

Tree Mortality in Mangrove Forests¹

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ABSTRACT

Twenty-eight worldwide reports of massive mangrove tree mortalities are reviewed. Massive mortality is defined as tree mortalities that occur in response to rapid environmental change and affect all size classes. Massive mortality occurs in addition to normal tree mortality. Normal tree mortality was described using structural data from 114 mangrove stands. This mortality is density dependent, follows orderly time dependent patterns dictated by stand maturation (related to average tree diameter), and usually occurs in the smaller diameter size classes. Disease and other biotic factors do not appear to be primary causes of massive mangrove mortalities. Instead, these factors appear to attack forests weakened by changes in the physical environment. Mangrove environments are dynamic and cyclical and mangrove associations adapt to such environments by both growing and dying fast. Mangrove species' characteristics such as the capacity to produce large quantities of propagules that take advantage of dispersal agents, sharp species zonation, and even-aged populations contribute to the rapid growth-mortality cycles in mangroves. Humans may tilt the balance towards higher mortality rates by introducing chronic stressors that inhibit regeneration mechanisms.

MANGROVE FORESTS ARE DYNAMIC ECOSYSTEMS. Factors such as sedimentation rates, soil subsidence, freshwater run-off, tidal forces, and changes in sea level influence mangrove growth and survival. In response, mangrove species arrange themselves in zones that reflect geomorphologic and hydrologic gradients (Lugo 1980). Consequently, significant changes in environmental conditions are generally followed by alterations in the vigor or zonation of vegetation. These alterations may include widespread tree mortality.

Natural tree mortalities in mangrove ecosystems have been reported by many authors (Table 1) but very little has been done to synthesize this information or seek causal forces. The need to understand mortality in mangroves is highlighted by the claim that in the 60,000 ha of mangrove forest in the Gambia River, 50–75 percent of the *Rhizophora* forest will die in three to five years due to an epidemic gall disease (Teas and McEwan 1982). The ecological magnitude of this "epidemic," its economic implications (an estimated 40 million dollars in timber loss) and the possible consequences to the management of the Gambian or other similar mangrove ecosystems call for a careful analysis of this subject. Mangroves are critical coastal ecosystems because they provide many services that are of direct benefit to humans and coastal and estuarine organisms (Lugo and Snedaker 1974). The

proper management of mangrove ecosystems requires basic understanding of their growth and death cycles.

The objective of this article is two-fold: 1) to synthesize information on natural massive mangrove mortalities and investigate the possible causal forces involved, and 2) to analyze the evidence available on the Gambia "epidemic." We limit the analysis to natural mortalities because human-induced mortalities have been reviewed recently (Lugo *et al.* 1981).

Our working hypothesis is that massive mangrove mortalities are caused by rapid natural fluctuations in environmental conditions rather than by biological factors. However, mortality attributed to biological agents can attain significant proportions within weakened or stressed forests.

NORMAL MORTALITY

For the purpose of this paper we will differentiate between normal and massive tree mortality. Normal tree mortality is a fairly well understood and documented phenomenon (Cody and Diamond 1975, Harper 1977, Etherington 1982). The process is associated with the normal interaction between individuals and their environment and occurs independent of drastic environmental change. The numerous causes for its occurrence are generally density dependent and involve processes such as inter- or intra-species competition, herbivory, endemic diseases, and senescence (Harper 1977).

Normal mortality, expressed as a reduction in tree density, occurs as a negative power function of the mean

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TABLE 1. Summary of reported massive tree mortalities in mangrove forests.

Location	Forces associated with tree mortality	Area affected	Reference
Hurricanes, tsunamis, and storms			
Australia	Hurricane/siltation	Extensive	Heinson and Spain 1974
Belize	Hurricane	Patches	Vermeer 1963
Dominican Republic	Tsunami	4500 ha	Sachtler 1973
Florida	Hurricane	Patches	Craighead 1964
Florida	Hurricane	4000 ha	Craighead and Gilbert 1962
Florida	Hurricane	Patches	Simpson 1932
Florida	Hurricane	Fringe	Stoddart 1971
Florida	Hurricane	Extensive	Tabb and Jones 1962
Puerto Rico	Hurricane	Several ha	Wadsworth and Englerth 1959
St. Croix, USA	Hurricane/siltation	Extensive	Borgensen 1909
Changes in hydrology			
India	Flooding	Patches	Blasco 1975
Java	Flooding/siltation	42 ha	Soerianegara 1968
Malaysia	Impoundment	Patches	Watson 1928
Puerto Rico	Impoundment/hypersalinity	Patches	Patterson-Zucca 1982
South Africa	Flooding	Many ha	Breen and Hill 1969
Surinam	Impoundment	Extensive	Augustinus 1978
Trinidad	Runoff diversion	Extensive	Bacon 1970
Erosion			
India	Subsidence/flooding	Patches	Sangal 1968
Mexico	Erosion	Fringes	Thom 1967
New Zealand	Erosion	Fringes	Chapman 1976
New Zealand	Erosion	Fringes	Ward 1967
Salinity			
Guadeloupe	Hypersalinity	Extensive	Servant <i>et al.</i> 1978
Puerto Rico	Hypersalinity	Fringes	Cintrón <i>et al.</i> 1978
Frost			
Florida	Frost	Extensive	Lugo and Patterson-Zucca 1977
Texas	Frost	Extensive	West 1977
Other			
Australia	Pollution/fungus	Extensive	Pegg <i>et al.</i> 1980

tree diameter at breast height (dbh) of the stand (Fig. 1). During the early stages of stand development, a one centimeter increment in average dbh results in the death of a larger percentage of stems than in more mature stands. The process of stand development has four phases: colonization, early development, maturity, and senescence (Fig. 2).

Colonization of a suitable substrate follows soon after space is made available. The rate of colonization is a function of the rate of arrival of seedlings (proximity of site to seed sources), the rate at which seedlings are uprooted and washed away (site exposure), and the rate of mortality of established seedlings. During this phase seedlings can attain densities of up to 40–70 per m² for red mangroves and 140–330 per m² for black mangroves.

Early development is a phase of strong competition for space. Initially high tree densities can be reduced 250-fold in less than five years from more than 500,000

propagules/ha to about 2000 stems/ha with a mean dbh of 2.5 cm. The rate at which plants die during this phase is a function of the speed at which the stand develops. In a rapidly growing stand, competition is intense, mortality is rapid, and the stand is quickly dominated by fewer but larger trees.

Maturity is reached when the growth rate of trees slows down. During this phase, competition for space is reduced and mortality may be mostly due to the death of suppressed individuals or of late recruitment. At this point, the stand reaches the maximum development allowed by the site's energy signature (*i.e.*, the sum of all forces converging on a mangrove forest corrected for energy quality; Lugo 1978). Most of the available energy is used for stand maintenance and less is available to cope with significant changes in the external environment.

The stage of senescence is seldom reached in mangrove forests. Senescent forests are dominated by few old

and large trees. Wide gaps in the canopy and lack of regeneration are typical of this stage. The mechanisms responsible for the lack of regeneration are unknown. In Figure 2, we have depicted this stage by a discontinuity in the stem density line.

The net result of all mortality is standing dead trees. Table 2 is a summary of available structural data for 34 stands known to us in which dead tree basal area and density have been assessed. The average tree dbh is computed from the average basal area of tallied trees. Sampling in the unpublished sites was conducted with a prism ($baf = 1$) using five plots per site.

The density or basal area of dead trees in a stand is a highly variable parameter. Site factors such as rate of tree growth, intensity and frequency of stress periods, geomorphologic stability, decaying rate of dead wood, and initial diameter of trees are related to the amount of dead standing wood. Standing dead trees can reach a high density within a mangrove stand but those in Table 2 oscillate around 19 percent of live tree density. This fraction is related to the average dbh of dead trees because tree mortality is a function of average tree dbh (Fig. 1). In the case of the stands represented in Table 2, the dbh of most dead trees oscillates around 9 cm which corresponds to a 16 percent rate of mortality. In most instances, the average dbh of standing dead trees (and therefore the dead basal area of the stand), is smaller than that of the living forest (Table 2). This supports the hypothesis that normal mortality is highest in the smaller suppressed stems.

MASSIVE MORTALITY

DEFINITION.—Irregular or massive tree mortality occurs as additional attrition. This mortality is characterized as involving larger numbers of individuals and affecting all size classes in a relatively short period of time. Even though the process appears to be common in many types of forests (Mueller-Dombois 1980, Stewart and Veblen 1982), it is inadequately documented and poorly understood.

EXAMPLES AND CAUSES.—In mangrove ecosystems massive tree mortality has been associated with the extensive destruction caused by hurricanes and tsunamis (Table 1). These phenomena cause death by direct mechanical action including breakage of trunks, loosening and shredding of bark, windthrow, and severe defoliation (Wadsworth and Englerth 1959, Stoddart 1971). Indirect effects of these events (*e.g.*, flooding and siltation), also account for a significant portion of massive tree mortality. These secondary effects are discussed below.

Many of the active geomorphologic processes occurring in the mangrove habitat are directly or indirectly responsible for extensive mortality within the forest. For example, natural erosional episodes have caused consid-

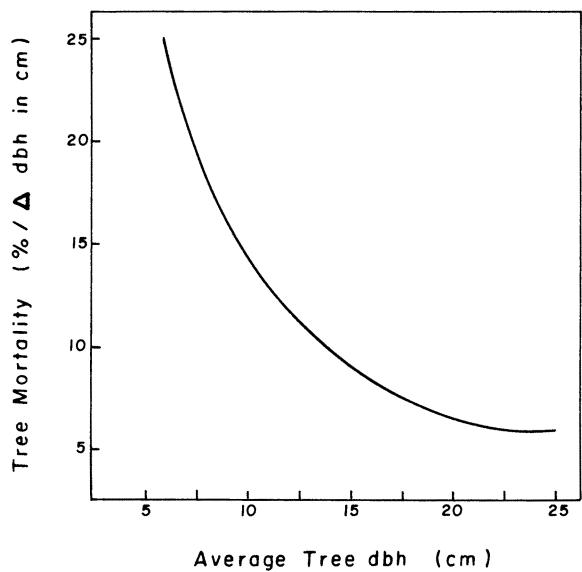


FIGURE 1. Relation between instantaneous mortality and average tree diameter at breast height (dbh). Mortality was calculated from changes in tree density in stands of known basal area. The relation between average tree dbh (x , in cm) and stem density (y , in trees/0.1 ha) was $y = \ln 7496 - (1.4934) \ln x$; ($N = 114$ new world mangrove stands; $r^2 = 0.73$). Data for 102 stands were published in Cintrón *et al.* 1985 and the additional 12 stands were collected recently by the authors.

erable mangrove mortality (Ward 1967, Wells and Coleman 1981). Wave activity and tidal scouring associated with marine transgression periods produce erosion of the seaward margin of fringe mangrove forests. The removal of muck and underlying peat from these margins results in tree-fall and death of trees regardless of their age. Coastlines subjected to cyclic erosional and depositional episodes (*e.g.*, Surinam) experience, as a result, cyclic events of mangrove colonization and massive tree mortality (Augustinus and Slager 1971, Augustinus 1978, Wells and Coleman 1981).

Massive tree mortalities also occur near the latitudinal limits of mangrove distribution due to periodic frost events (Simpson 1932, Egler 1952, West 1977, Lugo and Patterson-Zucca 1977). Temperatures of -3 to -11°C have produced heavy defoliation and death in many areas of southeastern United States, southern Australia, and New Zealand (Davis 1940, Macnae 1966, Chapman 1976, Lugo and Patterson-Zucca 1977). An overflight of all mangrove forests in Florida after the 1977 frost, established that massive tree mortality was significantly more severe in the basin mangrove forests where tidal flushing was least frequent (Lugo and Patterson-Zucca 1977, Shines 1979).

Any drastic reduction in the intensity and/or fre-

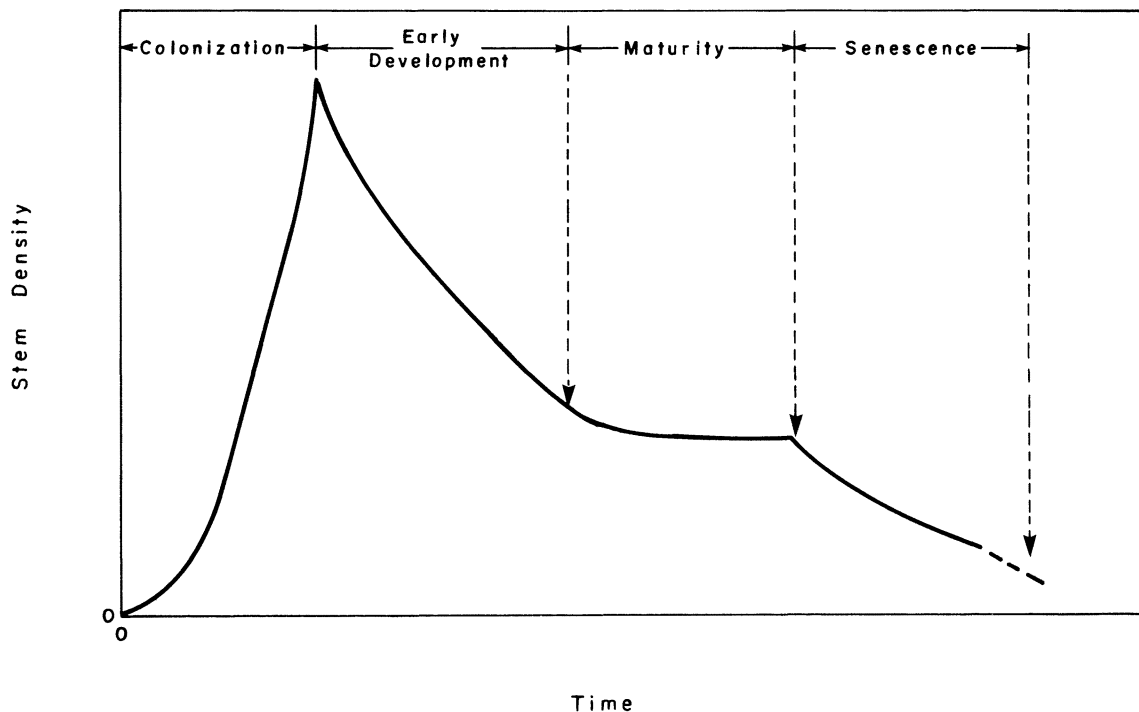


FIGURE 2. Normal changes of stem density as a mangrove stand matures in the absence of catastrophic environmental change. Massive mortality due to external forces often prevents stands from reaching the senescent phase.

quency of runoff and flushing within a mangrove stand generally leads to changes in the structure, vigor, and mortality patterns of the stand (Lugo and Snedaker 1974, Lugo *et al.* 1981). Diversion of terrestrial runoff, reduction in river discharge, changes in tidal regimes, and decreased rainfall are the primary factors that cause changes in such edaphic characteristics as salinity, fertility, degree of anoxia, and so on. For example, reductions in runoff and flushing enhance the concentration of toxic sulfides and decrease the availability of nutrients in the mangrove soil (Carter *et al.* 1973). Reductions in freshwater input allow the concentration of salts in the soil and promote hypersalinity in arid or seasonal climates (Cintrón *et al.* 1978). Finally, reductions in flooding promote the oxidation of reduced compounds in the soil and this results in a rapid lowering of pH (Hesse 1961, Thornton and Giglioli 1965). Massive tree mortalities have been associated with one or several of these factors (Bacon 1970, Augustinus 1978).

Massive tree mortality also occurs when mangroves are flooded chronically (Lugo *et al.* 1981). Natural causes for chronic flooding are numerous. Subsidence can expose forest patches to a more intense and prolonged flooding (Soerianegara 1968). Large amounts of water poured on by catastrophic phenomena such as hurricanes or tsunamis

can raise water level for unusually long periods of time in areas with poor drainage (Breen and Hill 1969). Natural impoundments, such as cherniers or sandbars, can obstruct the drainage patterns of the forest producing water stagnation (Augustinus 1978). In these instances massive tree mortality is due to the interruption of gas exchange in the root systems of trees. In arid regions, low oxygen content and high temperatures also develop in stagnated waters. This produces a synergistic effect with hypersalinity (Bacon 1970, Augustinus and Slager 1971, Cintrón *et al.* 1978).

Rapid rates of sedimentation within the forest may account for massive tree mortality in mangroves. This phenomenon is normally associated with catastrophic events such as hurricanes and storm floods. Human activities such as dredging and watershed deforestation also increase the rate of siltation in mangroves (Lugo and Snedaker 1974). Siltation interferes with the nutrient recycling of the forest and the gas exchange between the rhizosphere and the water column or the atmosphere (Lugo *et al.* 1981).

There is no evidence in the literature which indicates that biotic factors have ever caused massive tree mortality in mangroves. An exception is the Gambia case which will be discussed later. Fungal infestation has been asso-

TABLE 2. *Density and basal area of live and dead trees in mangrove forests of Florida, Puerto Rico, and Panama.*

Forest type and location	Dead trees		Dead and live trees		Average dbh		Reference
	Density tree·ha ⁻¹	Basal area m ² ·ha ⁻¹	Density tree·ha ⁻¹	Basal area m ² ·ha ⁻¹	Dead (cm)	Live (cm)	
Florida							
Basin	650	6.25	5130	29.4	11.1	8.1	Lugo <i>et al.</i> 1980
Basin	710	3.85	3790	19.4	8.3	8.1	Lugo <i>et al.</i> 1980
Basin	978	6.53	7611	28.5	9.2	6.5	Lugo <i>et al.</i> 1980
Basin	1150	12.73	6000	30.2	11.9	6.8	Lugo <i>et al.</i> 1980
Basin	1015	9.96	5514	31.2	11.2	7.7	Lugo <i>et al.</i> 1980
Basin	233	4.68	3633	40.2	2.6	11.5	Lugo <i>et al.</i> 1980
Basin	433	0.56	3033	13.5	4.1	7.9	Lugo <i>et al.</i> 1980
Puerto Rico							
Fringe	—	1.5	—	21.7	—	—	Cintrón <i>et al.</i> 1978
Fringe	—	2.63	—	16.1	—	—	Cintrón <i>et al.</i> 1978
Fringe	189	1.0	1630	17.0	8.2	11.9	Cintrón, unpublished
Basin	2340	12.5	9050	45.0	8.2	7.8	Martínez <i>et al.</i> 1979
Basin	530	6.0	1760	35.0	12.0	17.3	Martínez <i>et al.</i> 1979
Basin	3520	12.0	5770	22.0	6.6	7.5	Martínez <i>et al.</i> 1979
Basin	3317 ^a	13.6	5650	25.3	7.2	8.0	Patterson-Zucca 1982
Basin	3550 ^a	9.9	5500	18.6	6.0	7.5	Patterson-Zucca 1982
Basin	1276 ^a	3.5	3947	18.1	5.9	8.3	Patterson-Zucca 1982
Basin	1053	2.5	5790	33.4	5.5	9.1	Patterson-Zucca 1982
Basin	972	2.7	3660	22.5	5.9	9.7	Patterson-Zucca 1982
Basin	760	1.5	2259	7.6	5.1	7.2	Patterson-Zucca 1982
Basin	53	0.5	889	17.5	11.0	16.1	Cintrón, unpublished
Basin	219	2.0	1636	24.5	10.8	14.2	Cintrón, unpublished
Basin	1440	6.5	2839	24.5	7.6	12.8	Cintrón, unpublished
Basin	233	1.0	2900	24.0	7.4	10.5	Cintrón, unpublished
Basin	284	1.0	1165	12.5	6.7	12.9	Cintrón, unpublished
Basin	117	2.5	720	33.5	16.5	25.6	Cintrón, unpublished
Basin	1578	3.0	3776	17.0	4.9	9.0	Cintrón, unpublished
Basin	357	3.5	1168	17.0	11.2	14.6	Cintrón, unpublished
Basin	369	3.0	1324	19.0	10.2	14.6	Cintrón, unpublished
Basin	1264	4.5	2409	18.0	6.7	12.3	Cintrón, unpublished
Basin	156	2.0	539	13.5	12.7	19.6	Cintrón, unpublished
Basin	905	4.0	5565	24.0	7.5	7.4	Cintrón, unpublished
Panama							
Basin	1186	7.0	3767	34.0	8.7	11.5	Cintrón, unpublished
Basin	18	2.0	473	23.5	37.6	24.5	Cintrón, unpublished
Basin	292	1.0	1735	14.5	6.6	10.9	Cintrón, unpublished

^a Human-induced mortality.

ciated with extensive killings in Australia, but the disease outbreak was recognized as a symptom of environmental changes (Pegg *et al.* 1980).

Rapid environmental change in mangrove environments appears to be the common denominator to the reported cases of natural massive tree mortalities. The extent of damage caused by these changes will be a function of the intensity and persistence of the phenomena (Lugo 1978), the species involved, and the forest type affected. Damage can be reduced if a mitigating subsidy (*e.g.*, freshwater or rapid flushing) is available, or it can be accentuated if the ecosystem is already under a severe stress (*e.g.*, hypersalinity, low temperature, silting; Lugo and Patterson-Zucca 1977, Lugo *et al.* 1981). We ex-

pect, for example, that basin forests subjected to reduced flushing are more susceptible to massive tree mortalities than riverine or fringe mangroves where waters are always in motion.

The development of even-aged stands following extensive disturbance enhances the opportunity for massive tree mortality because the synchronous senescence of trees facilitates the occurrence of simultaneous mortality by any increase of environmental stress. The process appears to be self-perpetuating. Furthermore, in mangrove stands that are characteristically monospecific or species poor, the system's threshold to stress of the individual components of the system are uniform. Stressors which exceed a critical level may thus trigger widespread tree mortality.

TABLE 3. Stand tree density and basal area and gall information on stems of *Rhizophora mangle* in Panama and Costa Rica.

Location	Tree density (trees·ha ⁻¹)	Infected trees (%)	Total basal area (m ² ·ha ⁻¹)
Panama			
Agua Dulce	322	68.6	14.5 ^a
Darien	501	23.6	17.0 ^b
Costa Rica			
Puerto Soley	1701	0	19.7
Tamarindo	908	20	37.5
Pochote	1220	19.6	21.0
Jicaral	1773	0.8	7.3
Puntarenas	2370	0	19.8
Quepos	1850	25	29.0
Sierpe	1660	16.6	26.8
Moin	494	19.1	27.9

^a 72.4% of the basal area infected.

^b 58.8% of the basal area infected.

Many of the alterations that cause massive tree mortality follow defined cycles. Lugo *et al.* (1976) suggested that hurricane cycles of 20 to 24 yr determine the structural characteristics of mangrove ecosystems in the Caribbean. Egler (1952) observed that destructive cold spells affect southern Florida about every five years. Most droughts and reductions in river discharge may be associated with long-term climatological cycles (Oliver 1982). Tree populations reflect these cycles with successive periods of establishment, rapid growth, and rapid mortality.

ECOSYSTEM RESPONSE.—In spite of the variety of factors that can cause their massive mortality, mangrove associations are adapted to these events. An abundant production of seedlings, fast rearrangements in species zonation, and rapid rates of succession and tree growth allow mangrove ecosystems to quickly recover after a major disturbance. The speed of recovery is dependent on the nature of the disturbance, its persistence and recurrence, the type of forest affected, and the availability of seedlings. In general, areas fringing channels or water bodies are quickly colonized because of forces such as tides, wind, and high waters associated with storms. These forces also do the work of re-seeding the inland portions of the forest by carrying seeds and seedlings inland.

Recovery after a natural perturbation is generally faster than after human-induced perturbations. Human alterations are usually chronic or create new ecological conditions unsuitable for the regeneration of mangrove trees. For example, oil and its toxic derivatives tend to remain unaltered for long time periods in the anoxic mangrove soils (Lugo *et al.* 1981). Channelization, dam construction, dredging, or construction of dikes chronically alters

the hydric and edaphic conditions of mangroves. Under these conditions regeneration is retarded in proportion to the change in conditions.

Our survey of the literature indicates that massive tree mortality is a frequent and natural event in mangrove ecosystems. The phenomenon is closely related to the dynamic nature of mangrove environments and in some cases is part of the normal successional processes of the forest. Forests frequently affected by periodic alterations (*e.g.*, hurricanes, drought, frost) exhibit lower structural development and more frequent tree mortality than those growing in less stressful environments. But in spite of the high tree mortality observed in some instances, mangrove ecosystems appear to be very resilient to these forces because they continue to recover and exhibit cyclic successions (Lugo 1980).

THE GAMBIA CASE

Teas and McEwan (1982) reported an epidemic dieback in the mangroves of The Gambia. A gall disease, similar to the one caused by a fungus (*Cyclindrocarpon didymum* (Hortig) Wallenw.) in Florida mangroves, was reported as responsible for the massive mortality of *Rhizophora* spp. trees. In extensive areas, they said, 95 percent of the tall (>20 m) and medium sized (7–20 m) *Rhizophora* trees were killed by this disease. No evidence was given to relate the tree mortality to a fungal disease, for the apparent “preference” of the disease for tall trees, or for the claim that most *Rhizophora* trees in the 60,000 ha forest will die within three to five years.

Galls such as those described by Teas and McEwan have been observed in several localities around the Caribbean. In Florida mangroves, Olexa and Freeman (1978) reported areas of 100 percent infestation although the disease was not an important cause of mortality. We have observed the galls in *Rhizophora* mangroves of the Pacific coasts of Costa Rica and Panama, and of the Caribbean coast of Costa Rica (Table 3). These stands were sampled using the Cottam and Curtis (1956) point-quarter method (Costa Rica) or prism plots replicated five times per stand (Panama) and neither were found to show any abnormal tree mortality. In most of the stands, less than 25 percent of all stems were infected. However, the percentage of total basal area affected was high because the oldest stems (with largest diameters) appeared to be preferentially attacked.

While more than 75 species of fungi have been reported in mangrove forests (Kohlmeyer 1969), there is no evidence of any gall disease reaching epidemic proportions. Fungi, like most biological agents, tend to kill only those hosts weakened through some other cause (Plank 1960, Harper 1977).

There are, in fact, more plausible explanations for any tree mortality that could occur in the Gambian man-

groves. The Gambia river watershed has a strongly seasonal climate. Rainfall (averaging 1000 mm/yr) is minimal between June and October, and there is a seven-month drought. As a result of the aridity of the area, a distinctive species zonation and high soil salinities are characteristic (Giglioli and Thornton 1965).

Usually, riverine mangrove forests in arid environments require freshwater inflows from wetter areas upstream. This is the case in the arid Pacific coast of Ecuador (Rio Guayas estuary) and in the lower Gambia basin. However, in contrast to the steady water supply produced by the Andes in Ecuador, the Gambia river watershed is also subjected to erratic and variable rainfall. Partial crop failures occur one year in five due to irregular rainfall (Arid Lands Information Center 1981). Annual river flow oscillates with rainfall between 3 and 14 billion m³ (Arid Lands Information Center 1981). Rainfall in the basin has followed a negative slope ($m = -19.9$ mm/yr, $P = <.05$) for the last 23 years of record.

Changes in riverine freshwater discharge affect the mangroves through changes in soil salinities (Carter *et al.* 1973), lowering soil pH by allowing the oxidation of reduced sulfur compounds (Thornton and Giglioli 1965), excessive and prolonged flooding (Soerianegara 1968), and siltation or geomorphologic changes (Thom 1967).

Massive tree mortality associated with changes in river discharge in the Gambia have been recorded by Johnson (1978). He suggested that this phenomenon was associated with a drought period during 1972–1976. More

recently, Blasco (1983) reported that the recent mortality in the Gambia mangroves affected less than 10 percent of the 60,000 ha forest. He suggested that a change in the tidal regime was the cause of the mortality. Both authors attributed the tree mortality in the Gambian mangroves to changes in the hydrological regimes, whether riverine or tidally generated. The claim by Teas and McEwan appears to be exaggerated and without basis.

CONCLUSION

In general, catastrophic die-offs may be interpreted as the result of episodes of brief but extreme stress which are typical of many mangrove areas. Weakening of the trees by a primary stressor will make the forest more vulnerable to disease. However, the condition of the forest is principally due to the operation of the primary stressor. Finding a cure for a specific parasitic disease (such as in the Gambia example) will not save a forest which is adjusting to a significant change in environmental conditions. These diseases may in fact be considered to be merely accelerating the readjustment of the forest to a new steady state.

Neither massive die-offs nor parasitic infections are "catastrophic" in the sense that mangroves are unable to cope with these conditions. The real catastrophes occur when human misunderstandings of how these systems work allow irreversible environmental changes from which no recovery is possible.

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Announcement: New Secretary-Treasurer for the ATB

Dr. Elsa Zardini accepted the office of Secretary-Treasurer of the Association for Tropical Biology at the annual meeting in Gainesville, Florida. The office passed to her from Dr. Laurence Skog, who served the ATB as Secretary-Treasurer for five years. Under his fiscal guidance, the ATB has remained both a non-profit and non-debit organization, while the ATB expanded its membership, the size of *Biotropica* and produced two special issues of *Biotropica*. The editor particularly expresses his gratitude for Dr. Skog's wisdom and hard work.

Dr. Zardini should receive all correspondence related to membership, subscriptions, page charges, and contributions to the Clifford Evans Memorial publication fund. Her address is: Missouri Botanical Garden, 4344 Shaw Blvd., St. Louis, Missouri 63110, U.S.A.