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ECOLOGICAL HISTORY, CATASTROPHISM, AND HUMAN IMPACT ON THE MISSISSIPPI/ALABAMA CONTINENTAL SHELF AND ASSOCIATED WATERS: A REVIEW

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ABSTRACT The Mississippi/Alabama continental shelf and associated coastal waters together form a complex ecological system of interrelated parts. The biological system of the area has become established during the period of sea level rise following the last continental glacial maximum about 18,000 years ago. Contemporary biological populations of the inshore waters are subject to episodic catastrophic events caused by exceptional cold fronts, flooding, major storms, hypoxia, red tide outbreaks, and major droughts. Most of these events are not known to affect the shelf populations directly, but indirect effects through food chain disruptions are likely. Loop Current intrusions and entrainment of deep Gulf waters could directly impact the shelf species. Imposed upon these events are various human intrusions which have severely reduced the quality and quantity of inshore habitats. Increase in commercial and recreational fishing pressure in the inside waters and on the continental shelf during the past two decades has been accompanied by dramatic decline in populations of demersal and pelagic fish species. In order to be able to manage resources of the area successfully, there is an urgent need to understand the natural functioning of the entire complex ecological system.

Introduction

The Mississippi/Alabama continental shelf and the surrounding marshes, bays, estuaries, and lagoons form a large complex ecological system of interconnected components. The subsystems are related through the flow of nutrients, suspended particulates, and migratory species. Major efforts to bring portions of this system into focus include those of Christmas (1973), Darnell and Kleypas (1987), and Vittor (1985). However, virtually all of our knowledge of the larger system derives from study of individual components, and dynamic relations between the subsystems are poorly understood. Yet a comprehensive understanding of the larger system is essential if management efforts are to be successful in maintaining basic ecological relationships in the face of mounting human intrusion. The present article provides a focus on the larger system by reviewing pertinent literature concerning ecological history, natural catastrophic events, and human impacts. This is viewed as a necessary first step in examining the larger picture.

Ecological History

During Pleistocene time, the coastal and continental shelf environments off Mississippi and Alabama underwent dramatic changes. Associated with repeated advance and retreat of the continental ice sheets, the sea level receded nearly to the outer edge of the continental shelf and then rose again to approximately its present stand or higher. With each retreat of the sea, the shelf became exposed to subaerial erosion and oxidation, and streams passing through the area carved deep valleys. Subsequent rise in sea level saw filling of the valleys and smoothing of the surface. Associated changes involved shifting of the position of the Mississippi River delta, barrier island formation and destruction, and formation and filling of bays and estuaries.

Following the last glacial maximum about 18,000 years ago, the sea level has risen to its present stand, and repopulation of the northern Gulf shelf, bays, and estuaries has taken place. New tropical immigrants brought in by the Gulf Loop Current and possible other means (Humm and Darnell 1959; Darnell and Kleypas 1987) have been added to the normal biota of the northern Gulf. Considering the variability of the environments, the recency of their availability, and the periodic addition of new faunal elements from the south, it is reasonable to conclude that the processes of genetic adjustment are still underway.

This conclusion is borne out by the fact that at least the key species of the ecological system appear to exhibit R-type life history strategies---that is, they are opportunistic pioneering species with short life histories and high reproductive rates. They are adapted for rapid exploitation of new ecological opportunities and for persistence in the area despite local habitat loss, great variability in environmental factors, and the occasional occurrence of natural catastrophes. These key species include the brown and white shrimp, blue crab, gulf menhaden, sand seatrout, spot, Atlantic croaker, and striped mullet (all estuary dependent), as well as the longspine porgy and several flatfish (non-estuary dependent). Despite wide annual variations in abundance, these species have persisted and flourished in the area and have contributed to the stability of the shelf ecological system.

NATURAL CATASTROPHISM

The coastal environments of the northern Gulf of Mexico undergo regular cycles of seasonal changes in atmospheric, hydrographic, and oceanographic factors. Likewise, the life histories of the various species involve annual responses to the regular environmental changes (Benson 1982). However, on the continental shelf and in related coastal environments of the Mississippi-Alabama area, certain major changes occur irregularly, and these episodic events may interrupt the normal biological patterns. Some are known to result in mass mortalities, and probably place major stress on populations of the area. Biological effects of these events (Table 1) have not been studied adequately.

TABLE 1

Major catastrophic events which affect the environments and biota of the Mississippi-Alabama marine systems.

Catastrophic Events	Effects	
	Estuaries	Continental Shelf
Cold fronts	Recorded from Mississippi and Alabama	Not known to affect species on the shelf but may induce some stress.
	Can cause mass mortality of invertebrates and fishes.	Probably limits establishment of tropical species in shallow water habitats.
Floods	Recorded around Mississippi River Delta, Lake Pontchartrain, Lake Borgne, Mississippi Sound, and Mobile Bay.	Recorded from the southwestern half of the shelf.
	Short term effect is to place much fresh water, sediment, and debris into estuaries, destroy bottom habitat and oyster reefs, and kill or chase out mobile species.	Short term effect is to increase young fishes on the inner shelf and move older fishes to deeper water.
	Long term effect is to bury pollutants and increase fertility.	Long term effect may be to increase fertility.
Major storms and hurricanes	Affect entire coastline	Affect the entire coastline.
	Cause major flooding and extensive habitat damage (sedimentation of bottoms, destruction of marshlands and submerged vegetation, burial of oyster reefs, and erosion of shorelands).	Induce strong currents; stir up bottom sediments to a depth of 8 m or more; may restructure barrier islands.
		Biological effects unknown.
Hypoxic events	Known from Lake Pontchartrain and Mobile Bay.	Not known from the Mississippi/ Alabama continental shelf.
	May cause mass mortality of invertebrates and fishes.	
Red tide outbreaks	Recorded from Chandeleur Sound, Lake Borgne, Mississippi Sound, and Mobile Bay.	Reported between and near barrier islands off Louisiana and Mississippi.
	Small fish kill reported.	

Cold fronts

During exceptional winters, major cold waves strike the northern Gulf Coast and rapidly chill the estuarine and lagoonal waters. Immobilized by the sudden chill, invertebrates and fishes are unable to escape and die in great numbers. Such events have been reported along most of the northern Gulf Coast from south Texas through the Florida peninsula. Low temperature fish kills have been reported from coastal waters of Mississippi (Christmas 1973; Overstreet 1974) and from Mobile Bay (Reagan 1985; Johnson and Seaman 1986). No effects of low temperature have been reported for populations of the shelf, but it is likely that some tropical species which have become established on the shelves of south Texas and peninsular Florida are excluded from the Mississippi-Alabama shelf by exceptional extremely cold conditions.

Floods

Flooding of low coastal areas in the Mississippi River delta was a normal occurrence prior to the construction of artificial levees (Gunter 1952). Today it occurs east of the delta when the Bonnet Carré spillway is opened to permit floodwaters to pass through Lakes Pontchartrain and Borgne and Mississippi Sound to the Mississippi-Alabama shelf. Flooding may also occur when heavy rains fall in the drainage basins of the coastal streams, particularly the Pascagoula and Mobile Rivers, or when the coastal areas themselves are inundated from winter rainstorms or summer tropical depressions. The immediate physical effects are to replace or greatly dilute the saline waters of bays, estuaries, and sounds; markedly increase the level of suspended sediments; reduce oxygen values in the hypolimnion; and deposit a carpet of new sediments on the bottom (Schroeder 1977; Schroeder *et al.* 1990). Runoff erodes the banks and may bring much terrestrial debris into the bays and estuaries. Depending upon the season, the freshwater inflow may cause a dramatic temperature shift. These physical changes may also occur on the continental shelf if the flooding is persistent.

Biological effects of flooding in the Mississippi-Alabama area have been reported by Butler (1952), Butler and Engle (1950), Christmas (1973), Dardeau *et al.* (1990), Dawson (1965), Gunter (1952, 1953, 1979), Hawes and Perry (1978), Poirrier and Mulino (1975, 1977), Russell (1977), and Stout (1990). Marine plankton is replaced by freshwater species within bays and sounds (Hawes and Perry 1978; Simmons and Thomas 1962; Thomas and Simmons 1960). Some benthic species die, and bottom areas suffer a reduction in species abundance and diversity. Immobile forms such as the American oyster are buried, and large populations simply perish (Butler 1952; Butler and Engle 1950; Stout 1990). The young of estuary-related species, such as shrimp and the Atlantic croaker, are unable to penetrate to the estuaries and remain on the inner continental shelf. Adults are forced to move to deeper waters of the middle or outer shelf (Russell 1977). Mortality among these mobile species is not known, but certainly there must be major losses among the eggs, larvae, and juveniles which are barred from entering the nursery areas. The blanket of sediments deposited is generally rich in nutrients so that when recovery begins the following year, biological production may be higher than normal for a few years thereafter.

Major storms

Major storms and hurricanes frequently strike the northern Gulf Coast, accompanied by high winds, torrential rains, elevated sea levels, heavy wave action, and extensive coastal flooding. Strong water currents are generated out on the continental shelves, and bottoms may be stirred to a depth of at least 80 m/260 ft (Dinnel 1988). Impacts on coastal waters and on barrier islands and other land forms may be dramatic. Effects of major storms on the biota of bays and estuaries of the area have received little attention, but they have been addressed by Dardeau *et al.* (1990) and Stout (1990). Since the storms are generally accompanied by heavy precipitation, all the effects of flooding discussed above occur. In addition, the waves and strong water currents may cause direct physical damage to hard bottom species such as oysters, uproot submerged vegetation, tear up marshlands, and bury soft bottom species (Stout 1990). There have been no reports on the effects of major storms on the biota of the Mississippi-Alabama continental shelf.

Hypoxic events

Waters of the bays, lagoons, and continental shelf normally contain high levels of dissolved oxygen. However, the oxygen in the near bottom waters may be reduced to very low levels (hypoxia) or used up completely (anoxia) under conditions of high organic loading, rapid bacterial decomposition, and poor circulation (often due to summer stratification of the water column). Seawater is rich in sulfates, and under anoxic conditions, the sulfate becomes chemically reduced to the highly-toxic hydrogen sulfide gas and metal sulfides, some of which are soluble in seawater. Depending upon the severity of the event, hypoxia may induce avoidance, stress, or death in a few sensitive species, or it may result in mass mortality in many species due to asphyxiation and hydrogen sulfide intoxication.

In the Mississippi-Alabama area, hypoxia has been reported from Lake Pontchartrain (Junot *et al.* 1983; Poirrier 1979; and Sikora and Sikora 1982), St. Louis Bay, Biloxi Bay, Pascagoula River marshes (Christmas 1973), and Mobile Bay (Dardeau *et al.* 1990; Loesch 1960; May 1973; Schroeder and Wiseman 1988; and Schroeder *et al.* 1990). In Lake Pontchartrain, low diversity in benthic communities accompanied hypoxic conditions. Small fish kills have been associated with hypoxia in Mississippi. In Mobile Bay, severe summer hypoxia results in mass avoidance and mass mortality of many invertebrate and fish species. Hypoxic conditions have not been reported from the Mississippi-Alabama continental shelf area.

Red tide outbreaks

Phytoplankton blooms are a regular occurrence in the inshore and nearshore waters of the northern Gulf. Two phytoplankton species produce chemical substances into the water which are extremely toxic to other marine life. These are the dinoflagellates *Gonyaulax monilata* and *Ptychodiscus breve*. When appropriate conditions prevail, extremely dense populations of one of these species may develop, giving the surface waters a reddish tint. Hence, the occurrence is called a "red tide." Such events have been recorded off most of the northern Gulf Coast. In the Mississippi-Alabama area, a single red tide event was reported by Perry *et al.* (1979) due to a bloom of *Gonyaulax monilata*. This bloom persisted for about two weeks until dissipated by a hurricane. It was most intense in the western sector of Mississippi Sound south of St. Louis Bay, in the pass between Cat and Ship Islands, and in the upper portions of Chandeleur Sound. Lower concentrations extended eastward through Mississippi Sound into Alabama and on the nearshore shelf off Horn and Petit Bois Islands. Some of the Alabama blooms were apparently heavy (Perry *et al.* 1979). Only a small fish kill was reported.

Other events

The present section has documented five types of natural catastrophic events which may affect coastal populations of the Mississippi-Alabama area. Two additional types of events may be added to this list. Prolonged droughts reduce the amount of freshwater entering coastal bays and estuaries, leading to greatly elevated salinity levels in the inside waters. Populations of mobile and immobile estuarine species with low salinity tolerances are greatly reduced and replaced by high salinity forms. Normally excluded marine parasites and predators range freely and exact a significant toll on oysters and other estuarine species (Stout 1990). Another event of possible significance is the periodic intrusion of Loop Current water or of deep Gulf water up DeSoto Canyon. However, nothing is known about the biological consequences of such intrusions.

Implications of natural catastrophic events

The episodic events reported here often cause mass mortalities which can lead to major fluctuations in population abundances of the coastal species. Although the primary effects are generally felt by species inhabiting the inside waters, some of the events directly affect populations of the continental shelf. In either case, the ecological systems of the shelf are affected through reduction in food supplies and subsequent modification of the shelf food chains. Except for extreme cold weather which may limit the distribution of tropical species, none of the events is likely to eliminate species populations from the area. Although recovery from an event eventually takes place, population levels may be reduced during and after an event, and the surviving individuals probably are under some measure of physiological stress. Thus, they would be more susceptible to additional stress imposed by human activities. Considering the wide fluctuations imposed upon the populations by natural events, discernment of the impacts of specific human activities may be extremely difficult.

HUMAN INFLUENCES

Estuary-related species of the Mississippi-Alabama area utilize four basic nursery areas and appear to migrate seaward through the passes (Figure 1). Such migratory pathways would be consistent with adult distribution patterns observed on the continental shelf (Darnell 1985). In any event, this division of the nursery areas provides a convenient basis for the discussion of the local human activities and their major environmental effects (Table 2).

Area 1 - Mississippi River delta through Biloxi marshes

Human activities and their effects in this area have been addressed by Craig and Day (1977), Craig *et al.* (1979), Gagliano and vanBeek (1970), and Rounsefell (1964). Leveeing of the lower Mississippi River during the past century has deprived much of the lower delta of its normal annual nourishment of silt. As a result, subsidence and erosion are causing a land loss of over 14 feet per year. The Mississippi River Gulf Outlet Canal constructed in the early 1960s and related waterways have modified drainage patterns and permitted saltwater intrusion well into the productive Biloxi marshes.

Area 2 - Lake Pontchartrain through western Mississippi Sound

Human activities and environmental effects in this area have been discussed by Craig *et al.* (1979), Christmas

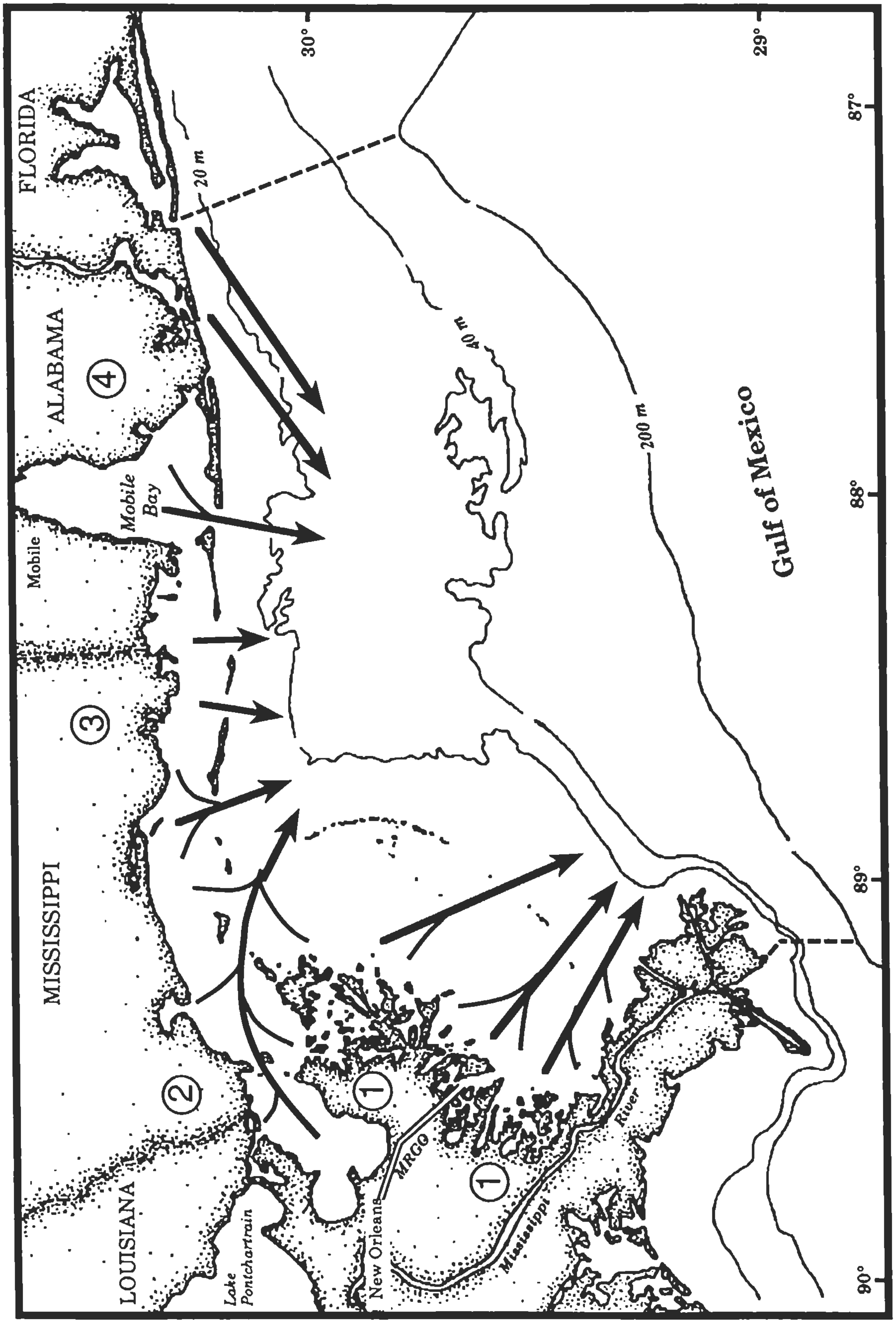

Figure 1. Estuarine nursery areas and presumed migratory pathways for estuary related species which inhabit the Mississippi/Alabama continental shelf.

TABLE 2

Summary of human activities and major effects on estuarine and continental shelf environments of the Mississippi-Alabama area.

Human Activities	Major Environmental Effects
Estuarine areas	
Area 1. Mississippi River Delta through Biloxi Marshes	
- Leveeing of Mississippi River	- Loss of estuarine habitat
- Channelization of marshes	- Saltwater encroachment
Area 2. Lake Pontchartrain through western Mississippi Sound	
- Leveeing and revetment of shorelines	- Loss of estuarine habitat
- Land development	- Reduction of submerged vegetation
- Shell dredging	- Loss of organic detritus food resource
- Dumping of municipal and industrial wastes	- Deterioration of soft bottoms
- Agricultural runoff	- Saltwater intrusion
	- Eutrophication
	- Creation or intensification of hypoxia
	- Accumulation of chemical pollutants
Area 3. Central and eastern Mississippi Sound	
- Land development	- Loss of estuarine habitat
- Dredging and spoil placement	- Interference with natural circulation
- Dumping of municipal and industrial wastes	- Creation or intensification of hypoxia
	- Chemical pollution
Area 4. Mobile Bay through Pensacola Bay	
- Land development	- Loss of estuarine habitat
- Dredging and spoil placement	- Reduction of submerged vegetation
- Channelization	- Modification of circulation
- Addition of municipal and industrial wastes	- Saltwater intrusion
- Agricultural runoff	- Creation or intensification of hypoxia
- Logging	- Chemical pollution
Continental Shelf	
- Overfishing	- Drastic reduction in fish populations

(1973), Englande *et al.* (1979), Junot *et al.* (1983), Poirrier (1979), Sikora and Sikora (1982), Sikora *et. al* (1981), Stone (1980), Stone *et al.* (1982), and Turner *et al.* (1980). During the past four decades, the environment of Lake Pontchartrain has been modified substantially by human activities (Stone *et al.* 1982). Levees and stone revetments placed along the south shore have cut off shallow wetlands and reduced wave erosion of the marshes. As a result, prime nursery areas have been sealed off, and the major source of organic detritus, formerly important in the local food chains, has been eliminated. Persistent and extensive shell dredging has reduced most of the lake bottom to a thin clay gel incapable of supporting the weight of adult rangia clams (Sikora *et al.* 1981). Virtual elimination of rangia and other benthic species has further reduced the food supply for estuary-related species (Sikora *et al.* 1981). Disposal into the lake of large volumes of domestic sewage by municipalities of Jefferson Parish and street runoff by the city of New Orleans have added organic matter and many chemical pollutants. Additional pollutants now enter the lake from agricultural and industrial sources along the northshore streams and from the industrial canal. The latter permits intrusion of a bottom saltwater wedge bringing various heavy metals and a high oxygen demand. Hypoxic areas or "dead zones" now occur periodically off the mouth of the industrial canal and extend well into the lake (Sikora and Sikora 1982). Frequent openings of the Bonnet Carré spillway during the past two decades have caused long periods of low salinity and high turbidity and have added fine sediments and additional chemical pollutants to the lake. Recent surveys have shown the submerged vegetation beds to be greatly reduced (Turner *et al.* 1980). As a result of these various human intrusions, the usefulness of the lake as a nursery area for estuary-related species has been greatly diminished.

The Pearl River marshes still appear to be largely intact, but sulfites and other chemicals from upstream paper mills and other industry may be reducing water quality. St. Louis Bay is affected by excess BOD loading, and hypoxic conditions with associated fish kills have been reported from this area (Christmas 1973).

Area 3 - Central and Eastern Mississippi Sound

Human activities and their effects in this sector have been reported by Christmas (1973) and McBee and Brehm (1979). The increasing human population has given rise to considerable land development, dredging and spoil placement, and dumping of municipal and industrial wastes. Such activities have been particularly prominent around St. Louis Bay, Biloxi Bay, and low reaches of the Pascagoula River. This has resulted in considerable loss of estuarine habitat, chemical pollution, and the creation or intensification of local hypoxic events accompanied by fish kills. Channel dredging and spoil placement have modified circulation patterns within the bays and facilitated saltwater intrusion (Christmas 1973). Spoil banks extending across the eastern sector of Mississippi Sound have created a virtual dam, resulting in separate circulation patterns east and west of the banks. Undoubtedly, these spoil banks constitute a barrier to the movement of many marine species as well.

Area 4 - Mobile Bay through Pensacola Bay

Human activities and environmental effects in the eastern sector have been discussed by Dardeau *et al.* (1990), Friend *et al.* (1981), Horn (1990), Isphording and Flowers (1990), Schroeder *et al.* (1990), and Stout (1990). Mobile Bay has been modified extensively by land development, dredging and spoil placement, channelization, logging, influx of municipal and industrial wastes, and upstream channelization and agricultural runoff into the Mobile River (Stout 1990). Documented changes in the bay include considerable loss of estuarine habitat and over 35 percent reduction of submerged vegetation beds. Remaining beds are being replaced by introduced and less desirable species (Stout 1990). Circulation patterns have been altered by dredging and creation of spoil mounds, ridges, and islands. Channelization has facilitated saltwater intrusion (Schroeder *et al.* 1990). Chemical pollution of the waters, sediments, and oyster tissue is severe (Isphording and Flowers 1990). Hypoxia in the bay appears to be a natural event, but certainly it has been exacerbated by human activities, especially through restriction of circulation and the addition of oxygen-demanding chemicals (Schroeder *et al.* 1990). Perdido and Pensacola Bays are less severely affected by human activities, but land development has reduced estuarine habitat, and some municipal and industrial pollution has occurred.

As noted by Darnell *et al.* (1976), certain river basin modifications may have profound effects on coastal systems. Upstream damming, channelization, and leveeing of floodplains are particularly important. In general, these entail retention of sediments and reduction in coastal beach nourishment. They often result in abnormal seasonal freshwater flow patterns in the receiving bays and estuaries. They may also diminish the contribution of leaf litter and other organic detritus from floodplains, thereby reducing the base of organic material supporting the coastal ecosystems. Stout (1990) discussed a number of anthropogenic changes in river basins feeding Mobile Bay, but specific biological effects were not documented. The recent opening of the Tennessee-Tombigbee Waterway could greatly influence the ecology of Mobile Bay, but no information has been found on effects of this development.

Continental shelf

The Mississippi-Alabama continental shelf has been modified by dredging and spoil disposal, channelization, creation of artificial reefs, and limited development of oil and gas resources (Vittor 1985). Whatever the local influences may have been, these activities are not considered to have caused major or widespread effects on the environment or biota. Commercial fishing on the shelf has been growing since the Second World War, and it has been particularly intense during the past 1½ decades (Browder *et al.* 1990). Activities include purse seining for menhaden, trawling for demersal shrimp and fish species, and use of hook-and-line (trolling, bottom fishing, and longlining) for reef-related as well as coastal and offshore pelagic species. The port of Pascagoula, Mississippi reports the second highest level of commercial fish landings in the nation (U.S. Dept. of Commerce 1991). Since 1980, there has been a dramatic increase in the harvest of reef-related and pelagic species (Browder *et al.* 1990). Recreation fishing also has increased greatly during this period, with more fishermen using party/charter boats and private or rented craft capable of harvesting deeper reefs and larger pelagic species. Incidental fish species taken in the menhaden fishery have been reported by Christmas *et al.* (1960), and those caught by bottom trawls are listed in Darnell (1985), Darnell and Kleypas (1987), Franks *et al.* (1972), and McEachran *et al.* (1992). Invertebrates taken by bottom trawls have been reported by Defenbaugh (1976), Franks *et al.* (1972), and Soto (1972).

Intensified fishing efforts have been accompanied by alarming declines in the estimated sizes of remaining fish stocks (Browder *et al.* 1990; Brown *et al.* 1990). Data for these estimates (Figures 2-5) encompass the shelf area from west of Barataria Bay, Louisiana to DeSoto Canyon, and are pertinent to the Mississippi-Alabama shelf (Browder, personal communication). Between 1960 and 1988, the menhaden harvest more than doubled and the shrimping effort almost quadrupled (Figure 2). Between 1972 and 1987, the biomass of bottom fishes declined from 116 kg/ha to around 26 kg/ha, approximately 22 percent of the original level (Figure 3). Despite greatly intensified fishing effort, the annual red snapper harvest declined between 1979 and 1986 from 16 million to about 4.5 million pounds (Figure 4). During the same period, the spawning stock of king mackerel declined to about one-third of its former level (Figure 5). Similar decreases have been observed for Spanish mackerel as well as in offshore pelagic species

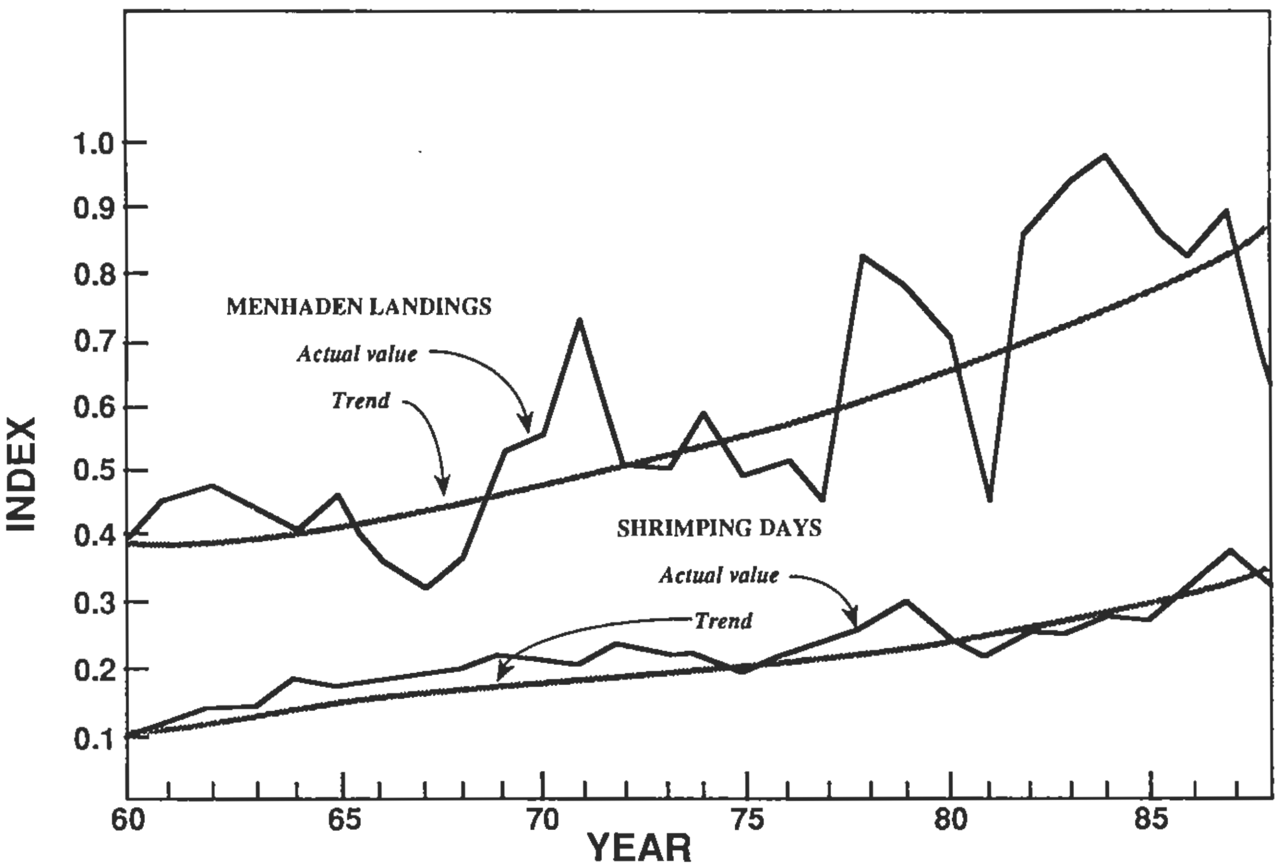

Figure 2. Trends in the harvest of menhaden and shrimping effort on the north central Gulf shelf between 1960 and 1988. (After Browder *et al.*, 1990 and Brown *et al.*, 1990.)

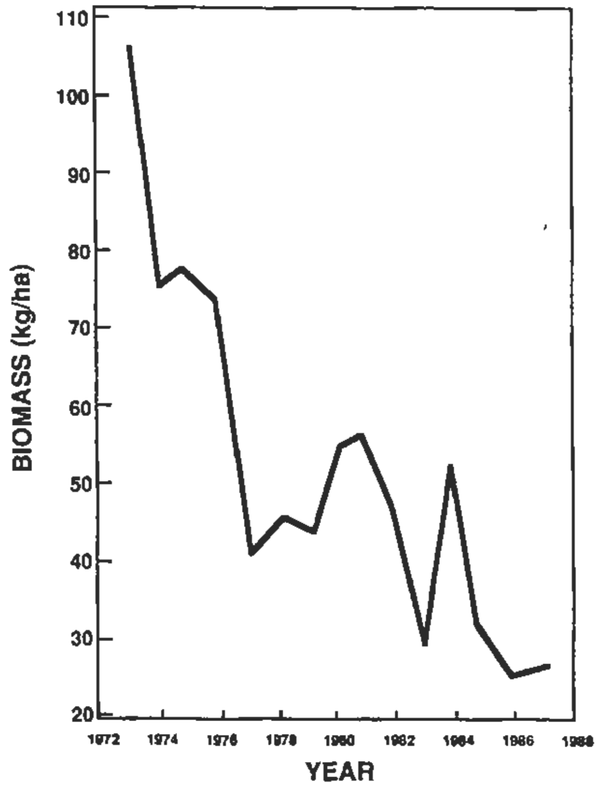

Figure 3. Estimated biomass of bottom fishes on the north central Gulf shelf between 1972 and 1987. (After Browder *et al.* 1990 and Brown *et al.* 1990.)

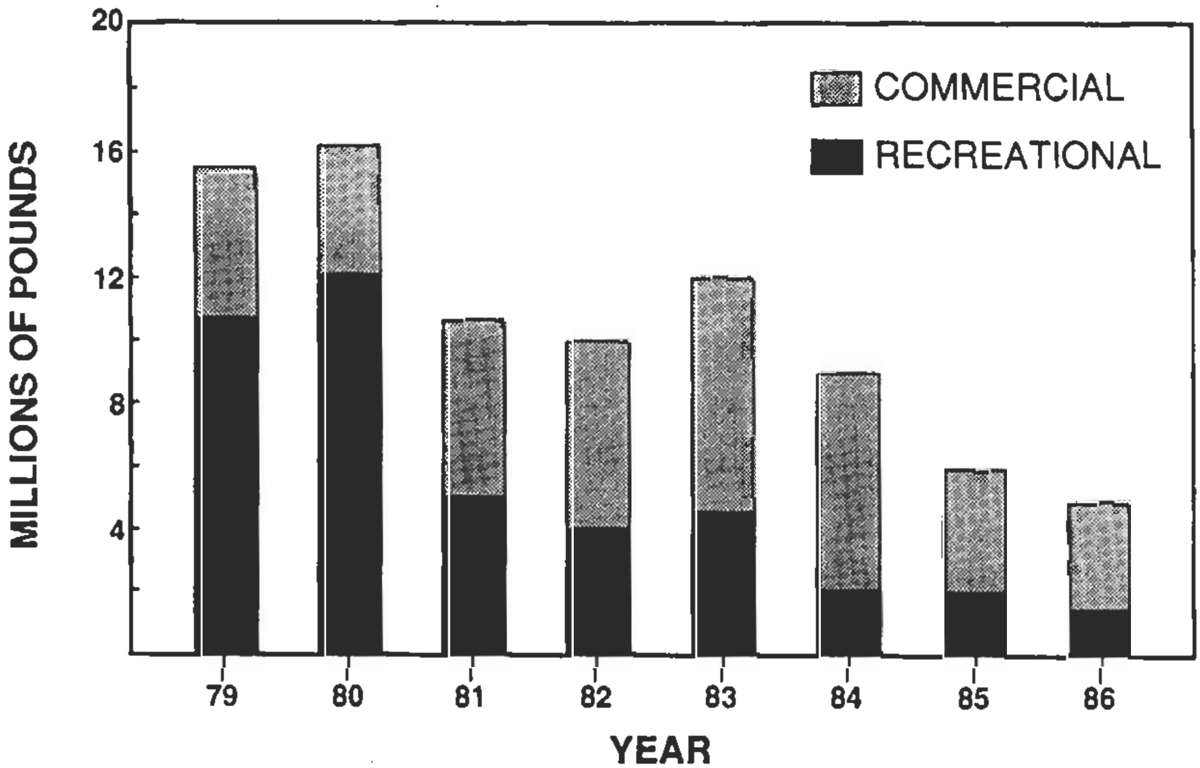

Figure 4. Commercial and recreational harvest of red snapper in the north central Gulf between 1979 and 1986. (After Browder *et al.* 1990 and Brown *et al.* 1990.)

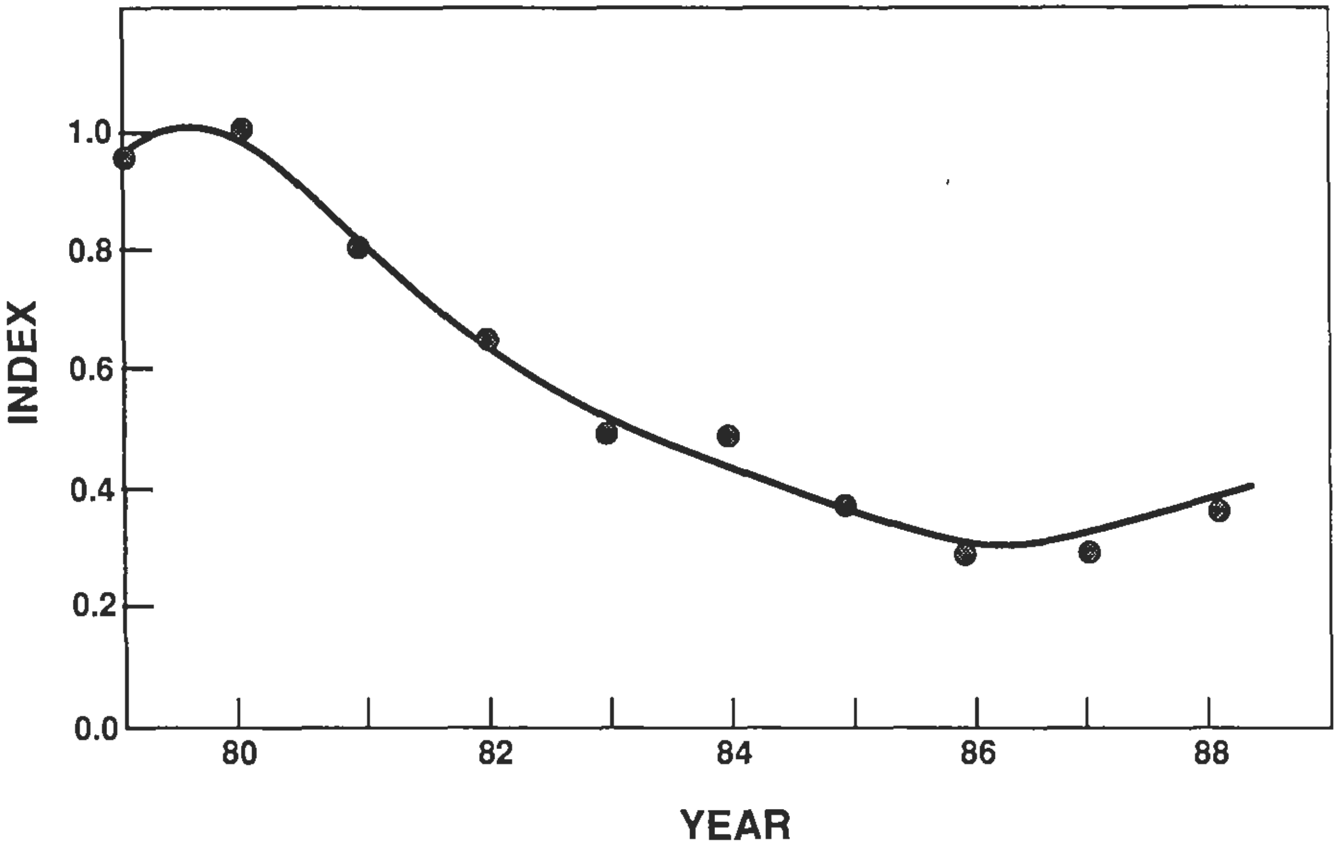

Figure 5. Estimated spawning stock of the king mackerel in the north central Gulf from 1979 through 1988. (After Browder *et al.* 1990 and Brown *et al.* 1990.)

(including bluefin tuna, swordfish, and others). Overfishing appears to be the primary reason for the declines. However, as noted earlier, there has been a simultaneous reduction in both the extent and quality of the nursery areas for estuary-related species. Significant diminution in the annual crop of estuary-related species would reduce the level of prey species and modify food chains of the continental shelf. In turn, this would likely be reflected in food chains supporting the larger predators just beyond the shelf edge. Undoubtedly, both overfishing and inshore habitat deterioration are responsible for this decline of fish stocks.

Conclusions

The Mississippi-Alabama continental shelf and related coastal waters have undergone certain long-term changes related to Pleistocene sea level stands. On shorter time scales, the system is subject to modification by natural catastrophic events, some of which may alter population levels over periods of one or two years. Imposed upon these natural trends and events is the recent massive intrusion by human activities which has had major effects upon the nearshore and possibly offshore environments and populations. The contributing factors are many and complex, and the biological data are too recent and unrefined to permit association of each cause with its specific effects or to understand synergistic effects of several factors acting in combination. It is against this background that efforts must be made to interpret the current ecological systems of the Mississippi-Alabama shelf and related coastal waters. Considering the rate of coastal habitat deterioration and population decline, the need to develop a comprehensive technical understanding of this complex system is most urgent.

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