Effects of Climate Change on Fishery Species in Florida

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Abstract. Recreational and commercial fishery species in Florida and elsewhere are under serious stress from overfishing and many types of habitat and water quality degradation. Climate change may add to that stress by affecting an array of biological processes, although the range of some subtropical and tropical species may expand northward in the state. It is expected to trigger sea level rise and changes in hurricanes and precipitation levels in Florida and elsewhere. Perhaps the most significant impacts of climate change on fishery species will also associated with changes in seagrasses and mangroves that function as Essential Nursery Habitats. Seagrasses in estuarine and coastal areas are limited by water depth and light penetration. Increases in sea level and in precipitation-induced turbidity may restrict the extent of seagrass habitats and their role in fishery production. Expanded efforts to reduce nutrient and sediment loading into seagrass habitats may help minimize the potential loss of a valuable fish nursery habitat. Mangroves have also been affected by human activities, and are the subject of restoration efforts in many areas. Potential sea level rise may cause an expansion of mangrove habitats in the Everglades, at the expense of freshwater habitats. This potential tradeoff of habitats should be considered by the water flow and habitat restoration programs in the Everglades.

Keywords: Climate Change, Fisheries, Mangroves, Seagrasses, Sea-Level Rise
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INTRODUCTION

Recreational and commercial fishery species have long been under severe stress across the world, due to intense overfishing, habitat destruction, alteration of river flow regimes, pollution and other anthropogenic stresses. Depletion of individual fisheries often triggers a switch to other fishery stocks, which often rapidly become overfished themselves. As the populations of forage fishes or predatory fishes decline, their roles in local ecosystems can change, resulting in dramatic alterations in the structure and trophodynamic interactions of marine and freshwater communities[1-3]. The economic and social implications of fisheries depletion on human societies are enormous.

Environmental responses to prospective global climate change constitute further potential impacts on ecosystems and fishery species, as well as the human populations that rely on fishery resources. This chapter utilizes Florida fish species and ecosystems to identify potential impacts of climate change on fish populations, and focuses on one of the most important limiting factors for fish recruitment: the quantity and quality of Essential Fish Habitat (EFH) utilized by juvenile fishes. EFH is a legal

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criterion established by the Sustainable Fisheries Act (1996) passed as a law by the United States Congress in 1996, and is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." Identifying potential impacts of climate change on EFH will help focus efforts to mitigate or minimize those impacts.

LIFE HISTORY OF FISHES AND VULNERABILITY TO CLIMATE CHANGE

Although fishes exhibit tremendous diversity in their life history strategies, some general patterns exhibited by many fishery species can be used to define EFH that are particularly vulnerable to climate change. Most coastal or estuarine demersal species in Florida (e.g. redfish, snook, sea trout, groupers, snappers, bonefish, tarpon) have a bipartite life history where adult spawning activity produces planktonic larvae[4-12]. Larvae remain in the water column for several weeks to a month or more prior to settling into shallow nursery habitats and metamorphosing into demersal juveniles. Critical habitats for juveniles are considered Essential Nursery Habitats (ENH). The juveniles typically migrate into different portions of the ecosystem as they grow, ultimately moving into their adult habitats by the time they reach sexual maturity.

Many of the abiotic and biotic processes affecting each life stage are potentially impacted by changing climate. Spawning seasonality of species is often affected by annual temperature cycles, and projected warmer temperatures may expand the spawning season of some species in Florida[13], and to increase the spawning success of fish populations near their northern limits of their ranges. The Indian River Lagoon on the east coast of Florida spans the boundary of temperate and subtropical zoogeographic provinces, resulting in very high fish diversity[14]. Warmer temperatures could thus increase the northward extent of subtropical and tropical components of the regional fauna, altering local community structure. Juveniles of some species such as snook and tarpon, are killed by episodes of cold weather near their northern limits[15], suggesting that warming environment could increase their survival in more northerly regions. Exotic freshwater fish species introduced into Florida (e.g. tilapia, Mayan cichlids, and armored catfish) may also shift northward as the climate warms.

The southward migration of temperate species may be negatively affected by increasing temperatures. Of particular concern is the anadromous American shad, an important fishery species that spawns in river systems from Canada to Florida. Juveniles and adults mature during their oceanic migrations along the east coast of North America before returning to their natal rivers to spawn. The St. Johns River along the northeast coast of Florida is the southernmost population of this species. Fish from populations in more northerly rivers are capable of making repeated spawning migrations over multiple years. The long spawning migration into the St. Johns River is apparently so energetically demanding, and fish are so near their limits of their thermal maximum, that these fish die after a single spawning season[16]. The St. Johns River population of American shad is thus probably more vulnerable to warming environmental conditions than any other fish species in the state.

The pelagic larvae of many marine fish species may also be impacted by changing climate conditions. Although entrainment into oceanic currents may drive long-distance transport of larvae, recent research indicates that an array of larval behaviors may enable the pelagic larvae to remain near their natal areas[17-19]. The increasing awareness of the potential for "self-recruitment" has important implications for development of fishery management strategies, including the design and management of Marine Protected Areas. However, alterations of current structures can influence the supply of larvae. In particular, storms and hurricanes have been shown to drive large pulses of larvae of groupers and tarpon into near-shore and nursery regions[12,20]. An increase in hurricane frequency, as suggested by some climate models, may thus affect the transport and recruitment of larvae into different habitats.

Although changes in temperature, currents and hurricanes may affect some aspects of fish reproduction and recruitment, the most likely impacts of climate change on many of Florida's fish populations are associated with changes in estuarine and coastal nursery habitats. Seagrasses and mangroves provide complex habitat structures and support productive trophic systems that make them extremely important habitats for juvenile fishes[4-11,14,22-27]. Typically located along land/ocean margins of Florida, seagrasses and mangroves have been heavily impacted by human activities over the last century. Some of these activities involved physical destruction of the habitats: dredging and filling for construction of buildings and other development projects, for causeways across bodies of water, for creation of navigation channels, and to eliminate mosquito breeding habitats. Degradation of water quality and alteration of water flow patterns in estuaries are less visible than outright destruction of seagrasses and mangroves, but are more pervasive and may have had greater impacts on overall ecosystem function and fish production.

Seagrasses are flowering plants that have evolved to live on the substrate in shallow waters. Their leaves, rhizomes and roots trap sediments and nutrients from overlying currents[28]. High light levels are required for photosynthesis and maintenance of both the exposed blades and the nonphotosynthetic rhizome and root structures. Primary limitations on the distribution of seagrasses include the clarity and depth of the water above the seagrass blades. Factors that reduce clarity, such as nutrient input and eutrophication, resuspension of sediments, and water depth all limit the distribution, abundance and productivity of seagrasses[29-31].

The primary production of seagrasses and epiphytes supports dense and diverse assemblages of benthic infauna and epibenthic invertebrates. The abundance of prey and the complex structure that provides protection from predators makes seagrasses vital habitats for juveniles of fishery species such as sea trout and redfish, and forage fishes (e.g. mojarras, pinfish, and pigfish). Reduction in seagrasses thus decreases the quantity and quality of Essential Fish Habitat for many species.

In the Indian River Lagoon, as elsewhere in Florida, seagrass abundance declined over many decades[29-32]. Seagrass surveys conducted by the Indian River Lagoon National Estuary Program enable the mapping of seagrass distributions and determination of temporal and spatial trends in seagrass abundance. The surveys and associated studies demonstrate that rapid human population growth, filling wetlands for development or mosquito control, construction of causeways that hinder water flow, discharge of untreated or minimally-treated storm water and wastewater, extensive fertilization of lawns and agricultural areas, and diversion of freshwater from the St. Johns River into the Indian River Lagoon all contributed to eutrophication, sedimentation and decline in light penetration into the Lagoon waters[31,32]. These factors, particularly the increase in turbidity, chlorophyll-a and color are influenced by sediment and nutrient loading, and are considered to be the primary reasons for the reduction of seagrasses in many parts of the lagoon. Parts of the lagoon adjacent to the area of the densest human populations have experienced a 70% loss of seagrass coverage since the 1940s, and seagrasses are generally limited to waters shallower than 1 m deep (Figure 1 [33]).

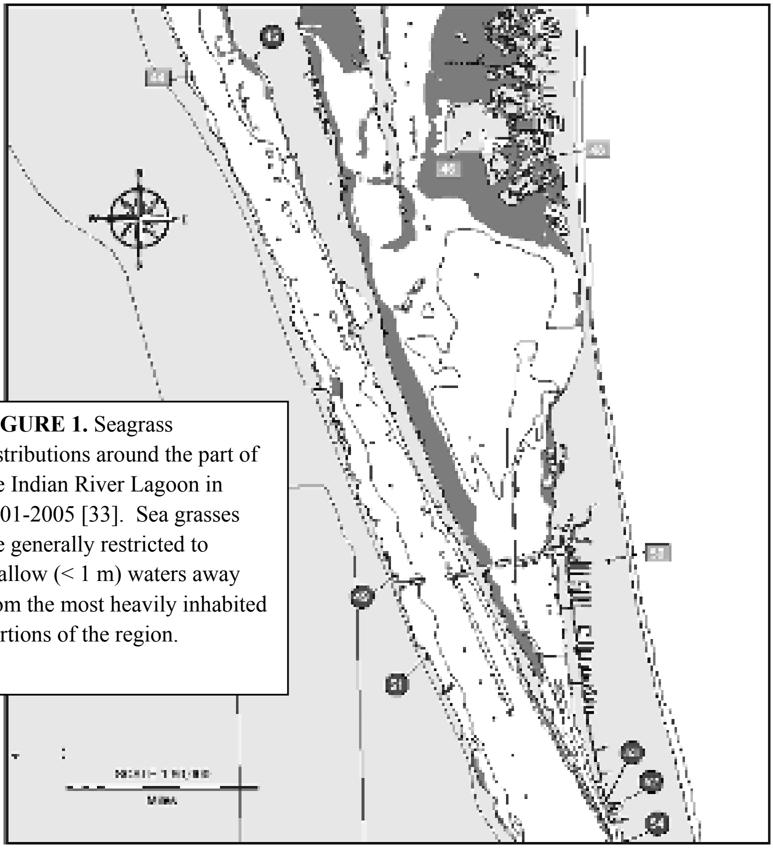

FIGURE 1. Seagrass distributions around the part of the Indian River Lagoon in 2001-2005 [33]. Sea grasses are generally restricted to shallow (< 1 m) waters away from the most heavily inhabited portions of the region.

Seagrass coverage has remained relatively stable in regions with limited human activity, such as near the federally protected NASA/Kennedy Space Center/Merritt Island National Wildlife Refuge[33]. Greater water clarity and minimal human impacts permit the growth of more extensive seagrass meadows (Figure 2).

Significant funding and effort have been expended by government agencies and citizens groups to minimize human impacts and restore seagrass habitats in the Indian River Lagoon and other coastal habitats in Florida and elsewhere. Reduced nutrient loading by elimination of wastewater discharges, control of turbidity by removing particulates from stormwater runoff, and restoring historical water drainage patterns have all contributed greatly toward the recovery of seagrasses in some regions.

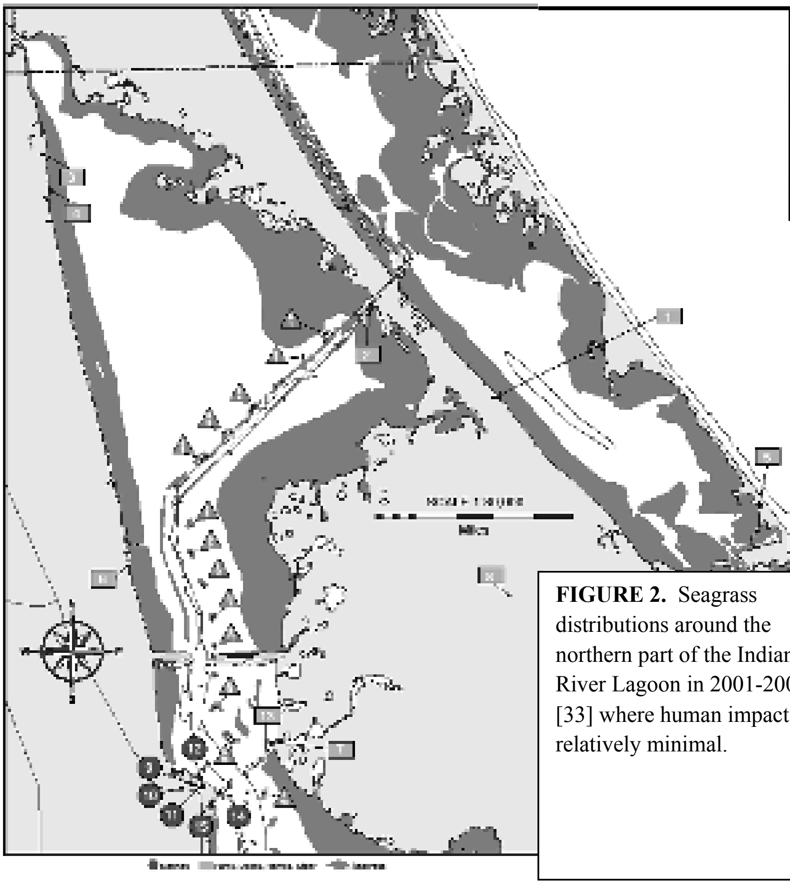

FIGURE 2. Seagrass distributions around the northern part of the Indian River Lagoon in 2001-2005 [33] where human impacts are relatively minimal.

Seagrasses are only one of the Essential Nursery Habitats for fishes in Florida. Mangroves that fringe the intertidal shoreline along much of peninsular Florida are another vital habitat. Three species of mangroves occur in narrow belts along the shoreline in some regions of Florida, while the southern region of the Everglades system comprises one of the largest mangrove forests in the world. The prop roots of red mangroves, pneumatophores of black mangroves and trunks of red, black and white mangroves provide complex habitats for juvenile fishes to hide. Mangroves provide significant sources of nutrients that drive secondary productivity, further increasing the value of these habitats as nurseries for juvenile fishes such as snook, tarpon, snappers and groupers. Some mangroves occur in hypersaline or highly variable salinity regimes, reducing the numbers of fish species that can utilize their structures[22].

An estimated 25-30% of mangrove habitat within portions of the Indian River Lagoon have been lost to direct human activity during the last 60 years [haddad 88], with many thousands of additional acres being incorporated into mosquito control impoundments in the1950s and 1960s. Although many impoundments have since been reconnected to the lagoon, reduced hydrodynamic circulation through the impoundments limits water exchange and poor water quality limits the use of these habitats to fishes such as juvenile tarpon and snook that are tolerant of low oxygen levels[4,22]. Government and public organizations sponsor mangrove reforestation efforts along the edges of the lagoon.

Both mangrove and seagrass habitats have been impacted by human activities, and restoration efforts have begun to increase their abundance in many parts of Florida. Anticipated changes in coastal ecosystems as a result of climate change have the potential to reverse or alter the recovery trend, further limiting the availability of these vital Essential Nursery Habitats.

Seagrasses are vulnerable to a number of stressors associated with climate change. Increasing temperatures can alter growth rates and other physiological functions including rates of flowering and sexual reproduction[34-36]. Perhaps most important will be the response of seagrasses to sea level rise, especially in areas where high turbidity already limits light penetration and restricts seagrasses to shallow waters. Anticipated increases in storms and rainfall may increase nutrient and sediment loading into the estuaries, further decreasing light penetration and the proportion of the habitat that can support seagrasses. Recent regulatory activities that call for significant reductions in nutrient and sediment transport into coastal habitats may mitigate at least a portion of the problem on increased turbidity and water depth.

If sea level rise were to occur at a slow pace in unimpacted habitats, it is likely that increased sedimentation would partly compensate for the increase in sea level, and that seagrasses would spread out into newly-flooded shallow areas. However, the human response to sea level rise may be to harden shorelines in many areas to limit flooding of private and public property. This alteration of shorelines would eliminate many areas from flooding and curtail the expansion of seagrasses into new areas.

A different response to sea level change is expected for mangroves, which are not limited by water turbidity. Hardening of shorelines would preclude mangrove reforestation in some areas, but other regions might experience an increase in mangrove coverage. Of particular interest are the Everglades, which support one of the largest mangrove habitats in the world. The nearly flat slope and sea level elevation of the Everglades provides an ideal habitat for mangroves[37,38]. Freshwater influx from peninsular Florida limits their present distribution to the seaward fringe of the Everglades.

The Comprehensive Everglades Restoration Plan seeks to reverse the diversion of freshwater flow that was altered for agricultural, development and municipal purposes. The planned increase of freshwater flow to the Everglades may, however, be offset by sea level rise and saltwater intrusion into freshwater swamps and other habitats. An integrated landscape model (Figure 3) developed to predict the changes in mangrove distributions associated with sea level rise suggests that mangrove distributions in the Everglades may increase dramatically with increasing sea level, at the expense of freshwater habitats[38].

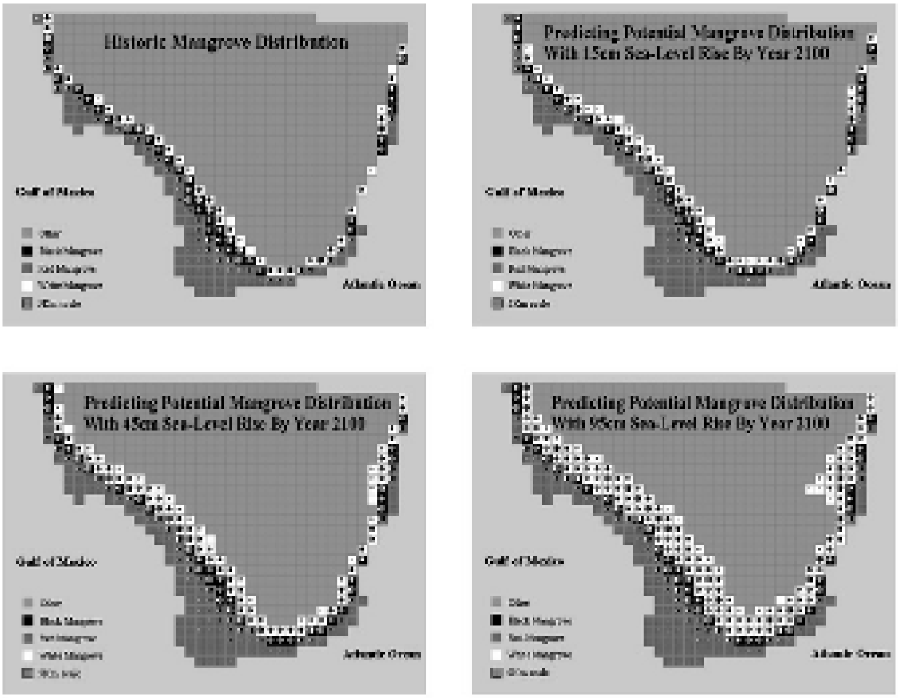

FIGURE 3. Projected distribution of mangrove species in the Everglades by 2100 under different sea level rise scenarios[38].

SUMMARY AND RECOMMENDATIONS

Climate change is expected to trigger sea level rise and changes in hurricanes and precipitation levels in Florida and elsewhere. Climate change may have direct impacts on distribution of some fish species, and on processes affecting their reproduction and growth. Significant impacts of climate change on fishery species will also be associated with changes in seagrasses and mangroves that function as Essential Nursery Habitats.

The distribution of seagrasses is limited by light penetration in shallow waters. Sea level rise is expected to reduce the amount of benthic habitat that can support seagrasses by increasing water depth over existing seagrass habitats and by reducing light penetration because of increased turbidity associated with changes in rainfall and hurricane patterns. The spread of seagrasses into newly-flooded shallow habitats may be limited by humans hardening shorelines to protect personal and public property. Successful completion of current efforts to reduce nutrient and sediment loading into estuaries are vital to at least partially mitigate the effects of sea level rise on seagrasses and juvenile fish populations.

Mangroves along the fringes of Florida are not as vulnerable to climate change, although they have been heavily impacted by other human activities. Restoration efforts for mangrove habitats are underway in many regions. Projected increases in sea level may put mangrove restoration into conflict with shoreline hardening and protection activities, although mangroves themselves have proven to be a buffer against hurricane-driven flooding. The potential increase in mangrove habitat in the Everglades, and concurrent loss of freshwater habitats, suggests that water flow restoration programs should consider and balance the value of each type of habitat.

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