The Origin of Florida Fish and Fisheries

R. GRANT GILMORE, JR.
Senior Aquatic Ecologist
Dynamac Corporation
Mail Code: DYN-2
Kennedy Space Center, FL 32899 USA

ABSTRACT

Today the Florida peninsula provides habitat for one of the most complex ichthyofaunas in the western Atlantic. High Floridian biodiversity and habitat complexity is principally due to Florida's geomorphology resulting in transitional climates associated with regional oceanographic currents which vary significantly around the peninsula. The majority of Floridian fish species are tropical, having migrated to the peninsula only recently, during the Holocene submergence of the Florida platform. These tropical invaders now form a heterogeneous group that often numerically dominate fish communities in southeastern Florida. Many tropical species form the basis for major recreational and commercial fisheries. Most fishery species life histories require estuarine, coastal or shelf edge spawning often with passive/active movement of pelagic eggs and larvae within estuaries, or across continental shelves and into, or from oceanic waters. Entrainment within oceanic currents allows larval transport for considerable distances downstream, loss of larvae from Florida waters, larval recruitment from Caribbean Provincial waters to Florida, or recruitment from Florida back to Floridian waters via eddies, gyres and meanders.

The differential distribution of suitable habitats and hydrological/climatic environments around the Florida peninsula creates differential faunal associations with the Caribbean Province, consequently, successful fishery larval recruitment from Caribbean. The Floridian marine and coastal environment can be divided into 26 faunal - biogeographic regions which support distinct communities of warm temperate, eurythermic and stenothermic tropical faunas. Using the speciose family serranidae as an example, the origination of various species from various regions of the western Atlantic can by hypothesized. These analyses give additional perspective on the evolution of the Florida fish fauna and its relationship with the Caribbean Sea. The differential association of Florida fishery species with the Caribbean Sea has major implications for regional and local fishery management and critical fishery habitat assessment.

KEY WORDS: Florida fisheries, ichthyofauna, biogeography

INTRODUCTION

The Florida peninsula provides habitat for one of the most complex and richest ichthyofaunas in the western Atlantic principally due to its geomorphology and transitional climate associated with regional oceanographic currents (Gilmore 1995). There are many historical accounts on the faunal composition of the tropical western Atlantic. Few new fish species are presently being described. Except for a few very rich families (ex. Gobiidae) most regional shallow water (< 200 m depths) species have been described and are well known. This allows the majority of the Floridian ichthyofauna to be adequately described and enumerated. However, considerable disagreement exists in the distribution and ecology of this fauna as seen in recent publications on the distribution of major fisheries groups such as the groupers and snappers.

In the past the normal historical procedure for describing the distribution of coastal marine fish species was to give their range in association with their collection site. However, typical marine fish life history strategies along with the mobility of water allows species to be distributed for hundreds and often thousands of miles beyond the range of their typical breeding habitats and ecosystems to which they have adapted. The dots on the range maps are misleading if they do not take into account species preferred habitat and breeding range. Capture records actually mean little to the life history of the animal. The often stated range for tropical species, "from Nova Scotia to Rio de Janeiro" can give a very erroneous picture of organismic biology, biogeography and critical habitat. This then creates gross errors in fishery species distribution or assessment of critical habitat. There are examples today of fisheries literature and public information sites (World Wide Web network) placing species in entire ocean basins (Gulf of Mexico or Caribbean Sea) where they are considered extremely rare or absent. World wide coverage of regional fisheries through FAO volumes on groupers (Heemstra and Randall 1993) and snappers (Allen,\ 1985) show false species range information in the tropical western Atlantic. An important fishery species, the mutton snapper, pargo criollo, *Lutjanus analis*, is listed as common in the Gulf of Mexico. The northern and eastern Gulf has been listed as critical habitat for this species by the NOAA Critical Fisheries Habitat program. Unfortunately, the mutton snapper does not occur in this region of the Gulf of Mexico. Other common valuable commercial and recreational fishes for which equally erroneous distributional information has been given are the striped mullet, *Mugil cephalus* (absent from the Caribbean, but commonly listed as occurring there, Thomson, 1963 Campton and Mahmoudi 1991, Pattillo et al. 1997) and black grouper, *Mycteroperca bonaci*, as common in the northern and eastern Gulf of Mexico but absent there. These species are the most conspicuous examples revealing erroneous distribution presentations in the literature.

Due to the inaccuracies in describing fish species distribution an effort is made here to describe basic fish biogeographic distribution patterns for the Floridian ichthyofauna based on species evolutionary history, eco-physiologies, comparative ecology, and life histories. This treatment attempts to take these biological and environmental factors into account, particularly sensitivities to hypothermia. However, the only comprehensive data is from repetitive quantitative fish collections and observations made by many investigators over the past fifty years. Phyletic relationships and sibling species associations are also important in determining the evolutionary history and distribution of fishes in the tropical western Atlantic. This analysis is done relative to oceanic as well as coastal environments which play a vital role in marine species survival and distribution. Data from quantitative ecological studies through the Gulf and Caribbean region are used for these analyses as well as information on hypothermal mortalities recorded from the Florida peninsula.

The central hypothesis that governs these analyses is that the Florida ichthyofauna consists of definable species groups or faunas, each fauna having similar biological, ecological and eco-physiological adaptations. Some species may have co-evolved showing similar distribution tracks while others reveal different evolutionary histories causing them to occupy different oceanographic, hydrological and climatic regions around the Florida peninsula.

There are a variety of important fishery questions that can be answered by a detailed study of regional biogeography. The basic objectives relevant to regional fisheries are to determine:

i) Which fishery species are in Florida?
ii) Why other species are not in Florida?
iii) How did the species that are in Florida, arrive in Florida?
iv) What allows these species to survive in Florida?

Methodologies entail a thorough review of coastal and continental shelf studies within the region as well as a thorough review of individual species ecologies from published and unpublished sources. In this presentation the range of the species is limited to its known breeding range, or where adults and juveniles predictably and commonly occur on at least an annual basis.

MIGRATORY STRATEGIES AND TRANSPORT MECHANISMS: INVASION OF THE FLORIDA PENINSULA

As the Holocene post-glacial sea level rose and warm equatorial current flows changed so did regional and local climates, sea surface temperatures and the size of tropical aquatic habitats in the western Atlantic. Tropial habitats were not limited to the open ocean but included complex coastal ecosystems. As tropical coastal ecosystems developed in Florida fishes were able to reach them by a wide variety of mechanisms.

Invasion Mechanisms

It is now well documented that besides actively swimming, often for substantial distances, fishes also passively utilize ocean currents, eddies and gyres, prevailing winds, storms, freshwater runoff and tides for short and long distance transport as well as local larval retention. Passive propagule, egg and larval movement is pervasive in the ocean and allows larvae to travel tens to thousands of miles with minimal energy expenditures (serranids, gobioids). Other species (ex. spotted seatrout, *Cynoscion nebulosus*) time their spawning activities at specific locations to insure local larval recruitment and retention to parental feeding grounds. Florida resides at the downstream juncture of two major oceanic currents: Caribbean Current via the Yucatan Straits and Gulf of Mexico (as the Loop Current) and the Antilles Current (via the Bahama - Cuba Channel). They combine within the Florida Straits to become the Florida Current passing between Florida, Cuba and the Bahama Platform (Figure 1). All originate in the equatorial North Atlantic before flowing into the Caribbean Sea (Caribbean and Guinea Currents) or along the northern edge of the Antilles and south of the Bahama Islands (North Equatorial and Antilles Currents). The prevailing southeasterly trade winds follow these currents and so typically, do hurricanes and tropical storms. The immense freshwater flows from the Amazon and the Orinoco dominate riverine input to the region impacting mostly the Antilles, but potentially giving propagules of euryhaline tropical peripheral species to the Florida peninsula. Prevailing easterly winds and continental shelf gyres on the west Florida shelf block drifter movement to inshore waters of the western side of the Florida peninsula. Consequently, Caribbean larval transport, to western peninsula Florida does not often occur (Gilmore and Hastings 1983, Rezak et al. 1985). Successful invasion also requires specific biotic and physical conditions as well as adequate habitat for survival at the settlement site. Seasonal hypothermal conditions on the west Florida shelf preclude survival of stenothermic tropical species. During the winter (January - February) shelf waters in the eastern Gulf of Mexico are considerably colder relative to the Florida east coast while the latter locale is under the influence of the warm Florida Current (Gilmore et al. 1978).

Eddies moving off of major coastal currents may carry larvae and juveniles onto adjacent continental shelves where cross shelf transport via Ekman phenomena, upwelling events, and prevailing winds as well as tides bring them onto near shore reef formations or into estuarine waters. Coastal counter-currents have been found to transport larvae from major ocean currents (Florida Current or Gulf Stream; Lee and Williams 1999). Fish larvae and juveniles are transported routinely enough from Caribbean sources to Florida that little genetic variation is seen in a variety of reef fishes known to have long duration 930+ days) pelagic larvae (serranidae and carangidae) examined from Florida and the Caribbean to date (Richardson and Gold 1993, Gold and Richardson 1998). Genetic exchange via passive larval transport may be often enough to reduce local gene pool isolation.

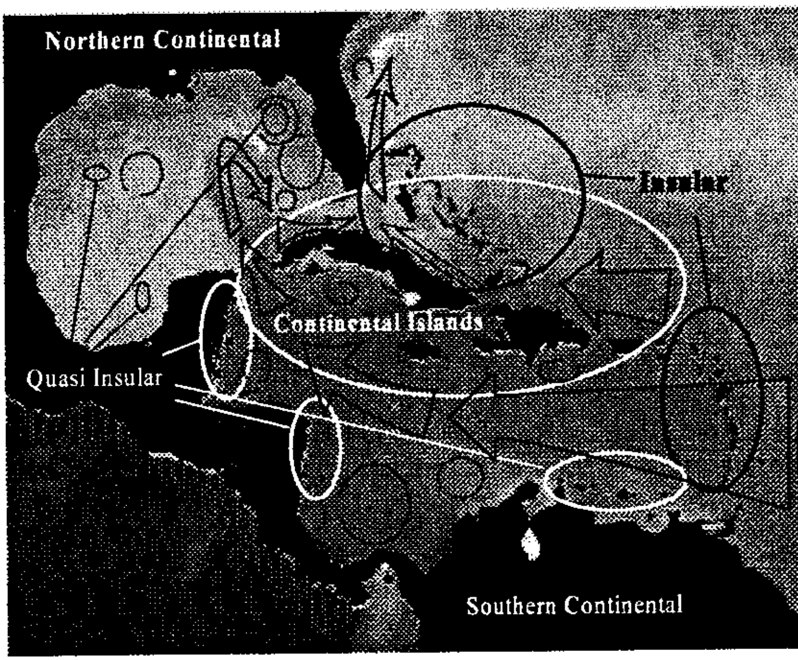

Figure 1. Geographic terrains in the tropical western Atlantic: continents, continental islands, quasi-insular and insular terrains; major ocean currents (arrows), gyres and eddies (dark open broken circles). Dark background water color indicates warmer water (from January 1998 image).

There are over 1,200 fish species recorded from the Florida peninsula. They are too numerous to list in this publication, is one of the most speciose families and is analyzed here as an example. The family serranidae is a basal perciform group which supports major fisheries throughout the region yet contains subfamilies of fishes that have great biogeographic, faunal, ecological and evolutionary significance. An analysis of serranid life histories and distributions is aided substantially by the fact that they are economically important and therefore sought after by fisheries throughout the region. They are of great conservation interest because of their depleted stocks due to overfishing and their popularity to the diving tourist. Serranids offer a wide variety of reproductive patterns and life history strategies. Serranid reproduction includes gonochorism and all varieties of hermaphrodism. Serranid ecological roles vary from small benthic predators to schooling planktivores and large roving predators. Study of this familial diversity presents further insight into regional fish community evolution and distribution.

Dispersal - Migratory Strategies and Faunal Movement Patterns

Major differences between marine and terrestrial, freshwater and estuarine environments with regard to organism isolation, migration and evolution is the potential for broad passive distribution. Many marine and euryhaline freshwater species utilize the mobility of water to complete life histories. The elopomorph fishes, the tarpon (sabalo), *Megalops atlantica*, and the American freshwater eels, *A. rostrata*, represent clear examples of passive oceanic mobility used predictably for coastal recruitment of larvae hatching in oceanic environments and recruiting as juveniles to adult coastal and freshwater habitats. Similar strategies are used by a large number of marine fishes. These species must find critical habitats on a broader geographic scale. This also means that marine species that spend early life histories in the open ocean are unlikely to be genetically isolated. When isolation does occur, it is typically associated with geographic isolation of ocean basins, the North Atlantic versus the South Atlantic or Eastern Pacific.

Limitations in survival will be principally associated with juvenile settlement site characteristics and adult spawning site characteristics. Pelagic environments would certainly influence larval survival, however, they are relatively stable when compared to coastal environments.

Those species which can guarantee adequate juvenile and adult environments downstream will be most likely to survive, and this may require adult migration to the most appropriate spawning location. Active adult migration to upstream spawning sites may allow passive larval migration back to parental habitats downstream. Indian River lagoon snook, *Centropomus undecimalis*, use this strategy for coastal larval recruitment to sites between 27° 00' and 28° 00' N. latitude by migrating to nearshore continental shelf spawning sites south of 27° 00' to 26° 00' N. latitude. In contrast, broadcast spawning into oceanic currents over continental shelf margins insures larval dispersal to potential new habitats on a broader regional scale. Gag grouper, *Mycteroperca microlepis*, spawn at a shelf edge (70-100 m depth) Oculina coral reef near 27° 30' N. latitude. Their larvae may remain in the Florida Current water mass along the shelf edge where they are likely to be entrained in eddies and wind driven shelf waters which move across the shelf to inshore settlement sites and nursery grounds. Tagged adult gag groupers from South Carolina have been recaptured off central Florida revealing a Carolina gag migration south to spawn off Florida. This would insure recruitment of larvae via north-northeasterly Florida Current - Gulf Stream flow (Van Sant et al. 1994, McGovern et al. 2001). Serranid larvae are morphologically adapted for pelagic dispersal. Therefore, larval entrainment in coastal pelagic currents is likely an evolutionary strategy for dispersal and survival in epinepheline serranids.

If these dispersal/migration strategies work, then many marine species should use them - and they do. Notable fishery species groups that use this strategy are the tarpons, or sabalos, megalopidae; snook or robalos, centropomids; groupers, serranidae; snappers, lutjanidae; porgies, sparidae; and jacks, carangidae. The most abundant pelagic open ocean larvae of coastal or continental margin fishes in the tropical western Atlantic are serranids, particularly anthiine serranids, gobioid fishes, carangids, clupeids and syngnathids (Richards et al. 1993). If all these families are casting larvae to ocean currents why are species within these families often limited in distribution? The most likely explanation is that juveniles and adults of these widely dispersed larvae are often stenoecious, requiring narrowly defined ecological and environmental conditions for survival. They have evolved under a variety of environmental and biological conditions associated with past climatic, hydrological and geological conditions in addition to biological interactions at population and community levels (trophic, spatial and spawning competition, and predation mortality). Many species showing the same distribution have apparently co-evolved, consistently occuring in the same habitat and represent the same fish community type.

Species Eco-physiology, Thermal Preferences and Biogeographic Distribution

Survival after Arrival: Historical work (Gilmore 1977, Gilmore et al. 1978, Gilmore and Hastings 1982, Gilmore 1985, 1995) has classified the Florida fish fauna into a variety of groups based on preferred temperature ranges and habitat preferences. Unfortunately, thermal preferences of many species have not been examined empirically through physiological experiments. However, many field observations have been made of thermal mortalities around the Florida peninsula over the past century (Gilmore et al. 1978, Snelson 1978). These observations have revealed differential temperature tolerances and lethal minimums for many tropical western Atlantic species. This allows a definition of thermal tolerance based on survival temperatures during natural hypothermal events. These thermal responses coupled with known abundance in preferred habitats and broad geographic distribution allow species to be classified as stenothermic tropical, eurythermic tropical, warm temperate and temperate.

Florida-tropical western Atlantic species can also be classified as principally "insular" or "continental" in provincial or sub-regional habitat preference. Regional insular species are recorded from the Lesser Antilles, Bahama Islands and Bermuda. "Quasi- insular" species are recorded from islands adjacent to continental margins (islands off the coast of Venezuela and Belize) and from continental islands (the Greater Antilles)(Fig. 2). Continental species occur primarily in continental habitats and only occur in insular ecosystems where adequate continental habitat types occur. Many continental species are found in the Greater Antilles.

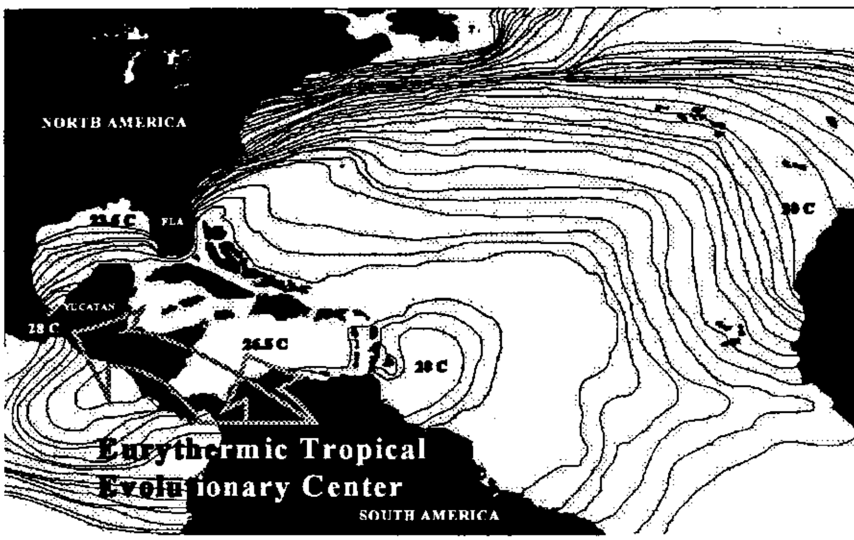

Figure 2. Glacial topography and hypothesized temperature patterns showing mean summer surface temperatures in the North Atlantic.

The preferred definitions for the fish biogeographic guilds used here are:
Stenothermic Tropical — Species that cannot withstand prolonged exposure (> 48 hours) to ambient water temperatures below 13 - 14°C without significant mortality at polyhaline/marine salinities, 20 - 35‰. They prefer water temperatures above 18 - 20°C. These species are more typical of tropical insular environments which typically do not reveal significant water temperature or salinity variation. These species are typically distributed to the margins of the tropical/subtropical climatic zones (25° 00 to28° 00 N. lat.) only in association with warm coastal currents. This is the typical West Indian or Antillean Provincial fauna (Province = 10% endemism, Briggs 1974). These species were probably limited to the windward Antilles and the South American coast southeast of the Orinoco River during glacial periods. Epinepheline serranid examples are: Nassau grouper, *Epinephelus striatus*; black grouper, *Mycteroperca bonaci*; Comb grouper, *M. rubra*, and Tiger grouper, *M. tigris*.

Table 1. Eco-physiology and habitat distribution in Serranidae. (#) = Total Western Atlantic. species.

	Eurythermic (47 Sp)				
	Euryoecious	Continental	Insular	Total	
Epinephelinae					
Epinephelini	2	8	5	15	-24
Liopropomini	1	2	0	3	(6)
Grammistini	1	1	0	2	(8)
Anthiinae	1	9	1	11	(11)
Serraninae	6	10	0	16	(35)
Totals	11	30	6	47	(84)
	Stenothermic (37 Sp)				
	Euryoecious	Continental	Insular	Total	
Epinephelinae					
Epinephelini	0	6	3	9	(24)
Liopropomini	0	3	0	3	(6)
Grammistini	2	3	1	6	(8)
Anthiinae	0	0	0	0	(11)
Serraninae	0	5	14	19	(35)
Totals	2	17	18	37	-84

Eurythermic Tropical — Species that can withstand ambient water temperatures to 6-8°C for 24 - 48 hrs,without significant mortality at polyhaline/marine salinities, 20-35‰. They prefer water temperatures above 14°C. These species are more often continental in their range and have evolved the physiological capability to withstand greater temperature and salinity variation than stenothermic insular species. They may even do well at locations which have seasonally warm/temperate to temperate climates as far north as 35° 00' N. lat. They also penetrate depths greater than 100 m, survive annual upper slope cold upwellings (6 - 8°C), and may penetrate the epibathyal region along island and continental escarpments at least to 700 m depths. This is the typical Caribbean or Central American Provincial fauna (Briggs 1974), divided by Miller (1969) up into the "Southern Cool Tropical Subregion" found in inshore waters along the coasts of northern South and Central America and the "Northern Cool Tropical Subregion" found along the southern Gulf of Mexico and southeastern Florida to 28° 00 N. However, we extend this fauna further north into continental shelf environments along the Atlantic coast to Cape Hatteras (35° 00 N) and on the continental shelves of the northern Gulf of Mexico. It is likely that this fauna originated during glacial periods in the southern Gulf of Mexico off Laguna de Terminos, in southern Cuba, the southeastern Bahamas and the Caribbean Sea where ambient water temperature means were 5°C below today's mean sea surface temperatures (Emiliani 1971, 1972).

Epinepheline serranid examples are: Red grouper, *Epinephelus morio*; Scamp grouper, *Mycteroperca phenax;* Snowy grouper, *E. niveatus..*

Warm-Temperate — Species which readily withstand ambient water temperatures below 6°C for prolonged periods (several days) without significant mortality. They prefer water temperatures below 35°C. These species are primarily continental in habitat preference and do not typically occur commonly in tropical geographic regions. However, they also do not prefer temperate ecosystems (north of 37° 00' N. latitude) and prolonged (multi-seasonal) significantly lower ambient water temperatures < 14°C. These species may have a phyletic relationship with tropical families, but are usually differentiated at the generic level. This is the typical Carolinian Provincial Fauna. Epinepheline serranid examples: Speckled hind, *Epinephelus drummondhayi*, Gag, *Mycteroperca microlepis, Black seabass, Centropristis striata..*

Temperate — Species which have a decidedly glacial heritage and withstand ambient water temperatures below 10°C. for months at a time. These are continental species which are often euryhaline but do not do well at ambient water temperatures above 30°C. Though these species may have an ancient phyletic association with tropical fish families they are often differentiated greatly having evolved in cold ambient water ecosystems. This is the typical Virginian and Acadian (Cold - Temperate) Provincial Fauna. Epinepheline serranid examples: None

Sibling species have formed from vicariant events associated with climatic change, glacial and inter-glacial periods and geological formations, isolation associated with greatly differing habitats, such as insular versus continental ecosystems. These species pairs are found in all subfamilies and tribes within serranidae. Apparent sibling (geminate)` species examples are the red and Nassau groupers (*E. morio/E. striatus*), the warsaw and misty groupers (*E. nigritus/E. mystacinus*), the wrasse and lineside basses (*Liopropoma eukrines/L. abberans*), the whitespotted and greater soapfishes (*Rypticus maculatus/R. saponaceous*), the swallowtail and nickol's basslets (*Anthias woodsi/A.nicholsi*), the belted sandfish and serrano de arena (*Serranus subligarius/S. flaviventris*).

Table 2. Habitat and sibling species pairs (geminate species) evolution in Serranidae

	Euryoecious	Continental	Insular	Siblings
Epinephelinae				
Epinephelini	2	11	11	6
Liopropomini	1	2	3	2
Grammistini	3	2	3	2
Anthiinae	1	9	1	1
Serraninae	6	15	14	7+
Totals	13	39	32	

PALEONTOLOGY OF THE FLORIDA PLATFORM AND THE EVOLUTION OF ITS ASSOCIATED ICHTHYOFAUNA

The geological boundaries of the Florida platform are considerably larger than the terrain that is presently above sea level. During the last glaciation, 72-12,000 ybp, the large (250 km wide) west Florida shelf had emerged and the Florida coastline was typified by sharp escarpments or steep slopes around most of the peninsula. Continental shelves were largely absent (Figure 2). The central plateau elevation was 100 m higher and colder. The climate of the peninsula and surrounding waters was temperate or warm-temperate. Habitat heterogeneity was considerably lower than that seen today. Consequently, the glacial Floridian fauna was more depauperate, containing many of the species associated with the Carolinian and Virginian Provinces today (Atlantic sturgeon, *Acipenser oxyrhynchus*; striped bass, *Morone saxatilis*; Atlantic shad, *Alosa sapidissima*; Atlantic menhaden, *Brevoortia tyrannus*; black seabass, *Centropristis striata*; weakfish, *Cynoscion regalis*). These species and others with similar temperate physiologies remain at isolated sites in northern Florida as glacial relicts.

The glacial ichthyofauna of the southern Gulf of Mexico was more diverse, particularly around the Laguna de Terminos. Paleoclimatological evidence reveals a warmer glacial climate west of the Yucatan peninsula than the remainder of the western Gulf of Mexico (Figure 2). This region probably acted as a thermal refugia for species preferring warmer waters during several Pleistocene glacial periods. The Gulf endemics with warm temperate affinities may have evolved here, such as the yellowfin menhaden complex, *Brevoortia gunteri/smithi*; goldspotted killifish, *Floridichthys carpio;* diamond killifish, *Adenia xenica* as well as certain warm temperate species with tropical family affinities, pinfish, *Lagodon rhomboides*; sheepshead, *Archosargus probatocephalus*; spotted seatrout, *Cynoscion nebulosus*. This area may have also acted as a evolutionary center for eurythermic tropical species that range into warm temperate waters today, Gag grouper, *Mycteroperca microlepis*, scamp, *M. phenax*, red grouper, *Epinephelus morio*; gray snapper, *L. griseus*; lane snapper, *L. synagris*; spottail porgies, *Diplodus holbrooki*; mojarras, *Eucinostomus gula, E. harengulus;* cocoa damselfish, *Stegastes variabilis*; slippery dick wrasse, *Halichoeres bivittatus;* emerald parrotfish, *Nicholsina usta*, Gulf surgeonfish, *Acanthurus randalli*, scaled sardine, *Harengula jaguana*.

Not only was the terrestrial Florida platform twice as large during the glacial periods, but so was the Yucatan platform, the Bahama platform and shelf areas off Nicaragua/Honduras and the Windward Islands of the West Indies. The Aves Ridge was closer to the surface also. Warm current flows into the Caribbean from the equatorial Atlantic were not as effective as they are today in entering the Sea. The Caribbean basin cooled down to a mean surface seawater temperature 5°C. lower than today's mean. Eurythermy in truly tropical species could have developed in the Caribbean basin during these glacial periods.

The more sensitive stenothermic tropical species were most likely limited to the Windward Islands and coastal South American from Trinidad south: Nassau grouper, *Epinephelus striata*; black grouper, *Mycteroperca bonaci*; tiger grouper, *M. tigris*; mahogani snapper, *Lutjanus mahogoni*; mutton snapper, *L. analis*; silver porgy, *Diplodus argenteus*; and many tropical coral reef fishes, as well as the euryhaline tropical peripherals: the fat snook, *Centropomus parallelus*, tarpon snook, *C. pectinatus*; Poey's snook, *C. poeyi*; burro grunt, *Pomadasys crocro*; opossum pipefish, *Mycrophis brachyurus lineatus*; bigmouth sleeper, *Gobiomorus dormitor*; esturarine stenothermic tropicals: patao, *Diapterus auratus*; slender mojarra, *Eucinostomus jonsei*; sea bream, *Archosargus rhomboidalis*; emerald parrotfish, *Cryptotomus roseus*; sailor choice, *Haemulon parra*.

With post-glacial global warming sea level rose, tropical western Atlantic land masses declined, warm ocean currents flowed more freely between these land masses and islands and tropical species were distributed to more northerly latitudes, including the Florida peninsula and survived. The majority of Florida fish species are tropical, having migrated to the Florida peninsula only recently, during the Holocene submergence of the Florida platform. These tropical invaders now form a heterogeneous group that often numerically dominate Florida fish communities, particularly those dependent on tropical habitats and ecosystems such as mangrove forests and coral reef formations. Many of these tropical species form the basis for major recreational and commercial fisheries. Most fishery species life histories require estuarine, coastal or shelf edge spawning often with passive/active movement of pelagic eggs and larvae into oceanic waters. Entrainment within oceanic currents allows larval transport for considerable distances downstream and, consequently, loss of larvae from Florida waters, conversely, larval recruitment from Caribbean biogeographical provincial waters.

Post-Glacial Faunal Movement

With the end of the Wisconsin glacial period and warming of waters around the Florida peninsula there was a regression of temperate and warm-temperate faunas northward. The Florida species most obviously impacted were those that prefer temperate climates and have life history strategies that require temperate climatic patterns or temperate ecosystems and habitats. Examples are the striped bass, *Morone saxatilis;* American shad, *Alosa sapidissima,* weakfish, *Cynoscion regalis,* Atlantic menhaden, *Brevoortia tyrannus,* black seabass, *Centropristis striata,* Atlantic sturgeon, *Acipenser oxyrhynchus,* and the sandtiger shark, *Carcharias taurus.* The only Atlantic sturgeon, striped bass and American shad populations remaining in Florida are found within extreme northern Florida, tributaries to the St. Johns River and the Appalachicola River. Striped bass are thought to be practically extinct from Florida today, resident populations being largely maintained by fish hatchery stocking (Dr. James Estes, Florida Fish and Wildlife Conservation Commission, pers. communication).

Warm temperate species still remain as important components of the Florida fauna on both coasts. However, they are interacting and competing with eurythermic and stenothermic tropical species particularly in estuaries from Florida Bay north to the southern Indian River Lagoon. Continental shelf faunas have undergone substantial change from temperate/warm-temperate glacial escarpment faunas to broad sub-tropical shelf faunas as far north as the northern Gulf of Mexico and Cape Hatteras.

With the recession of the temperate species came an expansion of eurythermic tropical species that may often be syntopic with warm-temperate species in estuarine or continental shelf environments. Notable eurythermic tropicals that have invaded the Florida peninsula after glaciation are the lane snapper, *L. synagris*, mangrove snapper, *L. griseus*, gag grouper, *M. microlepis*, scamp grouper, *M. phenax*, and red grouper, *E. morio*. Stenothermic tropical species have invaded continental shelves, estuaries and freshwater tributaries of tropical Florida. Examples are the mutton snapper, *L. analis*, tarpon snook, *C. pectinatus*, fat snook, *C. parallelus*, patao, *Diapterus auratus*, Mayan cichlid, *Cichlasoma uropthalmus*, black grouper, *M. bonaci*, Nassau grouper, *E. striata*, Cubera snapper, *Lutjanus cyanopterus*, and the dog snapper, *L. jocu*. The anthiine serranids and the *Epinephelus nigritus/niveatus/flavolimbatus/ mystacinus* grouper complex, along with the *Lutjanus campechanus/purpureus* complex may have remained in deeper waters around the Florida peninsula and Gulf of Mexico during glacial periods as they would be buffered from surface glacial temperatures to a degree and can withstand ambient temperatures down to 6 - 8°C. today.

MODERN FISH FAUNA OF FLORIDA: FAUNAL COMPLEXITY FROM A COMPLEX ENVIRONMENT

Physical Complexity: Geomorphology, Transitional Climate, Differential Regional Oceanographic Currents

Figures 1 and 3 illustrate the present Florida peninsula physiography and climatic complexity, and associated oceanic current patterns as well as various hydrographic eco-regions. These eco-regions each have a fairly consistent fish community associated with them. These communities can be defined by their complement of temperate, warm-temperate, eurythermic tropical and tropical species as defined above.

In order to analyze the quantitative contribution of various species to the Florida inshore/estuarine fauna nekton surveys which required repetitive long term quantitative sampling programs, typically using trawl and haul seine techniques were used. Many studies have now been conducted throughout the Florida peninsula and elsewhere in the Caribbean which now allow quantitative regional ichthyofaunal assessment. At least three to four separate quantitative surveys were used for each estuary. The extensive reference list used to produce Table 3 are given in Gilmore (1987, 1995). Only the top ten species ranked by number of individuals captured are listed. They are then classified to three thermal and provincial association categories and percentage contribution to the total site fauna calculated.

No stenothermic tropical species made it into the top ten species along the Florida Gulf coast north of Cape Romano to Apalachee Bay. The faunas north of Marco Island and Cape Romano were dominated by warm temperate species (60 - 80 %). Eurythermic tropicals made up 14-40 % of the fauna, north Marco

Island, 54% at Marco/Cape Romano.

In contrast, the southeast Florida, Florida Bay to southern Indian River Lagoon estuarine faunas contained stenothermic tropical species that were abundant and often numerically dominating the local ichthyofauna. Eastern Florida Bay and the southern Indian River Lagoon contained more stenothermic tropicals than warm-temperate or eurythermic species (38-64 % of the fauna). Biscayne Bay and southern Indian River Lagoon revealed a greater biodiversity containing more species in the top ten categories (34 for each estuary) than other Florida estuaries.

North of the southern Indian River Lagoon the estuarine fish faunas are more like those of the Florida Gulf coast. The northern Indian River Lagoon does not have the stenothermic tropical component in its top ten species, 80% being warm temperate. An out-group comparison with the extensive studies done in Pamlico Sound, North Carolina (35° N latitude) shows no eurythermic or stenothermic tropical species dominating the estuarine fauna.

When continental shelf faunas are compared around the state of Florida there is broader distribution of stenothermic tropical species on the Florida east coast, eurythermic tropicals extending to North Carolina on the mid and outer shelf, while Gulf shelf faunas are dominated by warm-temperate and eurythermic tropicals.

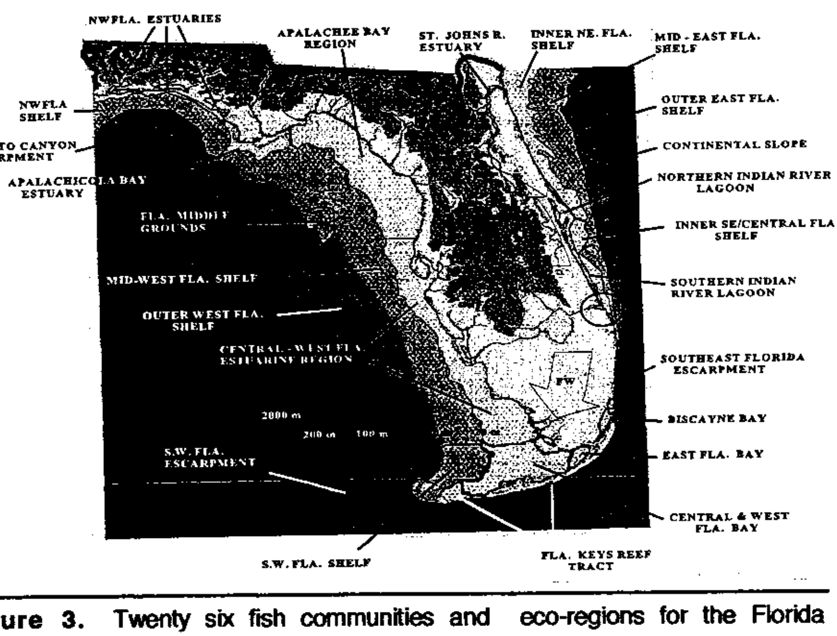

Figure 3. Twenty six fish communities and eco-regions for the Florida peninsula.

Table 3. Stenothermic tropical fishes contribution to Florida estuaries based on top ten species in 3-5 quantitative long term surveys per estuary or region. From studies cited in Gilmore 1987 and 1995. (IRL = Indian River Lagoon; Pam. Snd. = Pamlico Sound, NC)

Thermal Eco-physiological Status		East	Gulf	Estuaries		
	Apalachee (%)	Anclote Cedar K. (%)	Tampa (%)	Charlotte Harbor	Romano Marco (%)	Florida Bay (%)
Warm Temperate	6 (60.0)	11 (78.57	14 (66.67)	8 (80.00)	6 (46.15)	8 (34.78)
Eurythermic Tropical	4 (40.0)	2 (14.29)	7 (33.33)	2 (20.00)	7 (53.85)	9 (39.13)
Stenothermic Tropical	0 (0.)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	6 (26.09)
Total Species	10	14	21	10	13	23
		Atlantic	**Estuaries**			
	E. Fla Bay	Biscayne	S. IRL	N. IRL	Pam. Snd.	
Warm Temperate	0 (0.0)	5 (14.71)	11 (32.35)	12 (80.00)	15 (100.00)	
Eurythermic Tropical	4 (36.36)	18 (52.94)	10 (29.41)	3 (20.00)	0 (0.00)	
Stenothermic Tropical	7 (63.64)	11 (32.35)	13 (38.24)	0 (0.00)	0 (0.00)	
Total Species	11	34	34	15	15	
	West/south	Estuaries				
	Laguna De Terminos	Tx				
Warm Temperate	8 (42.11)	9 (69.23)				
Eurythermic Tropical	3 (15.79)	4 (30.77)				
Stenothermic Tropical	8 (42.11)	0 (0.00)				
Total Species	19	13				

FISHERIES IMPLICATIONS OF BIOGEOGRAPHIC PATTERNS

Effects on Fisheries and Fishery Management

Knowing the preferred habitat, climatic and hydrological setting for all fish species allows the fishery manager to realistically assess the regional survival and production of a specific species, or guild of species. Florida fishery management is complex due to its complex fish/fishery fauna. This also holds true for much of the Gulf of Mexico and Caribbean Sea. The stocking of cultured fish for fishery purposes often has not recognized the indigenous range and life history of the stocked species. This not only could jeopardize the survival of the stocked species wasting agency funds on low survival rates, but also deleteriously impacting fish communities with which the species is interacting as an alien. Classification of entire faunas based on biogeographic distributions, preferred habitat and climatic/hydrological zones, life histories and ecology is required for realistic and cost-effective regional fishery management.

The Florida fish fauna is constantly changing with global warming and, consequently, habitat change. Temperate salt marshes are being displaced by tropical mangrove communities along both coasts of Florida. Management for temperate fish species will eventually be replaced by management for tropical species in the northern estuaries of Florida. The common snook, *Centropomus undecimalis*, rarely landed north of 28.5 - 29°N. latitude on both coasts of Florida will eventually be commonly landed as far north as 30°N. Cichlids will play a greater role in both estuarine and freshwater ecosystems, though, unfortunately, many of these cichlid species are from the tropical western Atlantic, thus not having previously invaded the Florida peninsula during prior interglacial periods. Cichlids are already commonly consumed and sold in regional markets. Eventually it may no longer be feasible and cost effective to stock cold water temperate species such as striped bass in Florida. For these reasons it is important that fisheries managers throughout Florida utilize the most accurate fish distribution and life history data available before making broad management decisions

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