangrove forest in Borneo, showing dikes and enclosed shrimp ponds carved out of the mangrove habitat. Photo: Frans Lanting, Minden Pictures.

Comparisons with other tropical environments

Losses of terrestrial tropical forests have justifiably received much attention recently. By the end of the 20th century, human activities converted up to 30% of the original pristine acreage of terrestrial tropical forests to other land covers (Houghton 1995). Estimates by the Food and Agriculture Organization of the United Nations (FAO 1997) suggest that 1.54×10^7 ha y^{-1} of terrestrial tropical forest were lost during the 1980s, and 1.37×10^7 ha y^{-1} during 1990–1995. These losses translate into an annual loss of 0.8% of the area of terrestrial tropical forests. Losses of coral reefs have also received considerable press and scientific attention. Best estimates are that about 10% of the world's coral reefs have been lost and perhaps up to 30% will be degraded in 10–20 years (Wilkinson 1992).

For comparison, the world's area of mangrove forests has been reduced by about 35% on a worldwide scale since the 1980s, and 2.1% of the existing worldwide mangrove area is lost each year. The rate is as high as 3.6% in the Americas (Table 2). Such losses of mangrove forests are alarming rates of loss of a major coastal environment.

These comparisons speak to the enormous pressures being exerted on tropical environments by anthropogenic processes. The losses of rain forests and reefs are, rightly, widely acknowledged, and a measure of concern and response to the changes has been manifested. The information compiled here supports the alarm felt by those in the research and management communities with firsthand knowledge of what is happening in the boundary between land and sea, where mangroves grow. Although mangrove forests, especially in the Americas and Asia, are among the most threatened major environments on earth, this major transformation in the coastal tropics has received scant public or political recognition. Comprehensive research aimed at assessing the status of mangroves in many countries must be undertaken, as must restoration or conservation efforts that impel public and political notice of the dimensions of the problem. Although the data reviewed in this article are in many ways incomplete, they do demonstrate the significant global losses of mangrove forests and suggest the need for conservation of this valuable coastal environment.

Acknowledgments

Resources from the National Center for Environmental Assessment Office of the US Environmental Protection Agency, and from the National Oceanographic and Atmospheric Administration's Sea Grant Program at the Woods Hole Oceanographic Institution, were helpful in the preparation of this article. We acknowledge the assistance of S. Brunelle, J. Champagne, E. Koenig, L. McInerney, C. Watkins, and D. Weisbaum, students in the 1999 Marine Pollution course at the Boston University Marine Program, who first started collecting the information reported here. We thank Robert Twilley and two anonymous referees for useful critiques of an earlier version of the manuscript.

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