FISHERY ECOSYSTEM PLAN II

OF THE SOUTH ATLANTIC REGION

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South Atlantic Fishery Management Council

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ABBREVIATIONS AND ACRONYMS

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ACE	Ashepoo-Combahee-Edisto Basin National Estuarine Research Reserve APA Administrative Procedures Act
AUV	Autonomous Underwater Vehicle
B	A measure of stock biomass either in weight or another appropriate unit
B_{MSY}	The stock biomass expected to exist under equilibrium conditions when fishing at F_{MSY}
B_{OY}	The stock biomass expected to exist under equilibrium conditions when fishing at F_{OY}
B_{CURR}	The current stock biomass
CEA	Cumulative Effects Analysis
CEQ	Council on Environmental Quality
CFMC	Caribbean Fishery Management Council
CPUE	Catch per unit effort
CRP	Cooperative Research Program
CZMA	Coastal Zone Management Act
DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EBM	Ecosystem-Based Management
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EFH-HAPC	Essential Fish Habitat - Habitat Area of Particular Concern
EIS	Environmental Impact Statement
EPAP	Ecosystem Principles Advisory Panel
ESA	Endangered Species Act of 1973
F	A measure of the instantaneous rate of fishing mortality
$F_{30\%SPR}$	Fishing mortality that will produce a static SPR = 30%.
$F_{45\%SPR}$	Fishing mortality that will produce a static SPR = 45%.
F_{CURR}	The current instantaneous rate of fishing mortality
FMP	Fishery Management Plan
F_{MSY}	The rate of fishing mortality expected to achieve MSY under equilibrium conditions and a corresponding biomass of B_{MSY}
F_{OY}	The rate of fishing mortality expected to achieve OY under equilibrium conditions and a corresponding biomass of B_{OY}
FEIS	Final Environmental Impact Statement
FMU	Fishery Management Unit
FONSI	Finding Of No Significant Impact
GOOS	Global Ocean Observing System

GFMC	Gulf of Mexico Fishery Management Council
IFQ	Individual fishing quota
IMS	Internet Mapping Server
IOOS	Integrated Ocean Observing System
M	Natural mortality rate
MARMAP	Marine Resources Monitoring Assessment and Prediction Program
MARFIN	Marine Fisheries Initiative
MBTA	Migratory Bird Treaty Act
MFMT	Maximum Fishing Mortality Threshold
MMPA	Marine Mammal Protection Act of 1973
MRFSS	Marine Recreational Fisheries Statistics Survey
MSA	Magnuson-Stevens Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
NEPA	National Environmental Policy Act of 1969
NMFS	National Marine Fisheries Service
NMSA	National Marine Sanctuary Act
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OY	Optimum Yield
POC	Pew Oceans Commission
R	Recruitment
RFA	Regulatory Flexibility Act
RIR	Regulatory Impact Review
SAFE	Stock Assessment and Fishery Evaluation Report
SAFMC	South Atlantic Fishery Management Council
SEDAR	Southeast Data, Assessment, and Review
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SDDP	Supplementary Discard Data Program
SFA	Sustainable Fisheries Act
SIA	Social Impact Assessment
SSC	Scientific and Statistical Committee
TAC	Total allowable catch
T_{MIN}	The length of time in which a stock could rebuild to B_{MSY} in the absence of fishing mortality
USCG	U.S. Coast Guard
USCOP	U.S. Commission on Ocean Policy
VMS	Vessel Monitoring System

Document Background

In March 2018, the South Atlantic Fishery Management Council (SAFMC) approved sections to be included in the second SAFMC Fishery Ecosystem Plan (FEP II). FEP II was a mechanism to incorporate ecosystem principles, goals, and policies into the fishery management process. Additionally, FEP II was approved as meeting the requirements for the 5-year review of Essential Fish Habitat (EFH) that is mandated by the Magnuson-Stevens Fishery Conservation and Management Act.

The original vision for this document was to create a series of web pages that would be updated as needed, very similar to a living document. The webpages would include approved habitat policies and documentation, links to mapping tools, and other reference documents. However, with increasing staff workload, the transition to an updated webpage platform, interruptions in the implementation plan due to COVID, staff retirement, and the approval of the new Habitat Blueprint in September 2023, it was determined that the living structure of these webpages was no longer viable.

This is a compilation of all the documents and pages developed under FEP II including a summary of habitats in the managed area, a summary of managed species, habitat policies, the EFH User guide, research and monitoring links, links to mapping tools, and website wording that was used in the living webpages. This was built based on the table of contents for FEP II that was presented to the SAFMC in June 2017.

For further information please refer to the SAFMC webpage: https://safmc.net/fishery-management-plans/habitat/

Contents

Section 1 South Atlantic Ecosystem

South Atlantic Food Web and Connectivity – March 2018

Executive Summary

A key tenet of ecosystem-based fisheries management (EBFM) is the explicit consideration of indirect effects of fisheries, such as through food web processes, when developing harvest strategies and management plans. Examples of unintended consequences include the over exploitation of predators, an increase in abundance of their prey, and a decline of organisms two trophic levels below them, a phenomenon known as a trophic cascade (Carpenter et al. 1985). Fishing on lower trophic level species, planktivorous "forage" fishes for example, may ultimately lead to predator population declines due to food limitation (e.g. Okey et al. 2014; Walters and Martell 2004). Interspecific competition for food occurs when there are two or more species that overlap in time and space and utilize the same limited resource. Competition within a food web also has implications for management, for example when simultaneously rebuilding two competing species or when a non-native species becomes established. Changes in primary production can have noticeable effects on the food web. These "bottom-up" processes are largely driven by changes in climate or physical oceanography, particularly those that drive patterns of precipitation or upwelling and therefore nutrient input. While dynamics of lower trophic level species are more strongly tied to environmental forcing, for most species it's the combination of both fishing and environmental forcing that drive changes in population size (Chagaris and Mahmoudi 2009; Mackinson et al. 2009).

Food webs also serve to connect different components of the larger ecosystem. Seasonal and ontogenetic migrations by some species out of estuaries to coastal areas where they become prey is one mechanism that transfers energy from the inshore to offshore environments. Latitudinal (north-south) migrations provide a means to transfer energy from seasonally productive regions where prey is abundant to less productive regions at other times. Connectivity between the benthic and pelagic food webs is also important for transfer of pelagic and midwater production to seafloor communities and vice versa. Food web linkages connect pelagic forage fishes and their piscivorous predators or demersal carnivores. This connectivity between food webs over space, time, and depth creates multiple energy pathways that enhance ecosystem stability and resilience.

One way to incorporate food web processes into management is through models. Mathematical trophic-dynamic models are particularly useful because they can assist in determining the tradeoffs associated with harvesting fish from different parts of the food web while also allowing for examination of impacts resulting from changes in primary production and other bottom-up processes. Food web models are increasingly being utilized by fisheries managers as ecological prediction tools because they provide the capability to simulate the entire ecosystem from primary producers to top predators to fisheries. Food web models can serve to inform single species assessment and management and are capable of generating reference points (Walters et al. 2005) and ecosystem-level indicators (Coll et al. 2006; Fulton et al. 2005).

The overall objective of this chapter is to provide background, contextual information about food webs that should be considered by the SAFMC when developing single species and fisheries ecosystem plans in the South Atlantic. When possible we provided case studies and examples that are specific to South Atlantic species and ecosystems, however we also recognize that many of the principles discussed in this chapter have not been studied in the region. This is a critical realization as the primary current dynamics (Gulf Stream) makes our area substantially different from even the Gulf of Mexico which has many of the same species. This chapter begins with a brief overview of estuarine, nearshore, and offshore food webs of the South Atlantic Ecosystem. Next we discuss energy flow through food webs and provide contextual information on basal energy sources, the processes regulating energy flow, dominant energy pathways, and how these attributes are related to ecosystem stability and resilience. We then describe how various sub food webs are linked through inshore-offshore, benthic-pelagic, and seasonal connections. The fourth section describes important fishery and non-fishery related threats to food webs. The fifth section gives an overview of food web models and is followed by a brief description of food web indicators. Lastly, we end with a discussion of how these principles and topics can be applied in a fisheries management context and provide summary recommendations for improving our understanding of food webs.

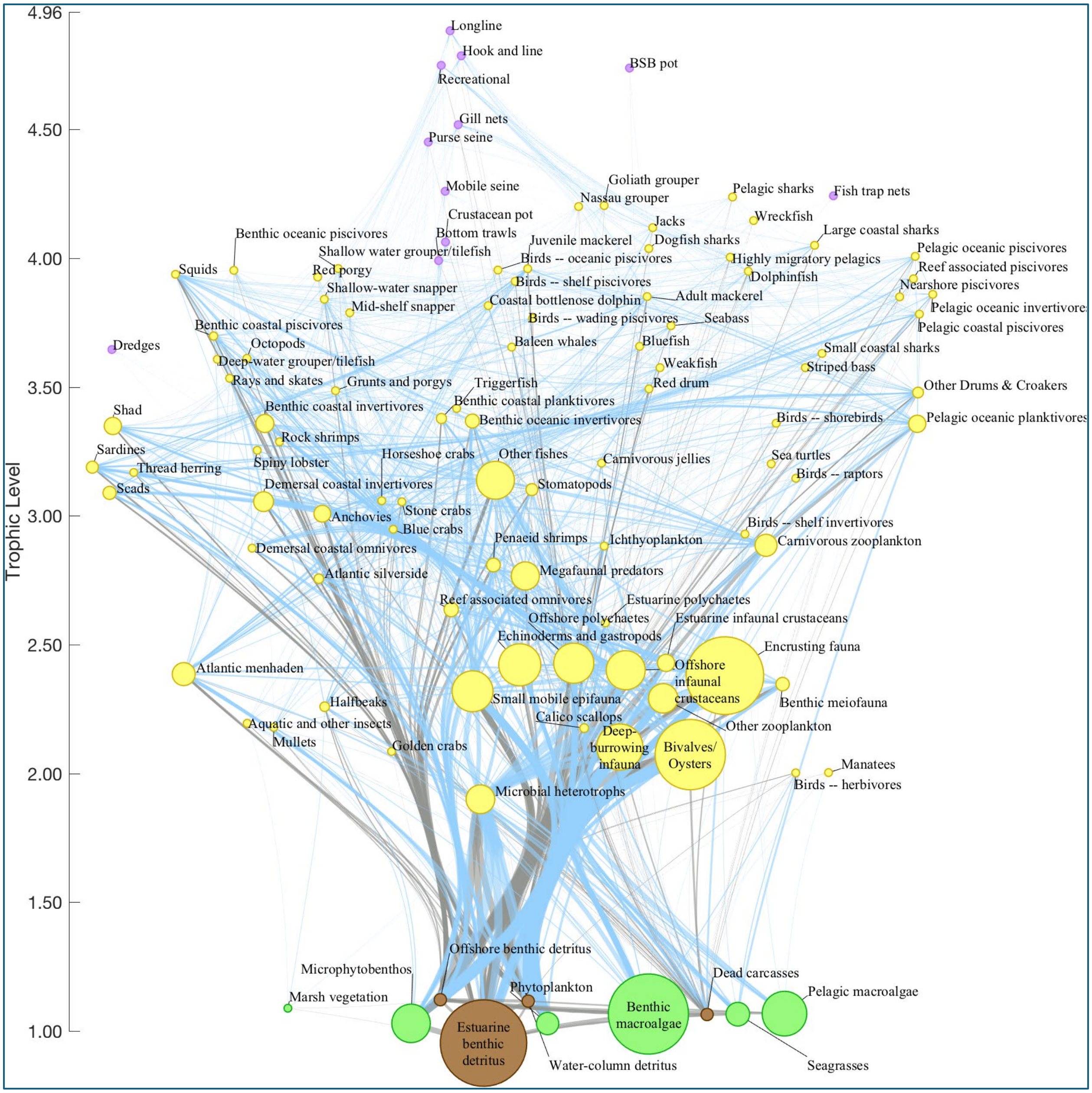

Figure 1-1. The marine food web of the South Atlantic Bight, based on the iteration of the SAB Ecopath model as described in Okey et al (2014), based originally on a preliminary model by Okey and Pugliese (2001). Nodes are colored based on type (green = producer, brown = detritus, yellow = consumer, purple = fleet). Blue for all edges except flows to detritus, which are gray. Diagram produced by Kelly Kearney, UW Joint Institute for the Study of the Atmosphere and Ocean and NOAA Alaska Fisheries Science Center, April 2015.

1. Description of South Atlantic Food Webs

1.1 Estuaries

The estuarine food webs of the South Atlantic are typical of temperate and sub-tropical areas. Primary productivity comes in the form of vascular plants, in particular sea grasses and marsh grasses, macroalgae, and to a lesser degree phytoplankton and mangroves. The primary bottom type in South Atlantic estuaries is soft sediment which supports a variety of diverse infaunal invertebrates that rely on phytoplankton and detritus derived from grasses. In turn, the infauna support a variety of mobile epibenthic invertebrates such as Penaeid shrimp and blue crabs, commercially and recreationally important fish such as spot, drum, menhaden, and flounder, and small reptiles such as terrapins and small mammals such as raccoon and fox (add reference). Oysters (*Crassostrea virginica*) are another key component of the estuarine food web that form large reefs and function to filter algae and particulates from the water column. Oyster reefs and the invertebrate communities they support are prey for most other animals in the estuary and may serve an important role in connecting hard and soft bottom food webs in the estuary due to the reefs providing refuge to animals that may move into soft bottom areas to forage.

Larger vertebrates also play an important role in estuarine food webs in the South Atlantic. A variety of birds are common components of estuarine food webs, with wading birds such as herons and egrets consuming benthic invertebrates and demersal fish and pelagic and diving birds such as gulls, terns, and pelicans consuming a variety of fish and invertebrates. Dolphins and manatees are often found in these estuaries, one foraging on fish and the other on algae and seagrasses, respectively. Humans are a major component of estuaries as their activities impact almost every component of the food web due to the proximity between the two (e.g. coastal development, hook and line fishing, net or seine fishing, crab pots).

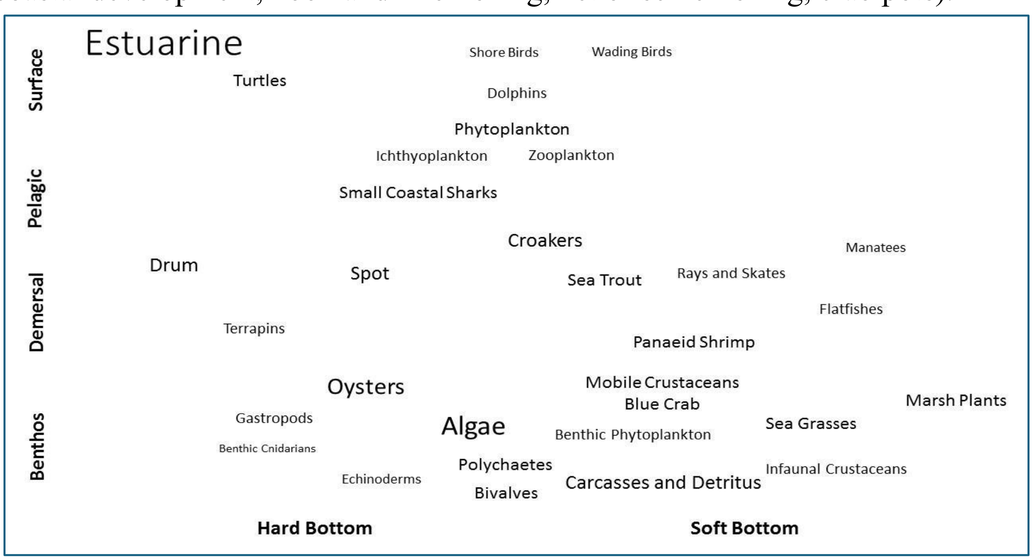

Figure 2-1. Typical components of an estuarine food web.

1.2 Nearshore

Nearshore habitats in the South Atlantic include both soft bottom and hard bottom. In most cases, nearshore hard bottom habitats are low relief, exposed limestone pavement (Henry et al. 1981; Riggs et al. 1996) with attached biota (macroalgae, some corals). In some cases, nearshore hard bottom has moderate relief due to boulders or small ledges (Powles and Barans 1980). The vast majority of the nearshore habitats, however, are soft bottom and support a variety of seagrasses and infaunal and epibenthic invertebrates and fish. Some of the most common mobile and pelagic invertebrates found in nearshore habitats are commercially important such as Penaeid shrimp, blue crabs, and horseshoe crabs. The diversity of fish increases in the nearshore relative to the estuary, although there is a fair amount of overlap in species composition. For example, spot, drum, croaker, weakfish, kingfish, and flounder all utilize nearshore soft bottom areas and are generalist predators that consume diverse diets including fishes, crustaceans, and polychaetes (Willis et al. 2015). Pelagic nearshore waters are inhabited by filter-feeding menhaden consuming phytoplankton and zooplankton, as well as bluefish and juvenile mackerels preying primarily on smaller fishes such as anchovies and Atlantic bumper (SEAMAP unpublished data). Small coastal sharks, skates, and rays also comprise a key component of nearshore ecosystems, feeding on fish and benthic invertebrates. Many of the same large mammals and seabirds that utilize the estuary also are found in the nearshore. Dolphins in particular consume fish in this area and humans extract fish and invertebrates with pot or trap fishing and hook and line. Sea turtles also commonly use the nearshore areas and consume seagrasses, sponges, cnidarians and other invertebrates.

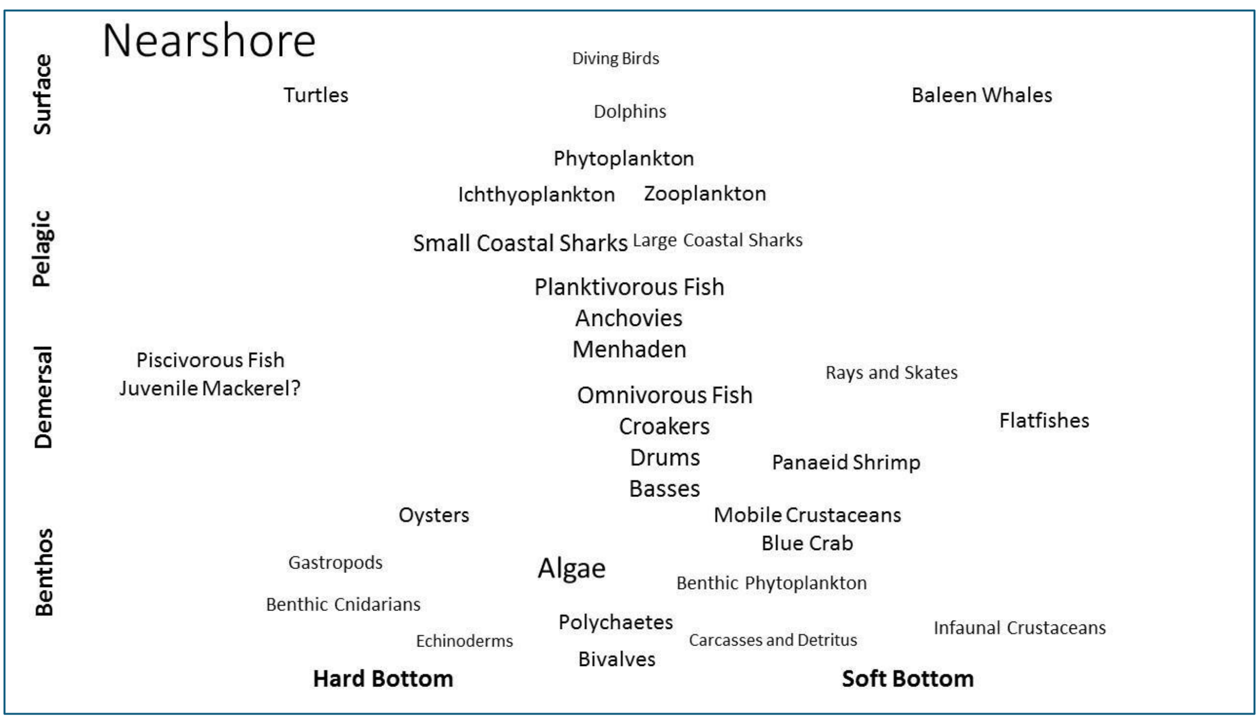

Figure 2-2. Components of a nearshore food web.

1.3 Offshore

Live or hard bottom habitats offshore in the South Atlantic support a variety of fish species, including groupers, snappers, grunts, and porgies as the most common. The majority of these species are piscivorous as adults, but many consume diverse diets. For example, Black Sea Bass (a small Serranid grouper) relies heavily on bony fish but nearly a quarter of the diet is comprised of crabs or other crustaceans (Hood et al. 1994). Red Snapper, a relatively large-bodied, fast growing snapper, consume a small fraction of benthic invertebrates as well as other fish (MARMAP, unpublished data). Vermilion Snapper also consume fish, yet are well adapted to feed on small pelagic and planktonic prey such as salps, copepods, and ctenophores (Grimes 1979, Sedberry and Cuellar 1993). Conversely, Red Porgy and Grey Triggerfish prey more heavily upon epifaunal invertebrates such as crabs, barnacles, bivalves, echinoderms, and polychaetes (Goldman et al., in review). Deep-water fish such as Snowy Grouper, Blueline Tilefish and Wreckfish generally prey upon other fish and squid, although diet studies are difficult for these species due to barotrauma during capture (Goldman and Sedberry 2011). Highly migratory species that feed in the pelagic zone of the South Atlantic Bight include kingfish, cobia, dolphinfish, wahoo, tunas, and billfishes. Most of these species rely on forage species like flying fish, squids, scads, ballyhoo, and menhaden as well as larger chub mackerel. Right whales are seasonal but important components of this food web as well as they rely on mid water zooplankton and can transfer energy along the coast (Lysiak 2009).

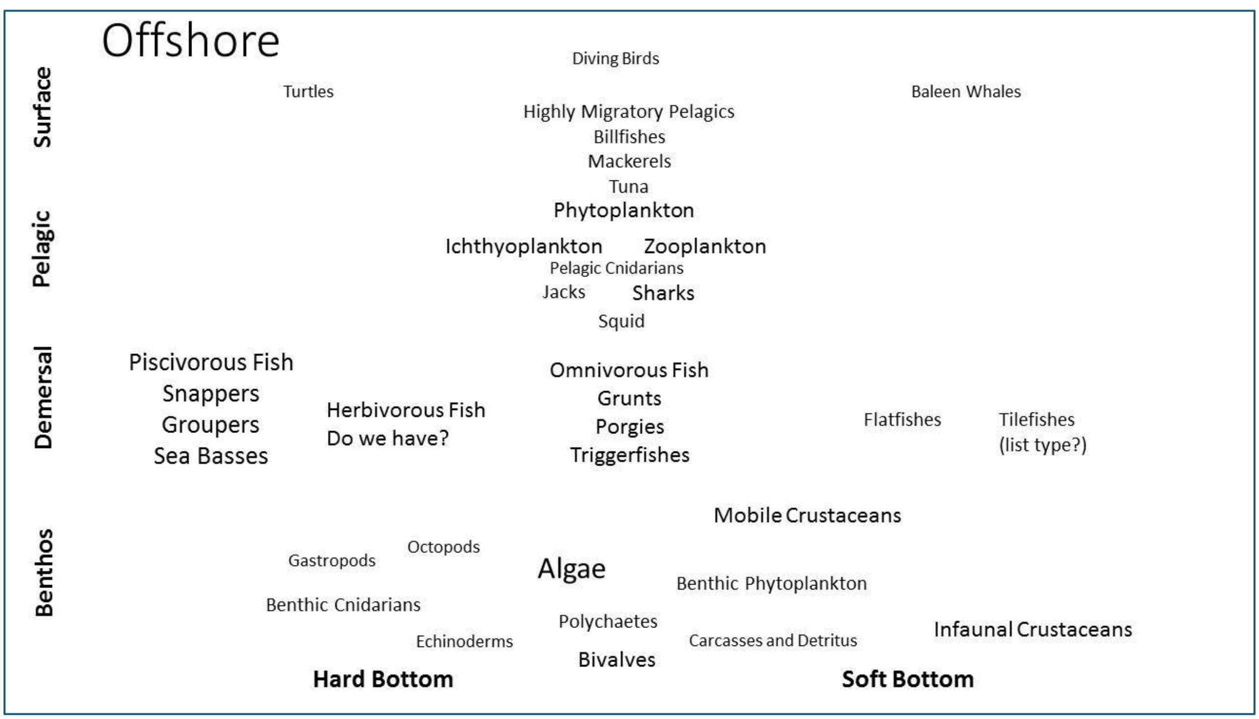

Figure 2-3. Components of the offshore food web

1.4 Species Interactions and Trophic Dynamics

Marine ecosystems are more likely to be impacted trophically by perturbations such as overfishing as the path lengths connecting marine food web components tend to be shorter on average than other ecosystems (Dunne et al. 2004). However, healthy, diverse ecosystems may be more resilient to perturbations due to increased complexity of trophic interactions and redundancy (Martinez 1993 and 1994; Saporiti et al. 2014). Compared to other U.S. marine ecosystems, the SAB standing biomass of ecological and economically important species is low, likely due to limitations in nutrient levels and primary productivity (Hargrave et al. 2009).

1.5 Life History Considerations

Many of the species in the South Atlantic have complex life histories, which often include several changes in habitat during their life cycles. Several endangered or threatened diadromous species are temporary components of one or more of the food webs mentioned above, including the American Eel (estuarine, nearshore, and offshore) and Sturgeon (estuarine and nearshore; add references). Gag Grouper are a large-bodied offshore piscivore as adults but their juveniles are found in oyster and seagrass beds in the South Atlantic estuaries, which are essential for their life cycle (Casey et al. 2007). Round Scad are an example of spatial partitioning in diet among life stages as adults occur either on the inner or outer continental shelf and juveniles are found mid-shelf (Hales 1987). There is a wealth of work supporting the importance of mangroves and marshes to many economically important species for a variety of life history stages (e.g. Kimirei et al. 2011).

1.6 Emerging Trends

There is a paucity of data for offshore fish that are not the most economically important and those that are more pelagic; thus we may be under-representing important links in this food web. This is especially true of species of forage fish that likely provide important links between primary and secondary consumers and large-bodied economically important snappers and groupers and among habitats (but see Sedberry 1985). Nevertheless, Okey et al. 2014 quantitatively characterized and modelled forage species within the South Atlantic Bight Ecopath (food web) model. There is also little known about the potential impacts of invasive species entering the SAB food webs. For example, Lionfish *Pterois* sp., have been shown to reduce recruitment in both nursery areas and on reefs (Barbour 2010) and to compete for both habitat and resources in the Caribbean (Albins and Hixon 2013). Additionally, porcelain crab *Petrolisthes armatus* may reduce predation pressure on native mud crabs (Hollebone and Hay 2008).

2. Energy Pathways

2.1 Basal Food Web Resources

The principal sources of carbon, and energy in marine and estuarine food webs include detritus, salt marsh grasses, seagrasses, phytoplankton, macrophytes, and filamentous algae. In estuarine waters of Sapelo Island, Georgia, *Spartina* detritus, phytoplankton, and benthic diatoms make up the major sources of organic matter that supports secondary production (Haines 1976; Peterson and Howarth 1987). In marine waters, organic carbon is more closely related to phytoplankton than marsh grasses (Rounick and Winterbourn 1986). Seagrass meadows can also constitute a significant source of carbon for certain species (Fry and Parker 1979). In oceanic waters, almost all of the water column and sediment organic matter is derived from phytoplankton production, with less influence from terrestrial inputs as one moves offshore. Therefore, the contribution of carbon from various basal resources varies over space, particularly along the inshore-offshore gradient, and time (or season) as production shifts between primary producers (Radabaugh et al. 2013). Ratios of carbon isotopes ($\delta^{13}C$) vary among primary producers and can be used to determine ultimate sources of dietary carbon in food webs. The ratios of $\delta^{13}C$ measured in organisms reflect long-term dietary patterns and the carbon sources that assimilate into biomass (Layman et al. 2012). Additionally, stable isotope ratios can be applied to evaluate community-wide aspects of food web structure (Layman et al. 2007).

2.2 Top-down and Bottom-up control

The dynamics of food webs are regulated through a combination of environmental, or 'bottom-up' effects, and 'top-down' consumer effects (harvest and predation) (McOwen et al. 2015; Power 1992; Reilly et al. 2013). Bottom-up factors are those that control how primary production enters into the food web over space and time and can include delivery of nutrients or changes in habitat and water quality. In systems where the food web is dominated by bottom-up control, the availability of prey has a strong effect on predator dynamics including migration, survival, and reproduction (Frederiksen et al. 2006). Bottom-up factors are influenced by processes such as nutrient loading (Paerl et al. 1998; Pinckney et al. 2001), large scale climate oscillations (ENSO, AMO) (Barber and Chavez 1983), and circulation patterns (Behrenfeld et al. 2006).

Top-down factors are those that drive consumer abundances and typically include harvest and predation. Top-down controls are therefore altered by processes such as overfishing and introduction of exotic species. Severe depletion of predator populations through fishing can induce trophic-cascades causing increases in their prey and decreases in prey two trophic levels below them (Frank et al. 2005; Steneck 2012). In cases where small fish consume the larval or early juvenile stages of a predator, this can lead to depensatory failures in recruitment of the predator species, and delay stock rebuilding (Walters and Kitchell 2001). Additionally, invasive species can exert top-down control on food webs through direct predation on native prey and competition with native consumers (Albins and Hixon 2008; Albins and Hixon 2013).

Marine food webs are usually regulated by a combination of top-down and bottom-up processes (Mackinson et al. 2009; McOwen et al. 2015) that vary over time and space. When a system is bottom-up limited, the availability of prey has a stronger effect on predator dynamics (Frederiksen et al. 2006). When the system is no longer bottom-up limited, top-down controls become more important. Additionally, the processes can be tightly coupled leading to a false dichotomy between the two (Vinueza et al. 2014). For example, overharvest of herbivorous fishes can lead to phase shifts from coral to algal dominated reef communities (Hughes 1994) and removal of seals has led to overgrazing of kelp forests by sea urchins (Estes et al. 2009). Within a system, the influence of bottom-up versus top-down drivers on various species and functional groups depends on trophic level and how energy flow is mediated by predator-prey interactions (Chagaris and Mahmoudi 2009; Mackinson et al. 2009).

Whether or not fisheries production within large marine ecosystems is driven by bottom-up or top-down forcing depends on oceanographic conditions, historical harvest, targeted species, and food chain lengths (McOwen et al. 2015). Anchovy and sardine fisheries, like those located along the eastern boundaries of the Atlantic and Pacific oceans, are believed to be influenced by bottom-up processes, i.e. the delivery of nutrients via upwelling (McOwen et al. 2015; Ware and Thomson 2005). In relatively low productivity systems such as the tropics and Northern Atlantic, fisheries production is best explained by fishing effort rather than environmental processes (McOwen et al. 2015).

2.3 Energy Pathways and Stability of Food Webs

Fast and slow energy channels refer to the turnover rates of populations (reflecting ecological and life history characteristics), which are related to energy fluxes and interaction strengths. Basal resources in aquatic food webs may be either pelagic (phytoplankton) based or benthic (detritus) based. In a meta-analysis of food webs, turnover rates in the pelagic compartment were found to be consistently higher than benthic compartments (Rooney et al. 2006). Thus the pelagic compartment is considered to be the “fast” channel. Many higher order consumers derive carbon from both channels. Coupling of these channels by consumers leads to more stable system dynamics (Gross et al. 2009). Stability is enhanced when energy flow between the pelagic and benthic channels becomes asymmetric and unsynchronized (more flow from either the fast or slow channel at different times). The fast and slow channels complement one another to produce stable recovery following a strong perturbation (Rooney et al. 2006; Rooney and McCann 2012).

The theory of asymmetry in energy pathways as a stabilizing structure of food webs has implications for management of marine resources. For instance, removal of predatory fish threatens to decouple the fast and slow energy channels and can destabilize the system (Bascompte et al. 2005). Nutrient loading can effectively homogenize production into the pelagic pathway or allow the pathways to become synchronized, also destabilizing the system. The fast channel allows for rapid recovery of predator populations while the slow channel ensures a less variable resource base for predators, allowing for a rapid but muted (i.e. more stable) return to equilibrium (Rooney and McCann 2012).

2.4 Dominant Pathways

The energy pathways in marine ecosystems that connect low and high trophic level species are dominated by forage species that serve as critical links to transfer energy and biomass through marine food webs (Anderson and Piatt 1999, Smith et al 2011, Cury et al. 2011, Pikitch et al. 2012). Some South Atlantic examples of important forage species include sardines, herring, menhaden, scad, shad, silversides, mullet, anchovies, halfbeaks, shrimp, pinfish, and other small pelagic planktivores (Okey et al. 2014). The most important characteristic of forage fish from an ecological and human perspective is that the higher trophic level predators are dependent on them either directly or indirectly for energy intake and biomass consumption. Indeed, the relative abundances of particular forage fish species with different energetic and nutrient contents can directly influence the fitness of predators in the ecosystem, the health of their populations, and subsequently the regulation and organization of biological communities in the ecosystem (Trites and Donnelly 2003, Wanless et al. 2005, Pikitch et al. 2012). In the South Atlantic Bight, forage species serve as important prey resources for popular sport fish species, such as snapper, grouper, mackerel, cobia, dolphinfish, and sailfish. Important commercial fishes such as mackerels, swordfish, amberjack, tuna, snappers, and groupers are also dependent on healthy abundances of forage species to grow and reproduce. Beyond economically important fisheries, many other apex marine predators such as migrating whales, coastal and pelagic sharks, as well as bottlenose dolphins rely on forage species for nourishment, and marine birds such as pelicans, skimmers, terns, and herons feed heavily on forage species and depend on them to successfully rear their chicks (Fins and Feathers Report, 2013).

Forage fish are generally small fast-growing species with high reproductive output and relatively short life-spans giving them the capacity for rapid population growth when environmental conditions are favorable (Checkley et al. 2009). At the same time, their propensity to form large schools make them easy to target and susceptible to overexploitation, especially at small stock sizes when their range is constricted but catch rates remain stable (Csirke 1989, Prince et al. 2008, Pinsky et al. 2011). Additionally, they may undergo high fluctuations in juvenile recruitment due to environmental variability and strong top down control from predators (e.g. Cisneros-Mata et al. 1995, Baumgartner et al. 1992).

2.5 Emerging Trends

Recent broad scale analyses of the science and management of forage fish populations have shown that conventional MSY catch limits for forage fishes can reduce the energy pathways that support marine mammals, seabirds, and economically important fish stocks by depleting their food supplies (Pikitch et al 2014, Essington et al. 2015, Koehn et al 2017, Hilborn et al 2017). While the magnitude and direction of the relationship linking forage fish abundance with predator abundance can vary on a case by case basis depending on model assumptions, taxonomic resolution, and functional groupings of predator/prey interactions, conservation and management of forage populations by explicitly accounting for their role as prey in marine food webs is fundamental to maintaining the overall health and stability of marine ecosystems. In order to ensure that the integrity of South Atlantic food webs and the interconnectedness of forage fish populations and their environments are maintained, essential science and monitoring information should be obtained to accurately account for the dietary needs of predators for forage species. In addition, the abundance of important forage species should be monitored and quantified for inclusion in stock assessments, ecosystem models, and other scientific tools and processes to enable comprehensive and sound management decisions that incorporate both ecosystem considerations and economic tradeoffs.

3. Connectivity among Food Webs

3.1 Introduction

Daily, seasonal and ontogenetic movements of fishes are often associated with optimal foraging strategies that include following of prey movements, engaging in specific feeding behaviors, and incorporating mechanisms to avoid predators while occupied with feeding (e.g., Fortier and Harris 1989, Sims 2013, Pereira and Ferreira 2013, Catano et al. 2016). Movements to optimal foraging grounds or to areas or times with reduced predator activity connect feeding grounds with areas where fish rest, spawn, and conduct other non-feeding activities. These non-feeding areas may include completely different habitats from feeding habitats, such as water column vs. reef, sand bottom vs. reef, seagrass vs. sand, and many other contrasting habitat connections. To understand how fishes distribute themselves in nature, and are thus available to local fisheries, it is important to know their preferred habitats, the distribution of those habitats, and the reasons why fishes select particular habitats (and not others) at certain times (Sims 2003).

Among reef fishes that dominate fisheries of the South Atlantic region, mobile invertebrate feeders represent the most abundant trophic group in subtropical and temperate environments, preying preferentially on crustaceans, mollusks and polychaetes associated with consolidated hard bottoms or unconsolidated substrate (Pereria and Ferreira 2013). Invertivores of the South Atlantic Bight include very abundant species such as grunts, porgies and smaller snappers that move among habitats and connect differing habitats through their foraging (Randall 1967, Sedberry 1983, Sedberry and Van Dolah 1984, Sedberry 1985, Sedberry and Cuellar 1994, Pereira and Ferreira 2013). These movements may alter predation risk to the invertivores, which often serve as prey for higher trophic levels like large snappers, groupers and sharks (e.g., Randall 1967, Delorenzo et al. 2015). Many predator habitat choices are related to prey availability and prey movements (e.g., Loefer et al. 2007, Pereira and Ferreira 2013). For many reef fishes, these choices include daily foraging excursions off the reef onto adjacent sand or seagrass areas (Sedberry 1985), or into the water column above the reef (Sedberry and Cuellar 1994), to feed at times or in areas where prey is abundant and the foragers are less vulnerable to predation themselves, and there is less competition with other fishes in diverse reef fish assemblages.

In addition to daily or other frequent foraging movements, the early life history and juvenile stages of fishes often move from less productive waters where they were spawned to more productive areas for feeding, rapid growth and predator avoidance. These ontogenetic movements may be superimposed upon seasonal movements that coincide with productivity patterns (Lindeman et al. 2000). As juvenile fishes then mature in nursery habitats, increased energy demands associated with gonad development cause them to move into different habitats where larger and more energy-rich prey organisms are available (e.g., Randall 1967, Sedberry 1983, Mullaney and Gale 1996, Young and Winn 2003, MacNeil et al. 2005). These ontogenetic movements that are associated with feeding connect different geographic areas and a variety of estuarine, coastal and oceanic habitats (Pereria and Ferreira 2013). Feeding movements transfer energy and biomass among habitats, and they couple less productive resting habitats with more productive feeding grounds, or provide trophic or energy subsidies from one habitat and faunal assemblage to another (e.g., Sedberry 1985, Weaver and Sedberry 2001, Goldman and Sedberry 2010).

3.2 Benthic-Pelagic Coupling

Grober-Dunsmore et al. (2008) reviewed benthic-pelagic coupling in regards to the effects of pelagic fishing on benthic communities and the role of MPAs to promote healthy fish stocks. They determined that, because of benthic-pelagic coupling mediated by food web connectivity, recreational pelagic fishing may not be compatible with benthic conservation in (1) high relief habitats; (2) depths shallower than 50–100 m (depending upon the specific location); (3) major topographic and oceanographic features; and (4) spawning areas. Much of the productive fishing grounds of the South Atlantic regions fall within these descriptions.

Auster and colleagues (Auster et al. 2009, Auster et al. 2011) demonstrated that pelagic piscivores (Great Barracuda, Greater Amberjack and other jacks, Spanish Mackerel) drive pelagic forage fishes toward rocky reef outcrops, where they become prey for demersal predators (Black Sea Bass, Bank Sea Bass, Gag, Scamp). Feeding behavior of mesopelagic piscivorous fishes connects pelagic waters with benthic habitats by inducing responses in prey fishes that produce feeding opportunities for demersal piscivorous fishes. Auster et al. (2009, 2011) described a web of predation behaviors and the responses of prey that indirectly link midwater and demersal piscivorous fishes. These fishes include important components of the Snapper/Grouper management unit.

The linkages between pelagic and demersal fishes can occur by demersal fishes feeding on pelagic prey species and vice versa. It can also occur through ontogenetic shifts in vertical distribution of demersal predators. For example, pelagic and plankton-feeding juvenile stages of Tomtate and other grunts settle to the seafloor to assume a demersal existence and then feed on benthic prey (Sedberry 1985, Pereira and Ferreira 2013). Tomtate are in turn fed on by several species of jack, grouper, snapper, eel and other reef fishes (Randall 1967), further connecting reef, pelagic and sand-bottom habitats.

Many different physical and biological processes contribute to interactions that transfer midwater production to seafloor communities (Grober-Dunsmore et al. 2008, Auster et al. 2009). Physically-mediated processes related to advection of oceanic waters onto the shelf enhance feeding opportunities of deep-reef demersal fishes such as Vermilion Snapper. Vermilion Snapper, a dominant demersal species of mid- and outer-shelf reefs (Sedberry and Van Dolah 1984) have a diet dominated numerically by planktonic species that include copepods, pelagic amphipods, pelagic decapods (including crab larvae), salps and fish larvae. At shelf-edge reefs, advection of oceanic waters and their plankton onto the shelf connects oceanic pelagic species to demersal reef predators. Vermilion Snapper that forage on oceanic plankton advected onto shelf-edge reefs transfer oceanic pelagic biomass to shelf reefs. Vermilion Snapper, in turn, are fed on by other demersal predatory fishes (Randall 1967, Sedberry 1988) and thus may provide trophic links among top-level carnivores and oceanic or shelf plankton, and reef benthos (Sedberry and Cuellar 1993).

Biologically-mediated processes (such as vertical migration behavior) also enhance feeding opportunities of deep-reef demersal fishes such as Wreckfish. Vertically-migrating zooplankton and their pelagic predators provide prey for demersal Wreckfish when daily migrations bring these species in proximity to the sea floor on deep reefs (Weaver and Sedberry 2001, Goldman and Sedberry 2011). Thus, demersal fishes that feed on planktonic invertebrates also couple pelagic and benthic habitats over shelf and shelf-edge reefs of the southeast. The greater biomass and diversity of fishes in rocky reef habitats in the region, compared with sandy areas, may be the result of trophic links through reef-associated fishes, such as Vermilion Snapper and Tomtate, with other ecotopes on the shelf (Sedberry and Cuellar 1993). Pelagic copepods and decapods are important prey in the diet of juvenile Tomtate, which shelter in the reef during the day, transferring energy to the reef in the form of feces and as prey for piscivorous fishes (Sedberry 1985, Auster et al. 2009). Vermilion Snapper, although reef-associated, do not feed heavily on reef species, and may be important in transferring energy from the water column and adjacent sandy areas to the reef (Sedberry and Cuellar 1993).

In summary, trophic links connect planktonic biomass to benthic habitats, and biomass from adjacent sandy areas to hard-bottom reefs. They also connect pelagic forage fishes and their piscivorous predators to demersal piscivores. The links include ontogenetic changes in habitats, and foraging migrations that occur on daily, seasonal and ontogenetic time scales.

3.3 Inshore-Offshore Connections

In subtropical and warm-temperate zones, many reef fishes undergo migrations to spawn at particular reef sites that probably possess hydrographic regimes or biological assemblages that enhance survival of offspring (Sedberry et al. 2006, Farmer et al. 2017). These migrations often involve cross-shelf movements to spawning sites at the shelf edge or insular drop-offs (e.g., Carter et al. 1994, McGovern et al. 2005, Sedberry et al. 2006). These spawning areas must be hydrographically connected to the habitats where post larvae settle from the plankton to benthic habitats. Larval durations vary and local settlement near spawning sites is possible; however, for some species such as Gag, larvae must be transported from shelf-edge spawning sites into distant estuaries were small post larvae settle (Keener et al. 1988, Lindeman et al. 2000, Sedberry et al. 2006). Later in life, these juveniles move out of estuaries and take up residence on offshore reefs (Sedberry and Van Dolah 1984, Mullaney and Gale 1996), eventually returning to the shelf-edge to spawn. The life histories of estuarine-dependent species such as Gag connect inshore coastal and estuarine productivity to offshore habitats. While Gag may be estuarine-dependent, facultative use of estuaries is more common in marine fishes and demersal stages of at least 50 reef fish species show some degree of ontogenetic migration across the shelf (Lindeman et al. 2000).

For some marine fishes exchange of individuals between estuarine and offshore habitats occurs primarily during a pelagic early life history stage (Cowen and Sponaugle 2009), although there may be daily, seasonal, reproductive and ontogenetic movement of fishes between offshore marine and inshore estuarine habitats, particularly in coral reef/mangrove areas. (e.g., Sedberry and Carter 1993, Sedberry et al. 1998, McGovern et al. 2005, Pikitch et al. 2005). Spawning strategies of offshore marine fishes ensure that the pelagic eggs and larvae will be delivered to the appropriate benthic settlement habitats at settlement time, which can be days to months after spawning and may include inshore estuarine areas (Lindeman et al. 2000). Fishes spawn within particular depth and/or latitudinal zones, with concomitant and predictable seasonal circulation patterns, to ensure that this delivery from offshore reefs to estuaries takes place.

3.4 Latitudinal Connections

Because of the complex ocean circulation off the southeastern U.S., there are dominant and predictable mechanisms for long-distance transport of water masses and planktonic stages of fishes. The Florida Current and Gulf Stream transport larvae northward from the tropics. While the Gulf Stream can carry larvae great distances, including expatriation from the region to northeastern North America (Markle et al. 1980, Olney and Sedberry 1983, Hare et al. 2009), Gulf Stream eddies on the western side of the current, where many fishes spawn, set up mechanisms for local retention of some water masses and any larvae they carry from local or more-southern spawning (Govoni et al. 2009, Govoni et al. 2013). These eddies also transport water masses and plankton inshore to coastal and estuarine nursery areas (Govoni et al. 2009). Drifter studies have indicated that transport of pelagic larval stages from south to north (and vice versa) through drift. Drift and active swimming facilitate exchange of eggs and larvae with non-spawning habitats and among MPAs (from north to south) in the region and ensure that post larvae settle into appropriate habitats (Lindeman et al. 2000, Marancik et al. 2005, Hare and Walsh 2007). Estuarine and coastal waters, where many shelf-spawning fish species spend their early planktonic or juvenile stages (e.g., Lindeman et al. 2000), are also connected hydrographically to offshore adult habitats.

There are a number of MPAs that restrict fishing in the region (Figure). In South Florida, this includes areas within Biscayne Bay National Park, Florida Keys National Marine Sanctuary (FKNMS) and its Tortugas Ecological Reserve. Up the Atlantic coast of the southeast, there are several MPA that restrict all fishing (e.g. the Research Area of GRNMS) or just bottom fishing (SAFMC MPAs and HAPCs). These protected areas include important reef fish spawning sites (Lindeman et al. 2000, Sedberry et al. 2006, Farmer et al. 2013). These MPAs are connected by Gulf Stream flow (Hare and Walsh 2007, Lesher 2008), and these include connections from known spawning areas within and outside of the MPAs. For example, Gag, Scamp, Red Grouper and Gray Triggerfish are common as juveniles and small adults at Gray's Reef National Marine Sanctuary, which has a no-fishing zone off Georgia, but spawn mainly at shelf-edge reefs (around 55 m), including SAFMC MPAs at the shelf edge. As mentioned earlier, Gag use shallow coastal or estuarine waters as nursery areas, but make either an ontogenetic shift or spawning migration to the outer shelf, spending part of that time at inner-shelf reefs like those at Gray's Reef. A combination of shelf-edge (SAFMC), estuarine (e.g., Sapelo Island National Estuarine Research Reserve) and inner shelf (Gray's Reef) protected areas appear to be connected during the life history of species such as Gag, thus maximizing the benefits of each of these MPAs (Green et al. 2015). Larval durations of Gag [31-66 d (Keener et al. 1988)] match well with drift times for water masses from offshore MPAs to coastal nursery habitats (Hare and Walsh 2007).

In addition to drift of early planktonic stages of fishes, there is active meridional migration by demersal stages that are related to many life history factors, including spawning, food availability, temperature preferences (Sedberry et al. 1998, McGovern et al. 2005, MARMAP 2007, mackerel and cobia papers). Gag, Cobia, and Greater Amberjack undertake extensive migrations along the coast, with individuals moving from the Carolinas into the Gulf of Mexico or Caribbean Sea. King Mackerel annually migrate between the Carolinas and south Florida (Sutter et al. 1991, Schaefer and Fable 1994). These migratory species spawn at shelf-edge reefs in depths from 50-100 m and have been (prior to seasonal closures) more easily accessed by fishermen off south Florida than areas north due to the narrow continental shelf from Jupiter Inlet through the Florida Keys. This narrow continental shelf off Florida increased fishing mortality for many other species by "funneling" them close to shore in the vicinity of the high human population (McGovern et al. 2005).

3.5 Seasonal Connectivity

Studies of larval fish assemblages in the South Atlantic region have shown that there is cross-shelf transport of water masses and fish larvae, with seasonal variability. Marancik et al. (2005) found that in spring, summer, and fall, larval fish assemblages determined by ordination of ichthyoplankton collections at a reef site off Georgia were similar to other inner-shelf (13-19 m average depth) stations, and that this grouping was similar to middle-shelf (20-40 m) stations in spring, summer, and winter. Larval fish assemblages at inner and middle-shelf stations were different from outer-shelf stations (40-50 m), indicating perhaps unique assemblages at the shelf edge, under greater influence of the Gulf Stream. The winter station ordination, however resulted in a less distinct cross-shelf pattern and perhaps more mixing in of waters across the shelf in winter. Generally, Marancik et al. (2005) found that assemblages of fish larvae from middle-shelf depths (between the 20- and 40-m isobaths) included taxa that were found across the shelf. Oceanographic studies of the Charleston Gyre indicate that this feature facilitates greater cross-shelf transport in winter than in other seasons, enhancing the cross-shelf transport of species that spawn at the shelf edge in winter but have estuarine-dependent larvae, such as Menhaden, Gag, Spot, Croaker and others (Bane, Govoni Bump and other papers). Seasonality of occurrence of larval fishes probably reflects seasonality of spawning and plankton productivity and spawning, which it timed to productivity pulses.

Recruitment of hard-bottom invertebrates is also seasonal in the South Atlantic region, with seasonal pulses of large numbers of invertebrates in winter (Van Dolah et al. 1988). These pulses may provide additional prey needed for fishes as gonads mature for winter and early spring spawning peaks that occur in most species (Sedberry et al. 2006).

3.6 Emerging Trends

There is evidence of climate change and ocean acidification on the southeast continental shelf. While the effects of this on fish assemblages are not known, experimental studies have shown that rearing juvenile fishes at high temperature (31.5 °C) and current (420 µatm) or slightly increased (530 µatm) CO_2 concentrations resulted in reduced food consumption and foraging activity. Rearing at high temperature and high CO_2 (960 µatm) further amplified this result. Maintaining food consumption and foraging activity in high temperature and CO_2 conditions that are predicted from climate change models may reduce fish's energy efficiency if the thermal optimum for food assimilation and growth has been exceeded. Thus, fishes may end up reducing their survivability by increasing their predation risk in order to effectively forage. These results suggest that changes in foraging behaviors caused by the interactive effects of increased temperature and CO_2 could have significant effects on the growth and survival of juvenile reef fishes by late century (Nowicki et al. 2012).

For species like Vermilion Snapper and juvenile Tomtate that forage in the water column (Sedberry 1985, Sedberry and Cuellar 1993), the patchiness of planktonic prey probably determines foraging range and success (Sims 2003). Few plankton studies have been conducted in the region. With newer acoustic technology available, it is possible to more rapidly determine location and residence times of plankton patches that support foraging fishery species like Vermilion Snapper.

In addition to continuing and expanding studies of feeding habits of fishes, we need additional data on available prey in the habitat (Sims 2003). As mentioned, plankton biomass can be obtained acoustically, but additional surveys are needed of benthic communities and infaunal biomass to determine important foraging habitats and prey availability of the many fishes like Tomtate and Scup that forage on infauna and transfer energy among benthic habitats. Testing Optimal Diet Models for predators of mobile prey may be possible by combining fine-scale tracking of individuals with detailed surveys of prey species present across different microhabitats such as hard bottom reefs and adjacent sand areas (Sims 2003). Comparing stomach contents to prey communities is a necessary first step to determining prey vulnerability in the wild (Sims 2003). Knowing what habitats fishes select and why they do so at given times over seasonal scales has obvious practical implications for determining not only catch rates of fisheries in specific regions, but also for their effective regulation (Sims 2003).

4. Impacts on Food Webs

A variety of environmental and human use factors can impact the overall health and integrity of food webs. Some of these impacts are direct, such as overfishing of individual species causing changes in food web dynamics, or the introduction of an invasive species. Other impacts are indirect, including changes in water quality or habitat characteristics which can in turn influence the fish populations and the overall food web. This section provides a brief overview of the relationship between core fishery and non-fishery related impacts on food webs in the South Atlantic. The *Threats to South Atlantic Ecosystems* section of the Fisheries Ecosystem Plan provides additional information on the overarching suite of threats that can impact the region.

4.1 History of change of the system

(Note: See references in other sections in the FEP: histories of the fisheries and habitat change.)

4.2 Fishery-related Impacts

Fishing activities can have a variety of impacts on South Atlantic food webs, both with direct impacts to fish populations and through impacts to critical habitats which in turn impact food web dynamics.

4.2.1 Overfishing and Trophic Cascades

Extraction of species from a system can impact community composition, diversity, and trophic structure. In addition to restricting populations of the targeted species, overfishing of a specific species or group of species can modify the broader ecosystem food webs. The role of fishing activities beyond the direct impact on the given population is critical to understanding food web dynamics. Trophic cascades can result when fishing impacts extend beyond a targeted population, influencing the broader food web. The direction of the impact within the food web depends on the trophic level of targeted and non-targeted species. This influence can be top-down, such as the loss of predators within a system, or bottom up, including the loss of forage fish or habitat.

4.2.2 Bycatch

The 2011 *U.S. National Bycatch Report* defines bycatch as discarded catch of any living marine resource plus unobserved mortality due to a direct encounter with fishing gear (NMFS 2011). The limited selectivity of fishing methods and gear results in fisheries affecting non-targeted species, including marine mammals, sea turtles, seabirds, finfish, elasmobranchs and invertebrates. Bycatch can result from incidental take of protected species; regulations on the retention of particular species, sexes, or size ranges; discretionary discards or catch-and release (NMFS 2011). The non-targeted species impacted varies by fishery and associated gear type.

Trawling, for example, is the primary gear used in the shrimp, whelk and jellyfish fisheries A variety of bycatch reduction methods have been put into place to help limit the amount of by catch, including the use of Turtle Exclusion Devices (TEDs) and Bycatch Reduction Devices (BRDs) on trawls in the shrimp fishery, the incorporation of escape panels in pots used in the blue crab fishery and the adoption of non-stainless steel hooks, descending devices and degassing methods the deeper water snapper grouper fishery.

4.2.3 Habitat Alterations

The coastal, nearshore and offshore food web descriptions provided earlier in this chapter highlight the critical role that benthic habitats, including seagrasses, marsh plants, oysters, and hard bottom have in the ecosystem dynamics of the South Atlantic. Fishing activities are amongst a variety of sources human and environmental factors that can influence the extent and health of these critical habitats. Specific connections between fisheries and bottom habitats in the region, include, but are not limited to bottom habitat alteration, particularly sand, from shrimp trawls, loss of fishing gear, and anchor damage. Limitations in the gear types (e.g. trawls) that can be used estuarine, nearshore and offshore areas, are designed to help mitigate the direct destruction of critical habitats.

4.3 Water Quality

The water column is habitat within our estuarine and marine ecosystems. As such, its condition has an impact on the broader food web. Nutrient levels can influence primary productivity, community composition and species diversity; contaminants can negatively impact fish reproduction and endocrine systems and have the potential to bio-accumulate up the food web. The sources of nutrients, pollutants, and contaminants are often land based (e.g., stormwater and agricultural runoff). There is a an broader review of water quality related sources and impacts in the "Threats to the South Atlantic Ecosystem" section of the Fisheries Ecosystem Plan; therefore, this section focuses on the specific relationship with food webs.

4.3.1 Nutrients

Nutrient pollution can result in a variety of ecological impacts. Excessive nutrients in estuarine and nearshore systems can result in fish kills due to oxygen depletion, seagrass die-offs, excessive and sometimes toxic algal blooms, and changes in marine biodiversity (NRC 2000). Studies conducted in southeastern tidal creeks have demonstrated shifts in invertebrate and fish populations with high nitrogen loads (REF). In turn, they may not support food chain and ecological assemblages needed to sustain desirable species and populations. Sources of nutrients include agriculture, silviculture, coastal development and stormwater.

4.3.2 Contaminants

In addition to nutrients, a number of contaminants in the water column can negatively impact fish communities and food webs. While some occur naturally in the environment, anthropogenic activities have resulted in increased concentrations of heavy metals (e.g. mercury), persistent organic carbons (e.g. polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)) and perfluorinated compounds (PFCs), in coastal and marine ecosystems (Jakimska et al 2011, Houde et al 2011). Excessive levels of these contaminants can result in direct mortality, hormone alterations, immune suppression and bioaccumulation. The latter correlates most directly with food web dynamics, as many of these contaminants undergo biomagnification when transferred across trophic levels, accumulating in the tissues and organs of carnivorous and apex species (Houde et al 2011).

Mercury is an example of a heavy metal found in the marine environment that transfers through trophic levels and raises a significant human health concern. Sources of mercury in the both natural (e.g. degassing of the earth's crust, volcanoes) and anthropogenic (e.g. coal combustion, waste incineration, and metal processing), primarily entering the marine environment through atmospheric deposition. Once in the system can accumulate in bottom sediments where bacteria convert it into methylmercury, a more toxic form of mercury which takes longer for organisms to eliminate (USGS). While there are a variety of local variables that influence methylmercury concentrations, a study on the differences in mercury levels between red and gray snapper in the Gulf of Mexico [MC3] can help inform the discussion of heavy metal bioaccumulation in South Atlantic food webs.

4.3.3 Harmful Algal Blooms

The ecosystem impacts of toxic and nontoxic harmful algal blooms range from loss of species (e.g. shellfish) and habitats (e.g. seagrass beds) to altered food web interactions. For example, brown tides in the Mid-Atlantic and Gulf of Mexico reduced light penetrations, led to seagrass die-offs, and reduced populations of hard clams, scallops and mussels. From a human health standpoint, marine toxins associated with harmful algal blooms can cause neurologic and gastrointestinal disease. Ciguatera, the most common marine toxin disease in the world, is associated with the consumption of subtropical and tropical reef fish such a barracuda, grouper, and snapper. This is a case of bioaccumulation within the food web, toxic dinoflagellates (e.g. *Gambierdiscus toxicus*) adhere to coral, algae and seaweed, are eaten by herbivorous fish, and then by carnivorous fish which are consumed by humans. A 2015 study projects an increase risk from ciguatera in the southeast as a result of climate change and warmer water temperatures (Kibler et al 2015).

4.4 Habitat Alteration

The food web diagrams provided earlier in this chapter highlight the dynamics between fish communities and habitats in estuarine, nearshore, and offshore environments. Many of the habitats on which South Atlantic food webs depend are themselves at risk from a variety of impacts and their loss can alter overall ecosystem dynamics. Discussion of the links between fishing and non-fishing threats and Essential Fish Habitat (EFH) is the crux of threats section of the FEP. This section focuses on a couple of key examples of how habitat alterations can modify broader food web dynamics.

4.5 Invasive Species

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 defines aquatic nuisance species as “nonindigenous species that threaten the diversity or abundance of native species, the ecological stability of infested waters, and/or any commercial, agricultural, aquacultural, or recreational activities dependent on such waters”. Often referred to as invasive species, they can enter marine ecosystems through shipping activities, such as ballast water discharge or transport on ship hulls, intentional stocking for fisheries, and through the aquarium trade.

Indo-Pacific Lionfish (*Pterois volitans/miles* complex) are the most significant marine invasive when considering larger food web implications in the South Atlantic Bight. Indigenous to coral reefs in the Red Sea, Indian and western Pacific oceans, lionfish are now found throughout the South Atlantic Bight region, from Florida to Cape Hatteras (Whitfield et al 2002, Hare and Whitfield 2003, Meister et al, 2005, Ruiz-Carus et al. 2006, Whitfield et al 2006). They are known to occupy a diverse set of hard bottom habitats, including seagrasses, mangroves, low relief hard bottom, rocky outcrops, and high relief artificial structures, at diverse depths (Whitfield et al 2006, Albins and Hixon 2010). Their already wide distribution in the South Atlantic demonstrates that they are successful marine fish colonizers in the region with the primary limitation to their distribution being minimum bottom water temperature. Recent climate models indicate that changes in sea temperatures will further expand the extent of suitable thermal habitat for lionfish by 45% over the next century covering 90% of the southeast continental shelf (Grieve et al. 2016). With no natural predators, defensive venomous spines, and extraordinary predatory behaviors, lionfish can decrease native prey fish biodiversity and biomass twice as fast as native species, and reduce recruitment of juvenile fishes by >80% including ecologically important reef species (e.g. parrotfish, gobies, damselfish) as well as economically important snappers (e.g. vermillion), groupers (e.g. seabass), flounders, and forage species (e.g. squid & scad) (Albin and Hixon 2008, Morris and Akins 2009, Green et al, 2012, Albins 2013, Dahl and Patterson, 2014).Their exceptionally fast growth rates and continuous year long spawning activities can allow them to reach extremely high densities in newly settled areas, and if left unchecked, can disrupt and alter energy flow pathways within food webs (Fig.# see imbed) (Albins and Hixon 2010, Cerino et al., 2013). Extirpation of lionfish from the South Atlantic is not possible, they are here to stay but mitigating their trophic impacts on South Atlantic food webs will require employing effective management tools and investing in research priorities to inform management decisions (Morris and Green, 2012, Green et al. 2014). Precautionary approaches *inter alia*, such as fishing regulations and marine reserves that protect and conserve native species like groupers that are capable of controlling some lionfish impacts are promising management options (Albins and Hixon 2010, Dodge 2015, National Invasive Lionfish Prevention and Management Plan, 2015).

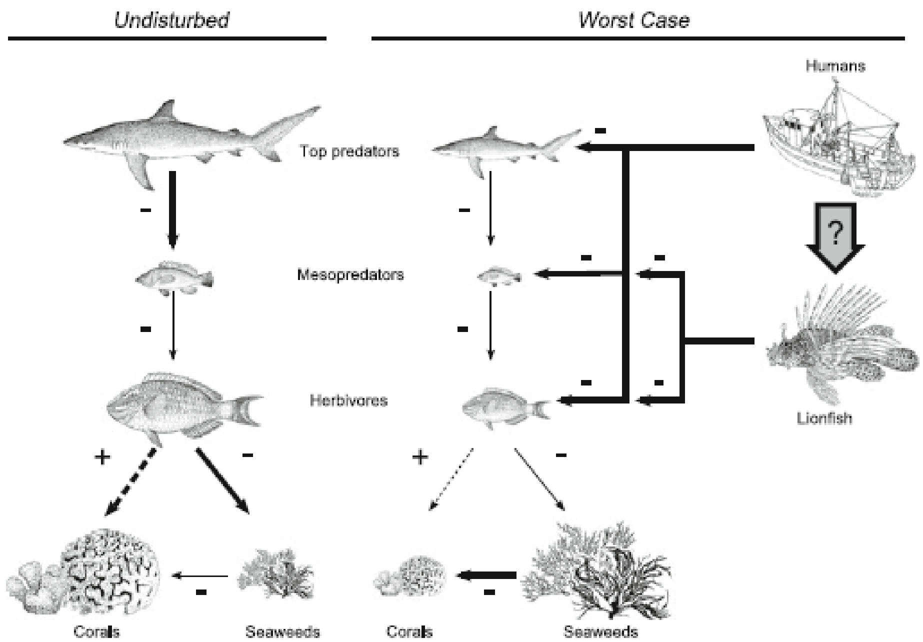

Fig. 2 Worst case scenario for future Atlantic and Caribbean coral-reef ecosystems caused by a combination of human overfishing of larger fishes of all trophic levels and invasive lionfish consuming small fishes and competing with other mesopredators (*right*), compared to an undisturbed system (*left*). The size of each kind of organism represents its relative abundance comparing the two interaction webs, and the thickness of each arrow represents the relative interaction strength between organisms. *Solid arrows* are direct effects representing predation (including fishing), except in two cases: competitive effects of (1) seaweeds on corals and (2) lionfish on other mesopredators and juveniles of some top predators (such as juveniles of large grouper species). The *dashed arrow* is the indirect positive effect of herbivores on reef-building corals. The unknown future effect of humans on lionfish is indicated by a *question mark*, and will be the focus of control efforts. Images courtesy of FAO

4.6 Climate Impacts

An overview of climate change impacts expected in the southeastern U.S. was provided in the 2009 Fisheries Ecosystem Plan of the South Atlantic Region (REF). Anticipated changes include, but are not limited to, increased water temperature, sea level rise, and ocean acidification. The range of climate change impacts in marine ecosystems include decreased ocean productivity, altered food web dynamics, reduced abundance of habitat-forming species, shifting species distributions, and a greater incidence of disease (Hoegh-Guldberg and Bruno

2010). Specific impacts will vary by location. Following are some climate change impacts being observed and tracked in the South Atlantic Bight.

- Coastal habitat shifts and potential loss
  - related to sea level rise, changes in rainfall, obstacles to migration (e.g. development)
- Population/regime shift
  - From FEP: Atlantic Multidecadal Oscillation can cause large scale ecological changes called regime shifts where temperature alterations favor or harm a particular species or groups
- Ocean acidification
  - From FEP (p. 97) Experimental evidence suggests that if these trends continue, key marine organisms, such as corals and some plankton, will have difficulty maintaining their external calcium carbonate skeletons (Orr et al. 2005). acidification of oceans is expected to have negative impacts on marine shell-forming organisms (e.g., corals) and their dependent species. [MC8]

5. Food Web Models

5.1 Models and Principles

Marine food webs and their broader ecosystems are complex, especially those in subtropical and tropical settings, and especially when considering spatial complexity. This high complexity makes such marine ecosystems inherently difficult to understand. Computer models are a useful tool to account for the myriad states and flows in the system, and thus to characterize and examine food web structure, functions, and dynamics. Such models can be used to explore questions relative to ecosystem health, community regulation and stability, ecosystem services, management strategies and policies, and the effects of global, regional, and local pressures on these food webs, ecosystems, and particular resources.

A variety of modeling approaches varying in complexity and theoretical foundation can be used to represent spatially explicit marine ecosystems and trophic interactions. Some examine individual level interactions and responses to environmental heterogeneity, which can scale up to whole populations and ecosystems, while other approaches model the states, flows, and dynamics of aggregate groups of species. These different approaches, while complementary, have very different applications for fisheries management and other conservation planning issues.

In many cases, we need to understand how species are distributed across space to understand and represent food webs and ecosystems. The simplest way to represent species distributions is to extrapolate presence and absence point pattern data to an area of interest by a statistical model. Collectively, the models used for extrapolating point pattern data to continuous areas are called environmental niche models, bioclimatic envelope models, or species distribution models.

There is currently no consensus regarding what bioclimatic envelopes, niche, or species distribution models represent in terms of observed spatial distributions. Recent authors (Soberon 2007, Peterson et al. 2011) suggest a species distribution is governed by physical variables (Grinnell 1917), community status (Elton 1927), and movement. Any combination of these three factors determines an actual distribution or potential distribution, including population sinks due to competitive exclusion or resource limitation.

While the first niche model, as we currently conceptualize them, was probably constructed by Ferrier (1984) to describe birds, these models have exploded in use over the past decade. Bioclimatic envelopes, niche, and species distribution models primarily use raster and GIS data to represent environmental conditions and species co-occurrence. The ease with which these data and methods are accessible via modern computing has renewed a focus in understanding their theoretical underpinnings.

Other models commonly used in fisheries applications are often based on foraging theory. Foraging theory refers to a wide class of explanations that describe individual energy intake and foraging time in terms of rate maximizing. In distribution models, spatial distributions can be quite literal in terms of environmental, dispersal, and competitive gradients. In contrast, distributions based on foraging more explicitly consider individual behavioral decisions due to trophic interactions, predator-prey functional responses, habitat quality, food availability, and vulnerability (e.g. MacArthur and Pianka 1966, Schoener 1971, Charnov 1976, Mangel and Clark 1986).

An early approach to modeling foraging behavior was a Markov state transition model by Marc Mangel (1987). A Markov process is a stochastic process that assumes a lack of process memory. A "state" refers to the current state of the organism and its dynamics (e.g. a population classified by size). A transition occurs between states based on a transfer probability. Mangel used this framework to describe the increase in fitness in an insect due to optimal clutch size on a host. In Mangel's example, he only needed information on survival probabilities to describe state transitions and a measure of fitness to describe current states. Using foraging theory, Mangel ran a series of Monte Carlo simulations to describe optimal oviposition behavior. While Markov models can be relatively simple to parameterize and can help us understand behavior, there are some key assumptions in foraging theory that need to be considered. Optimal foraging assumes that organisms act "optimally" in that they can make non-random decisions considering their fitness. Furthermore, the co-occurrence between predators and prey (or hosts/parasites, etc.) is assumed random, which we know is often not true.

The individual behavioral approach can extend into models that more explicitly consider dynamic systems. Dynamic models represent the full suite of interactions between species, their environment, and external stress as a series of population, trophic dynamic, biogeochemical, and/or hydrodynamic models. In fisheries, two related individual based models have emerged that describe multi-species interactions for natural resource managers: OSMOSE and Invitro.

OSMOSE was developed by Shin, Shannon, and Cury (2004) to explore size based predation rules in the context of trophic interactions. This model describes trophic interactions by assuming a fixed amount of food is required for each individual and a constant predator-prey size ratio exists (e.g., by using data from fishbase.org). In this regard, OSMOSE has theoretical underpinnings in food web ecology, where size selective predation has long been recognized as a complicating factor in describing marine food webs (Shurin et al. 2006). OSMOSE is limited in that it requires a large input of parameters for growth, reproduction, and survival, and does not handle environmental data and lower trophic levels. Furthermore, initial estimates of biomass, natural mortality, and fishing mortality are derived from another model (Ecopath with Ecosim). With the above limitations, this model seems best suited for comparison to other models. Indeed, Shin, Shannon, and Cury (2004) used OSMOSE to compare fishing effects on the Benguela fishing community to Ecosim (Plaganyi 2007).

Invitro, developed by Gray et al. (2006) in Australia, is essentially a model between the individual based OSMOSE and full ecosystem model of Ecopath with Ecosim that more explicitly considers human activities as an ecosystem component. As an agent based model, Invitro can model individuals separately or as aggregates in a group. Agent based flexibility allows the user to represent any one ecosystem component appropriately (even in three dimensions), but comes at a computational cost. Computational costs limit Invitro to 10 to 20 agents and have limited its application. The most well documented use of Invitro thus far is in Australia to evaluate management strategies (Plaganyi 2007).

The first and most common full ecosystem modeling approach is Ecopath with Ecosim (EwE). Ecopath was created by Polovina (1984) as a mass balance accounting system. EwE was further developed by Walters, Christensen, and Pauly (1997) to explore the consequences of foraging arena theory, prey vulnerability, and risk sensitive foraging in exploited food webs. Foraging arena theory (Walters et al. 1997) postulates that trophic interactions occur in restricted arenas where prey will limit growth for survival and predators compete with each other as prey decline in refugia.

The static component of EwE--Ecopath--makes two assumptions regarding functional groups. First, biological production is equal to the sum of fishing mortality, predation, migration, biomass accumulation, and other unexplained mortality. Second, consumption within a function group is the sum of production, respiration, and unassimilated food. The Ecosim component adds temporal dynamics to these assumptions by describing biomass flux between groups as a series of differential equations. The key innovation is the inclusion of a vulnerability term that specifies each predator-prey interaction in terms of foraging arena theory. A final component, Ecospace, runs the differential equations of Ecosim on a cell by cell basis to provide spatially explicit predictions of biomass. Habitat preferences in Ecospace can be parameterized by species distribution models.

While the data requirements for EwE are fairly straightforward (e.g., production, consumption, biomass, diet, etc.), it can be tempting to adjust parameter values with no empirical support. This problem is not unique to EwE, but EwE is the most widely used ecosystem model. Additionally, human activities beyond fishing mortality and potential marine protected areas are not handled in EwE as explicitly as Invitro. However, the computational limitations are substantially less.

The Atlantis model, developed by Fulton et al. (2004), is a different full ecosystem modeling approach that is well suited to include anthropogenic effects. Some Atlantis components are similar to EwE. Most Atlantis sub-models are deterministic differential equations, but the vulnerability term in Atlantis can handle a wider range of functional responses between predators and prey and a wider range of refugia. Additionally, Atlantis explicitly includes biogeochemical cycling and economic models, making it ideal for evaluating management strategies. However, the number of sub-models can be daunting and requires extensive collaboration. Running an Atlantis model requires an extensive amount of time and data, making it only appropriate for selective use.

Ultimately, the use of any one of these models to understand and describe spatially explicit marine ecosystems depends on a tradeoff between complexity and simplicity, deterministic and probabilistic methods, data availability, computational power, and theory. All of these tradeoffs can be viewed through a lens of ever changing and scale dependent management needs. In some cases, computational power has outpaced theory (e.g., niche modeling). In other cases, theory (food web ecology, foraging theory) has provided a strong foundation for complex models to stretch the limits of our computational abilities. While exciting, uncertainty inevitably increases with complexity.

5.2 Case Studies

5.2.1 The South Atlantic Bight Ecopath Model

A whole food web trophodynamic fishery-ecosystem model has been developed for the South Atlantic Bight ecosystem (Figure 1; Okey and Pugliese 2001, Okey et al 2014) using the freely available *Ecopath with Ecosim* (EwE) software. As described in the previous section, Ecopath models were originally developed by Polovina (1984) to describe the food web and trophic structure of the French Frigate Shoals ecosystem. Subsequent development including the capacity of both temporal and spatial dynamics (e.g. Christensen and Pauly 1992, Walters et al. 1997, Walters et al. 1999, Walters et al. 2000, Steenbeek et al 2013) has resulted in a very widely used ecosystem modelling approach for understanding marine ecosystems including the effects of fisheries and other stressors on broad ecosystem components and features, thus increasingly operationalizing ecosystem-based management and policy.

The South Atlantic Fishery Management Council sponsored the development of the first iteration of this South Atlantic Bight (SAB) model (Okey and Pugliese 2001) as part of its initial fishery ecosystem plan (FEP) development. This model was refined soon thereafter during an iterative process involving a broad cross-section of stakeholders and scientists to produce a second generation model during 2002. That refined model was re-structured and refined more recently to explore the importance and roles of forage species in the SAB (Okey et al. 2014).

This latest iteration of the SAB model (Okey et al 2014) is being used as a starting point for developing an updated EwE model, which can form the core of an SAB ecosystem model that will be informed by physical oceanographic and estuarine models and can address broad objectives in fisheries management, habitat protection, climate impact assessment, and understanding cross-system linkages and connectivities. This updating and refinement can be achieved using a wide variety of recently-available resources such as compiled and updated fisheries and diet composition information, fishery independent information, and recent model refinements such as the GOM gag model (Chagaris and Mahmoudi 2013), which was partially based on an original West Florida Shelf model (Okey and Mahmoudi 2002, Okey et al. 2004).

The SAB model domain extends from Cape Hatteras, North Carolina to Biscayne Bay, Florida, and from the intertidal zone to 500 m depth, as described in Okey and Pugliese (2001) and Okey et al 2014). This covers an area of approximately 174,331 km2. An attempt was made to include estuarine components in this overall broad-scale model, but this effort emphasized species assumed to have an influence on the whole spatial domain, and was thus somewhat selective. Some species in this region are distributed beyond and across the model domain boundaries, but the defined area tends to capture the center of distribution for many managed species. The baseline time period characterized by the Ecopath model of the South Atlantic Bight used here is the late 1990s (1995-1998). This is a model initialization period. Now that a variety of time series data are presumably available for this area, potentially over 18 years, the model can be calibrated dynamically.

This current iteration of the SAB model contains 99 functional groups (biomass pools), including 50 fish groups in total, 12 forage groups, 8 fish predators of principle interest to recreational sectors, 5 elasmobranch groups, 7 bird groups, 3 marine mammal groups, sea turtles, 27 invertebrate groups, 4 detritus groups, 6 primary producer groups, 4 zooplankton groups, and microbial heterotrophs. The most recent exploration of the roles and importance of forage species (Okey et al 2014) involved simulations in which the biomasses each of 12 forage groups were both increased and decreased to derive trophodynamic signatures of each of these groups and compare the character of these signatures.

5.2.2 The West Florida Shelf Reef Fish Ecopath Model

A West Florida Shelf (WFS) EwE model has been developed that is centered on regulated species on the WFS including reef fishes, coastal migratory pelagics, and highly migratory pelagics as defined by the GMFMC and the NMFS (Chagaris 2013; Chagaris *et al*. 2015). Gag Grouper, Red Grouper (*Epinephelus morio*), Black Grouper (*Mycteroperca bonaci*), and Yellowedge Grouper (*Epinephelus flavolimbatus*) were each divided into 3 age stanzas and Spanish Mackerel (*Scomberomorus maculatus*), King Mackerel (*Scomberomorus cavalla*), and Red Snapper (*Lutjanus campechanus*) were all divided into juvenile and adult age stanzas. Other reef fishes and pelagics were included either as a single-species biomass group or aggregated into a group of similar species. Coastal and inshore species were included because they interact with reef fish juveniles yet to migrate offshore. Aggregate groups of non-target fishes, invertebrates, zooplankton, and primary producers were necessary for a complete food web. The resulting model consisted of 70 biomass pools including one each for dolphins and seabirds, 43 fish groups (of which 11 are non-adult life stages), 18 invertebrate groups, 4 primary producers, and 3 detritus groups. There are 10 commercial fishing "fleets" and four recreational fishing fleets.

The WFS-EwE Ecosim model was calibrated and capable of reproducing historical trends in abundance and catch from 1950 to 2009. The WFS-EwE model has been used to forecast the ecosystem impacts of various harvest policies in the Gulf of Mexico (Chagaris *et al*. 2015). For example, rebuilding of gag grouper stocks was predicted to have top-down effects and cause potentially large (>10%) declines in biomass of black seabass, other shallow water groupers, and vermilion snapper. A policy optimization search was conducted in Ecosim to quantify the trade-offs between fishery profits and reef fish conservation (Chagaris 2013). Over the long term (40 years), profits were highest when total reef fish biomass was about 40-60% larger than 2009 levels, a realistic and achievable goal. Conditions in 2009 were sub-optimal in regards to reef fish biomass and profits. By simulating policy options in Ecosim and comparing them to the optimal solutions along the tradeoff frontier, the optimization analysis provides a scorecard for which to rank policy choices against broader multi-fleet and multi-species management objectives. Lastly, the Ecosim model was used to simulate the effects of invasive lionfish on native reef fishes and evaluate ways to mitigate such impacts through top down fishing and predation effects (Chagaris *et al.* 2015). In the invasion scenarios, strong negative effects were predicted for lionfish prey groups such as small-bodied reef fishes, small non-reef fishes, and shrimp. Several large bodied predators that support valuable commercial and recreational fisheries were also negatively affected by lionfish through competition for prey. Simulations demonstrated that increased harvest of native reef fish predators is associated with increased lionfish biomass, suggesting that historical overfishing of reef fish may have made the system more vulnerable to species invasions.

The geographic domain of the Ecospace model is 25-30.5 degrees north and 81-87.5 degrees west with a spatial resolution of 10 minutes (= 0.167 degrees or appx. 20 km^2) and has dimensions of 34 rows by 40 columns (Figure 3). This covers an area from the Florida Panhandle south to, but excluding, the Florida Keys and extends from shore out to a depth of 250 m. A bathymetry map was obtained from the NOAA National Geophysical Data Center Coastal Relief Model (NOAA 2014). A rugosity map for the WFS, representing the average elevation change between a grid cell and the eight neighboring grid cells (m/cell), was available from the United States Geological Survey (Robbins et al. 2010). Time-averaged maps for sea surface temperature (11 micron day) and chlorophyll-a from the MODIS aqua satellite were downloaded using the NASA Giovanni Interactive Visualization and Analysis website (Acker and Leptoukh 2007). A salinity map was obtained by subsetting and averaging output from the HYCOM + NCODA Gulf of Mexico hydrodynamic model.

Ecospace was used to simulate the performance of marine protected areas (Chagaris 2013). Existing MPAs (Madison-Swanson, The Edges, Steamboat Lumps, and Middle Grounds) that cover less than 2% of the shelf did very little to enhance grouper and snapper stocks (biomass increase < 5%). Some species were predicted decline under the MPA scenarios due to top-down effects (predation and competition) caused by build-up of predator species. Because biomass of fish spilled over into unprotected areas, some large hypothetical MPA scenarios had little negative impact on the fishery and in some cases provided net economic benefits. The win-win scenarios, where there was gain in both biomass and catch, usually required between 15%-30% of the WFS to be closed to fishing.

6. Food Web Indicators

Ecosystem indicators have been used to assess the health of ecosystems and their components across a wide range of terrestrial and aquatic habitat types (see Jorgensen *et al.* 2010). Food web indicators are a subset of ecosystem indicators that characterize energy flow, ecosystem resilience, and food web structure and functioning (Link 2005; Shin *et al.* 2012). An indicator may be descriptive and serve to track the abundance of a species or suite of species. Or, an indicator may be integrative and describe overall ecosystem attributes such as trophic diversity or resilience. Food web indicators may also serve as proxies for ecosystem-services (Kershner et al. 2011). Many indicators, especially the integrative type, respond slowly to ecosystem change and may appear to be conservative (Cury et al., 2005). Moreover, indicator responses can also be non-linearly related to ecosystem state and pressures (Fulton et al. 2005).

No indicator is all-encompassing and a carefully chosen portfolio of indicators is necessary to determine overall ecosystem status (Cury et al. 2005; Rice and Rochet ref). The International Council for the Exploration of the Sea (ICES) held a workshop in 2014 to identify useful food web indicators (ICES 2014). The goals of the workshop were to develop a short list of suggested food web indicators, with emphasis on pragmatic approaches that are operational now or in the near future. Forty candidate food web indicators were evaluated in categories of food web structure, functioning, and resilience. Each indicator was scored based on its measurability, sensitivity to the underlying pressure, theoretical soundness, ability to be easily communicated, and relevance to management (ICES 2014). Many of the indicators had clear links to food web function. The indicators describing ecosystem resilience scored poorly due to the complexity of measuring food web resilience and recovery, while the structural indicators scored highly and are most readily available. The top scoring indicators from the workshop are summarized in Table 7.1 for each category. The full list of indicators, along with brief descriptions and references, is provided in the workshop report (ICES 2014).

Indicator name	Description	Data needs
	Indicators Linked to Energy Flow	
Productivity (production per unit biomass, including seabird breeding success)	survival and reproductive output is affected by food quantity and quality; detects gross structural changes in energy flow	nesting surveys, number offspring, pregnancy rates, spawner abundance
Primary production required to support fisheries	characterizes ecosystem production and conversion of organic matter across trophic levels; difficult to communicate; requires estimates of transfer efficiency that are not readily available	food web model
Productive pelagic habitat index (chlorophyll fronts)	chl-a fronts are areas of efficient energy transfer from low trophic levels to top predators; implications for management are unclear	satellite imagery, oceanographic models
Ecosystem exploitation (fisheries)	useful to describe harvesting patterns and pressure of the fisheries on the food web	catch
marine trophic level (TL) indicators	based on average weighted trophic levels across a suit of species; integrated across the ecosystem; most useful for assessing food web effects of fisheries	food habits data, survey time series, catch, TL estimates
	Indicators linked to resilience	
Mean trophic links per species	reflects connectivity and stability; dependent on temporal and spatial characteristics; requires comprehensive diet data	food habits data
Ecological Network Analysis derived indicators (mean overall transfer efficiency)	a descriptor of ecosystem health; average TE varies across ecosystem types; requires comprehensive diet data	food web model
Gini-Simpson dietary diversity index	summarizes contributions of prey resources to consumers; requires comprehensive diet data	food habits data
	Indicators linked to structure	
Guild surplus production	productivity of functional guilds	survey biomass; catch
Large fish indicator (LFI)	sensitive to fishing pressure	survey biomass
total biomass of small fish	the amount of energy transferred from zooplankton to higher trophic levels is limited by biomass of small pelagic fish	survey biomass
proportion of predatory fish	captures changes in trophic structure and functional diversity of fish due to fishing and environmental pressures	survey biomass, food habits data
pelagic to demersal ratio	describes changes in trophic energy flow and community structure	survey biomass

7. Management Applications

Fisheries management in the South Atlantic follows the traditional process of setting harvest limits and regulations based on the outcome of single-species stock assessments. There are few, if any, cases where food web properties or predator-prey interactions have been considered under this current framework. Incorporating these processes does not require a complete shift from single-species to ecosystem-based fisheries management. Food web models can in fact make very important contributions at multiple stages of the assessment and management process (Link 2010). This section describes, in a general sense, practical application of food web models and indicators to single-species fisheries assessment and management.

7.1 Informing Stock Assessment

Stock assessment models usually assume that most life history parameters (e.g. natural mortality, growth, fecundity, recruitment) are constant over time or vary according to some simple random deviations. This is usually known not to be true, but lack of empirical evidence has largely prevented a move away from those assumptions. In the absence of such data, ecosystem models can provide estimates of these parameters over time. In particular, food web models predict changes in natural mortality over time as predator abundances vary or food become more or less available (Moustahfid et al. 2009). Alternatively, food availability or environmental conditions may affect growth or fecundity (Schirripa et al. 2009). There is some precedent for including simulated natural mortality time series in stock assessment. The stock assessment of Atlantic menhaden has used natural mortality output from the multi-species virtual population analysis (MSVPA) to account for predator needs (Garrison et al. 2010). In the Gulf of Mexico, natural mortality from two separate Ecosim models was used in sensitivity runs of the gag grouper stock assessment (Chagaris and Mahmoudi 2013; Gray et al. 2013). The increased use of the Stock Synthesis assessment model and similar modeling platforms facilitates these inclusions (Methot and Wetzel 2013).

7.2 Evaluating Policy Options

Harvest policies for one species are likely to have effects on other species due to trophic interactions. However, management decisions are based on projections of single-species stock assessment models that assume a constant environment and ignore any policies that are also being considered for other species. Using ecosystem models, managers (or the SSCs) can simultaneously evaluate multiple policy options for more than one species. For example, if a management goal is to rebuild multiple species that compete with one another for food and/or space (such as in a reef fish community) then rebuilding plans based on single-species models alone may be misinformed. Additionally, projections made with an ecosystem model can explicitly incorporate environmental uncertainty that can then be factored into decision-making (i.e. setting catch limits) following the p-star method. For this to be possible, the food web models must be able to demonstrate similar dynamics to the stock assessment model. To facilitate this, food web models can be calibrated to abundance or biomass trajectories from stock assessment models and derived reference points (Fmsy, MSY, B0) can be compared.

7.3 Using Indicators in Management

How to apply towards fisheries assessment and management; approaches to developing indicators can be complex so focus on describing why they're useful – efficient at measuring overall health and integrity of the system.

8. Summary and Recommendations

The variety of habitats in the South Atlantic support diverse food webs, that also are interconnected by proximity, energy pathways, migration / immigration, and by life history. Many components are shared among habitat-specific food webs, from algae to marine mammals. Ontogenetic, seasonal, spawning and diel migrations, predator avoidance, and foraging behaviors transfer energy and food web participants among the various habitats within the South Atlantic. While seasonal migrations may cover spawning aspects, the magnitude of seasonal migrations for a number of species (gag, greater amberjack, banded rudderfish, king mackerel, etc.) have significant effects.

Specific to this report, the paucity of data for offshore, non-commercially important species and pelagic species equate to a difficulty in applying EBFM. As in other sub-tropical to temperate areas, food webs in the South Atlantic rely heavily on grass detritus (marsh or seagrass) and phytoplankton as carbon sources. As one moves offshore, the reliance on phytoplankton increases as terrestrially-derived organic carbon diminishes. SA food webs are regulated by seasonal and long-term environmental variability (bottom-up; e.g. temperature, upwelling, day length, Gulf Stream Index, nutrient loading) and top-down factors such as fishing of large snapper-grouper and natural predation. Ultimately, energy flow within the system is tightly mediated by predator-prey interactions. Forage species (e.g. Menhaden, Shrimp, and Pinfish) are critical links in energy transfer within and among food webs in the SA and thus are also important in maintaining stability of these webs. Unfortunately, population dynamics of the vast majority of these critical species are poorly understood. Potential impacts of climate change on consumption rates, foraging behaviors, and the primary producers in the system are also unknown.

Food webs are impacted both directly (fishing, introduction of invasive species) and indirectly (water quality changes, alteration of habitats) and these impacts are often, if not primarily, anthropogenic in origin. Other systems provide well-documented examples of trophic cascades following perturbations and multiple perturbations likely have synergistic or cumulative impacts. Trying to predict impacts, whether they be positive such as the recovery of overfished species or negative such as habitat destruction, increasingly relies on modelling approaches. Modelling approaches often trade-off between being simplistic, needing very little data, but limited in predictive capabilities for whole ecosystems, or complex, needing extensive data sources and computational power, but better able to address multiple questions or hypotheses if uncertainty can be limited.

The goal of understanding food web components, connections, energy, and complexity is to provide useable information to direct management or future research needs. As such, indicators have been employed to summarize the state of knowledge of an ecosystem or food web and serve as a benchmark to inform future actions. Indicators may range from point estimates such as measures of diversity to those that are dynamic such as non-linear relationships between the ecosystem and pressures upon it. Suites of indicators are likely to increase in importance as we move from single-species management and assessment approaches to EBFM.

Food web models and indicators are essential tools to predict coupled, synergistic, or cumulative effects of management practices.

Prior to the development or use by managers of tools to characterize, quantify, and predict, the SA region has specific outstanding data needs. Diet, energy, and biomass for non-economically important species must be determined. Uncertainty in complex food web models must be minimized and empirical data such as those mentioned above are crucial to these efforts. Impacts of human activities and climate need to be determined specifically for the SA.

Summary Recommendations:

1. **Forage Fisheries** – Managers should consider forage fish stock abundances and dynamics, and their impacts on predator productivity, when setting catch limits to promote ecosystem sustainability. To do so, more science and monitoring information are needed to improve our understanding of the role of forage fish in the ecosystem. This information should be included in stock assessments, ecosystem models, and other fishery management tools and processes in order to support the development of sustainable harvest strategies that incorporate ecosystem considerations and trade-offs.
2. **Food Web Connectivity** – Separate food webs exist in the South Atlantic, for example inshore-offshore, north-south, and benthic-pelagic, but they are connected by species that migrate between them such that loss of connectivity could have impacts on other components of the ecosystem that would otherwise appear unrelated and must be accounted for.
3. **Trophic Pathways** – Managers should aim to understand how fisheries production is driven either by bottom-up or top-down forcing and attempt to maintain diverse energy pathways to promote overall food web stability.
4. **Food Web Models** – Food web models can provide useful information to inform stock assessments, screen policy options for unintended consequences, examine ecological and economic trade-offs, and evaluate performance of management actions under alternative ecosystem states.
5. **Food Web Indicators** – Food web indicators have been employed to summarize the state of knowledge of an ecosystem or food web and could serve as ecological benchmarks to inform future actions.
6. **Invasive Species** – Invasive species, most notably lionfish, are known to have negative effects on ecologically and economically important reef fish species through predation and competition and those effects should be accounted for in management actions.
7. **Contaminants** – Bioaccumulation of contaminants in food webs can have sub-lethal effects on marine fish, mammals, and birds and is also a concern for human seafood consumption.

Summary Research and Information Needs Addressing South Atlantic Food Webs and Connectivity

1. Scientific research and collection of data to further understand the impacts of climate variability on the South Atlantic ecosystem and fish productivity must be prioritized. This includes research on species distribution, habitat, reproduction, recruitment, growth, survival, predator-prey interactions and vulnerability.
2. Characterization of offshore ocean habitats used by estuarine dependent species, which can be useful in developing ecosystem models.
3. Scientific research and monitoring to improve our understanding of the role of forage fish in the ecosystem, in particular abundance dynamics and habitat use.
4. Basic data are the foundation of ecosystem-based fisheries management thus, fixing existing data gaps in the South Atlantic must be addressed first in order to build a successful framework for this approach in the South Atlantic.
5. NOAA in cooperation with regional partners develop and evaluate an initial suite of products at an ecosystem level to help prioritize the management and scientific needs in the South Atlantic region taking a systemic approach to identify overarching, common risks across all habitats, taxa, ecosystem functions, fishery participants and dependent coastal communities.
6. NOAA in cooperation with regional partners develop risk assessments to evaluate the vulnerability of South Atlantic species with respect to their exposure and sensitivity to ecological and environmental factors affecting their populations.
7. NOAA coordinate with ongoing regional modeling and management tool development efforts to ensure that ecosystem management strategy evaluations (MSEs) link to multispecies and single species MSEs, inclusive of economic, socio-cultural, and habitat conservation measures.
8. NOAA develop ecosystem-level reference points (ELRPs) and thresholds as an important step to informing statutorily required reference points and identifying key dynamics, emergent ecosystem properties, or major ecosystem-wide issues that impact multiple species, stocks, and fisheries. Addressing basic data collection gaps is critical to successful development of ELRPs.
9. Continued support of South Atlantic efforts to refine EFH and HAPCs is essential to protect important ecological functions for multiple species and species groups in the face of climate change.

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Executive Summary/Introduction and Role of Climate Considerations in Ecosystem-Based Fisheries Management

Ecosystem-based fisheries management is an approach that takes major ecosystem components and services, both structural and functional, into account in managing fisheries. It values habitat, embraces a multispecies perspective, and is committed to understanding the interconnections of marine life in an ever-changing environment. Its goal is to rebuild and sustain populations, species, biological communities and marine ecosystems at high levels of productivity and biological diversity so as not to jeopardize a wide range of goods and services from marine ecosystems while providing food, revenues and recreation for humans (U.S. National Research Council, 1998)

The ocean and coastal waters of the southeastern United States help drive local weather and regional climate conditions, support ecologically and economically significant ecosystems (which include important fisheries), and provide tourism, boating, and other recreational opportunities. Fish, fishing, and fisheries are major components of the economy, heritage, and ecological systems that support and sustain the unique culture of the southeastern states. In 2014, almost 2.7 million recreational anglers took 17.6 million fishing trips in the South Atlantic region (National Marine Fisheries Service, 2016). In Florida alone, over 2.3 million saltwater anglers contributed $3.9 billion in retail sales (Southwick Associates, 2013). Commercial fisheries in the South Atlantic earned $184 million in landings revenue (NMFS, 2016). These fishing opportunities supported approximately 16 million full- and part-time jobs (NMFS, 2016). Such statistics highlight the economic importance of healthy and sustainable fisheries.

Over the coming decades, climate change is expected to profoundly affect the dynamics of the marine environment across the world. In some regions, and for some attributes, the effect of climate change is expected to be gradual. In others, or for other attributes, the marine environment may change at a much more aggressive pace. This is because the ocean is a dynamic environment that is coupled to global processes at different scales and places. As a testament to this, today many parts of the ocean are already seeing the initial effects of climate change, with the marine environment changing rapidly due to factors such as increased temperature, changes in wind patterns, acidification, decreased dissolved oxygen, and sea level rise (e.g. Doney et al. 2012, Melillo et al. 2014, Nagelkerken and Connell 2015, Nicholls and Cazenave 2010).

Over shorter time scales, climate variability influences marine ecosystems in manners that can exacerbate or ameliorate the effects of long-term climate change. For the purposes of fisheries management, both climate variability (a result of natural variation in the ocean-climate system) and anthropogenic climate change should be considered. Both sources of variability impact the physical and biological conditions that affect the growth, distribution, and mortality of commercial and recreational marine species.

Marine organisms can be sensitive to such changes in their environment, necessitating a greater understanding of current and predicted conditions in the South Atlantic region. Changing conditions are expected to impact everything from migration patterns to life histories to habitat to ecosystem structure. Already, we are beginning to see shifts in species distributions due to climate changes for many species found along the east coast of the United States (Pinsky et al. 2013). These changes highlight the need for the incorporation of climate considerations into a more comprehensive, big-picture approach to management of marine resources through ecosystem-based fisheries management. This approach to management reflects the interconnectedness of ecosystem components and can help managers to ensure a healthy ecosystem and sustainable fisheries in the South Atlantic. Moving forward, climate considerations and associated environmental variability, coupled with a greater understanding of environmental drivers of ecosystem dynamics, will be important to creating more resilient, "climate ready" fisheries.

There is an immediate need to identify and evaluate alternative management strategies under different climate and ocean scenarios to assist managers with choosing the best possible actions for meeting management goals in a changing climate. Today's management practices may not be the best management practices of the future. Effective fisheries management in a changing climate will require increased coordination and responsiveness of both science and management to changing and perhaps unexpected conditions. Adaptive decision processes that can incorporate, track and respond to climate-related information and as well as the results of management actions will be essential for meeting management goals for fisheries and protected species. Effective production, delivery and use of scientific advice for management decisions can be as important as the management advice itself. Integration of climate science into the management process may necessitate some changes on both the delivery and receiving ends to ensure effective receipt and use of the information. A key step is adoption of climate-smart science and management processes that identify where best to incorporate climate-related information in the management process, use climate-related information to assess risks and best management options, and effectively evaluate and respond to changing conditions (Sobeck, 2015).

This chapter provides a comprehensive and up-to-date review of five related topics: 1) historical and current oceanographic conditions and characterization of the South Atlantic marine environment; 2) predicted future oceanographic conditions; 3) climate impacts on fish, fish habitat and fisheries; 4) knowledge gaps and research priorities related to management needs, and 5) links to South Atlantic Fishery Management Council (SAFMC) management decisions and ecosystem-based fisheries management.

1. Historical and Current Oceanographic Conditions and Characterization

1.1 Atmospheric Drivers

Atmospheric forcing (meteorology) and the Gulf Stream are the two most important forcing factors that control circulation in the South Atlantic. Atmospheric forcing can be described through monthly wind climatology and major episodic events (synoptic fronts and tropical cyclones).

Climatology

The climatology of wind stress on the SAB was systematically examined in the 1980s by Blanton et al. (1985). The seasonal wind patterns found over the area are directly related to the Azores-Bermuda High and the Icelandic Low that form the North Atlantic oscillation (NAO). The monthly climatology over the region is directly related to the position of the region that separates the southward-directed streamlines of the Ohio Valley dry air mass from the northward-directed streamlines of warm and humid air originated from the Azores High.

During spring (March–May) the Azores High contributes to the development of a northward-directed flow of warm humid air mass; it travels westward and turns toward the north over the Gulf of Mexico. This northward air flow intensifies during the summer (June–August) as the Azores High strengthens and shifts westward. During autumn (September–November) the air masses in the SAB are dominated by air masses originating from the Ohio Valley High and produce strong mean southwestward stresses. Details on the movement of these air masses can be found in Wendland and Bryson (1981) and Bryson and Hare (1974).

Weber and Blanton (1980) used wind observations from ships to produce monthly mean wind vectors over the South Atlantic Planning Area. This data set was later updated with ship observations from the Blake Plateau (Blanton et al., 1985), and a more extensive analysis including observations over the period 1945–1963 was produced. Analysis of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS release 2.5 completed in May 2009 with data covering 1662–2007, plus preliminary data and products for 2008 to near-real-time) by Blanton et al., (2003) confirmed the earlier wind climatology described in Weber and Blanton (1980) and Blanton et al. (1985) . Overall five seasonal wind regimes are identified: (i) Winter season (November–February) characterized by a strong southeastward (offshore) directed stress over the northern portion of the SAB, while the winds shift more toward the south in southern latitudes and are of reduced strength. A separation zone (high-pressure ridge) occurs over the Blake Plateau and winds are stronger on the shelf and weaker over the shelf break; (ii) Spring transition (March–May) when the winds gradually shift to eastward and northeastward (poleward) directions in the central portion of the region with more organized winds over the Blake Plateau; (iii) During summer (June–July) winds are westward and southwestward along the southern half of Florida, while the wind stress is more northward and northeastward in the northern half of the region and over the Blake Plateau. Stronger winds are found in July over the northern area and the Blake Plateau with winds largely upwelling favorable, being along-shelf and poleward directed along the entire eastern US coast. Later on in August, a transition regime is developing (Weber and Blanton, 1980) and as the re-analysis of Blanton et al. (2003), using the COADS data, showed weak winds begin to develop and shift counterclockwise from the along-shelf poleward upwelling-favorable summer regime toward the alongshore and south-directed downwelling-favorable direction; (iv) Finally during autumn (September –October) strong southwestward along-shelf wind stresses develop which do not extend all the way to the Blake Plateau; there the mean stress is smaller and mostly westward.

Synoptic fronts & Tropical Cyclones (Hurricanes)

Synoptic variations in meteorological forcing over the SAB are the result of the passage of low-pressure atmospheric frontal systems that are characterized as 1) cold fronts, 2) warm fronts, and 3) extratropical storms. Low-pressure systems associated with cold fronts move from west to east-northeast, and change the wind direction from northeast to southwest. Conversely, warm fronts are accompanied by an opposite change in wind direction. Extratropical storms moving nearshore rotate the wind direction slowly from southwest to southeast. Each storm system has a characteristic pattern of atmospheric pressure, air temperature and wind velocity. Analysis of meteorological records off South Carolina (Wu et al, in review) has shown that cold and warm fronts last on average 3.5 to 4 days while extratropical disturbances have an average duration of less than 2 days. The same analysis has shown that their frequency of occurrence is on average 30 cold fronts, 20 warm fronts, and 16 extratropical disturbances per year. These are typical for the region and can be found from North Carolina to Florida and contribute to mixing of the shelf waters and development of subtidal circulation over the shelf.

In addition to the synoptic fronts, the southeast US in general is subject to the influence of tropical cyclones. Their climatology for the Atlantic region is maintained and continuously updated by the National Weather Service (NWS) National Hurricane Center in Miami, Florida. Overall, the Atlantic (including the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico) hurricane season starts 1 June and extends to 30 November and the peak season is mid-September. Mann and Emanuel (2006) have suggested a positive correlation between sea surface temperatures and Atlantic basin tropical cyclones while Holland and Webster (2007) have found a doubling of the number of tropical cyclones over the past 100 years. These studies suggest that these increases are due to human-driven greenhouse warming. However, Landsea (2007) has argued that such conclusions are due solely to bias in the data set imposed by the improved monitoring systems that have been in place in recent years. In particular, Landsea et al. (2010) noted that the increase of recorded short-lived storms (duration up to two days) has led to the previously stated conclusions about the increased frequency of tropical storms.

1.2 Oceanographic Drivers

The presence of the warm Gulf Stream flowing northeast along the offshore edge of the outer shelf and continental break is a dominant oceanographic feature in the region. The warm waters of the current create a geographically narrow corridor of habitat suitable for tropical and subtropical species, particularly in demersal habitats where the wintertime cooling associated with low atmospheric temperatures is confined to the surface layers of the ocean. Ocean temperatures are more seasonably variable in shallower waters of the middle and inner shelf between the Gulf stream and the coast, particularly north of Florida. Waters of this region are warm in summer, and the horizontal temperature gradient between the coast and the outer shelf is small. In contrast, waters of the inner and middle shelf are reduced significantly in winter, and mixing of the water column leads to cool, temperate ocean conditions in shallower waters. Temperatures, particularly along the seafloor, increase from the inner shelf to the shelf break during winter. Further, interannual temperature variation on the inner shelf is greater during winter than in summer. An exception to this pattern is coastal Florida where interannual temperature variation is similar in winter and summer, which may reflect variable summer upwelling events. Overall, the seasonal climatology described above is modified by eddies and meanders of the Gulf Stream at weekly to monthly time scales.

The distribution of salinities in the South Atlantic Bight exhibits seasonal variation. During summer, surface and bottom salinity is relatively homogenous throughout the continental shelf region. However, during other seasons there is a cross-shelf gradient and lower salinities are found in shallower areas. Lowest salinities are observed in late-spring coincident with high river discharge, particularly on the inner shelf off South Carolina and Georgia.

The presence of the Gulf Stream also has a significant influence on the density stratification of the region. Waters of the shelf break are permanently stratified, with maximum stratification in summer. In shallower waters, rapid cooling in fall decreases stratification, and the water column is relatively well-mixed between November and March (Blanton et al., 2003). Stratification of shelf waters increases with the peak of freshwater discharge from local rivers in March and April (Atkinson et al., 1983). By July, stratification is strong throughout the shelf (Blanton et al., 2003).

Interannual variability in the hydrographic properties remains poorly characterized but is likely sensitive to variability in the seasonality of freshwater flux from rivers, surface heat flux, and position of the Gulf Stream.

The influences of the Gulf Stream are of particular importance because they provide an efficient avenue for the transport of nutrients, heat, and marine organisms between the sub-regions of the coastal southeast US, but also contribute significantly to cross-shore fluxes of momentum, heat flux, and nutrients.

Lee et al., (1991) described the two modes of Gulf Stream variability. The first signature is associated with mean onshore fluxes of nitrate off GA and NC, and it is related to Gulf Stream meander variability in the 3-20 day band. Meanders upwell deep cold nutrient-rich waters onto the outer SAB shelf, which subsequently can be advected onto the mid-shelf, under summertime stratification and upwelling favorable wind conditions. Regions of meander decay correspond to regions of net nutrient import, providing a large annual nutrient source for new production on the SAB shelf (Lee et al., 1991). Individual meander-forced upwelled intrusions on the Georgia shelf have been mapped, and volumes of water imported can exceed 35 km^3 (Paffenhofer et al., 1987). Summer intrusions have been tracked and mapped for periods of several weeks, although their frequency, variation in spatial extent, lifetimes on the shelf and ultimate export pathways are not explicitly defined. In winter, lack of vertical stratification and absence of upwelling favorable wind suppresses shoreward spreading of meander induced fluxes at the shelf break (Castelao, 2011), so while Gulf Stream meander variability is relatively independent of season, the extent to which meander intrusions promote subsurface fall and winter new production is not well quantified.

The second signature of Gulf Stream variability shown in Lee et al., (1991) is the cyclonic 'Charleston Gyre' found between the shelf edge and the offshore-deflected Gulf Stream off Long Bay. This feature is associated with local bathymetric features and its presence is related to documented shifts in the Gulf Stream position off Long Bay. In this location, the GS occupies one of two preferred (weakly and strongly) deflection states (Bane and Dewar, 1988; Lee et al., 1991, Savidge et al., 1992), for several weeks at a time, and abruptly switches from one state to the other. Gulf Stream position affects shelf circulation on the mid-shelf and outer shelf. Savidge et al., (1992) demonstrated that larger offshore displacement of the Gulf Stream is associated with reduced northward shelf flow in Long Bay.

Over the SAB, along-shelf flow is primarily wind forced, especially on the inner and mid-shelf (Lee et al., 1991). In general, shelf circulation follows the prevailing wind forcing (northward in spring and summer, southward in fall, and predominantly southeastward in winter, see Weber and Blanton 1980; Blanton et al., 2003). These general patterns are modulated by the short (3-5 days) synoptic fronts described earlier (warm, cold and extratropical fronts). Seaward of the 40m isobath to the shelf break, shelf circulation also responds strongly to the adjacent GS (poleward flows), whose edge follows the shelf break along the SAB shelf except off Long Bay. In there the Charleston Gyre often modifies wind-driven circulation driving southward directed flows.

1.3 Hydrologic drivers

The Southeast has a humid climate with an abundance of precipitation. Recent studies (e.g., Labosier and Quiring, 2013) however, suggest that the region is characterized by significant precipitation variability marked by heavy, intense precipitation, interspersed with dry periods. Consequently, both floods and droughts may become more common in the future. The relationship between climate indices and hydrological cycle in the southeast is being established. Generally speaking, warm El Niño phases lead to positive precipitation anomalies in much of the region, while cold La Niña phases result in negative precipitation anomalies. Less well-studied are other established oceanic–atmospheric indices, including the Pacific Decadal Oscillation, and the Arctic Oscillation. Despite their destructive potential, tropical cyclones (TC) contribute heavily to the Southeast's annual precipitation and are fundamental to the region's hydro climatology. TC-induced precipitation plays a significant role in the spatial and temporal patterns of water resources throughout the region, especially in coastal and near coastal areas. TC-precipitation accounts for a significant proportion of precipitation in many locations in the Southeast, and a lack of it can lead to serious soil moisture deficits and droughts. Likewise, TCs have the potential to alleviate drought conditions. Increasing trends in TC-induced precipitation are present throughout parts of the region.

More investigation of precipitation variability on interannual and interannual timescales is necessary. While year to year variability and total annual precipitation may remain constant, variability may shift within years leading to significant management and planning implications. It is also not well understood what factors drive the recent variability seen in the region. Future studies will need to decipher natural versus anthropogenic drivers, as well the degree to which each influences hydroclimate variability. Furthermore, downscaling of climate model output will be necessary to make climate projections more useful for the water resource manager. Alongside future hydroclimatic change are also changes in land use/land change and population growth that will also contribute to the already complex hydro climatology of the Southeast.

Nutrients

Excess nitrogen and phosphorus loading impacts not only local waters, but also downstream waterbodies and coastal systems. The USGS National Water-Quality Assessment (NAWQA) program assessed total nitrogen and total phosphorus yields in over 8,000 stream reaches throughout the southeastern United States using the USGS watershed model SPARROW (Spatially Referenced Regression On Watershed Attributes). The southeast regional SPARROW model integrates Federal, State, and local agency monitoring data at over 300 stations with geospatial data describing nutrient inputs from fertilizer or agricultural land use, animal waste, urban land use, atmospheric deposition (nitrogen only), weathering or mining of rock (phosphorus only), and wastewater discharges, as well as physical characteristics of the watershed properties such as soil properties and precipitation).

Results from the southeast regional models can be used to assess:

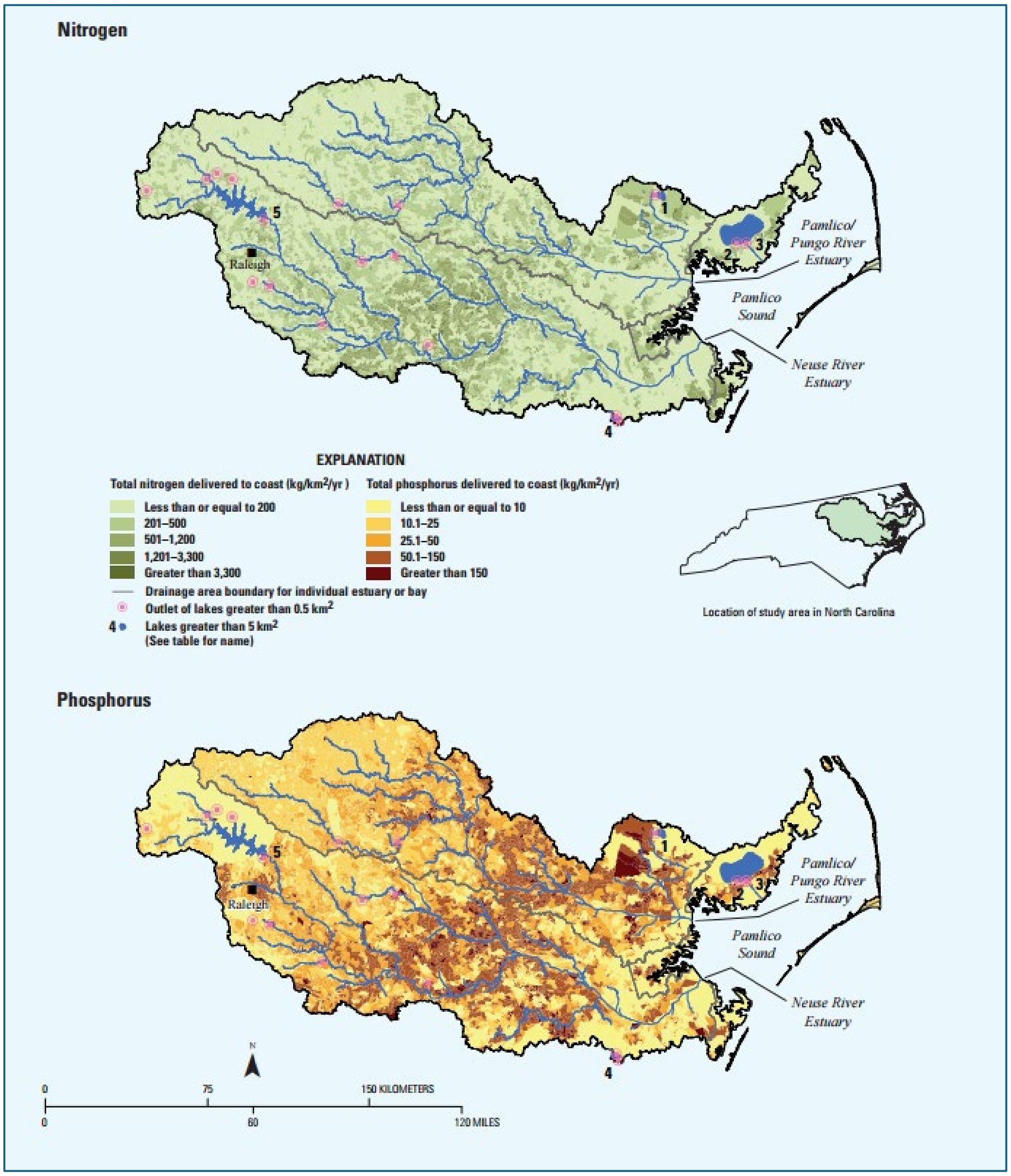
- transport of nitrogen and phosphorus to streams from watersheds,
- removal of nitrogen by processes within streams,
- contributions of nitrogen and phosphorus from different sources in watersheds,
- transport and delivery of nitrogen and phosphorus to receiving water bodies, including the 16 major estuaries along the South Atlantic and Gulf Coasts,
- conditions and transport in unmonitored streams,
- priorities for future monitoring and assessment, and
- response of nutrient levels to proposed management actions.

Estimated statewide total nitrogen (TN) and total phosphorus (TP) loads and yields, as predicted by the regional USGS SPARROW models.

State	Net incremental TN load (1000 kg/yr.)	Average TN yield (kg/yr./km^2)	Net incremental TP load (1000 kg/yr.)	Average TP yield (kg/yr./km^2)
Florida	37,286	359	7,465	72
Georgia	60,007	396	6,168	41
North Carolina	59,194	465	6,493	51
South Carolina	28,173	355	3,049	38

Major sources of nitrogen and phosphorus delivered to the coast often occur far up into the watershed. Large agricultural areas and major cities in the coastal plain and piedmont ecoregions typically contribute the most nutrients to the coast (Moorman et al., 2014)

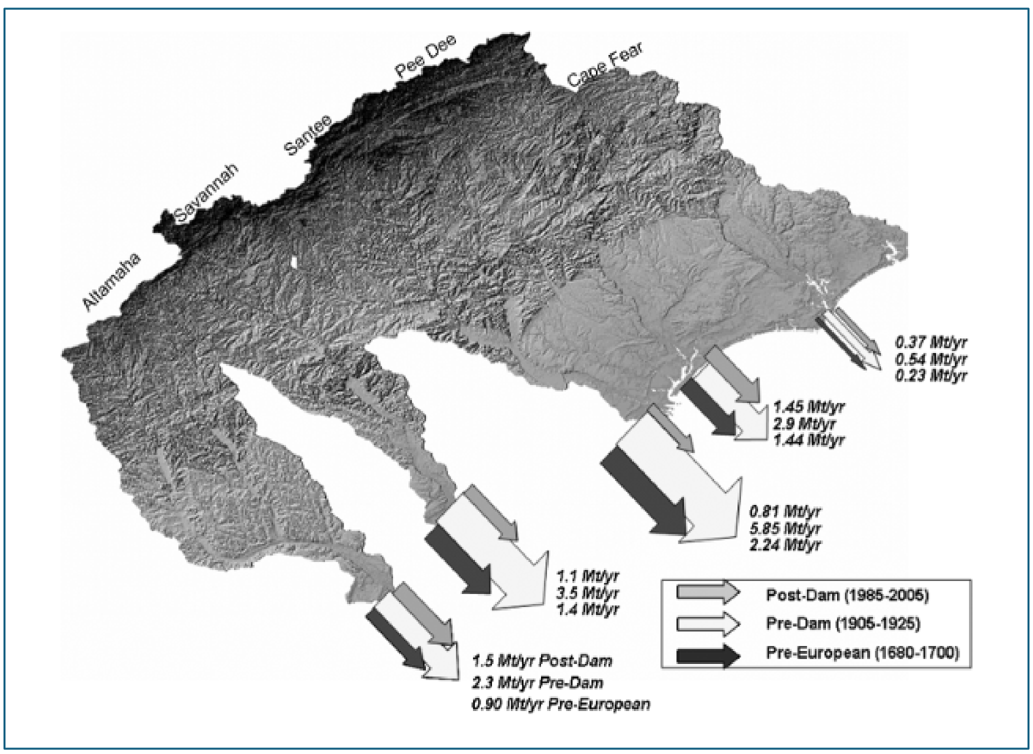
Contributing watersheds and nutrient yield for Pamlico Sound and Pamlico/Pungo and Neuse River Estuaries based on USGS SPARROW models (Moorman et al., 2014).



Sediment

Sources and amount of suspended sediment delivered to the South Atlantic Bight from major rivers has changed significantly since pre-European settlement (McCarney-Castle et al. 2010). The arrival of European settlers, and subsequent deforestation greatly increased sediment delivery through most of the 1900s. Starting in the 1970s, the large-scale creations of dams and reservoirs in the region drastically reduced sediment delivery to levels close to pre-European levels (McCarney-Castle et al. 2010).

Climate changes over the last 300 years appear to have had very little impact of sediment delivery and most changes seem to be driven by anthropogenic decisions (McCarney-Castle et al. 2010). It is difficult to predict future changes in sediment loads. While sediment loads may increase due to ongoing removal of dams from fish passage and restoration efforts, they may also decrease as increasing water demand from rapidly growing urban communities in the Piedmont leads to construction of new reservoirs.



Predicted historic and modern sediment load into the South Atlantic Bight from 5 major river basins (McCarney-Castle et al. 2010)

- History (Past sources, particularly previous land clearing for farming)
- Hydrologic alterations limiting sediment movement
- Current trends in decreasing sediment loads

1.4 Lower-trophic-level ecosystem properties

Analyses of remotely-sensed ocean color in shelf waters of the South Atlantic Bight indicate that chlorophyll concentrations exhibit a high level of seasonal variability, with a strong, inverse correlation with surface temperatures. Chlorophyll concentrations are greatest during cool months of the year (November through March) and lowest during summer months due to stratification of the water column, which leads to nutrient limitation (Barnard et al., 1997; Miles and He, 2010). Chlorophyll concentrations are also generally higher on the inner continental shelf and vary regionally. For example, greater and more variable rates of primary production are present on the Florida continental shelf due to the influence of upwelling events in this area (Miles and He, 2010). Seasonal variability and correlations with ocean temperatures are reduced near the shelf break, where the presence of the Gulf Stream minimizes the seasonal cycle in temperature, mixing, and nutrient supply.

2. Predicted Future Oceanographic Conditions

In coming decades, surface air temperatures are expected to increase as a result of anthropogenic emissions of greenhouse gases. Ocean temperatures are also expected to warm, with a general poleward movement of isotherms. However, future temperature changes in the South Atlantic Bight are expected to differ slightly from this global mean. While the basin-scale orientation of temperature gradients are in the meridional direction, gradients in the South Atlantic Bight generally follow bathymetric contours and are a function of the offshore location of the warm Gulf Stream and the wintertime cooling of waters on the inner and middle shelf. Future warming is expected to result in a shift of warm isotherms toward the coast, particularly in winter when the gradient in water temperature is the steepest (Grieve et al., 2016).

Changes in the seasonal timing of density stratification over the continental shelf of the South Atlantic Bight is expected to be sensitive to changes in surface heat flux and seasonal winds. Over scales relevant to anthropogenic climate change, density stratification of shelf waters is expected to occur earlier in the year. As a consequence, the period of low chlorophyll concentration that is associated with nutrient limitation in summer is also expected to occur earlier in the year and persist later in the fall.

2.1 Ocean Chemistry

Given the continuing increase in atmospheric concentrations of carbon dioxide, the future oceans will be characterized by reductions in the carbonate and aragonite saturation states and pH. Since pre-industrial times, surface ocean pH has declined about 0.1 pH units, equivalent to a 30% increase in the concentration of hydrogen ions (Feely et al., 2009). These changes in the mean state of the ocean carbon chemistry are well understood, and decreases in carbonate saturation state have been shown to negatively impact the formation and maintenance of aragonite and calcium carbonate shells (Feely et al., 2008). However, impacts of ocean acidification on marine populations and ecosystems remain an area of active research. Shallow, highly productive environments are naturally subject to a high degree of variability in the carbon concentrations at a variety of time scales, a result of diurnal and seasonal variability in primary production (and the consequent changes in CO_2 flux). Organisms in these environments have adapted to such variability, and their susceptibility to anthropogenic ocean acidification remains uncertain.

Increases in ocean temperatures and decreases in ventilation (i.e., reduced mixing resulting from increased density stratification) acts to reduce dissolved oxygen content of surface and subsurface waters. In coastal estuaries where increasing supply of both organic and inorganic nutrients may be associated with coastal development, increases in microbial respiration may also lead to decreased concentrations of dissolved oxygen and development of hypoxia, even in ecosystems that are relatively well vertically mixed (Verity et al., 2006). Additionally, shelf waters may be subject to episodic intrusions of waters with low dissolved oxygen concentrations that are associated with upwelling forced by southwesterly winds. Project long-term changes in this process remains to be quantified (Sanger et al., 2012).

In January 2016, the Southeast Ocean and Coastal Acidification Network held a workshop to discuss the state of ocean acidification science, prioritizations and vulnerabilities of the region (Wickes 2016). The meeting sought to accomplish three objectives: 1) summarize key findings, prioritize research needs, and identify research and laboratory capabilities that could address ocean and coastal acidification research questions; 2) identify why the Southeast region is unique and its vulnerabilities to potential impacts of ocean acidification; and 3) summarize why ocean acidification matters to stakeholders. Some of the key conclusions from the meeting included:

- Ocean and coastal acidification is driven by local and regional processes such as eutrophication, upwelling, and freshwater flow to the coast, as well as by global ocean uptake of carbon dioxide (CO_2) that is increasing in the atmosphere due to the burning of fossil fuels, land use change, and cement production.
- Ocean acidification affects all marine waters, and has been shown in laboratory experiments to negatively impact those marine species that grow by producing shells of calcium carbonate minerals such as oysters, clams, mussels, and corals
- The Southeast region is unique from other U.S. coastal regions because it spans subtropical to tropical climate zones, and displays unique and extreme environmental conditions, stressors and gradients.

- Many species in the Southeast are adapted to highly variable estuarine conditions, including wide fluctuations in pH, but how this affects their vulnerability to ocean and coastal acidification is unknown.
- Shellfisheries and coral reefs, which are important to the culture and the economy of the Southeast region, are particularly vulnerable because acidification can directly impair the growth of species with carbonate shells and skeletons. A number of shellfish hatcheries have experienced significant die-offs, although the cause is not currently known.
- We have a good base of information to help build our knowledge on impacts to the Southeast, and ways to prepare society to manage the consequences.

2.2 Sea Level Rise

Sea level rise has been documented by diverse geophysical studies in the southeast U.S., with regional variation identified in rates and societal vulnerability (e.g., Kemp et al. 2009; Tebaldi et al. 2012). Most areas in the southeast U.S. region are projected to experience an approximately 0.75-1m rise in sea level by 2100 (Kopp et al. 2014, Parris et al. 2012), but this will differ on local scales. For example, Parkinson et al. (2015) examined rates of current and predicted rise for seven regions throughout Florida. On the east coast of Florida, the region of highest vulnerability consists of Palm Beach, Broward, Miami-Dade, and Monroe with increases that will range from 5-20 mm/yr. These rates of sea level rise will result in coastal flooding, seawater intrusion, and loss of estuaries and coastal wetlands. Important habitats such as salt marshes, shoals, mud flats, and mangrove forests may be lost (Glick and Clough 2006). These impacts may negatively impact estuarine species less tolerant of salinity changes and lead to changes in estuarine productivity (National Marine Fisheries Service, 2017).

Sea level rise will also have impacts in terms of socio-economic changes (e.g., levels of habitation of the Florida Keys and Dade County by 2100), losses of or transitions in coastal waterfronts (including seafood off-loading and processing areas), and other factors that could emerge in coming decades. However, many policy responses to sea level rise involve complex socio-economic and communication challenges and are explicitly unaddressed in coastal Florida and North Carolina (Lindeman et al. 2015).

2.3 Temperature, Precipitation and Hydrology

U.S. National Climate Assessment (Melillo, et al., 2014) reports that temperatures across the Southeast and Caribbean are expected to increase during this century, with shorter-term (year-to-year and decade-to-decade) fluctuations over time due to natural climate variability. Major consequences of warming include significant increases in the number of hot days (95°F or above) and decreases in freezing events. Although projected increases for some parts of the region by the year 2100 are generally smaller than for other regions of the United States, projected increases for interior states of the region are larger than coastal regions by 1°F to 2°F. Regional average increases are in the range of 4°F to 8°F (combined 25th to 75th percentile range for A2 and B1 emissions scenarios).

Projections of future precipitation patterns are less certain than projections for temperature increases. Because the Southeast is located in the transition zone between projected wetter conditions to the north and drier conditions to the southwest, many of the model projections show only small changes relative to natural variations. However, many models do project drier conditions in the far southwest of the region and wetter conditions in the far northeast of the region, consistent with the larger continental-scale pattern of wetness and dryness. In general, annual average decreases are likely to be spread across the entire region. Projections further suggest that warming will cause tropical storms to be fewer in number globally, but stronger in force, with more Category 4 and 5 storms. On top of the large increases in extreme precipitation observed during last century and early this century, substantial further increases are projected as this century progresses.

3. Climate Impacts on Fish, Fish Habitat and Fisheries

3.1 Abundance and Distribution

Climate variability plays a major role in the abundance and availability of fishery resources each year (Hare et al. 2016). The influence of climate can be observed at multiple temporal scales. Interannual variation (e.g., cold vs. warm year) can drive the abundance of short-lived species, including many valuable forage species like anchovy, squid and shrimp. For example, white and pink shrimp are vulnerable to winter kills, and closures may be enacted to protect the spawning stock of these species in the southeast (Shrimp FMP, Amendment 9). Commercial catches of other fisheries in the southeast, such as Spanish mackerel and bluefish, have also been related to interannual variability in temperature (Morley et al. 2016).

Climate change, however, operates on a larger scale and can influence fisheries in multiple ways. Temperature sets boundaries on the geographic ranges of marine species (Sunday et al. 2012). For any given species, climate change may lead to a spatial shift in the location of suitable temperatures, which in turn changes the distribution of habitat (Pinsky et al. 2013). Mobile-pelagic species often respond rapidly to shifts in preferred thermal habitat because of the directed movement of individuals, while responses of benthic species may be more complex (Sunday et al. 2015). For example, suitable habitat for species within the snapper-grouper complex off the southeast U.S. occurs where preferred temperatures and benthic attributes overlap (Bacheler and Ballenger 2015). Therefore, distribution shifts of these species will depend on the availability of suitable structured habitat as preferred temperatures expand into new areas.

Increased temperatures can also change the seasonal availability of migratory species or can affect the productivity of a stock in a given region. For example, in 2015 and 2016 the recreational landings for cobia (NY to GA) and blueline tilefish significantly exceeded the annual catch limits (NMFS Southeast Regional Office, 2017). These years coincided with unexpected high catches in the mid-Atlantic region, so cobia and blueline tilefish may be responding to increasing temperatures in the northeast. However, these issues remain unresolved and indicate a strong need to examine how climate change may influence traditional stock boundaries of fishery resources in the southeast.

3.2 Thermal Envelopes

A vast majority of species targeted by fisheries are ectothermic, which means their body temperature conforms to the surrounding water temperature. All metabolic processes (e.g., protein synthesis and growth, swimming speed, etc.) are highly dependent on temperature. Every species is adapted to perform well within a specific range of temperatures, which is described as the thermal envelope of a species (Pörtner and Knust 2007). At temperatures beyond (either above or below) the thermal envelope, individuals become increasingly limited in their ability to maintain basic metabolic processes (Pörtner 2002). For example, the ventilation (i.e., gills) and circulatory systems supply oxygen to the body, and these systems have an optimal performance temperature. As temperatures increase beyond this level, oxygen supply declines, despite continued increases in basic metabolic needs. This results in a reduced growth potential and scope for activity at temperatures outside of the thermal envelope. Extreme temperatures are typically lethal due to a breakdown of cellular functioning.

One concern is that the rate of climate change will exceed the rate of adaptive change to changing environmental conditions. If this occurs, the options available to marine species to mediate the impacts of climate change are limited. They can respond in two major ways: exhibit spatial distribution shifts and/or phenology changes. Both responses reflect the species attempt to cope with changing environmental conditions.

Spatial distribution changes result from a species tracking its thermal envelope as it shifts across the seascape, which can result in latitudinal shifts or changes in depth (Pinsky et al. 2013). Northward shifts and/or expansions of species ranges have been documented in the South Atlantic for species such as cobia and white shrimp (Pinsky et al. 2013) and in the northern Gulf of Mexico for species such as red grouper and yellowtail snapper (Fodrie et al. 2010). The mechanisms behind such shifts depend on species motility (e.g., coastal-migratory vs. reef oriented vs. sedentary), reproductive strategy (e.g., wide larval dispersal vs. locally retained larvae), and juvenile thermal tolerance in some species. For example, the adult range of gray snapper in the southeast U.S. is largely limited by the overwinter survival of juveniles which may change geographically with the warming of waters in current northern boundaries (Wuenschel et al., 2012). In regions of rapid temperature change, such as the northeast U.S., species can respond rapidly. For example, distributions of scup and black sea bass in the Mid-Atlantic Bight have shifted northward by 150-200 km in the past four decades (Bell et al. 2015). Unfortunately, species exhibiting low motility (e.g., corals, attached bivalves, etc.) and limited larval dispersal (e.g. oyster toadfish, seahorses, etc.) have a limited scope to account for climate change with species distributional shifts. A similar distributional shift may occur in the face of changing ocean acidification, which we expect to occur in a warmer ocean (Calosi et al. 2017).

3.3 Phenology

Shifts in species phenology, which refers to the annual timing of life history events (e.g., timing of reproductive period, timing of migrations, etc.), result from species attempting to account for changes in the average environmental conditions experienced by individuals in a population. For example, species may shift their reproductive season as environmental conditions, particularly temperature, is critical for successful reproduction, as early life stages have specific and narrow requirements for survival (Rijnsdorp et al. 2009). Reproductive strategies evolve to maximize the probability that offspring will experience favorable environmental conditions, and thus maximize the probability that their young survive to reproduce. By doing so, the fitness of individuals will be maximized. Climate change can affect both the timing of reproduction and the spatial extent of suitable spawning habitat. Unless there is enough plasticity in the reproductive strategy of the species to account for such shifts, the reproductive potential of the population will ultimately be affected. Another potential shift in phenology may occur with regards to the annual timing of migration (either across shelf or alongshore) for migratory species (Mills et al. 2013, Morley et al. 2016, Sims et al. 2001). Such migrations evolved to facilitate the presence of individuals of that species being in particular areas (e.g. for feeding or reproduction) at certain times of the year. Timing of migrations are often cued via environmental conditions (e.g. temperature), so climate variability can impact the seasonal availability of fishery resources in particular areas (Mills et al. 2013) and affect the "growth potential" of the population by altering mortality rates (e.g. higher mortality because mistimed presence on appropriate foraging grounds) and/or reproductive potential (e.g. not on spawning grounds when chances of survival are maximized).

3.4 Spawning, Dispersal, and Connectivity

For many South Atlantic species, particularly sessile invertebrates and benthic fishes, dispersal during the pelagic larval stage is a key feature of the life cycle. Larval transport provides demographic connectivity that links distant portions of the habitat. This connectivity can provide resilience against local disturbances, and is critical to understanding population persistence (reviewed by Botsford et al. 2009, Cowen and Sponaugle 2009). Larval dispersal distances are shaped by a complex interaction of ecological factors: the timing of spawning, larval development time, ocean circulation, larval behavior (e.g., vertical migration, navigation), and the planktonic food supply available to larvae. Many of these factors are likely to shift in the face of a changing and increasingly variable climate. For example, temperature affects metabolism rates and is a major driver of gonadal development and spawning (Lowerre-Barbieri et al. 2011), and therefore climate-induced changes in temperature regimes can be expected to influence spawning times and locations. Indeed, changes in temperature have been linked to alterations in spawning times for a number of marine fish species such as North Sea mackerel (Jansen and Gislason 2011), flounder (Sims et al. 2005), cod (Wieland et al. 2000) and Bluefin tuna (Muhling et al. 2011). As the phenology of both spawning activity and primary productivity shifts, this may lead to mismatches between the time larvae are in the water and the availability of their prey (Durant et al 2007, Edwards and Richardson 2004) causing starvation and high mortality, and lower energetic reserves in surviving larvae (McLeod et al. 2013, Kristiansen et al. 2014).

Because fish and invertebrate larvae are ectothermic, we generally expect larval durations to shorten and larval growth to speed up. This leads to the general expectation that overall dispersal distances will shorten, reducing connectivity (O'Connor et al. 2007, Munday et al. 2009). However, experimental results (most of which have been conducted with tropical fishes) do not always follow this pattern; if warming exceeds the thermal optima for fish development then larval durations may actually lengthen in warm conditions (McLeod et al. 2013). Additionally, the temperature-dependent acceleration in larval development also increases larval food requirements: a combination of high temperatures and low food availability can further lengthen larval durations (McLeod et al. 2013). The effects of reduced planktonic productivity are of particular concern in the South Atlantic Bight due to expectations that increased stratification will lead to earlier, longer periods of low summertime chlorophyll (see Future Ocean Conditions). Ocean acidification is also likely to affect connectivity, both via impairments to navigation and habitat selection by late-stage larvae (Munday et al. 2010) and by imposing additional physiological costs on larvae that impair development and increase mortality (Munday et al 2009).

Climate change and variability will affect multiple processes associated with larval dispersal and connectivity simultaneously, and in possibly different directions. For example, increasing temperatures and shifts in prey availability may either shorten or lengthen development times, and changes in ocean circulation may either hasten or slow current velocities, depending on location and season. These complex interactions make it difficult to draw general conclusions regarding likely shifts in connectivity. Instead, such predictions require site-specific modeling of both oceanography and larval behavior to quantify the relative contribution of each process. Such work has been completed for other regions but not the South Atlantic (e.g., Lett et al. 2010, Aiken et al. 2011, Andrello et al. 2015). However, we can make the general prediction that increased variability in larval survival will lead to net decreases in population density. This is because the recruitment of most species is governed by a nonlinear, density-dependent stock-recruit relationship that reflects competition for resources (food, predator refuges, etc.) among new recruits. As a consequence, the magnitude of positive fluctuations in larval survival ('good years') are damped by density-dependent competition, while the magnitude of negative fluctuations ('bad years') is not. Thus good years cannot balance out bad years, and the net effect of increasing variability is reduced mean recruitment over the long term (Armsworth 2002).

Many species in the region undergo ontogenetic migrations, sometimes recruiting as larvae to upper estuaries then migrating to the lower estuary and finally offshore as adults (Able and Fahay 2010). This movement is another form of spatial connectivity that is essential to the understanding of population dynamics in these species (St. Mary et al. 2010, Grüss et al. 2011, White 2015). However, there are few specific predictions of the effects of climate variability on ontogenetic migrations. In general the life stage most vulnerable to variable conditions is the larvae and early juveniles; these stages will also be found in the upper estuary where they are vulnerable to both high temperatures and increasingly frequent hypoxic conditions.

3.5 Trophic Interactions

Climate change may alter food web dynamics and trophic structure throughout the region. Alterations in primary and secondary production may lead to changes that cascade through the food web and have a direct impact on fish and fisheries (Brander 2010). The physiology and behavior of organisms is changing and impacting size structure, spatial distribution, and seasonal abundance of both prey and predators which may lead to altered species interactions affecting a range of organisms from phytoplankton to marine mammals (Doney et al. 2012). For example, warming ocean temperatures can lead to increased consumption rates and stronger top-down effects (Sanford 1999, Philippart et al. 2003). Ocean acidification can negatively impact important prey species which depend on calcium metabolism, such as diatoms, shellfish, and both soft and hard corals (Doney et al. 2012). Changing environmental conditions can lead to asynchronous shifts in seasonal phenologies of predator and prey populations (i.e. match-mismatch hypothesis) and disrupt existing trophic interactions (Doney et al. 2012). As scientists and managers seek to better understand the impacts of climate change on marine ecosystems, it will be important to look at these community level impacts. For additional information see the Food Webs and Connectivity chapter of the Fishery Ecosystem Plan.

3.6 Disease and parasites

Increasing water temperatures have been linked to increases in the prevalence and distribution of marine disease outbreaks (Harvell et al. 2009). This is likely due to the expansion of pathogen ranges as temperatures warm and increased susceptibility by the host due to environmental stress. The severity of disease is also expected to increase as pathogens are generally favored by warmer temperatures relative to their hosts (Harvell et al. 2002). For example, warming in the early 1990s led to the spread of the oyster parasite, *Perkinsus marinus*, across a 500 km range and caused mass fatalities in the oyster's populations. Research shows that increased temperatures are also associated with increased frequency of disease and bleaching events in reef-building corals (Bruno et al. 2007).

3.7 Invasive Species

The climatology of the South Atlantic Bight is a major factor shaping the distribution and abundance of invasive species in this region. Lionfish (*Pterois volitans*, *P. miles*) have received much attention because they threaten fisheries associated with the structured habitats on the continental shelf. The distribution of adult lionfish is restricted to areas where winter temperatures remain above 15°C (Whitfield et al. 2014), because low temperatures cause cold stress and mortality (Kimball et al. 2004). This prevents adult lionfish from occupying depths below 27 m north of Florida (Whitfield et al. 2014). However, in structured habitats of the outer continental shelf lionfish are a dominant species and can outnumber most targeted fishery species including groupers and porgies (Whitfield et al. 2007, 2014). The predatory impact of lionfish at high densities is large (Cerino et al. 2013), and they have similar feeding habits as economically important species like scamp grouper (Munoz et al. 2011). However, lionfish impacts on the productivity of important fisheries remains poorly understood. In their native range lionfish occupy shallower habitats, so increasing temperatures in the southeast region may lead to an expansion of suitable habitat into shallower areas. Evidence for this prediction comes from an earlier warming period off North Carolina before lionfish were established. Parker and Dixon (1998) found that a region of North Carolina's continental shelf, known as 210 rock, experienced an increase in the number of tropical species following a period of increased winter-water temperatures during the 1980s. It is noteworthy that multiple tropical-Pacific fish species, in addition to lionfish, have been observed off Florida (Semmens et al. 2004).

In estuarine habitats, interannual variability in winter temperatures may limit the northward expansion of potentially invasive tropical species from south Florida and the Caribbean (Canning-Clode et al. 2011). Some of these species are native to tropical regions, but have the potential to thrive off the southeast coast. One example is the green porcelain crab (*Petrolisthes armatus*), which is widespread in the tropical Atlantic occupying structured coastal habitats (see Hollebone and Hay 2007). It is an emerging invasive species of the southeast U.S. where it occupies oyster reefs and is capable of outnumbering native crab species and also reaching densities that are far greater than what is reported in its natural range (Hollebone and Hay 2007). However, the permanent establishment of this species north of Florida appears to be limited by periodic cold events during winter (Canning-Clode et al. 2011). Climate variability may also play a key role in limiting the northward spread of invasive species that are established in the tropical Atlantic. For example, Asian tiger shrimp are a widespread invasive that may already be established in the South Atlantic Bight (Fuller et al. 2014). However, to predict the impact of this species in the region, a better understanding of how temperature variability interacts with reproduction and life history is needed.

3.8 Age-structure Truncation and Sensitivity to Climate Variability

Aside from reducing overall abundance, size-selective harvest has the additional effect of truncating the population age distribution. As older ages become less abundant, reproduction is compressed into just a few age classes (in the extreme, populations can become effectively semelparous, spawning only once on average before being harvested). The consequence of this truncation is a heightened sensitivity to environmental variability at particular characteristic frequencies. Essentially, if a climatic anomaly produces a strong (or weak) recruit year class, that anomaly will continue to resonate in future years as the cohort matures and reproduces, producing a second anomaly in recruitment. This ‘echo effect’ or ‘cohort resonance’ is amplified as the age structure is truncated, and also if a dominant mode of environmental variability coincides with the generation time (i.e., resonance frequency) of the population (Botsford et al. 2011, 2014). Modes of environmental variability likely to affect populations in the South Atlantic include the North Atlantic Oscillation and the Atlantic Multidecadal Oscillation (e.g., Condron et al. 2005, Hare and Able 2007, Buchheister et al. 2016).

Impacts on People and Fisheries

3.9 Catchability

Climate variability can affect catchability of a species, both in terms of availability to the fishery and vulnerability to gear (e.g. Wall et al. 2009). Changes in availability to the fishery can be a result of changes in the spatial distribution of stocks, as well as the timing of their migrations (Morley et al. 2016). When the preferred physical habitat (e.g., in terms of temperature, oxygen levels, or current regimes) of a fish species is altered, fish can migrate away from traditional fishing grounds to locations that are less accessible to fishers, thereby reducing availability. Changes in timing of migrations may also make stocks less predictable for targeting; for example, warming earlier in the year may force fish to migrate to northern areas sooner and more extensively, making them less available to fishers in some areas while simultaneously increasing availability in other areas. These affects can produce increases or reductions in landings and catch rates that are not proportional to actual changes in the stock biomass. Catch rates can also be increased or decreased due to changes in vulnerability (Stramma et al. 2012). For example, if surface waters increase in temperature and fish distribute deeper in the water column, then some surface gears may become ineffective in catching the fish. Some fishers will respond by adapting and making use of subsurface fishing techniques; however this process of adaptation can take days or weeks. During this time, catch rates will fall independently of the true abundance of the fish. Such changes in catchability make it challenging to track stock trends based on fishery-dependent data and can then complicate efforts to assess the status of populations.

3.10 Sea Level Rise

Sea level rise is expected to directly impact many fishing communities throughout the region (see map). Given the close proximity of these communities to the coast, infrastructure and businesses closely tied to commercial and recreational fishing industries will be vulnerable. Communities will be disproportionately affected (Weiss et al. 2011), but projections show that coastal communities will be increasingly impacted by submergence, erosion, and coastal flooding, all directly impacting commercial and recreational fishing infrastructure (Gesch et al. 2009). There may be a need to relocate critical infrastructure, such as piers, docks, and seafood markets.   A recent study by Colburn et al. (2016) establishes a set of social indicators to assess the impact of sea level rise on critical fishing infrastructure. They found several coastal communities in the South Atlantic to be considered highly vulnerable, with southeastern Florida and the Florida Keys having the highest concentration of impacted communities.

3.11 Socio-Economic Impacts

By altering the abundance, distribution, and phenology of marine fish in the southeast U.S., climate variability and change will also affect the fishing opportunities available in the region. These changes may drive social and economic transitions for coastal towns and cities that rely on fishing for their culture, identity, and economy (Pinsky and Fogarty 2012). For example, changes in distribution can increase travel time and costs for fishers as previously nearby fishing grounds shift further away. However, the fishing industry may also see opportunities to catch new species that arrive, and may choose to adapt processing and fishing gear and infrastructure to take advantage of these opportunities. The choices available to the fishing industry are strongly constrained by social, economic, and regulatory factors, and given the uncertainties of future changes, fishermen may cope in part by diversifying among fisheries, joining together in cooperatives, and diversifying among sources of income. Other management measures that can foster adaptation include transferable quotes, vessel buybacks, effort to promote alternative and underdeveloped fisheries, reduction of perverse subsidies, and endowment funds.

In addition, because fishing is a social-ecological system, the impacts of climate change must be considered in light of feedbacks between the behavior of fishers and the species they exploit. Reduced fishing on newly arrived species will hasten their establishment, for example, and may prove beneficial in the long run if it allows a viable fishery to develop more quickly. On the other hand, continued fishing on trailing edge populations might prolong an existing fishery and ease the economic transition to new species, but may also trigger a disruptive population collapse.

4. Knowledge Gaps and Research Priorities Related to Management Needs

The following areas were identified as knowledge gaps in the South Atlantic region and research should be prioritized to advance our understanding of impacts of climate variability on fisheries resources and management:

4.1 Ocean Observations

With respect to the fisheries resources in this region the most significant climatic changes are likely to be changes in circulation (in particular the strength and position of the Gulf Stream), changes in local wind fields responsible for cross shelf transport and upwelling, precipitation resulting in runoff into and changes in salinity in the estuarine systems serving as nursery habitats, sea level rise within the estuarine zones, changes in pH, oxygen, and water temperature. Both the climatic average and the degree of variability for these parameters are expected to change (or in some cases may already be changing). Monitoring networks for some if these parameters, such as precipitation, tidal heights, and littoral winds, are well established, but as we move offshore less data is available. While remote sensing data and *in situ* data collected by many organizations are helping to fill the gap, there are still significant gaps in observations from the estuaries through the US Exclusive Economic Zone that result in our inability to provide integrated nowcasts and forecasts of present and future ocean conditions. Filling these gaps is a research priority.

4.2 Improved Regional Climate Prediction

There are two additional main issues that are related to this inability to provide reliable nowcast and forecasts: 1) the availability of adequately verified and calibrated downscaled coupled models over the spatial domain of interest; and 2) making predictions on inter-decadal (versus longer) time scales. Decadal scales (10-40 yrs.) are technically challenging even on basin or global scales (e.g., see World Climate Research Programme, 2013) where skill is limited and when one combines this issue with the necessity to predict on regional scales the problems are compounded. While large-scale directional change is relatively well understood (e.g. Melillo et al. 2014), integrated analyses indicating direction or rate of change occurring in the southeast region are lacking. Such analyses and addressing the inter-decadal gap are a research priority.

4.3 Species and Habitat Vulnerability to Climate Change

The lack of rigorous scientific understanding of the overall responses of South Atlantic marine communities to climate variability and change limits our ability to describe the vulnerability of resources to future conditions in the region. This lack has a number of inter-related causes. First, the magnitude of historical climate variability in our region is rather small in comparison to the interannual-to-decadal variability evident in other regions of the US (e.g., the Northeast US continental shelf or US west coast). In those regions the relationships between climate variability and fisheries have received considerably more attention (Mantua et al. 1997, Hollowed et al. 2001, Checkley and Barth 2009, Friedland and Hare 2007, Runge et al. 2010) and mechanistic understanding is more advanced. In addition there has been less systematic documentation of the overall community of marine populations along the southeastern coast of the US are lacking. While surveys of adult stocks are routine (e.g., MARMAP), the region lacks regular research surveys of zooplankton, ichthyoplankton, and hydrography that have become standard in other regions (e.g., EcoMon in Northeast and CalCOFI along the west coast). Projections suggesting that species' distributions will shift poleward or shoreward with future warming in the region are based on basic temperature-preference assumptions or laboratory studies on adult fish (e.g., Grieve at al. 2016), and such assumptions may be inadequate to describe species responses in the dynamic marine environment. Lack of time series data and a limited history of fisheries oceanographic work in the region regarding the influence of climate processes on ocean physical and biological parameters challenge our ability to make projections about ecological responses to future change. Obtaining these data and conducting this research should be a priority.

Predictions of future physical states of the South Atlantic can be used in conjunction with information on vulnerability of species to help characterize the future states of marine and coastal ecosystems and the specific population responses. For example, the risk assessment framework proposed by Gaichas et al. (2014) combines quantitative changes in physical variables (e.g., temperature, salinity, stratification) with life history characteristics of key species to predict the level of risk to different fish communities. Such an assessment would be helpful for prioritizing research activities in the region and for highlighting the potential vulnerabilities to fishing-dependent communities. NOAA Fisheries has developed a framework for conducting vulnerability assessments and has completed them in the Northeast Region (Morrison et al. 2015). This framework has been internally vetted and peer-reviewed (Hare et al. 2016), and could be used for carrying out vulnerability assessments for the Southeast Region.

4.4 Social Impacts and Fisheries Responses to Climate Variability

Changes in the distribution, abundance, vulnerability and availability due to environmental variability and climate change will result in a gradation of socio-economic impacts in the southeastern U.S. depending upon whether the fish and fishermen are able to move with shifting habitats. Important questions need to be answered. Will the fish move so far from their traditional fishing grounds that the fishermen either have to move with the fish to new jurisdictions, target other species, or stop fishing? Will fishermen have to change techniques and gear as the catchability (availability and vulnerability) of the species change? What will happen to existing fish processing and transportation infrastructure as species change distribution and abundance? Will new infrastructure need to be developed in new fishing areas? What will be the change in associated overhead and profit? How will families and communities respond to the change in fisheries? Answering these questions is critical to management and must be an ecological and sociological research priority.

A number of recent studies have provided a groundwork for understanding human community response to climate change, though these methods largely have yet to be applied to the South Atlantic region. Jacob and Jepson (2009) used the Fish Stock Sustainability Index (FSSI) to understand the combined levels of sustainability of stocks on which community incomes depend. The Northeast region recently received $5 million to support projects largely related to understanding the impacts of climate change on fishing communities (http://www.st.nmfs.noaa.gov/ecosystems/climate/northeast-shelf-climate-impact), and it is possible that the South Atlantic could apply some of the resulting methodologies to the region. Jepson and Colburn (2013) recently developed a suite of community vulnerability indicators for the entire U.S. Atlantic coast, and these can serve as a basis for monitoring changes due to climate and other pressures on the marine ecosystem.

4.5 Indicator Selection

The Integrated Ecosystem Assessment process has been successfully applied in other FMC regions (e.g. the Gulf of Mexico) and a process of indicator selection employing Primary, Data and Communication criteria in this context was described by Fletcher et al. (2014). The process has been successfully applied to both climate parameter indicators and to ecological indicators. It can and should be emulated by the SAFMC. The selection (and possibly development) of a parsimonious set of indicators needs to be a research priority.

4.6 Major Observation Gaps

There are large gaps in the biological data required for an IEA of this region. As noted earlier there is a dearth of plankton data (with the requisite synoptic physical data) over much of the region. There are regular demersal fish surveys, but these surveys are limited in time and space. They do not provide the data needed to evaluate apparent changes in environmental conditions in a coherent manner as they are not standardized surveys that repeatedly sample the same stations at regular intervals. The same can be said with respect to forage fishes not targeted by the commercial fleet.   Overall in comparison to some other regions fisheries independent sampling is generally lacking in the SE and obtaining these data should be a research priority.

An additional problem is that catches (and effort estimates) are not known at the spatial and temporal resolution needed to determine relationships between the catch and the environment because only landings are reported. Vessel monitoring systems are not required, nor are there many vessels involved in cooperative research to provide needed data. Tools that would address this problem to provide the spatial and temporal resolution necessary should be a priority along with cooperative research.

4.7 Implications for Management

Informing short-term tactical management essentially requires obtaining and delivering a mechanistic understanding of climate effects on various processes at the scales at which management acts. In the Gulf of Mexico, operational models are currently being developed to predict climate effects on the dynamics of select species in the snapper-grouper complex. Such initiatives include an index of natural mortality for grouper species based on red tide events (Walter et al. 2013) and predictions of recruitment strength for red snapper (Karnauskas et al. 2013a). Such efforts should be expanded to the South Atlantic. These predictions can be incorporated into stock assessments for these species to inform key parameters (natural mortality and recruitment). When understanding the specific mechanisms driving population dynamics is not possible, other statistical methods can be used to make one-year-ahead predictions of population parameters (e.g., Harford et al. 2014). Applying these statistical methods to SE species (and validating the predictions made) needs to be a research priority.

Incorporating climate information into medium-term fishery management essentially entails the use of management strategy evaluation (MSE), a tool which can be used to determine whether current harvest strategies are robust to future changes. Incorporating various climate scenarios into the MSE framework depends on understanding the range of plausible future ecosystem states. For example, models of future predicted physical conditions could be used to estimate how fish recruitment will fluctuate, and these estimates could be incorporated into MSE to understand whether current practices are robust to expected changes in productivity. In the Southeast region, work is currently being carried out in both single-species and multi-species frameworks, to understand the potential effects of red tides on the Florida West Shelf. Management strategy evaluation is being used to determine whether current harvest control rules are robust to increasing episodic natural mortality events (Harford et al., in prep). Such exercises should be extended to the South Atlantic to determine whether management policies are robust to the expected changes in stock dynamics.

Inclusion of climate information in the management process can sometimes represent a significant burden on an already over-complicated management process. Including environmental forces suspected to alter population dynamics then adds an additional level of complexity to the process. A prioritization exercise should be carried out to understand where the inclusion of climate information could realistically improve the management process. In some cases, focused research programs may help us to effectively detect and respond to climate influences on populations; in others, detecting such effects may be cost-prohibitive and we may be required to focus on risk-adverse management policies. Given limited resources such a systematic prioritization effort is needed to set climate-related fisheries research priorities in the region.

Overall, adaptive decision processes in the South Atlantic that can respond to climate should evolve through increased dialogue between scientists, managers, and stakeholders, and through studies focused on when and where climate information has the greatest capacity to improve management. Initiatives such as Ecosystem Status Reports (e.g., Karnauskas et al. 2013b) can serve to motivate this dialogue and highlight to science and management communities the range of drivers that may be important to consider. Such information can be tailored to the management process; for example, in other regions various management documents are accompanied by “ecosystem considerations” summaries that then help form the basis of decision-making. We need to apply the same process in our region.

Last, as noted by Schindler and Hilborn (2015), scenario planning versus reliance upon forecast models which are likely to remain highly uncertain is likely more applicable to the problem of EBFM in the climate change context. The precautionary principle should be interpreted as requiring flexibility (versus rigidity) in any policy adopted and reliance upon adaptive management given the apparent non-stationarity in many key ecosystem relationships. The lack of information on effort and catch along with knowledge of the species vulnerabilities have generally prevented the development of environmentally adjusted catchability coefficients in the stock assessment process. Thus, the variances of the estimates of abundance of the stocks are larger than they would be if quantitative catchabilities were used. This prevents precise estimates of abundance and estimates of the status of the stocks. Therefore, scenario planning is recommended and validation of the predictions made needs to remain a research priority.

5. Links to SAFMC Management Decisions and Ecosystem-Based Fisheries Management

Effective management of variable, uncertain, and non-stationary systems has received considerable attention in recent years, particularly with the recognition of climate change and variability as major concerns. General principles include the importance of 1) evaluating management approaches under a wide range of possible scenarios, 2) efforts to maintain ecosystem heterogeneity and diversity (and hence options), 3) ongoing monitoring and assessment of ecosystem state, and 4) maintaining management flexibility and responsiveness. In the context of climate variability, populations and ecosystems facing fewer non-climate stressors will tend to be more resilient to changes in climatic conditions.

Climate variability has important implications for the spatial management of marine species. Fish populations often react to changing ocean conditions. As discussed earlier in the chapter, as the ocean temperatures change, many fish species are expanding their range or shifting their distributions toward the poles or into deep areas to find cooler waters (Jones and Cheung 2014). In the South Atlantic, scientists are observing changes in the distribution of cobia which are shifting northwards during their spring migration. Available thermal habitat is also expected to increase for invasive species such as lionfish permitting the species to invade new habitats year-round in the coming decades (Grieve et al. 2016). Black sea bass are being caught further south off Florida and Walker (2016) documented an increase in probability of occurrence in recent years around Cape Canaveral, Florida which could be related to cooler near surface water resulting from more frequent upwelling events in recent years. Such events need to be investigated comprehensively. As conditions change and fluctuate, other South Atlantic fish populations could follow suit. This is particularly important because the movement of species into other jurisdictions can affect existing management plans and perhaps require modification of existing management strategies.

Changing ocean conditions have the potential to alter existing fisheries and create opportunities for new fisheries in other regions. Sometimes this can happen before managers have an opportunity to consider the potential impacts of the new fishery on the ecosystem and put appropriate management measures in place (e.g. Atlantic cobia and blueline tilefish in the Mid-Atlantic are two potential examples). As climate variability leads to range expansions and distribution shifts, new opportunities may develop leading to a cascading effect on other fish species and habitats, and highlighting the need for a precautionary approach.

The extent and degree of changes expected in the South Atlantic are not fully known and the consequences of these changes cannot always be predicted. Such changes have implications for both stock assessments and fisheries management decisions. Changes in distributions impact stock boundaries, survey indices, allocations, and fisheries operations. Each of these unknowns requires adaptive management strategies and necessitates managing for a higher level of uncertainty and proceeding with caution.

Changes in land and water use inland can also amplify climate variability impacts of fisheries. Conservation partnerships in these areas are beginning to consider how these changes inland might affect marine ecosystems and fisheries in the face of increased climate variability. SAFMC should work with large multi-organizational partnerships (e.g., South Atlantic Landscape Conservation Cooperative, Southeast Aquatic Resources Partnership, SECOORA) to identify ways coastal and inland actions can help sustain fisheries under increasing climate variability.

Climate considerations should also be incorporated into System Management Plans for Marine Protected Areas (MPAs) and Special Management Zones (SMZs). MPAs are frequently proposed as a strategy to buffer fished populations against disturbance and variability, and stabilize catches in the face of both environmental variability and management uncertainty (Allison et al. 2003, Hopf et al. 2016). Recently, several authors have reviewed how MPA design could be tailored to anticipate climate change and climate variability and provide better ecological resilience for fished populations (McLeod et al. 2009, Green et al. 2014). In general these studies presume that the major climatic impact on larval connectivity is to shorten dispersal distances (Gerber et al. 2014), so the recommendations typically center on increasing the number of MPAs and decreasing the spacing among them in an effort to improve connectivity and spread the risk of climate-related disturbances. It is also generally recommended to focus protection on locations that have historically experienced greater environmental variability, with the expectation that populations in those locations will be better adapted to the highly variable conditions of the future ocean (McLeod et al. 2009, Green et al. 2014). However, a critique of many of these broad recommendations is that they frequently lack specific ecological data to support them or to guide targeted MPA planning in a particular location (Magris et al. 2014). Again, targeted local modeling efforts would be needed to produce informative planning guidelines.

One recommendation to improve MPA implementation in a variable climate is to use a flexible marine spatial planning approach, potentially shifting protected areas in response to climate conditions (Gerber et al. 2014). However, too-frequent shifts in MPA boundaries could jeopardize a key benefit of MPAs, which is the accumulation of adult biomass and populations with a full age structure un-truncated by fishing (White et al. 2013, Barnett and Baskett 2015). These features lead to improved resilience to disturbance and thus augment population persistence (Barnett and Baskett 2015). However, MPAs could also lead to unanticipated negative impacts; for example, intense fishing outside MPAs could blunt the leading edge of a species undergoing a climate-driven range shift, slowing the shift velocity and threatening population persistence (Fuller et al. 2015). For this reason (and to improve MPA performance in general), MPA planning should always be integrated with fishery management to control harvest outside MPA boundaries (White et al. 2010, Hopf et al. 2016).

Accounting for climate-driven changes in population dynamics and in particular stock abundance also remains a challenge for future management. Variations in the climate can contribute to stock distributional shifts, stock expansions (both vertical and horizontal), changes in catchability, and alterations in vital rates – all of which can manifest themselves similarly in the quantities we observe through fishery data collection. For example, the recent increases in landings of blueline tilefish in the Mid-Atlantic region could have resulted from a northward expansion of the stock, increases in abundance of the species in the northern portion of its range, or increases in fishing effort in that region. Disentangling these effects – which often are not mutually exclusive – will thus require not only cooperation among Councils and survey efforts, but also new scientific and statistical approaches.

The development of fishery-independent surveys, particularly those that are coordinated across regions, will be helpful in parsing apart changes in fishing behavior from changes in local abundance. Increased coordination of surveys across jurisdictions will help in the detection of shifts in stock distributions. Still, fishery-independent surveys have their own set of problems relating to climate variability, as they typically rely on fixed stations or grid cells which sample an underlying environment in constant flux. Abundance indices from standardized surveys can be refined by including environmental covariates in order to remove the effect of annual variability on the apparent relative abundance. However, such methodologies must be approached with caution, particularly when the underlying mechanisms of the fish-environment relationship are unknown. Environmental variability can also have an effect on individual vital rates such as growth or maturity, which can result in increases or decreases in abundance and biomass at the population level. In such cases, including environmental covariates in the analysis of catch-per-unit-effort can result in removal of an abundance trend when it is actually present and necessary to account for. Differentiating whether environmental processes affect catchability or production (or both) will likely require additional research as well as the development of novel statistical approaches. Coordination with other management, research, and observational efforts will also be important in gaining a mechanistic understanding of climate impacts (e.g., whole watershed, cumulative impacts, SECOORA, SALCC, other Councils, see Appendix A).

Given that abundance indices and other quantities derived from fishery data generally give the most direct information on changes in population size in a stock assessment framework, the degree of accuracy of these measures will impact the derived reference points and management benchmarks. Yet even when climate-driven population impacts are tracked and well-understood, there will still be logistical issues that arise, such as how stock assessments get carried out when stocks have fluid boundaries spanning multiple jurisdictions, and how to determine allocations for stocks in cases where abundance or productivity is changing relative to boundaries.

Another issue that has concerned fishery managers for hundreds of years is obtaining an understanding the environmentally-driven causes of recruitment fluctuations, and this topic becomes increasingly relevant under changing climate conditions. Understanding recruitment fluctuations can be of particular interest for the management of fisheries that are sustained by infrequent, strong year classes (e.g., many grouper species). Given that time and resources are necessary to gain a mechanistic understanding of the environmental causes of recruitment fluctuations, it is necessary to evaluate when such information can actually improve the management process. For a stock that is operating at a biomass roughly around the theoretical maximum sustainable yield, the stock-recruitment curve (regardless of the specific parameterization – e.g., Beverton-Holt, Ricker) often approximates a horizontal line. Thus, even under situations where recruitment levels are highly stochastic, one can successfully manage a stock over the long term, in the absence of an understanding about the causes of recruitment fluctuations. When stocks managed at or around this level, additional information on recruitment predictions might help optimize quotas from year to year and thereby increase long-term yield, particularly in cases where the fishery is composed of a substantial proportion of new recruits. In other cases, where new cohorts have an influence on the fishery only after being detected by management and incorporated into quotas, such predictions may provide little benefit.

A lack of understanding of the environmental drivers of recruitment strength can become problematic when the stock-recruitment relationship breaks down; i.e., when a significant shift in average recruitment occurs. This can be particularly problematic if a sudden downward shift in recruitment levels leads to the stock being nudged toward the (typically unknown) point where low recruitment years become more probable, collapse becomes more likely, and recovery trajectories become more uncertain. Still, depending on the severity of the shift, the nature of the fishery, and the available data with which to track such changes, management may have the capacity to respond to such recruitment regime shifts without necessarily understanding the drivers behind the change in productivity.

The most robust method for determining the value of information to the management process is to use management strategy evaluation (MSE), whereby the entire fishery system – data collection, assessment, and management – are modeled in a simulated environment. In the MSE process, a simulated natural system is subject to data collection, assessment, and management processes that approximate those used in the real world. This management system is then run forward in time to determine whether the process, when implemented over the long term, results in predetermined management goals being met. Because the simulated natural system is a "known" truth, but the management system is implemented "blindly" with only the information available in real life, the process enables one to identify where the management system has the potential to succeed or fail. One can then test, for example, whether spending resources to obtain additional data on the strength of incoming year classes will actually improve long-term yields without increasing risk of stock collapse for a given species and management system. When climate impacts on stocks are suspected, management strategy evaluation can be a useful tool for determining where research efforts are best focused to ensure that management objectives can be achieved under potentially changing conditions.

Efforts to develop indicators of the influential climate processes affecting stocks can also be helpful for informing management in the near-term scales. These indicators are often summarized in ecosystem status reports or ecosystem considerations chapters that accompany management documents. Indicators inform rates of change and, when considered as a suite, can highlight wholesale changes in ecosystem components that would be expected to reverberate through the entire system (e.g., the arrival of a previously unseen temperature regime). Typically, these indicators are not used quantitatively in determining management advice, but they can be used to refine management decisions. For example, a sudden drop in primary productivity, or a significant change in a process thought to affect recruitment of commercial stocks, might be taken into account when considering the appropriate buffer around a management benchmark. Such efforts allow the effects of climate variability to be inserted into the management process on at least some level, and represent preliminary steps toward ecosystem-based management.

With the impacts of climate becoming increasingly apparent, and the resulting recognition that stocks cannot be managed without consideration of other ecosystem components, the concept of ecosystem-based reference points has also received increased attention. However, in a region of both high biological diversity and few long-term fishery-independent data collection efforts, we often lack the ability to track trends in individual species. Tracking ecosystem components, and making management decisions based on the states of these components, represents an even more daunting challenge. To date, the most pragmatic example of an ecosystem-based reference point in the South Atlantic is the Atlantic Menhaden Technical Committee's effort to identify reference points that account for the Atlantic menhaden's role as a forage fish species. This effort has not yet led to specific recommendations, as the Committee determined that more explicit statements of ecological goals were necessary and that further research was needed to evaluate the expected performance of proposed ecological reference points. Working on comparative studies with other relatively more data-rich regions may be one way to progress in this regard

Summary Recommendations

- As species expand/shift their distributions due to changing ocean conditions and/or market demands, it is the Council's policy that the SAFMC will proactively work with:

    - State agencies, other Councils, Atlantic State Fishery Commission, and NOAA Fisheries to manage species that span multiple jurisdictions.
    - South Atlantic LCC, NOAA RISAs, Southeast Climate Science Center, and other multi-organizational partnerships.
    - The fishing industries, fishing communities, and other interested civil stakeholders.
- A priority list of climate indicators should be developed by NOAA or regional partners or selected that likely track ecological, social, and economic trends and status. The Council requests annual summaries of these indicators, species likely to be influenced, and fisheries trends that appear to be due to changing ocean environmental conditions in the South Atlantic ecosystem.
- Climate change requires the consideration of tradeoffs. Changing ocean conditions necessitate responses ranging from increasing buffers due to a higher level of uncertainty to adjusting quotas upward or downward to account for predicted and realized increases or decreases in productivity.
- Given the uncertainty of climate impacts, the precautionary principle should be invoked as possible for future management decisions on issues that can be influenced by climate change.
- Careful scientific and management evaluation should be undertaken as new fisheries develop, including consideration of how to avoid harmful impacts on essential fish habitat.

Summary Research Needs Addressing Climate Variability and Fisheries

1. Scientific research and collection of data to further understand the impacts of climate variability on the South Atlantic ecosystem and fish productivity must be prioritized. This includes research on species vulnerabilities in terms of distribution, habitat, reproduction, recruitment, growth, survival, and predator-prey interactions.
2. As appropriate, climate data and the effects of climate variability should be integrated into stock assessments. Climate impacts could also be a focus of the new proposed stock assessment research cycle.
3. More three-dimensional ocean observations of ocean conditions are needed to characterize the coastal-estuarine-ocean habitats.
4. Management Strategy Evaluations are desired to allow the Council to analyze potential regional climate scenarios and determine whether current harvest strategies are robust to future changes.
5. Greater understanding of the socio-economic impacts and fisheries responses to climate variability is needed.
6. Characterization of offshore ocean habitats used by estuarine dependent species that may be useful in developing ecosystem models.

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Appendix A

Useful links to other regional efforts including associated with climate impacts:

a. IOOS/SECOORA: www.secoora.org
b. NOAA Fisheries National Climate Strategy: http://www.st.nmfs.noaa.gov/ecosystems/climate/national-climate-strategy
c. NOAA Fisheries South Atlantic Climate Science Regional Action Plan: http://www.st.nmfs.noaa.gov/ecosystems/climate/rap/index
d. NOAA Ecological Forecasting Roadmap: http://oceanservice.noaa.gov/ecoforecasting/
e. Oceanadapt for tracking changes in species distribution (http://oceanadapt.rutgers.edu)
f. Bonefish Tarpon Trust: http://www.bonefishtarpontrust.org/research-programs/research-programs.html
g. Audubon Society: http://www.audubon.org/conservation/climate-change
h. National Science Foundation Coastal SEES: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504816
i. Virtual Climate Adaptation Library: https://research.fit.edu/ccal/

Section 2 South Atlantic Habitats

Shallow Water Coral and Coral Reefs -March 2018

Shallow Coral Reef Habitat

Description and distribution

Shallow water coral reefs and coral communities exist within the southern geographical areas under Council jurisdiction and in state waters where the Council has authority to designate essential fish habitat (EFH). In this document these habitats are defined as occurring in depths generally less than 50 meters. Depending upon many variables, stony corals (those secreting reef-building habitat structure) may dominate a habitat, be a significant ecosystem component, or be individual colonies within a community characterized by other fauna (e.g., sponges or macroalgae). In some areas, stony corals have grown in such profusion that their old skeletons accumulate and form reef structure (e.g., coral reefs). In other areas, corals grow as a less dominant component of benthic communities on geologically derived hard substrates (e.g., coral communities). Octocorals, though they do not contribute to reef framework, do contribute greatly to reef complexity and diversity. This section focuses on those ecosystems under Council authority having Scleractinians as an important member of the community. Hardbottom communities that have little or no Scleractinians are addressed in the Live/Hardbottom Habitat section of this document.

1. Reef Biogeography, Habitat, and Community Types

North Florida to North Carolina

Coral assemblages from north Florida north to North Carolina, are dominated by ahermatypic stony coral species and gorgonians, although some hermatypic species do occur off North Carolina (MacIntyre and Pilkey 1969) and Georgia (Hunt 1974). The very limited coral assemblages within this area are found on shallow-water hardbottom habitats ((Johnston 1976); off Georgia and South Carolina (Stetson et al. 1962; Porter 1978 personal communication; Thomas 1978 personal communication); and North Carolina (Huntsman 1984; MacIntyre and Pilkey 1969)) and deep-water banks (*Oculina* spp.). These are further described in the deep water coral Section of this document.

North Florida to St. Lucie Inlet

From St. John's Inlet to St. Lucie Inlet, coral assemblages are relatively sparse and low in diversity as compared to reefs further south. Coral colonies are commonly located on non-coral-derived consolidated carbonate sediments (Avent et al. 1977). Corals are most common in the nearshore hardbottom and along two reef tracts (20 m, 30 m). The two major reef tracts consist of ledges of up to 3 m relief; while the outer 30 m shelf tract runs through the majority of this region, the 20 m shelf tract runs intermittently. Coral assemblages include octocorals (*Lophogorgia, Leptogorgia, Eunicea, Antillorgia* spp.) and scleractinian coral (*Oculina diffusa*, *Oculina varicosa*, and *Siderastrea* spp.). Both temperate and subtropical fish and invertebrate species are represented in this region. At the shelf-edge, high relief (up to 25 m) pinnacles begin at 50 m depth where *Oculina varicosa* form massive branching colonies (Reed 1980). For a more extensive review of the deep water *Oculina* reefs see Section XXX.

Southeast Florida

The Florida Reef Tract (FRT) extends approximately 577 km from the St. Lucie Inlet (Martin County), southward to the Dry Tortugas banks. Off the mainland coast of southeast Florida, the northern extension of the FRT extends from Martin County approximately 170 km south into Miami-Dade County. From central Palm Beach County south to, in particular offshore Broward County, southern Miami-Dade County the reef system is described as a series of linear (Inner, Middle, and Outer) reef complexes (referred to as reefs, reef tracts, or reef terraces). These complexes run parallel to shore, generally at depths approximately 6m to 20m. In addition there are extensive nearshore ridges and colonized pavement areas nearer to shore (Moyer et al. 2003; Banks et al. 2007; Walker et al. 2008). Although these high latitude habitats are near the environmental threshold for significant coral reef growth, they are colonized by an extensive coral reef community which is quite similar within the linear reefs. This region has a similar diversity of key functional groups (stony corals, octocorals, sponges, and macroalgae) to that of the southern regions of the FRT (the Florida Keys and Dry Tortugas) but contributions of these groups to benthic cover may vary (Ruzicka et al. 2010; Ruzicka et al. 2012, Gilliam et al. 2015).

The nearshore ridges and colonized pavement areas occur within one km of shore in water depths generally less than 5 m and are most prominent off Palm Beach, Broward, and Miami-Dade counties. This habitat is defined as flat, low relief, solid carbonate rock with variable sand cover within the most nearshore areas (Walker et al. 2008). In Palm Beach and Martin Counties, the sessile community in less than 3 m is dominated primarily by turf and macroalgae. The dominant scleractinian at these depths are *Siderastrea* species (CSA 2009). In a number of these shallow water areas, the sabellariid polychaete *Phragmatopoma lapidosa* (know as worm rock) can be a dominant component of the habitat. South of these counties, these habitats have been documented to contain areas with the highest stony coral cover and the greatest abundance of larger (>2m) stony corals (dominated by *Montastrea cavernosa* and *Orbicella faveolata)* in the region (Gilliam et al. 2015; Gilliam et al. 2015, Walker et al. 2012) In this area, this habitat also contains perhaps the most abundant population of staghorn coral, *Acropora cervicornis,* in the U.S. South Atlantic (Vargas-Angel et. al 2006, Walker et al. 2012, Gilliam et al. 2015; Gilliam et al. 2015, D'Antonio et al. 2016).

The Inner Reef occurs within 1 km of shore and crests in 3 to 7 m depths. The Middle Reef crests in 12 to 14 m depths, and Outer Reef crests in 15 to 21 m depths. A large sand area generally separates the Inner and Middle, and the Middle and Outer, reef complexes. The Inner and Middle Reefs extend from northern Broward County south into Miami-Dade County. The Outer Reef occurs within 3 km of shore and is the most continuous reef complex extending from central Palm Beach County south into Miami-Dade County. The community in these reefs includes over 30 species of stony corals and a diverse assemblage of gorgonians and sponges (Gilliak et al. 2015). The common stony coral species include: *Montastrea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Solenastrea bournoni*, *Meandrina meandrites*, and *Dichocoenia stokesii*. Octocorals (gorgonians) and sponges generally have a greater density than stony corals. Some of the common octocoral genera include: *Eunicea*, *Antillogorgia*, *Muricea*, *Plexaurella*, *Pterogorgia* and *Icilogorgia* (Goldberg 1973). Very large (>1m wide) barrel sponges, *Xestospongia muta*, are conspicuous and quite abundant in certain areas of the Middle and Outer Reefs.

Florida Keys

The southernmost component of the Florida Reef Tract includes the area south of Soldier Key to the Dry Tortugas banks. Along the nearshore environs to the deep fore reef adjacent to the straits of Florida, coral-associated habitats consist of nearshore hardbottom communities, patch reefs, and a semi-continuous series of offshore bank-barrier reefs (reef flats, spur and groove) (summarized in Marszalek et al. 1977, Jaap 1984, and Chiappone 1996). These habitats boast a wide bathymetric distribution, from the intertidal to great depths, and are currently colonized by calcifying algae (e.g., *Halimeda*), sponges, octocorals, and a few species of stony corals. Local environmental conditions, driven by water exchange between Florida Bay and the Atlantic Ocean, dictate which species colonize the substrate.

Low relief hardbottom communities occur within 2 km of shore on the Florida Bay and Atlantic sides of the islands. These communities are highly diverse (as described in Chiappone and Sullivan 1994) and dominate the Florida Keys in terms of areal extent (Chiappone 1996).

The patch reef habitat is constructed by a few species of massive stony corals; most often the principal species is *Orbicella annularis*, boulder star coral. Other common foundation building species include *Colpophyllia natans* and *Siderastrea siderea*. Common octocoral genera found on patch reefs include: *Antillogorgia*, *Pseudoplexaura*, *Gorgonia*, *Muricea* and *Plexaurella*. Patch reefs are concentrated in the area off Elliott Key (Biscayne National Park), north Key Largo (John Pennekamp Coral Reef State Park, Florida Keys National Marine Sanctuary, FKNMS), and in the Hawk Channel area from Marathon to Key West (FKNMS).

The outer bank reefs are the seaward-most reefs in the Florida Keys coastal ecosystem. These reefs are most commonly visited by the diving and snorkeling charters. Their principal, unique feature is the spur and groove system (Shinn 1963). The system is a series of ridges and channels facilitating water transport from seaward to inshore. The coral most responsible for building the spurs was *Acropora palmata* (Shinn 1963), whose population has since experienced significant decline. The spur and groove systems occur in depths that range from a few centimeters to 10 meters. Beyond 10 meters, the spur and groove formation may or may not continue seaward as very low relief structures. Often, this habitat subunit is referred to as the fore-reef and may continue to about 30 m depth. Seaward, sediment beds separate the fore-reef from deeper reef formations in 40 m depth. Stony coral cover has significantly declined over time in this system at both shallow and offshore fore-reefs, and a transition to octocoral dominance is most evident at shallow fore-reefs (Ruzicka et al. 2014). Octocorals of the genus *Antillogorgia*, *Gorgonia*, *Pseudoplexaura, Muricea*, *Eunicea* and *Plexaurella* are commonly found in these outer bank reefs.

The Tortugas Banks are a variation of the deeper reefs found in Dry Tortugas National Park. The depths are greater than 20 m and extend to 40 m. The foundation is Pleistocene karst limestone. The extensive banks host a major grouper and snapper fishery, including a critical 46 square mile spawning ground currently protected as a Research Natural Area. The banks have abundant coral of a few species. Black coral (Order Antipatharia) are common on the outer edge of the bank.

2. Ecological Functions

Coral reefs and hardbottom have many functional roles for species under the Council's jurisdiction. These functions include complex issues such as trophic relationships, shelter, and cross-shelf and large-scale population connectivity via reproduction. High diversity of reef residents support complex trophic relationships and novel routes of productivity, including significant bio-calcification which provides the architectural structure. The details of these relationships and functions have been examined in several recent large compilations such as Mora (2015) and Birkeland (2015).

3. Use

Healthy coral reefs are among the most biologically diverse and economically valuable ecosystems on earth, providing valuable and vital economic goods and ecosystem services. Coral ecosystems are a source of food for millions; protect coastlines from storms and erosion; provide habitat, spawning, and nursery grounds for economically and recreationally important fish species; provide jobs and income to local economies from fishing, recreation, and tourism; are a source of new medicines; and are hotspots of marine biodiversity.

4. Current Habitat Management

Federal

Essential Fish Habitat

The 1996 federal reauthorization of the Magnuson Stevens Act (the Sustainable Fisheries Act) mandated that all eight federal fishery management councils identify Essential Fish Habitat (EFH) in their jurisdiction and amend all Fishery Management Plans (FMPs) as applicable. The SAFMC followed the enabling language and treated EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity". The SAFMC also identified EFH - Habitat Areas of Particular Concern (HAPCs), which are EFH areas that include one of these four attributes: provide important ecological functions; are sensitive to environmental degradation; include a habitat type that is/will be stressed by development; or include a habitat type that is rare (SAFMC, 1998a).

EFH applies to each life stage of managed species and different life stages of the same species often use different habitats. All coral and hardbottom habitats are designated as EFH-HAPC for the 55 reef species currently in the Snapper Grouper FMP as well as the Spiny Lobster. Additionally, other components of reef habitat such as sponges are EFH for Spiny Lobster. The habitat source document for these designations (SAFMC, 1998b) provided much rationale and content used also in first FEP document. Many administrative details on how EFH is used in coral conservation permitting among federal, state, and local agencies are reviewed in Lindeman and Ruppert (2011).

Place-based management

The South Atlantic region includes a range of federally managed areas with coral reef habitats, most notably the Florida Keys National Marine Sanctuary (NOAA) and two units of the National Park Service (Dry Tortugas and Biscayne National Parks). Each of these areas has its own management plan, including some areas set aside as marine reserves.

The Florida Keys National Marine Sanctuary (FKNMS) was designated in 1990 for protection in response to concerns about the decline of the reef ecosystem in the area (FKNMS Protection Act 1990). Today, the FKNMS protects more than 9,946 km2 (2,900 nautical mi2) of Florida Keys coastal and ocean waters. With the designation, several protective measures were immediately put into place, such as prohibiting oil exploration, mining, or any type of activity that would alter the seafloor, and restricting large shipping traffic. Anchoring on, touching, and collecting coral are all restricted within sanctuary waters. The FKNMS is jointly administered by the State of Florida and the National Oceanic and Atmospheric Administration (NOAA). The FKNMS management plan was first established in 1998 and implemented a network of zones and protected areas as well as strategies including mooring buoys and a water quality protection program. Additional Ecological Reserves were implemented in the Dry Tortugas region in 2001. NOAA is currently undertaking the first comprehensive review of the management plan, zoning plan and regulations. This review is a public process that will eventually culminate in an updated management plan and potential modifications to regulations, marine zones, and the sanctuary boundary.

Two components of the National Park system manage coral reef habitats in the south Atlantic region, Biscayne National Park and Dry Tortugas National Park. Biscayne National Park was designated in 1980 (after prior status as Biscayne National Monument) and protects habitats adjacent to the south Florida urban area including Biscayne Bay, the barrier islands, and out to the reef tract. Biscayne NP recently released its first general management plan (June 2015) which includes a marine reserve zone incorporating both fore-reef and patch reef habitats. Dry Tortugas, administered under the management of Everglades National Park, was designated in 1992 and protects relatively remote marine habitats, 113 km southwest of Key West with visitation largely limited to ferry or sea plane. The general management plan for Dry Tortugas NP was amended in 2001 incorporating a zoning scheme including 46% of the park area in a Research Natural Area, the highest level of habitat protection where natural processes are protected from human impact (including fishing).

Endangered Species Act Critical Habitat

Under the Endangered Species Act of 1973, critical habitat may be designated by NOAA Fisheries for the conservation of threatened and endangered species under its jurisdiction. Critical Habitat designations were made for ESA listed corals, *Acropora palmata* and *A. cervicornis*, in 2008 to include hardbottom habitats < 30m depth deemed suitable to support recruitment of these corals (namely, stable hard substrate free of algae and sediment). Under this designation, over 3,000 sq km of habitat in the south Atlantic region are protected from destruction or 'adverse modification' by actions undertaken, funded, or permitted by federal entities.

State of Florida

In 2009, the Florida Legislature passed the Coral Reef Protection Act (CRPA, s. 403.93345, Florida Statutes [F.S.]) to increase protection of coral reef resources on sovereign submerged lands off the coasts of Martin, Palm Beach, Broward, Miami-Dade, and Monroe counties.

The CRPA authorizes the Florida Department of Environmental Protection (FDEP), as the state's lead trustee for coral reef resources, to protect coral reefs through timely and efficient assessment and recovery of monetary damages resulting from vessel groundings and anchoring-related injuries. To carry out the intent of the Act, the FDEP also has the authority to enter into delegation agreements with state and local government agencies with coral reefs in their jurisdictions. The CRPA is overseen by the FDEP Coral Reef Conservation Program which works with FDEP regulatory or legal entities to ensure the Act is enforced.

In addition to the CRPA, the FWC's Marine Life Rule (Rule 68B-42.009, Florida Administrative Code [F.A.C.]) also provides protection for coral reef resources through the prohibition of take, destruction, and sale of marine corals, sea fans, and encrusting octocorals.

State Parks and Aquatic Preserves

In the State of Florida, many state parks and aquatic preserves include marine and/or estuarine waters (Chapter 258, F.S.). FDEP's Division of Recreation and Parks administers the state park system and it is their policy, in part, "to promote the state park system for the use, enjoyment, and benefit of the people of Florida and visitors" and to "conserve the natural values" of the parks (258.037, F.S.). The Florida Legislature established aquatic preserves to "set aside forever" the "state-owned submerged lands in areas which have exceptional biological, aesthetic, and scientific value…for the benefit of future generations" (258.36, F.S.).

When a state park or aquatic preserve's boundary extends into the nearshore marine environment, FDEP manages submerged lands within these boundaries while FWC manages fisheries resources.

State Park boundaries for John D. MacArthur Beach State Park in Palm Beach County, John U. Lloyd Beach State Park in Broward County, Bill Baggs Cape Florida State Park in Miami-Dade County, and Indian Key, Long Key, Curry Hammock, and Bahia Honda State, and Fort Zachary Taylor Historic state parks in Monroe County extend into the water up to 400 ft. from the Mean High Water Line (F.A.C 62D-2.014.9b). Other coastal managed areas such as St. Lucie Inlet Preserve State Park in Martin County; Biscayne Bay-Cape Florida to Monroe County Line Aquatic Preserve in Miami-Dade County; Lignumvitae Key Botanical State Park, San Pedro Underwater Archaeological Preserve State Park, and Lignumvitae Key and Coupon Bight Aquatic Preserves in Monroe County extend up to a mile offshore. As the first undersea park in the U.S., John Pennekamp Coral Reef State Park, was dedicated in 1960 and encompasses approximately 70 nautical square miles.

Local Action Strategies

In 1998, Presidential Executive Order #13089 established the United States Coral Reef Task Force (USCRTF) to lead U.S. efforts to preserve and protect coral reef ecosystems. In 2002, the USCRTF adopted the Puerto Rico Resolution, which called for the development of Local Action Strategies (LAS) by each of the seven member U.S. states, territories and commonwealths. These LAS are locally driven roadmaps for collaborative and cooperative action among federal, state, territory, and non-governmental partners that identify and implement priority actions needed to reduce key threats to coral reef resources. The goals and objectives of a LAS are closely linked to those found in the U.S. National Action Plan to Conserve Coral Reefs, adopted by the USCRTF in 2000.

With guidance from the USCRTF, the FDEP coordinated the formation an LAS known as the Southeast Florida Coral Reef Initiative (SEFCRI) in 2004. SEFCRI is a team of interagency marine resource professionals (state, regional, local, and federal), scientists, and reef resource stakeholders. It is a non-regulatory body coordinated and chaired by FDEP. Their mission is "to develop an effective strategy to preserve and protect southeast Florida's coral reefs and associated reef resources, emphasizing the balance between resource use and protection, in cooperation with all interested parties" (FDEP SEFCRI Charter art. 2).

SEFCRI identified the state waters containing reefs from St. Lucie Inlet in Martin County to the northern boundary of Biscayne National Park as their area of focus because these coral habitats are close to shore and co-exist with intensely urbanized areas that lack a coordinated multi-agency management plan like that of the Florida Keys National Marine Sanctuary. SEFCRI identified issues and threats to southeast Florida's coral reef resources and developed projects and actions to address causes of coral reef degradation and provide a road map for conservation and management.

Between 2013 and 2016, FDEP staff and the SEFCRI team developed and implemented a community planning process known as Our Florida Reefs. Our Florida Reefs brought together local residents, reef users, business owners, and visitors in Miami-Dade, Broward, Palm Beach, and Martin counties to discuss the future of coral reefs in this region. The process was designed to encourage public input from a broad range of community members and reef stakeholders and to identify potential management strategies for southeast Florida's reefs.

The Our Florida Reefs process developed recommended management actions (RMAs) to address issues ranging from land-based sources of pollution; maritime industry and coastal construction; fishing, diving, boating, and other uses; enforcement; education and outreach; and place-based management. The Our Florida Reef Community Working Groups broadly supported the majority of these RMAs; however, the fishing representatives and larger fishing community strongly opposed the place-based and some other fishing-related RMAs. (Note: During the development and the first approval of the RMAs, the majority of the Our Florida Reefs participant slots reserved for representatives from the fishing community were vacant and not filled until later in the process. This limited the fishing community's engagement and input in the RMAs.)

5. Ongoing Threats

Many local actions create or exacerbate detrimental impacts to shallow coral reef ecosystems. Coastal construction and infrastructure development are particularly common near the urban centers from Palm Beach to Miami-Dade counties (Shivlani et al. 2011, Walker et al 2012). Dredge and fill activities such as beach nourishment and port maintenance and expansion result in direct loss of habitat and cumulative, as well as acute, effects to coral communities through increased turbidity and sedimentation (Wanless and Maier, 2007; Jordan et al. 2010). Beach nourishment activities are on-going especially within Palm Beach, Broward, and Miami-Dade counties. Recent (2015) port dredging at Port Miami greatly exceeded planned impacts by sedimentation to coral reef habitat, with another large dredging project upcoming at Port Everglades (Fort Lauderdale).

Coral disease is both a local and global threat to coral reef ecosystems. Disease has been identified as the main culprit for reductions in Acropora abundance in the Caribbean, including Florida (Precht and Miller 2007). Loss of Acropora, a major reef-building coral, reduced the complex structure of reefs. In the 1980s and 1990s, diseases such as white-band disease led to declines in Acropora abundance by nearly 100% in many areas (Precht and Miller 2007). Currently, a white-plague disease outbreak is affecting at least 13 coral species in southeast Florida, with reductions of some species to less than 3% or their initial population densities (Precht et al. 2016). This current disease outbreak has been called "one of the most lethal ever recorded on a contemporary reef" (Precht et al. 2016).

Disease also affects species that help maintain the reefs, such as long-spine sea urchins. In 1983, a waterborne pathogen caused mass mortality amongst long-spine sea urchin (*Diadema antillarum*), which was one of the main herbivores on Caribbean reefs (Lessios 2016). On average, this mass mortality event reduced the abundance of this species by 98% throughout the Caribbean (Lessios 2016).

Overfishing has been suggested to result in a global decline of piscine predators with subsequent significant changes in the numbers of herbivores (Mumby et al. 2006). In the Caribbean, parrotfish overfishing has been hypothesized to be pivotal in adversely affecting corals in this region (Jackson et al. 2014). Decreases in parrotfish could result in increased macroalgae which directly outcompetes corals for space or inhibits coral recruitment. In recent years, harvest of parrotfish in the Florida Keys has occurred at low-levels (approximately 3,000 fish per year) and has been stable (M. Smith, personal communication, July 3, 2017). Fishing activities such as that of trap fisheries more clearly create disturbance to reef benthic communities. Although trap fishers report generally avoiding coral reef habitats, ocean dynamics result in an accumulation of trap debris in coral-associated habitats (Uhrin et al 2014). These authors estimate the presence of almost two million items of lobster trap debris in the Florida Keys National Marine Sanctuary. The cover of benthic sessile fauna is reduced by ~ 10 % in areas affected by trap movement events occurring over a wind threshold of 2 days duration at 15 kt (Lewis et al. 2009).

Water quality degradation from regional water management activities, sewage, coastal runoff, and local use likely have detrimental impacts (reviewed by Gregg 2013) with documented detriments to coral health (see Section 3 Threats). However, reef-scale impacts of water quality are difficult to partition from the myriad stressors which co-occur on reefs in the region. It is highly likely that both coastal hardening/construction and coastal water quality degradation will be exacerbated in the near future by rapid sea level rise from global climate change (Koch et al. 2015).

Invasive lionfish (*Pterois* spp.) likely continue to alter the structure of coral reef fish and invertebrate communities (Albins and Hixon 2008; Albins 2013, 2015; Green et al. 2014), and thus potentially alter coral reef ecosystem function. Lionfish impacts arise predominantly via direct predation (lionfish are voracious generalist predators - Morris and Akins 2009, Muñoz et al. 2011), but also likely occur through competition (e.g., for habitat or prey). Assessing the community- and broader-level impacts of lionfish is a critical need (see related text in Section 6).

6. Summary Recommendations

The United States Coral Reef Task Force (USCRTF) was established in 1998 by Presidential Executive Order to lead U.S. efforts to preserve and protect coral reef ecosystems. The USCRTF includes leaders of 12 Federal agencies, seven U.S. States, Territories, Commonwealths, and three Freely Associated States. The USCRTF helps build partnerships, strategies, and support for on-the-ground action to conserve coral reefs. (From http://www.coralreef.gov/ecosystem/)

USCRTF Recommendations

- Understand coral reef community dynamics and the impacts of human-caused and natural stressors;
- Identify possible management strategies to mitigate negative impacts; and
- Evaluate the effectiveness of these management actions after they are implemented.

Knowledge Gaps

- Tropicalization: effects of anticipated shifting species assemblages with warming temperatures.

- Where needed, expand knowledge of the distribution and benthic community attributes of coral reef ecosystems (e.g., via expanded mapping efforts in intermediate depths, 30-50m)

Lionfish

- While there have been multiple studies documenting local-scale effects of invasive lionfish (*Pterois* spp.) predation on native fish species (Albins and Hixon 2008; Albins 2013, 2015; Green et al. 2014), none of those studies have occurred in SAFMC-managed waters (a majority of the studies were performed in Bahamian waters), and no studies in any area have assessed the effect of lionfish predation over relatively broad scales. Barbour et al, 2011 developed a model which predicted an annual exploitation rate between 35 and 65% would be required to cause recruitment overfishing on lionfish populations. Research is needed to further assess the realized effects of lionfish, via predation and potentially competition, on coral reef fish community structure at broader spatial scales (e.g., sub-regional, regional, ecosystem).

- There is considerable interest in controlling, reducing or depleting local lionfish populations through culling efforts (e.g., via spearfishers). Usseglio et al. 2017, has developed a framework that allows managers to predict the removal effort required to achieve specific targets (represented as the percent of lionfish remaining on the reef). Green et al. 2014 found that reductions in density of 25-92%, depending on the reef, were required to suppress lionfish below levels predicted to overconsume prey. On reefs where lionfish were kept below threshold densities, native prey fish biomass increased by 50 70%. Additional research may be needed to refine (1) the effectiveness of culling efforts, in terms of the frequency and intensity of culling needed to maintain lionfish below targeted densities, (2) what target densities are most appropriate (e.g., near-zero, low, moderate…) in terms of reducing probable ecosystem impacts, and (3) assessing the trade-offs between the costs of culling efforts and the benefits (ecological and fishery-related) derived from those efforts.

Habitat and Use Characterization of Reefs

- Assess and monitor spatial and temporal patterns in use of coral reef ecosystems in terms of fishing, snorkeling / diving and other uses.

- Assess efficacy (direct and indirect results) of management actions such as MPAs.

- Identify fish and invertebrate spawning habitats or locations, and the degree to which spawning aggregations are targeted by fishers.

- Due to repeated reef impacts from large dredging and beach projects in the area, from direct disturbance and ongoing turbidity, (Wanless & Maier 2007), there is a need for better understanding chronic and acute turbidity and/or sedimentation on coral reef habitats.

Summary Management Recommendations

- Develop and implement numeric water quality standards, including for turbidity, that are protective of coral reef habitats (Gregg 2013)

- Mitigate key habitat issues by implementing focused removal of submerged trap debris from especially vulnerable habitats such as reefs and hardbottom where trap debris density is high (Uhrin et al 2014)

- Diadema restoration (Acropora Recovery Plan, and Florida Pillar Coral Action Plan)

- Coral reef habitats are impacted by ongoing and repeated damage from dredging and coastal construction projects in the region. Given increasing environmental stressors on coral reefs in the region, added stress from construction projects may be temporally partitioned from predictable sensitive ecological processes and stressors (Fraser et al. 2017). Much construction-related damage should also be preventable under existing regulations, but improvements in permitting, monitoring, implementation, compliance and enforcement are needed. Specific recommendations for such improvement are provided in Lindeman and Ruppert (2011) include
    - Development of a template by permitting agencies with standard language for 'special conditions' to avoid, minimize, and monitor coral impacts
    - Development by NMFS of regulatory criteria to identify 'destruction or adverse modification' of ESA Critical Habitat, replacing the current working definition.

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SHALLOW WATER CORALS

Coral as used in this document means *Gulf and South Atlantic prohibited coral*, as defined in 50 CFR §622.2 as follows:

Gulf and South Atlantic prohibited coral means, in the Gulf and South Atlantic, one or more of the following, or a part thereof:
(1) Coral belonging to the Class Hydrozoa (fire corals and hydrocorals).
(2) Coral belonging to the Class Anthozoa, Subclass Hexacorallia, Orders Scleractinia (stony corals) and Antipatharia (black corals; though these are predominantly distributed in deeper (>50m) habitats).

1. Taxonomy and Life History

Stony corals are marine invertebrates that secrete a calcium carbonate skeleton. Stony corals include members of both the Class Hydrozoa (fire corals and lace corals) and Order Scleractinia (true stony corals). Most reef-building corals are zooxanthellate, hosting symbiotic algae from the genus *Symbiodinium* in their gastrodermal cells. These symbionts provide a phototrophic contribution to the coral's energy budget, enhance calcification, and give the coral most of its color. The largest colonial members of the Scleractinia help produce the carbonate structures known as coral reefs in shallow tropical and subtropical seas around the world.

For the purpose of this plan, Octocorals include species belonging to the Class Octocorallia , Order Alcyonacea (soft corals and gorgonians). Similar to stony coral corals, octocorals are colonial animals with a polyp as the individual building unit and may contain endosymbiotic algae (zooxanthellae). Unlike stony coral, octocorals do not secrete a calcium carbonate skeleton but have an axial skeleton mainly composed of collagen fibers in a proteinaceous matrix.

Table 1. Classification of corals included under the Council's Coral, Coral reefs and Live/ Hard Bottom Fishery Management Plan.

Phylum Cnidaria
- Subphylum Medusozoa
  - Class Hydrozoa
    - Order Anthoathecata
      - Suborder Capitata
        - Family Milleporidae (fire, stinging corals)
      - Suborder Filifera
        - Family Stylasteridae (lace corals)

Subphylum Anthozoa
- Class Anthozoa
  - Subclass Hexacorallia (or Zoantharia)
    - Order Scleractinia
  - Subclass Octocorallia
    - Order Alcyonacea (soft corals)
      - Suborder Alcyoniidae (soft corals)
      - Suborder Scleraxonia (gorgonians)
      - Suborder Holaxonia (gorgonians)
      - Suborder Calcaxonia (gorgonians)

Corals can reproduce asexually when fragments break off and reattach to the reef. However, corals also have a complex life cycle including pelagic (sexual) larval and sessile, usually colonial, adult phases. There are a multitude of breeding systems described among scleractinian corals (Baird et al. 2009) with the primary categories being brooding vs. broadcast spawning, and hermaphroditic vs. gonochoric. The primary reef-building species in the region, including *Acropora* spp. and *Orbicella* spp. are hermaphroditic (colonies produce both eggs and sperm), broadcast spawners (gametes are shed into the water column where they undergo fertilization and development). Dilution, advection, and other environmental stressors in the open ocean environment yield lower rates of fertilization, higher rates of larval mortality, and greater average dispersal distance by broadcasted, compared with brooded larvae. Brooded larvae are released with symbionts inherited from the parent colony enabling them to renew energy reserves via photosynthesis and are generally able to settle soon after they are released from the parent colony. In contrast, broadcast larvae must rely on lipid reserves from its egg and remain in the water column from a few days to weeks to complete larval development prior to settlement competence. Hence, broadcasting species (with few exceptions, predominantly *Siderastraea siderea*) generally display much lower rates of larval recruitment than brooding species, in some cases vanishingly low. It is likely that both low larval production and declining habitat quality (due to sediments, turf and macroalgae) contribute to low recruitment in broadcast-spawning, reef-building corals in the region.

After metamorphosis onto appropriate hard substrata, metabolic energy is diverted to colony growth and maintenance. Because newly settled corals barely protrude above the substratum, juveniles need to reach a certain size to reduce damage or mortality from impacts such as grazing, sediment burial, and algal overgrowth (Bak and Elgershuizen 1976; Birkeland 1977; Sammarco 1985). Generally, mounding corals grow slowly; most growth rates (linear extension) for *Montastraea*, *Porites*, and *Diploria* are less than 1 cm per year. Hubbard and Scaturo (1985) report average extension rates of 0.12-0.45 cm/yr. for several species including *Stephanocoenia intersepta*, *Agaricia agaricites*, *Diploria labyrinthiformis*, *Colpophyllia natans*, *Montastraea cavernosa*, *Porites astreoides*, and *Siderastrea siderea*. Growth rates for branching species are generally higher, with branch extension rates over 10 cm per year commonly reported for *Acropora cervicornis* in the Florida Keys, and even higher rates of total productivity in local in situ *A.cervicornis* nurseries (Lirman et al. 2014). However, long term reductions in coral growth rates are expected under near term future scenarios of climate warming/temperature extremes and acidification (refs) as these stressors reduce the efficiency of calcification.

Octocorals have not been studied as extensively as scleractinian corals and their reproductive biology is poorly known for most species. In 2009, Simpson performed a review of published literature on octocoral reproduction and all known reproduction systems of octocorals are described therein. Like scleractinian corals, both sexual and asexual reproduction have been documented in octocorals. Types of asexual reproduction include fragmentation, fission (commonly observed in encrusting species), and development of new colonies from stolons or runners. Asexual reproduction is known to be more common in true "soft corals" and is limited to only a few octocoral species found in Florida. The vast majority of gorgonian octocorals reproduce sexually by broadcast spawning or brooding (either internally or externally). The reproductive strategy of external or surface brooding has been documented in octocorals, where eggs are released passively onto the surface of the colony (Benayahu and Loya 1983, Brazeau and Lasker 1990, Gutiérrez-Rodriguez and Lasker 2004). While sampling female colonies of *Antillogorgia* (*Pseudopterogorgia*) *elisabethae*, Gutiérrez-Rodriguez and Lasker (2004) did not find developing embryos or planulae inside the polyps, and they suggested that fertilization occurred either internally immediately before the eggs were released or externally on the surface of the maternal colony.

As with stony corals, octocoral planulae settle onto an appropriate substratum and undergo metamorphosis into a feeding polyp. Octocorals are known to settle in shaded microhabitats, such as the underside of settlement plates, small cavities in the substratum or under clumps of macroalgae. Studies suggest that this settlement behavior may be influenced by turbulent eddies that facilitate larval settlement and an avoidance response to unfavorable conditions such as high light intensity, low tides, predator grazing pressure, and sedimentation (Simpson 2009, Benayahu and Loya 1987). Studies have indicated that successful settlement and recruitment into a population occurs at a low rate (Lasker et al. 1998, Simpson 2009). Lasker et al. (1998) suggested that extremely high post-settlement mortality of new recruits indicates that successful settlement may be more related to water column and post-settlement survival than to gamete production and fertilization rates. Despite low recruitment rates, octocorals are excellent spatial competitors and are known to have much higher growth rates in general as compared to most species of scleractinian corals. Cary (1914) discussed the obvious advantage of young octocorals over stony coral recruits in that their most rapid growth is perpendicular to the substratum, keeping the most active growing part of the colony in a favorable position for resource allocation.

2. Abundance and Trends of Coral Populations

Scleractinians

Southeast Florida

The reefs offshore the mainland coast of southeast Florida, the northern extension of the Florida Reef Tract (FRT), have a similar stony coral diversity to that of the southern regions of the FRT (the Florida Keys and Dry Tortugas) and much of the Caribbean, but benthic cover, 2-5%, is generally lower and colony size, average less than 20 cm diameter, is generally smaller (Gilliam et al 2014, Gilliam et al 2015). Nearly 30 species of stony corals have been identified, but six species (*Montastraea cavernosa*, *Siderastrea siderea*, *Porites astreoides*, *Stephanocoenia intersepta*, *Agaricia agaricites*, and *Meandrina meandrites*) contribute greatly to benthic cover and colony density (Gilliam et al 2014, Gilliam et al 2015). Three of these species (*M. cavernosa*, *S. siderea*, and *P. astreoides*) were also identified as being three of the most common species in the Florida Keys (Ruzicka et al. 2013) and in the Dry Tortugas (Ruzicka et al. 2012). Two long-term monitoring programs have been operating since at least 2003 and neither had documented a significant trend in stony coral benthic cover up until 2015 (Gilliam et al 2014, Gilliam et al 2015), in contrast to much of the Caribbean (Gardner et al. 2003, Jackson et al. 2014) and the southern regions of the FRT (Ruzicka et al. 2014). However, severe thermal stress events and a continuing coral disease outbreak have resulted in severe declines in colony density for several scleractinian species, approaching local extinction for *Dendrogyra cylindrus, Meandrina meandrites*, and *Dichocoenia stokesii* by 2016 (Gilliam et al. unpubl data).

Florida Keys

Following major losses to disease and bleaching throughout the past several decades, coral reefs are in a state of transition in the Florida Keys (FLK). Following the 1997/1998 El Niño event, stony corals showed little recovery and continued to be a dwindling part of the benthic assemblage at deep and shallow forereefs. The declines in stony coral cover at the deep and shallow forereefs can be attributed to the continued loss of the dominant, framework-building coral *M. annularis* (Ruzicka et al. 2013). Within the Florida Keys, patch reefs contain the highest cover of any habitat while backcountry patch reefs have the lowest. Coral cover in 2015 was 6.2%, nearly 1% lower than the steady trend recorded in 2013 and 2014 (FWC 2016). In terms of abundance, aggregated for the 40 CREMP sites, *Siderastrea siderea*, *Porites astreoides*, *Stephanocoenia intersepta*, and *Undaria/Agaricia agaricites* are the four most common corals. Of these four, only *Siderastrea siderea* and *Porites astreoides* are top contributors to coral cover. Corals like *Undaria/Agaricia agaricites* are relatively small in size and contribute little to overall coral cover. Between 2014 and 2015, the abundance of eight of the nine corals was not significantly different in 2015 as compared to previous years. *Undaria/Agaricia agaricites* was the only coral that demonstrated a significant decline in abundance between 2015 and all other years tested. It is plausible that even though the abundance of the other most abundant species has remained similar, partial mortality inflicted as a result of the 2014 bleaching event could have reduced the amount of living tissue associated with these corals.

Octocorals

Southeast Florida

Octocorals are a significant component of the reef community along the FRT. Offshore southeast Florida octocoral colony density and species diversity tend to be greater than those of stony corals. Octocoral benthic cover, 3-20%, is also generally higher than stony coral. Octocoral cover has shown a significant decreasing trend in parts of the region (Gilliam et al 2015) which is in contrast to significantly increasing trend identified in the Florida keys (Ruzicka et al. 2014).

Florida Keys

An overall trend of increasing cover was reported for octocorals Keys-wide and across all reef types, resulting in a shift in community structure at the deep and shallow forereefs (Ruzicka et al. 2013). Octocoral cover continued to rise following the 2010 winter cold-water mortality and is the second greatest contributor to benthic cover after macroalgae. Since the 2014 bleaching event, octocoral cover has declined from 15% to 12.8% between 2014 and 2015. The transition from stony coral to octocoral-dominated communities has been reported before; however, all examples are exclusive to the Pacific Ocean (Fox et al. 2003, Stobart et al. 2005).

3. Threats

Mounting threats of myriad sorts have resulted in drastic declines in scleractinian corals, both in the South Atlantic region and throughout the Caribbean, over the past few decades. Recent analyses of extinction risk for seven coral species concluded that global changes (including warming and changing ocean chemistry) along with disease pose the greatest threat to coral extinction (Brainard et al 2011). These global threats are superimposed and interaction with additional stressors at the local level (also reviewed in Brainard et al. 2011). The relative importance of these local stressors vary somewhat across the South Atlantic region, related to the local human population density and use along the coast.

Global climate change has already caused significant coral declines in the region, with notable increases in year-round local reef sea surface temperature documented over the past century and is estimated at an annual rate of 0.9ºC over the past 3 decades (Kuffner et al 2014). As a result, the occurrence of warm temperature stress above bleaching thresholds is projected to occur annually within the next decade, much sooner than global climate models predict (Manzello 2015). Mass coral bleaching events have resulted from warm temperature extremes in 1997-8, 2005, 2014 and 2015. Many corals die directly from bleaching and also from subsequent coral disease outbreaks following the physiological stress of bleaching (Brandt & McManus 2009). Due to high latitude, episodic cold water events also affect South Atlantic corals, particularly in

2010 when cold water caused mass coral mortality, especially in nearshore patch reef habitats (Lirman et al. 2011).

Coral disease is both a local and global threat to coral reef ecosystems. Disease has been identified as the main culprit for reductions in *Acropora* abundance in the Caribbean, including Florida (Precht and Miller 2007). Loss of *Acropora*, a major reef-building coral, reduced the complex structure of reefs. In the 1980s and 1990s, diseases such as white-band disease led to declines in *Acropora* abundance by nearly 100% in many areas (Precht and Miller 2007). Currently, a white-plague disease outbreak is affecting at least 13 coral species in southeast Florida, with reductions of some species to less than 3% or their initial population densities (Precht et al. 2016). This current disease outbreak has been called “one of the most lethal ever recorded on a contemporary reef” (Precht et al. 2016).

Disease also affects species that help maintain the reefs, such as long-spine sea urchins. In 1983, a waterborne pathogen caused mass mortality amongst long-spine sea urchin (*Diadema antillarum*), which was one of the main herbivores on Caribbean reefs (Lessios 2016). On average, this mass mortality event reduced the abundance of this species by 98% throughout the Caribbean (Lessios 2016).

Coastal water quality in the region is affected by broad scale regional water management actions, sewage via both offshore outfalls and seepage from septic tanks, runoff and stormwater. The effect of these combined constituents, including endocrine disruptors, pesticides, nutrients, freshwater, etc. are poorly characterized (but see Downs et al. 2005, Edge et al 2013, Ross et al. 2015) but most certainly detrimental to health of corals in the region, consequently reducing their physiological scope to deal with global stressors.

Meanwhile, fishes are engaged in important positive feedbacks with corals including grazing to maintain benthic habitat quality and nutrient delivery (Shantz et al. 2015). Although parrotfishes are not highly targeted in local fisheries as in other Caribbean regions allowing persistence of high grazing (Paddack et al. 2006), this is a factor which should be monitored as fisheries preferences may change over time.

While the effects of many stressors causing direct coral mortality are relatively easy to observe, many sublethal stressors such as sedimentation, water-born toxicants, acidification, chronic temperature stress, and non-lethal diseases impair the replenishment capacity of coral populations both by impairing larval output and by impairing larval survival and/or recruitment (e.g., Jones et al. 2015, Albright et al 2010).

The effects of ocean acidification (i.e. changes in the carbonate chemistry of ocean waters), water quality, and trophic disruption threats are less well characterized for octocorals, though warm temperature bleaching and disease have both been documented, particularly in sea fans. Unlike Scleractinians, some octocorals are also subject to harvest (Miller et al. 2014).

4. Management

Scleractinian corals are currently managed under a zero-take FMP and are protected as Essential Fish Habitat - Habitat Areas of Particular Concern. Seven species in the region are also protected as threatened species under the US Endangered Species Act, with one of these (*Dendrogyra cylindrus*) previously designated as a Threatened species by the state of Florida. Hence, an ESA Recovery Plan (for *Acropora palmata* and *A.cervicornis*) and Florida Species Action Plan (for *D. cylindrus*) both provide relevant actions for coral conservation and restoration in the region.

Octocorals are currently managed by the State of Florida under chapter 68B of the Florida Administrative Code (FAC). The State of Florida defines octocorals as "any erect, non-encrusting species of the Subclass Octocorallia, except the species *Gorgonia flabellum* and *G. ventalina*" which are prohibited (FAC 68B-42.002). Up to six octocoral colonies per day may be collected recreationally with a Florida Recreational Saltwater Fishing License (FAC 68B-42.005). There are no trip limits on the harvest of octocorals for commercial purposes, though the fishery is limited to properly licensed commercial harvesters. However, the annual quota for octocorals harvested in State of Florida and adjacent Federal waters is 70,000 colonies (FAC 68-42.006). No power tools may be used to harvest colonies and only one inch of attached substrate around the perimeter of the base of the octocoral holdfast may be removed (FAC 68B-42.006, 68B-42.007, FAC 68B-42.008). Octocorals must be collected and landed live and stored in a re-circulating live-well or oxygenated system aboard the collection vessel (FAC 68B-42.0035).

Areas that are closed to octocoral collection include Atlantic Federal waters north of Cape Canaveral, Biscayne National Park, and in the Stetson-Miami Terrace Deep Water Coral Habitat Area of Particular Concern, as well as the Pourtales Terrace Deep Water Habitat Area of Particular Concern adjacent to Florida state waters (68B-42.0036 F.A.C.). Additional area closures for marine life collection exist in southeastern Florida, including National Parks (Everglades, Biscayne, Dry Tortugas) and specific areas within the Florida Keys National Marine Sanctuary, including the Key Largo Management Area (formerly Key Largo National Marine Sanctuary), the Looe Key Management Area (formerly Looe Key National Marine Sanctuary), and various smaller no-take zones including sanctuary preservation areas, special-use/research-only areas, and ecological reserves (Miller et al. 2014). For further information, Miller et al. (2014) prepared an in-depth description of the U.S South Atlantic Octocoral Fishery.

5. Summary Recommendations

Coral Knowledge Gaps:

- Efficacy and improvement of coral (proactive) restoration strategies (Hunt and Sharp 2014)
- Efficacy of coral predator removal or other mitigation (Acropora Recovery Plan)
- Carrying capacity of coral disease, predation, (Acropora Recovery Plan)
- Impact threshold levels for nutrients, sedimentation, toxicants (Acropora Recovery Plan)
- Determine causal factors in coral disease impacts, especially regarding interactions with temperature and local anthropogenic stressors. (Acropora Recovery Plan)
- Due to repeated reef impacts from large dredging and beach projects in the area, from direct disturbance and ongoing turbidity, there is a need for better understanding of chronic and acute turbidity and/or sedimentation on all life phases of shallow corals, including recruitment.
- Efficacy of disease remediation

Coral Summary Management Recommendations

- Coral population enhancement/gardening (Acropora Recovery Plan and Our Florida Reefs Recommended Management Action (OFR-RMA))
- Install mooring balls in sensitive areas (Florida Pillar Coral Action Plan; OFR-RMA)
- Enhance legal enforcement of Florida Coral Reef Protection Act (Florida Pillar Coral Action Plan)
- Improve coastal construction project permitting/compliance/mitigation to achieve 'no net loss' of coral
- Develop improved water quality standard for turbidity that is protective of coral (OFR-RMA)

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Artificial Reef Habitat - December 2017

Artificial reefs, sometimes called “man-made reefs”, “fish havens”, or “constructed reefs”, are broadly defined as any structure placed on the seabed, either deliberately or accidentally (e.g., shipwrecks), that acts similar to natural hard-bottom reefs and enhances fish habitat (Seaman 2000; Seaman and Sprague 1991). Artificial reefs may be composed of a wide variety of materials ranging from natural rock or discarded materials, such as concrete rubble, to entirely manufactured materials. Natural reefs artificially enhanced or rehabilitated by transporting and attaching living corals are usually not considered artificial reefs.

Properly sited artificial reefs can provide habitat for a wide variety of invertebrates and finfish, improve survival for species that are hard-bottom limited (Broughton 2012), serve as memorials, or stabilize coastlines. They can also enhance existing ecosystems or create new ones to fill in gaps where EFH has been damaged or lost (Ambrose 1994; Koenig 2001; Dupont 2008). The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Seaman 2000; Baine 2001). Artificial reefs may provide essential habitat while simultaneously acting to deflect pressure from surrounding natural hard bottom (e.g., Streich et al., 2017), including specially managed areas (e.g., Harmelin 2000); however, increased productivity may be offset by increased fishing pressure (Seaman 2000, Powers et al. 2003). For these reasons, permitted artificial reef sites are considered EFH by the SAFMC.

Here we focus on the use of artificial reefs in an ecosystem approach to fisheries. This focus is on fish and invertebrate fisheries, with the recognition that other biota are important ecological factors that influence fisheries as sources of food, habitat, and mortality for exploited species. Artificial reefs can be considered fishery management tools.

Artificial reef programs in the southeastern U.S. are overseen by individual states (Florida, Georgia, South Carolina, and North Carolina) and require construction permits by the Army Corp of Engineers with review with approval by the U.S. Coast Guard, NOAA Fisheries and the Environmental

Protection Agency, as appropriate. Some individual states, counties, and some local municipalities may require additional review or approval by other state or local agencies, particularly if reef construction is to take place inside state waters. While artificial reefs have been in use along the U.S. South Atlantic since the 1800s, their development in this region was somewhat limited through the mid-1960s. From the late 1960s to the present, reef development off the South Atlantic states (as measured by the number of permitted construction sites) has increased dramatically, with over 300 reef sites currently permitted in the coastal and offshore waters of the South Atlantic. Roughly half of these sites are in waters off the east coast of Florida alone. Artificial reef locations are considered live/hard bottom habitat and are available on the Council's Internet Mapping System accessible at www.safmc.net.

The total area of South Atlantic states' ocean and estuarine bottoms permitted for artificial reef development at present is approximately 210,000 acres (or 250 nm2). This small percent area of shelf and natural hard bottom is managed by the SAFMC. Due to the practical limitations of all artificial reef programs, it is likely that only a very small percentage of permitted reef sites have actually been fully developed through the addition of suitable hard substrate. However, since in most cases permitted sites can be reauthorized or extended, construction activities may continue indefinitely on these sites (or at least until those sites reach capacity), the percentage of hard bottom habitat developed will continue to rise as new materials are added.

Recreational anglers are the chief users of artificial reefs in this region. Financial resources made available directly or indirectly through many saltwater sportfishing interests have been a prominent factor in most reef development projects. Due to favorable environmental conditions throughout most of the year along South Atlantic states, recreational divers have also been a driving force in establishing artificial reefs in recent years. This relatively new user group will likely continue to grow as diving becomes more popular. Finally, commercial fishing interests use some artificial reefs, but are less common users compared to recreational fishing and diving users.

Marine resource management agencies in all four South Atlantic states are actively involved in various aspects of artificial reef planning, development, management, and monitoring in their own state waters as well as contiguous federal waters. All four states have, or are in the process of developing, their own state artificial reef management plans. North Carolina, South Carolina and Georgia control all artificial reef development through programs within their respective natural resource management agencies, and hold all active permits for reef development.

Florida's reef development efforts are carried out by individual county or municipal programs with the Florida Fish and Wildlife Conservation Commission acting as a commenting agency for proposed permits. Reef construction permits in Florida are therefore held by county and municipal government agencies or programs.

North Carolina

North Carolina has a rich history in recreational fishing, with long standing support for artificial reef development. Prior to the 1970s, reefs were mostly constructed by fishing clubs and local residents. By the mid-70s, North Carolina Division of Commercial and Sports Fisheries, began to take responsibility for artificial reefs and subsequently absorbed many privately owned reefs into its network. In 1985, the North Carolina Division of Marine Fisheries (NCDMF) Artificial Reef Program gained financial support through Federal Sportfish Restoration funds, allowing the state to administer a more organized enhancement effort. Today, the NCDMF Artificial Reef Program exists to develop, maintain, and administer a successful system of artificial reefs to enhance fishing, diving, biological, and ecological opportunities for North Carolinians and visitors. In trusted stewardship of public funds, it is the responsibility of the Artificial Reef Program to coordinate reef planning and construction, secure permits and maintain compliance, encourage research, and clearly communicate with the public.

At present, the NCDMF maintains forty-two artificial reefs the Atlantic Ocean, designed to serve as recreational opportunities for fishermen and SCUBA divers. In the ocean, reefs are located one to thirty-eight miles from shore and are strategically located near popular ocean inlets. Ocean reef sites are circular by design, with a typical area of 162 acres each, though several are larger.

Artificial reef materials placed within these boundaries account for roughly 1% of the total area. In addition to ocean reefs, NCDMF has established twenty-five reefs in estuarine waters which are intended to function as EFH, nursery habitat, and in some cases, oyster sanctuaries. These 25 estuarine artificial reefs encompass a cumulative total area of 807 acres.

Reef enhancement operations are an annual occurrence in North Carolina and the primary objective of the Artificial Reef Program. Approximately four reef construction projects are completed each year, with support from state and federal funds and with support from private fundraising or material donations. A variety of materials may be used in enhancement projects, including vessels, concrete pipe of various sizes, prefabricated reef structures (e.g. Reef Balls™), bridge spans and pilings, limestone marl, concrete rubble, train boxcars, aircraft, basalt, granite, and other experimental concrete reefs structures. In most cases, small-scale reef construction (less than 1,000 tons) is completed using NCDMF staff and vessels, while large scale enhancements are contracted. Reef construction at all artificial reef sites is allowed under a general permit issued by the U.S. Army Corps of Engineers (USACE). In state waters, a Coastal Area Management Act (CAMA) permit is also required and issued by the North Carolina Division of Coastal Management. In addition to USACE and CAMA construction permits, aids to navigation permits, issued by the U.S. Coast Guard, are maintained for reefs which require markings. No artificial reefs in North Carolina have been designated as special Management Zones.

While primarily focused on construction of habitat, the Artificial Reef Program also performs annual monitoring of reef sites to examine physical and biological attributes over time. Diving, side-scan, and bathymetric surveys are used to evaluate material stability and durability in terms of lateral movement, subsidence, decay, and sedimentation. Diver surveys at some locations also include a biological characterization of various sites and materials, observing such metrics as oyster population density, fouling organisms, finfish, and pests. In estuarine waters, water quality data loggers are maintained at four sites each year to monitor localized trends in salinity and dissolved oxygen. During underwater operations at any reef, divers collect any trash or marine debris that can be safely recovered.

Public support and outreach are also a pivotal component of the NC Artificial Reef Program. In addition to maintaining constant contact with public interests through presentations and public meetings, the Artificial Reef program actively maintains an artificial reef guide for public consumption. The guide, which was recently published in 2016, exists in printed form and as an interactive web-based map. The reef program recently completed high resolution side-scan

surveys of all ocean and estuarine reefs and “digitized” material for easy identification. In the new guide, both printed and online, Artificial Reef users will be able to select certain materials at a given reef site and review specific information such as type, GPS location, vertical relief, acreage, tonnage, and vessel specifications.

South Carolina

The use of artificial structures to enhance fishing activities in South Carolina‘s coastal waters was first documented during the mid-1800s when anglers began placing wooden crib-like structures in estuarine waters to attract sheepshead and other popular inshore species. During the mid-1960s the construction of offshore and coastal artificial reefs for the benefit of saltwater recreational anglers was carried out by numerous private organizations. In 1967 the state provided funding for its first artificial reef construction project, and in 1973 an on-going state-sponsored marine artificial reef program was established. This program is currently maintained by the Marine Resources Division of the South Carolina Department of Natural Resources (SCDNR) within the Division’s Office of Fisheries Management. Funding for the program consists of state support through the South Carolina Marine Recreational Fisheries License, federal support through grants from the U.S. Fish and Wildlife Service’s Sport Fish Restoration Program and donations from private fishing and diving clubs and other civic organizations.

The primary focus of the South Carolina Marine Artificial Reef Program (SCMARP) is the coordination and oversight of all activities within the state of South Carolina concerning the management of a viable system of marine artificial reefs in both state and contiguous federal waters. The primary goal of these artificial reefs is the enhancement of hard bottom marine habitats, associated fish stocks and resulting recreational fishing activities that take place on and around them. The SCMARP's responsibilities include reef planning, design, permitting, construction, monitoring, evaluation, research and marking. The program also plays a key role in interfacing with the public in areas related to general fisheries management issues as well as in providing specific reef-related information to user groups.

All artificial reef development and management in South Carolina is guided by the South Carolina Marine Artificial Reef Management Plan, adopted in 1991. As of December 2015, the state's system of marine artificial reefs consisted of 48 permitted sites (13 inside state waters) along approximately 160 miles of coastline. These sites range in location from estuarine creeks to as far as 50 miles offshore. Each artificial reef site consists of a permitted area ranging from several thousand square yards to as much as 24 square miles. Approximately 40 square miles of coastal and open ocean bottom has been permitted, of which less than 2 percent has actually been developed through the addition of artificial reef substrate.

Saltwater recreational anglers are the primary group associated with marine artificial reef utilization in South Carolina. Their annual fishing activities on artificial reef sites alone account for greater than 200,000 angler-days, which result in an estimated total economic benefit to the state of over 83 million dollars each year (Rhodes and Pan 2007). While some use of permitted artificial reefs by commercial fishing interests has been reported over past decades, this activity has been difficult to quantify since these practices do not have popular support with the majority of the fishing public, or may in some cases be illegal. Recreational divers comprise the second most common user group relying on the presence of marine artificial reefs. While sport divers have traditionally not been as large a user group as the saltwater recreational fishing community, significant expansion of the recreational diving industry in the state has resulted in a noticeable increase in this type of usage over the past two decades.

In an attempt to better manage the use of permitted artificial reefs in offshore waters and to ensure their long-term viability, the SCDNR has, through the South Atlantic Fishery Management Council, obtained Special Management Zone (SMZ) status for 29 of the 35 permitted reef sites located in federal waters. Fishing on those reef sites granted SMZ status is restricted to hand-held hook and line gear and spearfishing (without powerheads) and take is limited to the current recreational bag limits. In 2014 the program began construction of a first-of-its-kind deep-water (>300 ft) artificial reef Marine Protected Area (MPA) with the goal of creating spawning habitat for deep-water snapper and grouper species and protecting spawning

stocks. In addition, the SCDNR has established two experimental artificial reefs in order to examine the feasibility and possible benefits of establishing no-take artificial reefs in nearshore and offshore waters solely for the purpose of stock and habitat enhancement. These sites have also recently been given MPA status by the SAFMC. For additional information visit: www.dnr.sc.gov/marine/pub/seascience/artreef.html.

Georgia

The continental shelf off Georgia slopes gradually eastward for over 80 miles before reaching the Gulf Stream and the continental slope. This broad, shallow shelf consists largely of dynamic sand/shell expanses that do not provide the firm foundation or structure needed for the development of reef communities, which include popular gamefish such as groupers, snappers, sea bass, and amberjack. It is estimated that only about 5% of the adjacent shelf features natural reefs or live bottoms anchored to rock outcrops, with most of these found well offshore. Large areas of Georgia's estuaries similarly feature broad mud and sand flats lacking the firm substrate needed for the growth of oyster reefs, which provide prey and shelter for seatrout, sheepshead, drum, and other popular sportfish in an otherwise highly energetic environment. Ditching, pollution, and coastal development have also impacted water quality and further restricted use of inshore areas by not only fish, but also fishermen, resulting in even greater demands on the remaining estuarine habitat.

Sporadic attempts to develop artificial or artificial reefs in Georgia began in earnest in the late 1950s by sport fishermen, who knew that good angling opportunities existed on scattered shipwrecks and other artificial structures found in estuarine and offshore waters. Only short-term benefits were realized through these limited initiatives when deployed materials rapidly silted in, deteriorated, or were lost. Working with coastal sport fishing clubs, the Georgia State Game and Fish Commission began experimenting with artificial reef construction in the 1960s, focusing initially on estuarine areas and expanding later to offshore waters in the 1970s.Today, the program is housed within the Georgia Department of Natural Resources (GADNR), Coastal Resources Division, Habitat Restoration and Enhancement Unit, and is funded through State fishing license revenues, the Federal Aid in Sport Fish Restoration (SFR) program, and private donations, including the support of fishing and conservation organizations, tournaments, businesses, individuals, military services, and other branches of State and federal government.

Goals of Georgia's artificial reef program are to 1) create and enhance fisheries habitat and associated marine communities; 2) develop increased, more accessible recreational fishing opportunities; 3) facilitate and support fisheries management; and 4) generate economic benefits for coastal communities and the State. To date, GADNR has permitted 30 artificial reef areas located 2½ to 70 nautical miles (nm) offshore and reef construction has been initiated at 21 of those sites. The majority of the artificial reefs off Georgia are located in adjacent EEZ waters 6 to 23 nm in 30 to 70 feet of water east of coastal trawling grounds. Development of two

experimental deep-water reefs in 120 to 160 feet of water 50 to 70 nm offshore has also been initiated to address a growing recreational component targeting tunas, wahoo, and other blue water gamefish. The GADNR 30 permitted artificial reefs cover a 116 square mile area and consists of 20 offshore reefs, two 400-yard diameter beach reefs sited in the State's territorial sea, and eight Department of Defense Tactical Aircrew Training System Towers.

Georgia's 90-mile coast also contains 15 permitted estuarine reefs constructed within inter-tidal areas in order to promote oyster reef development and to provide fish habitat enhancement. All artificial reefs constructed in inshore waters within Georgia's 3 nm territorial sea require U.S. Army Corps of Engineers (USACE) (Programmatic General Permit No. 37) and State (Coastal Marshland Project Act Permit No. 682) permits. In the adjacent EEZ, the State conducts artificial reef development under the authority of a USACE Regional Permit No. 36 that encompasses 30 offshore reef locations. While the permitted estuarine and coastal beach reef sites are limited in size, the offshore EEZ sites typically average 4 nm2. These larger areas allow for the development of multiple patch reefs, a design that improves material performance and helps disperse fishing pressure.

Artificial reef development in Georgia has largely relied on stable and durable secondary use materials or materials of opportunity to create fisheries habitat. Material complexity and surface area are other important factors. Similar to other early U.S. artificial reef development efforts, the Georgia program also initially utilized tires, which were bound into compressed 8-tire units using rebar and anchored with concrete. While many tire units remain intact at Georgia's offshore reefs, several have also deteriorated; however, due to early concerns expressed by the trawler fleet in coastal waters, most units were placed well offshore and many have sunken into the soft sand bottoms at the reef sites closest to shore.

Perhaps the best known and most popular materials of opportunity used for artificial reef development are metal vessels, which have been employed as materials off Georgia for over fifty years. Prior to sinking, all vessels are cleaned, cut down to satisfy required water depth clearances, and modified to promote sunlight and water flow. As vessels age and collapse, they often become more complex, improving the overall growth and development of associated reef communities. Ranging from 29 to 447 feet in length, approximately 86 vessels are found on Georgia's offshore reefs, including tugs, barges, landing craft, sailboats, steel trawlers, a dredge, a USCG buoy tender, a former Japanese research vessel, and two Liberty ships -- the Edwin S. Nettleton and the Addie Bagley Daniels.

Emulating the rock outcroppings underlying temperate natural reef communities, marine grade concrete is another preferred material of opportunity used for reef development in Georgia's estuarine and adjacent offshore waters. To date, almost 200,000 tons of concrete pipe, pilings, and bridge/wharf rubble generated through coastal construction projects have been deployed on Georgia's artificial reefs. Other notable materials of opportunity also utilized for offshore artificial reef development in Georgia include approximately 800 metal poultry transport cages, 55 U.S. Army battle tanks, and 200 New York City Transit Authority subway cars. Designed for stability, complexity, and long-term service, several thousand concrete fisheries enhancement units have been deployed by the program since the mid-1990s on Georgia's inshore and offshore artificial reefs. Commercially available, the final unit design selected is dictated by project goals, site characteristics, cost per-unit-deployed, and the availability of comparable reef materials.

Normally occurring during the warmer months, SCUBA diving at Georgia's artificial reefs primarily takes place on the reef sites 15 nm and further offshore due to poor water visibilities and strong tidal influences found closer to shore. The larger wrecks popular with divers are also found on the artificial reefs located further offshore in deeper water depths. However, Georgia's artificial reefs are constructed to first provide enhanced fisheries habitat and recreational angling opportunities and are not specifically designed for diving. Entanglement and entrapment are diving hazards unavoidably associated with artificial reef structures, especially as the materials age, deteriorate, and collapse.

Nineteen of the 30 artificial reefs located in Georgia's adjacent EEZ waters have been established as Special Management Zones (SMZs) under the SAFMC's Snapper-Grouper Fishery

Management Plan. SMZs assist in increasing numbers of fish in an area and or create fishing opportunities that would not otherwise exist. In conjunction with this designation, allowable gears on the reefs are restricted to handheld hook-and-line and spearfishing gear, including powerheads or bangsticks. Powerheads may only be used to harvest a recreational bag limit and any powerhead catches in excess of the bag limits aboard a vessel at a SMZ is considered prima facie evidence of a violation. Further information on Georgia's marine artificial reefs may be obtained through the Coastal Resources Division, Habitat Restoration and Enhancement Unit, One Conservation Way, Brunswick, GA 31520; phone (912) 264-7218, or by going to http://coastalgadnr.org/ArtificialReef.

Florida (East Coast)

Encompassing 34 of 35 different coastal counties spread along 2,184 kilometers (1,357 miles) of ocean fronting coastline (1,362 kilometers fronting the Gulf of Mexico and 822 kilometers fronting the Atlantic Ocean), Florida manages one of the most diverse, and most active artificial reef programs in the United States. Florida leads the nation in the number of public artificial fishing reefs developed. The first permitted artificial reef off Florida was constructed in 1918.

Artificial reefs are found in waters ranging from eight feet to over 400 feet with an average depth of 65 feet. As of August 2017, no fewer than 1,069 deployments of artificial reef materials off the Florida East Coast are on record with the Florida Fish and Wildlife Conservation Commission (FWC). Over the last 50 years the state artificial reef program has experienced a gradual transition in construction materials use, funding sources, and recognition of the importance of measuring effectiveness.

The State's involvement in funding artificial reef construction began in the mid-1960s when the Florida Board of Conservation awarded a limited number of grants to local governments to fund reef development projects. In 1971 a Florida Recreational Development Assistance Program grant was awarded to a local government by the DNR Division of Recreation and Parks for reef construction. Between 1976 and 1980 the DNR Division of Marine Resources received, and oversaw the preparation and placement of five Liberty ships, secured as a result of passage of the Liberty Ship Act, which facilitated the release of obsolete troop and cargo ships for use as artificial reefs.

In 1978 a systematic state artificial reef program was begun. The Division of Marine Resources received a large grant from the Coastal Plains Regional Commission for artificial reef development. Rules for disbursing these funds were developed, defining a grants-in-aid program with projects selected through a competitive evaluation of local government and non-profit proposals. In 1979 the State Legislature appropriated general revenue funds for reef construction which continued on an annual basis, with the exception of one year, through 1990. In 1982, in addition to receiving general revenue funds, the program was officially established as a grants-in-aid program by law (s. 370.25, Florida Statutes). One staff position was assigned responsibility for program administration.

The rapid proliferation of publicly funded artificial reefs in Florida beginning in the mid-1980s is the result of increased levels of federal, state and local government funding for artificial reef development. Prior to that, other state funding sources intermittently provided reef development assistance. In 1966 there were seven permitted artificial reef sites off Florida in the Atlantic Ocean. By 1987, this number had grown to 112. Consistent federal funding for Florida's reef program became available in 1986 as a result of the Wallop-Breaux amendment to the 1950 Federal Aid in Sport Fish Restoration Act (Dingle-Johnson). During the decade of reef-building activity from 1986 to 1996, Sport Fish Restoration Funds provided almost three million dollars to complete 164 Florida reef projects.

In January 1990, Florida instituted a saltwater fishing license program. About 5% of the revenue from the sale of over 850,000 fishing licenses annually became available for additional artificial reef projects. Additional personnel were hired into the state artificial reef program to assist with coordination, information sharing, grant monitoring/compliance and monitoring assessment of artificial reefs. Funding in Florida remained steady during the following years, with funds from the Federal Aid to Sport Fish Restoration Program matched with state saltwater license funds.

Florida is the only South Atlantic coastal state active in artificial reef development which does not have a direct state-managed artificial reef program. For the last 30 years, Florida's artificial reef program has been a cooperative local and state government effort, with additional input provided by non-governmental fishing and diving interests. The state program's primary objective has been to provide grants-in-aid to local coastal governments for the purpose of developing artificial fishing reefs in state and adjacent federal waters off both coasts in order to locally increase sport fishing resources and enhance sport fishing opportunities. As of 2016, all active permitted reef sites are held by coastal counties or cities.

Reef management expertise at the local government level is variable. Reef programs are found in solid waste management, public works, natural resources, recreation and parks, administrative, and planning departments. Local government reef coordinators range from biologists and marine engineers to city clerks, grants coordinators, planners, and even unpaid volunteers. Reef management and coordination are generally collateral duties for most local government reef coordinators.

In response to long-range planning initiatives, in 2003 the FWC completed a long-range Artificial Reef Strategic Plan (Florida Fish and Wildlife Commission, 2003) to serve as a blueprint for both the FWC and the local coastal government reef programs. Representing the broad range of public interests in artificial reefs throughout Florida, the plan is comprised of guiding principles, goals, and objectives that optimize biological and economic benefits, provide policy guidance, support research and data collection, pursue additional funding opportunities, provide a framework for public education and outreach, and provide guidance for operational planning at the state, regional, and local levels of artificial reef construction and monitoring. The Strategic Plan is available at http://myfwc.com/media/131588/FLARStrategicPlan2.pdf.

In 2011 the FWC and Florida Sea Grant published a guidelines document for Southeast Florida titled "Guidelines and Management Practices for Artificial Reef Siting, Use, Construction, and Anchoring in Southeast Florida" which is available at: http://edis.ifas.ufl.edu/sg101.

Due to its long coastline, ideal conditions, and large number of academic and research-oriented institutions, a significant quantity of the existing body of field research dealing with artificial reefs has been conducted in waters off Florida. Artificial reef research projects undertaken with over $4.5 million dollars in state funding since 1990 have included studies on reef spacing and design, material stability and storm impact studies, long term studies of reef community succession, residency of gag grouper on patch reefs through tagging and radio telemetry, juvenile recruitment to reefs, impacts of directed fishing, remote biological monitoring techniques, and the effects of unpublished artificial reefs.

As with most other artificial reef programs in the U.S., there has been a shift in the types of materials used in the construction of artificial reefs in Florida waters over the past 50 years.

Through experience, reef builders have learned which materials work best in providing effective long-lived artificial reefs. Modern construction practices have evolved to a point where reef programs are much more selective in the types of materials they use.

Concrete materials, chiefly culverts and other prefabricated steel reinforced secondary-use concrete, were the primary reef material in nearly 42% of the 3,264 public reef deployments in waters off Florida as of August 2017. Engineered artificial reef units have been a growing component of the state's artificial reef development efforts since the early 1990s and now represent 28% of the artificial reefs off Florida. Most, but not all, units designed specifically for use as artificial reefs have proven to be durable and stable in major storm events. Prefabricated units designed specifically for use as artificial reefs have focused on improving habitat complexity, stability and durability, as well as providing a standard design for research and monitoring projects.

Secondary use materials such as obsolete oil platforms and steel vessels have also been used off Florida in the development of artificial reefs. Twenty-four percent of Florida's artificial reef structures are metal structures, including 518 sunken vessels and barges. These vessel reefs have catered to fishermen fishing for pelagic species, and a rapidly expanding resident and tourist diving population. The majority of vessels sunk as artificial reefs are concentrated off Miami-Dade, Palm Beach, and Broward Counties Partnerships with U.S. Customs has resulted in opportunities to receive confiscated vessels at little to no cost for reefing. On May 18, 2006, in partnership with the U.S. Navy, Florida's artificial reef program and Escambia County successfully deployed the Oriskany, an 888 foot-long aircraft carrier, 23 miles southeast of Pensacola, FL. The Oriskany is presently the largest vessel in the world intentionally deployed as an artificial reef.

Ecological Role and Function

Artificial reefs have the effect of changing habitats from a soft substrate to a hard substrate system or of adding higher relief to low relief (< 1m) hard substrate systems. Historically, fishermen created artificial reefs as fish attractants (Lindberg and Seaman 2011). An ongoing debate within the scientific community exists as to whether artificial reefs simply aggregate current individuals or actually enhance production (e.g., Bohnsack 1989, Pickering and Whitmarsh 1997; Lindberg 1997, Osenberg et al. 2002; Powers et al. 2003; Brickhill et al. 2005). The answer to that question can only be determined by viewing individual artificial reefs in a broader ecological context. For example, are fisheries habitat-limited (production) or recruitment-limited (aggregation) (Lindberg and Seaman 2001)? When well sited, the augmentation of species composition and local abundance of important species in a specific area are often seen as the primary benefits of reef deployment activities.

Although artificial reefs are not identical to naturally occurring hard-bottom areas or coral reefs, demersal reef-dwelling finfish, pelagic planktivores, and pelagic predators can use natural and artificial hard substrates in similar ways and often interchangeably (Arena et al 2007). In addition to location, temporal variation exists: elevated fish densities occur quickly after deployment (Bohnsack 1989), but substantial uncertainty remains about estimating overall fish production long-term (Powers et al. 2003, Lindberg et al. 2006). Finally, artificial reefs may affect species and life history stages differently: many reef-associated species occur on both natural and artificial reef habitats, with significant differences in the fish communities (Patterson et al. 2014; Streich et al. 2017).

Newly placed or exposed hard substrate is colonized when marine algae and larvae of epibenthic animals successfully settle and thrive. Species composition and abundance of individuals increase quickly until all suitable primary space is used by the epibenthos. At some point, a dynamic equilibrium may be reached with the number of species and number of new recruits leveling off, although recent studies indicate that this may take decades to achieve (Burgess 2008; Nicoletti et al 2007). Competition for space and grazing pressure become significant ecological processes in determining which epibenthic species may persist (Kirby-Smith and Ustach 1986; Paine 1974; Sutherland and Karlson 1977). The reef community itself should remain intact as long as the supporting hard substrate maintains its structural integrity and does not corrode or become buried under too great an overburden of sediment.

Concurrent with the development of the epibenthic assemblage, demersal reef-dwelling finfish recruit to the new hard-bottom habitat. Juvenile life stages will use this habitat for protection from predators, orientation in the water column or on the reef itself and as a feeding area. Adult life stages of demersal reef-dwelling finfish can use the habitat for protection from predation, feeding opportunities, orientation in the water column and on the reef and as spawning sites.

Pelagic planktivores can occur on hard-bottom habitats in high densities and use these habitats for orientation in the water column and feeding opportunities. These species provide important food resources to demersal reef-dwelling and pelagic piscivores. The pelagic piscivores use the hard-bottom habitats for feeding opportunistically. Most of these species do not take up residence on individual hard-bottom outcrops, but will transit through hard-bottom areas and feed for varying periods of time (Sedberry and Van Dolah 1984).

As long noted by researchers, the physical characteristics of artificial reef habitat may result in differences in the observed behavior of fish species on or around such structures in contrast to behavior observed on equivalent areas of natural hard-bottoms (Bohnsack 1989; Lindberg et al 2006). Some reef structures, particularly those of higher relief, seem to yield generally higher densities of managed and non-managed pelagic and demersal species than a more widely spread lower relief, natural hard-bottom or reef (Rountree 1989; Collins et al 2016, Streich et al. 2017). However, many fishes in Gulf of Mexico studies have been documented as older and more fecund on natural reefs (Glenn et al. 2017; Karnauskas et al. 2017). The fishery management implications of these differences must be recognized and taken into consideration when planning, developing, and managing artificial reefs as EFH (Lindberg and Seaman 2011).

Other artificial hard substrates in marine and estuarine systems provide habitat of varying value to fisheries resources. Coastal engineering structures such as bridges, jetties, and breakwaters can also provide significant hard substrate for epibenthic colonization and development of an associated finfish assemblage (Van Dolah 1987). Some of these structures also provide habitat in the water column and intertidal zone which differs significantly from typical benthic reefs. The result of the different ecotones provided by these coastal structures is often higher species diversity than was present before the structure was placed on site. These structures also may provide refuge from predation as well as feeding opportunities and orientation points for juvenile and adult life stages of important finfish species in the South Atlantic region. They differ from artificial reefs as defined above, in that there is generally no direct intention in their design or placement to achieve specific fishery management objectives. However, their impacts should be considered just as any other activity which modifies habitats in the marine environment.

Fisheries Enhancement

The proper placement of artificial materials in the marine environment can provide for the development of a healthy reef ecosystem, including intensive invertebrate communities and fish assemblages of value to both recreational and commercial fishermen. The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Strelcheck et al. 2007). Artificial reefs have developed an impressive track record of providing beneficial results, as estimated in recent models and measured by fishing success for a wide range of finfish species (e.g., Pitcher et al. 2002, Gallaway et al. 2009). To date, artificial reefs have been chiefly employed to create specific, reliable, and more accessible opportunities for recreational anglers. They have been used to a lesser extent to enhance commercial fishing probably because artificial reef total area is small compared to much larger, traditionally relied-upon, natural commercial fishing grounds.

In their present scale and typical design, most artificial reefs, while well-suited for use by recreational anglers, would be unable to withstand intensive commercial fishing pressure, especially for many of the popularly sought-after demersal finfish species, for more than a short period of time. Currently, most artificial reef programs receive the majority of their funding through sources tied directly to recreational fishing interests.

Special Management Zones

Conceptualized by the South Atlantic Fishery Management Council within the Snapper/Grouper Management Plan, several Special Management Zones or SMZs have been established in the South Atlantic off South Carolina, Georgia, and Florida to provide gear and harvest regulations

for defined locations including many artificial reef sites. The basic premise of this concept is to reduce user conflicts through gear and landings regulations at locations that feature limited resources, managed for specific user groups. Generally, artificial reefs have been developed for recreational use utilizing recreational resources. The ability to regulate gear types utilized over the relatively limited area of a artificial reef enables fisheries managers to prevent rapid depletion of these sites and promote a more even allocation of reef resources and opportunities.

Present SMZ regulations apply to about 50 artificial reef sites off South Atlantic States, with several more proposed. Since regulations concerning the management of SMZs are tied to specific gear restrictions and bag limits, it is possible that the use of SMZs in the future could be expanded to a point where any possible type of fishing gear could be restricted for a set period of time or indefinitely. This could provide fishery managers with the ability to turn individual artificial reef sites on or off as the specific needs of the fishery in question dictate. The ability to have some degree of control over fishing activities on these sites would give managers more power to use artificial reefs as a true fishery management tool.

Hard-bottom Habitat Enhancement

Habitat enhancement through the construction of artificial reefs can be achieved by converting some other type of bottom habitat into a hard-bottom community. Mud, sand, shell or other relatively soft bottom habitat can be converted into a hard bottom community by the addition of hard structure with low to high profile to add to the total amount of hard-bottom reef environment in a given area. While it would be difficult and particularly costly to construct artificial reefs with an equivalent area of most typical hard-bottom found off the southeastern U.S., substantial areas of ocean bottom can be effectively converted to hard-bottom over time given sufficient planning, proper design and adequate resources.

In areas where existing hard-bottom habitat is limited spatially, temporally, or structurally, artificial structures may be used to augment existing habitat. Hard-bottom with no live bottom and with or without a thin veneer of sediment constitutes a preferred substrate for the stability of artificial reef development, as opposed to sand and mud bottoms; however, deployment of structures in already productive areas carries a certain degree of risk. Existing hard-bottom may be directly damaged or impacted by modified current regimes, movement of materials and potentially increased user pressure. Although sparse, the hard-bottom may constitute valuable juvenile habitat and refugia that may be severely compromised by creating additional habitat conducive to predators. On the other hand, a properly planned and designed artificial reef could be constructed without impact to existing resources by utilizing stable materials that are designed to enhance juvenile habitat and survival.

In cases where critical hard-bottom habitat is damaged or lost due to ship groundings, beach nourishment or natural forces such as severe storms or burial, the addition of artificial reef material could be used to compensate for this loss on site or in adjacent areas. Artificial reef structures can also be used to

repair damaged habitat or mitigate for its loss. Artificial reefs can provide the closest in-kind replacement, or at least provide the long-term base for the eventual re-establishment of the hard-bottom reef community that was originally impacted.

Artificial Marine Reserves

Marine reserves, marine protected areas (MPA's), and marine sanctuaries are a proven management technique that has been implemented successfully worldwide to protect essential fisheries habitat and sustain fisheries stocks and genetic variability. Although the concept of protected areas is gaining support in the southeastern United States, the actual application of this management measure has generated resistance among user groups who feel that the establishment of such reserves will adversely impact fishing opportunities by limiting access to existing habitat. For areas with little fisheries habitat, these impacts are viewed as significant.

The potential role that artificial reefs could play as marine reserves has only recently begun to be explored. As part of its efforts to protect deep water snapper and grouper species, the South Atlantic Fisheries Management Council in 2007 created a series of Type II Marine Protected Areas in offshore waters from North Carolina to Florida. A Type II MPA prohibits bottom fishing while allowing surface trolling for pelagic species such as billfish or tuna. One of these newly regulated protected areas encompasses an old shipwreck known locally as "The Snowy Grouper Wreck". Although not a deliberately created artificial reef, this artificial structure is known to hold spawning aggregations of snowy grouper, an overfished species in serious need of protection.

Another of these newly established MPA's is, in fact, the first deliberately created artificial reef marine protected area on the east coast. The Charleston Deep Reef, off South Carolina, was permitted by the South Carolina Department of Natural Resources specifically with the intention of creating protected habitat for deep-water species. The permitted area includes no known hard-bottom habitat so that the created habitat can be studied and compared to other, natural bottom MPAs to determine the effectiveness of artificial reserves in stock enhancement.

If created habitat such as these areas can be shown to enhance fisheries stocks, additional marine reserves consisting of artificial structures could be developed in habitat-limited areas to assist specifically in such roles as habitat and stock enhancement without impacting existing fisheries practices or asking local anglers to give up traditional fishing grounds.

Enhancement of Eco-Tourism Activities

Along with other ecotourism activities, recreational diving is one of the fastest growing sports in the United States. Properly planned, artificial reefs can be designed to encourage diving and to reduce spatial conflicts with other user groups, including fishermen. Specific SMZ or other regulations established for a artificial reef could conceivably allow non-extractive uses only,

including diving, underwater photography, snorkeling, and other ecotourism activities. Materials selected could be designed and deployed to create specific fisheries habitat for tropical, cryptic, and other species valued by tourists, conservationists, naturalists, photographers and other non-extractive users.

The establishment of additional hard-bottom reef communities in areas with thriving dive-related industries could be used to reduce diving-related pressures on existing natural reefs, especially in the case of sensitive coral reefs in the Florida Keys (Leeworthy et al. 2006). Finally, a non-extractive, conservation reef would essentially constitute a sanctuary, providing fisheries and the associated habitat with de facto protection.

Artificial Reef Construction Practices

Artificial reefs have been built from a wide variety of materials over the years. Throughout the present century, most construction materials relied upon in the South Atlantic states have been forms of opportunistic scrap or surplus; some more suitable for this purpose than others. In an effort to decrease dependency of successful reef development on the availability of scrap or surplus materials, and to improve the overall effectiveness and safety of artificial reefs, most artificial reef programs have, in recent years, designed, manufactured and/or evaluated a number of specifically engineered reef habitat structures which may become a more viable option for future reef development projects. Due primarily to improved financial support for most artificial reef programs in the South Atlantic states and a willingness within private industry to develop new and affordable designed reef structures, the use of such reef construction material is now much more feasible.

Whether specifically designed or secondary-use materials are utilized to construct artificial reefs, individual state resource management agencies should be able to define particular materials that are deemed acceptable for use as reef structures in their coastal and adjacent offshore waters.

Some states and individual counties have specific stability requirements that materials must meet regarding horizontal and/or vertical movement. The decision to allow or disallow the use of certain materials should be based on existing state and federal regulations and guidelines, as well as any soundly based policies established by a particular state. Materials should only be considered for use if they possess characteristics which allow them to safely meet the established objectives for the artificial reef project under consideration, and present no real risk to the environment in which they are being placed. The document entitled Guidelines for Marine Artificial Reef Materials (Gulf States Marine Fisheries Commission, 2004) provides detailed information of the experiences, benefits, and drawbacks of past uses of a variety of materials by state resource management agencies. This, as well as other related documents (e.g. National Artificial Reef Plan, EPA Ship Preparation Guidelines), and the collective experiences of individual artificial reef programs, may be relied upon as the best available data in making decisions regarding the use of certain types of materials in artificial reef development.

Secondary Use Materials

Although past artificial reef development in most states has been directly tied to the availability of surplus or secondary use materials due to budgetary constraints, this has not been the most desirable situation for long-term planning and development of reef construction efforts. While a total dependency on scrap and surplus materials is not the most effective means of managing reef development activities, some secondary use materials, when available in the proper condition, are very desirable in carrying out artificial reef construction projects and should continue to be utilized to enhance fisheries habitat. The ability to easily deploy and stack this material can create large areas of unique and complex crevices for a variety of fish species.

In some cases naturally occurring materials such as quarry rock, limestone, or even shell have been utilized to construct artificial reefs. While these are not by definition scrap materials, their availability is sometimes dictated by a desire to move them from an existing site where they may no longer be desired. In these cases, they could be classified as a material of opportunity. In other cases, as in the intent to build a reef to provide a rocky bottom substrate, material such as quarry rock or limestone may be the most suitable material available to create the intended habitat, and may be specifically sought after.

In the South Atlantic states individual state artificial reef programs, resource management agencies, or other approved reef programs serve as the central contact and coordination point for evaluating, approving, distributing and deploying secondary use materials on a given state's system of artificial reefs. Before approving any materials for use in reef construction, the managing or oversight agency must carefully inspect the items and ensure that they are environmentally safe, structurally and physically stable, needed, practical, and can be deployed in a cost-effective and safe manner. A detailed discussion of the benefits, limitations and problems encountered in using the almost limitless list of secondary use materials that have been employed over the years in the construction of artificial reefs is well beyond the scope of this document. However, the Atlantic and Gulf State Marine Fisheries Commission's, as well as other individual artificial reef programs have produced publications which cover in great detail, many of the strengths and weaknesses of secondary use materials which have been employed in reef development.

Designed Habitat Structures

If an artificial reef program is to function in a manner that is conducive to effective long-term planning and the pursuit of realistic (fishery management driven) reef development goals, it cannot continue to base reef construction solely on the unpredictable availability and diminished quantity of acceptable scrap or surplus materials. The only practical solution is to consider the incorporation of manufactured reef structures into planned reef development activities.

Manufactured artificial reef structures can be developed which possess the characteristics desired of a reef substrate for a specific environment, application, or end result. Although the initial costs in procuring these reef materials may be higher than those involved in obtaining many secondary use materials, the transportation, handling and deployment costs could be similar depending on how stackable the materials might be,

and the lack of expense in having to clean or otherwise prepare these structures can often balance out some cost difference. Being able to engineer into a reef material design specific qualities of stability, durability, structural integrity, transportability and biological effectiveness also gives manufactured reef structures an advantage over most secondary use materials which are often limited in how they can be modified or deployed.

Manufactured reef units can be deployed in any quantity, profile and pattern required, allowing them to provide for maximum efficiency of the materials used in achieving the desired results. Secondary use materials such as ships are typically deployed in a single unit, often with a great deal of the total material volume being taken up in vertical profile. The same volume of designed reef materials that would be found in a vessel can be spread over a much larger area of ocean bottom with much less relief, allowing for more dispersed access to a larger number of reef users and a more natural appearance in the layout of the reef.

One of the administrative advantages offered by the use of designed reef structures is the ability to procure them in any quantity whenever they are needed. This allows reef managers to plan ahead and make the best possible use of available funding, as well as predict exact costs needed to accomplish specific reef construction objectives from month to month or year to year. When depending on secondary use materials for reef development, in the absence of long-term waterfront staging areas where secondary materials could be stockpiled, this type of short and long- term planning is rarely available.

Standards for Artificial Reef Construction

The National Fishing Enhancement Act of 1984 (Title II of P.L.98-623) provides broad standards for the development of artificial reefs in the United States. The purpose of the Act was to promote and facilitate responsible and effective efforts to establish artificial reefs in the navigable waters of the US and waters superjacent to the outer continental shelf (as defined in 43 USC, Section 1331) to the extent such waters exist in or are adjacent to any State. In Section 203, the Act establishes the following standards for artificial reef development. Based on the best scientific information available, artificial reefs in waters covered under the Act...shall be sited and constructed, and subsequently monitored and managed in a manner which will:

(1) enhance fishery resources to the maximum extent practicable;

(2) facilitate access and utilization by U.S. recreational and commercial fishermen;

(3) minimize conflicts among competing uses of waters covered under this title and the resources in such waters;

(4) minimize environmental risks and risks to personal health and property; and

(5) be consistent with generally accepted principles of international law (e.g. MARPOL) and shall not create any unreasonable obstruction to navigation.

Section 204 of the Act also calls for the development of a National Artificial Reef Plan consistent with these standards. This plan was first published by the National Marine Fisheries Service in 1985 and includes discussions of criteria for siting and constructing artificial reefs, as well as mechanisms and methodologies for monitoring and managing such reefs. While the Plan itself lacked any degree of regulatory authority, adopted regulations subsequently developed by the U.S. Army Corps of Engineers for dealing with the issuance of artificial reef construction permits were based on the standards set forth in the Act as well as wording taken from the Plan. The National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs (NOAA, 2007) was approved in 2007 and is available at https://media.fisheries.noaa.gov/dam-migration/noaa_artificial_reef_guidelines.pdf .

Each state artificial reef program has its own set of standards for the development and management of artificial reefs. In most cases these state standards were developed with the federal standards from the National Fisheries Enhancement Act and the National Artificial Reef Plan in mind. While specific state programs may differ in matters involving technical operation or specific management issues, they are all very similar in their adoption of the national standards that exist.

Artificial Reefs as Essential Fish Habitat

Earlier sections have discussed the ways in which artificial reefs are specifically used by both invertebrate and finfish species. Since artificial reefs are established by marine resource managers throughout the entire South Atlantic Bight, the diversity of species present on and around such structures is extremely wide. Artificial reefs are used in almost every possible marine environment, from shallow-water estuarine creeks to offshore sites up to several hundred feet in depth. Due to the broad distribution of reef sites along the South Atlantic states, many different species may interact with artificial reefs at different life-stages and at different times.

For species which may be to some degree habitat-limited, the establishment of additional suitable habitat targeted to specific life-history stages may improve survival (Herrnkind et al., 1997).

Additional artificial habitat designed specifically to promote survival of targeted species in protected areas could potentially enhance existing ecosystems or create new ones to fill in gaps where essential fish habitat had been damaged, lost, or severely overfished. Artificial structures also may provide essential habitat while simultaneously acting as a deterrent to illegal fishing practices in specially managed areas (e.g. Oculina HAPC).

Since the majority of the artificial reefs constructed along the southeastern U.S. are in coastal and offshore waters, the species most often present on these sites are predominantly the adult and/or sub-adult stages of virtually all species within the South Atlantic Snapper Grouper Complex, as well as all species managed within the Coastal Migratory Pelagics Fishery Management Plan. Depending on environmental conditions on a specific reef site, and the behavior patterns of certain fish, species within the Snapper Grouper Complex tend to be long to short-term reef residents, while those among the Coastal Pelagics tend to be more transient visitors to the reefs as they migrate up and down the coast. Red drum and spiny lobster, as well as some of the managed shrimp species, may be found on and around specific reef sites at different times of the year, depending on the exact location and design of the reef. While some species of managed corals may occur on reef structures as far north as the Carolinas, the waters off South Florida are the predominant site where such species are found attached to artificial substrate.

In conclusion, artificial reefs are constructed from a wide range of materials, and are used for a variety of purposes. They function by enhancing natural habitat and are especially popular sites for fishing and diving. Socioeconomic studies clearly indicate positive returns from artificial reef construction (Johns et al. 2001; Rhodes and Pan 2007). Considerable evidence also exists that artificial reefs both attract and produce a variety of marine finfish species, in some cases exhibiting greater reproductive productivity than natural areas (Danson 2009). While the creation of successful and productive artificial reefs requires careful preparation and planning, they constitute a habitat-based tool with considerable potential that, ideally, should be incorporated into an integrated holistic approach to fishery management.

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Live/Hard Bottom Habitat

Summary

The continental shelf off the southeastern United States, commonly called the South Atlantic Bight (SAB), extends from Cape Hatteras, North Carolina, to Cape Canaveral, Florida (or according to some researchers, to West Palm Beach, Florida). The northern part of the SAB is known as the Carolina Capes Region, while the middle and southern areas are called the Georgia Embayment, or Georgia Bight. The Carolina Capes Region is characterized by complex topography. The prominent shoals there extend to the shelf break and are effective in trapping Gulf Stream eddies, whereas the Georgia Embayment to the south is smoother.

Shelf widths of the South Atlantic Bight vary from just a few kilometers off West Palm Beach, FL, to a maximum of 120 km off Brunswick and Savannah, Georgia. Gently sloping shelves (about 1m/km) can be divided into the following zones based on depth. The shallowest is the nearshore zone (0-5m) followed by the inner-shelf zone (5-20 m, 16-66 ft.), which is dominated by tidal currents, river runoff, local wind forcing and seasonal atmospheric changes (Table 1). The mid-shelf zone (20-30 m, 66-98 ft.) is dominated by winds but influenced by the Gulf Stream. Stratification of the water column changes seasonally; mixed conditions, in general, characterize fall and winter while vertical stratification prevails during spring and summer. Strong stratification allows offshore upwelled waters to advect farther onshore near the bottom and, at the same time, facilitates offshore spreading of lower-salinity water in surface layer. Further offshore, the outer-shelf zone (30-50 m, 98-164 ft.) is dominated by the Gulf Stream.

Generally, the shelf edge or break occurs between 50-100 m depth (164-328 ft.) but occurs shallower to the south of Cape Canaveral into the Florida Keys. The shelf edge is the transition from a gradually sloping shelf area to relatively steeper slopes. Offshore of the shelf edge, the upper slope occurs in 100 to 300 m (328 to 984 ft.), and the mid slope is slightly deeper at 300-400 m (984-1,312 ft.). The slope areas include habitats such as the Big Rock, Blake Plateau, Charleston Bump, Miami Terrace, and Pourtales Terrace. Deep offshore and deep areas occur in depths greater than 400 m (1,312 ft.).

To facilitate development of a regional mapping strategy for SAFMC Fishery Ecosystem Plan II (FEP II), a Managed Species Writing Team provided input on the spatial partitioning of offshore habitat identified in Table 1 to allow general evaluations of existing mapping efforts and further develop the Strategy in cooperation with the Southeast Area Monitoring and Assessment Program (SEAMAP) Species Habitat Characterization and Assessment Workgroup, the SAFMC Habitat Protection and Ecosystem Based Management Advisory Panel and other regional partners. This effort builds on the Council's Habitat and Ecosystem Atlas (https://ocean.floridamarine.org/safmc_dashboard/index.html) and provides an evolving prioritization to facilitate regional collaborative acquisition of data on the physical and biological characteristics of the South Atlantic region. The Strategy is being developed as a living online functional tool highlighted in the Digital Dashboard (http://ocean.floridamarine.org/safmc_dashboard/) and accessible through the Services presented in the SAFMC Habitat and Ecosystem Atlas.)

Table 1. Approximate depth distribution of bottom habitat zones in the South Atlantic region.

Habitat Zones	Depth (m)	Depth (ft)
Nearshore	0-5	0-16
Inner-shelf	5-20	16-66
Mid-shelf	20-30	66-98
Outer-shelf	30-50	98-164
Shelf-edge	50-100	164-328
Upper-slope	100-300	328-984
Mid-slope	300-400	984-1,312
Deep-offshore	400-5,000	1,312-16,404
Deep	>5,000	>16,404

1. Ecological Roles and Functions

Hardbottom is defined as exposed rock or other hard benthic substrate. Hardbottom provides protective cover for numerous fish and invertebrate species and increases the surface area available for colonization by sessile invertebrates and macroalgae through increased relief and irregularity of the structure. The variability in abundance and diversity of fish on hardbottom and artificial reefs is related to the amount and type of structural complexity of the reef (Carr and Hixon 1997, Schobernd and Sedberry 2009) and likely explains invertebrate diversity and abundance similarly. Because of their structural complexity, natural reefs can sustain >10 times the fish biomass compared to non-reef open shelf bottom (Huntsman 1979, Wenner 1983). In addition, areas with small patches of hardbottom surrounded by sand bottom supported greater fish abundance and diversity than one large area of equal material, suggesting the importance of habitat edge and diversity to ecosystem productivity (Bohnsack et al. 1994, Auster and Langton 1999).

Nearshore and inner-shelf hardbottom areas can serve as important settlement and nursery habitat for early life history stages of many important fisheries species (Lindeman and Snyder, 1999; Jordan et al. 2004). Species within the SAFMC Snapper-Grouper complex that have been commonly recorded as settlers on nearshore hardbottom (0-5 m) include Lane Snapper (*Lutjanus* *synagris*), Yellowtail Snapper (*Ocyurus chyrsurus*), White Grunt (*Haemulon plumerii*), French Grunt (*Haemulon flavolineatum*), Black Margate (*Anisotremus surinamensis*) and others. Nearshore hardbottom also serves as intermediate nursery habitat for late juveniles emigrating out of estuaries (CSA 2009).

In addition to providing important settlement and nursery habitat, hardbottom areas provide important spawning habitat for some reef fishes (Heyman et al. 2005, Sedberry et al. 2006, Coleman et al. 2011), including red snapper (Farmer et al. 2017). Spawning occurs on nearshore hardbottom for Black Sea Bass (*Centropristis striata*), Sand Perch (*Diplectrum formosum*), Sheepshead (*Archosargus probatocephalus*), Atlantic Spadefish (*Chaetodipterus faber*) and some additional non-fishery reef species (Powell and Robins 1998, F. Rohde, DMF, pers. com., 2001, CSA 2009). Spawning for most managed reef fish species occurs on mid- and outer-shelf reefs. Riley's Hump in the Dry Tortugas is a spawning location for Mutton Snapper (*Lutjanus analis*) and likely spawning location for multiple other snapper-grouper species (Lindeman et al. 2000, Locascio and Burton 2016). Similarly, many deep-water reef species spawn on the upper slope and Blake Plateau (Sedberry et al. 2006, Locascio and Burton 2016, Farmer et al. 2017). Other potential hardbottom spawning areas were included in the SAFMC Snapper Grouper Amendment 14 for MPA protection (Figure 1), and additional sites have been identified in the Snapper-Grouper Amendment 36 as Spawning Special Management Zones to further protect spawning reef fishes (Figure 2). In the Amendment 14 MPAs and Spawning SMZs, fish in spawning condition have been observed in the area or have been reported anecdotally (SAFMC 2007, SAFMC 2016, Farmer et al. 2017). Regulations for Spawning SMZs became effective 2017.

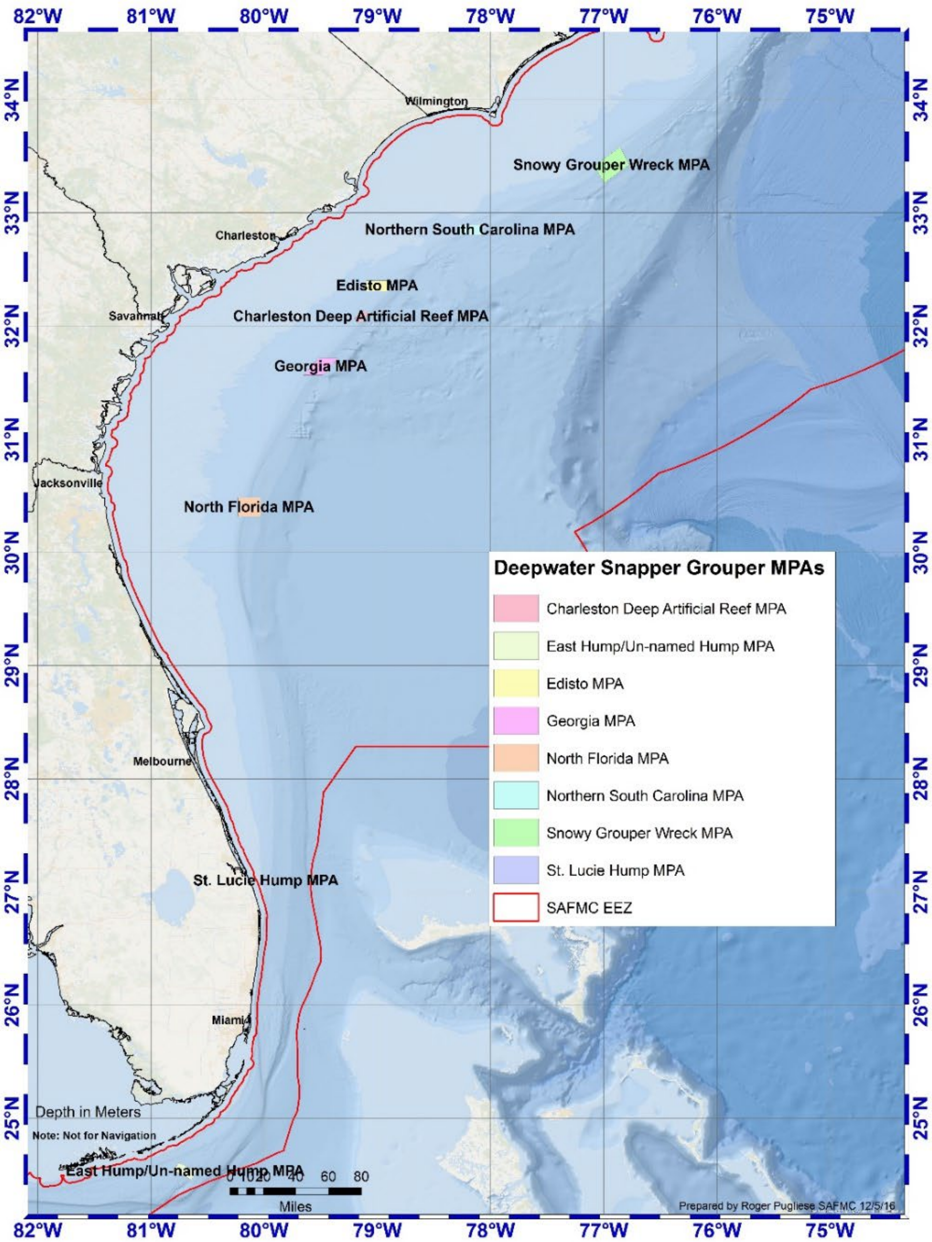

Figure 1. Map of the South Atlantic Region's Deepwater Marine Protected Areas (MPAs) (Source: Roger Pugliese, SAFMC Staff).

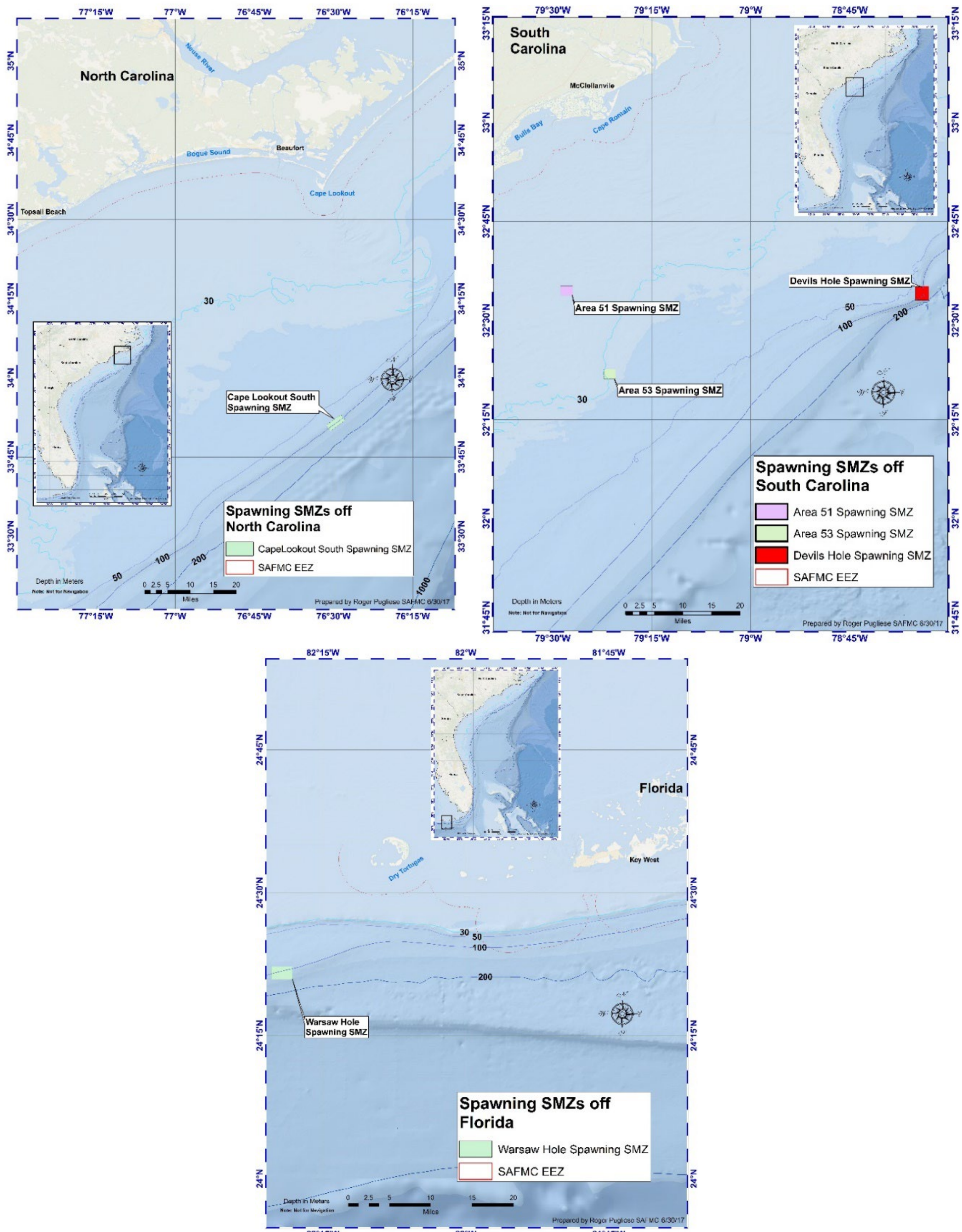

Figure 2. Maps of Spawning Special Management Zones off North Carolina, South Carolina and Florida East Coast (Source: Roger Pugliese, SAFMC, Staff).

2. Nearshore

Nearshore hardbottom habitats in the South Atlantic Region are predominantly found along the east coast of Florida in depths of 0-5 m. These habitats are primarily accretionary ridges of coquina shells, sand, and shell marl that lithified parallel to ancient shorelines during Pleistocene interglacial periods (Duane and Meisburger 1969) and are patchily distributed among large expanses of barren coarse sediments. The habitat complexity of nearshore hardbottom is expanded by mounds of tube-building polychaete worms (Kirtley and Tanner 1968; McCarthy 2001), and other invertebrates and macroalgae (Goldberg 1973; Nelson and Demetriades 1992). Hard corals are rare due to high turbidities and wave energy. However, hard corals that are found in the nearshore zone off southeastern Florida from St. Lucie to Broward counties include *Acropora cervicornis*, *Oculina diffusa, Oculina varicosa,* and *Siderastrea spp* (CSA 2009).

A large array of literature and many new species records are summarized for algae (277 species total), invertebrates (523 species), fishes (257) and sea turtles from nearshore hardbottom along the east coast of Florida (CSA 2009). Based in part on information in (Futch and Dwinell 1977, Gilmore 1977, Gilmore et al. 1983, Vare 1991, Gilmore 1992, Lindeman and Snyder 1999, Baron et al. 2004), at least 90 fish species that use nearshore hardbottom habitats are utilized in recreational, commercial, bait, or aquaria fisheries. Some of the more abundant taxa identified included haemulids (grunts), clupeids (herrings and sardines), carangids (jacks), and engraulids (anchovies).

Nearshore hardbottom fish assemblages of east Florida are characterized by diverse subtropical faunas which are dominated by early life stages. Based on visual censusing of fishes in three mainland southeast Florida sites over two years, 86 species from 36 families were recorded (Lindeman and Snyder 1999). Pooled early life stages (newly settled, early juvenile, and juvenile) represented over 80% of the individuals at all sites. Nearshore hardbottom habitats typically had more than thirty times the number of individuals per transect as natural sand habitats (Lindeman and Snyder 1999) and newly settled individuals were not recorded during any surveys of natural sand habitats.

Off mainland east Florida, nearshore hardbottom is often colonized by sabellariid worm reefs (*Phragmatopoma lapidosa*) that go through predictable patterns of annual change which include high recruitment in early autumn through winter, rapid reef growth (~0.5 cm/day) resulting in maximum structure in spring and summer, and decay by early autumn (McCarthy 2001; McCarthy 2003). As recruits grow, the structure of their reef changes and these changes are important in determining the resiliency of the reefs when disturbed. Juveniles form low-lying mounds and reefs that often survive winter wave and sand disturbance (McCarthy 2001). As individuals continue to grow and accrete sand, they form large reefs that reach maximum size during the summer. Many of the intertidal colonies grow into somewhat unstable mushroomshaped mounds whereas subtidal *P. lapidosa* mounds generally remain carpet-like in shape (McCarthy 2001).

Mortality of *P. lapidosa* colonies increases during the summer as a result of the effects of several disturbance agents (McCarthy 2001). In the early summer, some individuals at the tops of intertidal mounds perish, leaving the tops susceptible to decay. It is likely that this mortality is caused by desiccation and/or heat stress from extreme summer temperatures. By the late summer and early autumn, wave activity from hurricanes results in maximum physical disturbance to sabellariid reefs. A large percentage of both intertidal and subtidal reefs are severely damaged at this time. Intertidal worms are more susceptible to physical destruction of their colonies, whereas subtidal worms get smothered by sand but the sand reef remains intact.

Almost simultaneously with peaks in lethal disturbance, however, larvae of *P. lapidosa* arrive in large numbers to renew the colonies by massive recruitment in cracks or atop mounds of adults (McCarthy 2001). This process results in low lying reefs that are highly resilient and will eventually restore the structure of the reefs. Consequently, as disturbance lowers adult abundance and creates new settlement space, new individuals arrive in sufficient numbers to restore the populations. Therefore, local metapopulations may remain at fairly high abundances year after year while experiencing moderately high mortality from various agents of disturbance. When these seasonal data are integrated with those of other researchers (Gilmore 1977; Gilmore et al. 1981; Lindeman and Snyder 1999), they reveal important links between the seasonal cycle of sabellariid reef expansion and degradation, and the occupation of those reefs by juvenile and adult organisms.

Nearshore hardbottom habitats of the Florida Keys can differ both geologically and biologically from mainland areas. Within the Keys, nearshore hardbottom is widely distributed and shows compositional differences based on proximity to tidal passes (Chiappone and Sullivan 1994). Near tidal passes, these habitats can be dominated by algae, gorgonians and sponges. In the absence of strong circulation, such habitats are characterized by fleshy algae, such as *Laurencia* (Chiappone and Sullivan 1994). Hard corals are relatively uncommon in nearshore areas of mainland east Florida, presumably due to greater variability in key environmental parameters (temperature, turbidity, salinity).

3. Inner Shelf

In more temperate regions, the inner shelf has seasonally variable temperatures, less diverse populations of invertebrates, and are inhabited primarily by Black Sea Bass, Scup and associated warm-temperate species (Sedberry and Van Dolah 1984).

Most of the substrate on the inner shelf is covered by a vast plain of sand and mud (Newton et al. 1971) underlain at depths of less than a meter (Riggs et al. 1996; Riggs et al. 1998). The fish biomass associated with this sand- and mud-covered plain is relatively low. Scattered irregularly over the shelf, however, are patches of hardbottom characterized by highly concentrated invertebrate and algal growth, usually in association with marked deviations in relief that support substantial fish assemblages (Struhsaker 1969; Huntsman and Mcintyre 1971; Wenner et al. 1983; Chester et al. 1984; Sedberry and Van Dolah 1984; Sedberry et al. 1998; Sedberry et al. 2001). Studies that have examined fish assemblages on natural and artificial reef habitats include in the SAB inner-shelf-zone include Huntsman and Manooch (1978), Miller and Richards (1979), Grimes et al. (1982), Lindquist et al. (1989), Potts and Hulbert (1994), Parker and Dixon (1998), Ojeda et al. (2001), and Whitfield et al. (2014).

South of Ft. Pierce Inlet, Florida, the shelf becomes increasingly tropical through the Florida Keys. This is reflected in an increase in corals and associated organisms (see the Shallow Coral Chapter of the Fishery Ecosystem Plan II (SAFMC 2017) and Reigl and Dodge (2008) for greater detail). In southeast Florida, several parallel ridges of hardbottom reefs, derived from Pleistocene and Holocene reefs, begin in depths usually exceeding 8 m (Goldberg 1973; Lighty 1977). The geologic origins and biotic characteristics of these inner shelf reef systems are different from the nearshore hardbottom reefs (Lighty 1977), although reefs of both strata are lower in relief than reefs of the Florida Reef tract that parallels the Florida Keys. Using various collecting gears and literature reviews, Herrema (1974) recognized the occurrence of 206 fishes off the mainland southeast coast of Florida. Based primarily on offshore records, Perkins et al. (1997) identified 264 fish taxa from the shelf of mainland Florida as hardbottom obligate taxa.

4. Mid Shelf

Off the temperate South Atlantic region most live hardbottom habitats are found at depths of from 20 to 30 m (66 to 98 ft), especially off the coasts of North Carolina and South Carolina, and within Gray's Reef National Marine Sanctuary off Georgia. Studies of bottom areas from North Carolina to northern Florida (CSA, 1979; Wenner *et al*., 1983) revealed three habitat types: 1) emergent hardbottom dominated by sponges and gorgonian corals; 2) sand bottom underlain by hard substrate dominated by anthozoans, sponges and polychaetes, with hydroids, bryozoans, and ascidians frequently observed; and 3) softer bottom areas not underlain with hardbottom. See the Shallow Coral Chapter of the Fishery Ecosystem Plan II and Reigl and Dodge (2008) for greater detail on mid-shelf hardbottom and coral associated fauna.

The federal waters of the inner shelf off Georgia includes an MPA, Gray's Reef National Marine Sanctuary. The Sanctuary contains excellent examples of high- and moderate-relief ledges, low relief hardbottom (often covered with a veneer of sand) and sand plains. Roughly one third of the Sanctuary (eight square miles) is a no-fishing zone; the remainder is a popular recreational fishing site.

5. Outer Shelf

Miller and Richards (1980) and Sedberry et al. (2005) noted that there is a stable temperature on the outer shelf or the area between 26 and 51 m (85 to 167 ft) where the temperature does not drop below 15°C (59° F). Fisco (2016) identified a linear, often shore-parallel, low-relief feature, present in four of the five reef ecoregions off Florida east coast mostly occurring deeper than 20 m and consisting of hardbottom with sparse benthic assemblages likely due to variable and shifting rubble and sand cover. Some of the hard bottom contained exposed ledges where large fish like Goliath Grouper (Epinephelus itajara) and Nurse Shark (Ginglymostoma cirratum) may have aggregated. A deep complex of hardbottom ridges occurs off North Palm Beach and Martin ecoregions in depths of 20 m to 35 m (Fisco 2016) consisting of primarily low cover, deep assemblages dominated by small gorgonians, sponges and macroalgae, with denser areas existing near areas of higher relief with large areas of shifting unconsolidated sediments between ridges.

6. Shelf Edge

At the first break on the edge of the continental shelf, there are outcroppings of sedimentary rock and steep drop offs (10 m or more) in the zone from 50 to 100 m. High-relief rock outcrops are especially evident at the shelf break, a zone where the continental shelf ends and the upper slope begins; this area is often characterized by steep cliffs and ledges (Huntsman and Manooch 1978; Sedberry et al. 2001; Wenner and Barans 2001; Fraser and Sedberry 2008; Schobernd and Sedberry 2009). At the shelf edge, the topography is a discontinuous series of terraces before sloping or dropping off into steep slopes dominated by unconsolidated sediments, with submarine canyons, the relatively flat Blake Plateau, or deep Straits of Florida, depending on latitude.

The shelf-edge habitat extends more or less continuously along the edge of the continental shelf at depths of 50 to 100 m (164 to 328 ft). The sediment types vary from smooth mud to areas that are characterized by great relief and heavy encrustations of coral, sponge, and other subtropical and tropical invertebrate fauna. Some of these live hard bottoms may represent the remnants of ancient reefs that existed when the sea level was lowered during the last glacial period. Fish that generally inhabit the shelf-edge zone are more tropical, such as wrasses, snappers, groupers, and porgies. Fish distribution is often patchy in this zone, with fishes aggregating over live hard bottom in associations similar to those formed at inshore live bottom sites and are important spawning grounds for many species of managed reef fish (Sedberry et al. 2006; Schobernd and Sedberry 2009; Farmer *et al*. in prep.).

7. Slope

The upper slope has a predominantly smooth mud bottom, but is interspersed with rocky and very coarse gravel substrates. In addition to rocky outcrops and manganese-phosphorite pavements, there are areas of rough bottom formed by iceberg scours. From North Carolina to south Florida, the retreat of the Northern Hemisphere ice sheets during the last deglaciation (20 to 6 thousand years ago) was accompanied by the discharge of meltwater and icebergs to the southeastern waters of North America, where they encountered then-shallow waters and created plow marks, rock piles and rough bottom (Hill et al. 2008, Hill and Condron 2014). Subsequent sea-level rise has submerged these features on the upper continental slope. These various rocky and mixed bottom types are where Snowy Grouper (*Hyporthodus niveatus*), Yellowedge Grouper (*H. flavolimbatum*) and tilefishes (Malacanthidae) are found (Schobernd and Sedberry 2009, Yeckley, in prep.). This habitat and its association of fishes roughly mark the transition between the faunas of the continental shelf and the slope. Depths represented by this zone range from 100 to 400 m (328 to 1,312 ft), where bottom water temperatures vary from approximately 11° to 14°C (51° to 57°F). Some species inhabiting the deeper live- or hard-bottom areas may be particularly susceptible to heavy fishing pressure due to limited habitat and life history characteristics.

The continental slope off North Carolina, Georgia and Northern Florida is interrupted by the relatively flat Blake Plateau, which divides the slope into the Florida-Hatteras Slope and the Blake Escarpment. On the northern Blake Plateau are important fish habitats, including coral mounds and the Charleston Bump, an important habitat for Wreckfish.

8. Deep and Deep Offshore

While there are extensive hardbottom habitats offshore this section focuses on the Blake Plateau. Discontinuous large mounds of deep-sea coral reefs occur between the 360-500 m (1,181 to 1640 ft) depth contours on the Blake Plateau. While this deep coral habitat was previously described (Squires 1959; Stetson et al. 1962; Rowe and Menzies 1968), submersible dives have documented more information on their location and species composition (Popenoe and Manheim 2001; Ross 2006; Partyka et al. 2007). The mounds consist primarily of dense thickets of the branching ahermatypic coral *Lophelia pertusa*, although other coral species have also been identified. As coral colonies die, others form on top of the mound, and extensive coral rubble accumulates to the sides of the mound. In North Carolina, two areas of mounds have been documented off Cape Lookout and one area off Cape Fear. The vertical height of the mounds was estimated to range from 50 to 80 m over 0.4 to 1.0 km distance. Over 43 benthic or benthopelagic fish species have been identified on these coral mounds (Ross et al. 2004).

The Charleston Bump is a deep-water rocky bottom feature on the Blake Plateau southeast of Charleston, South Carolina (Sedberry et al. 2001). It includes a shoaling ramp and ridge/trough features on which the seafloor rises from 700 m to shallower than 400 m within a relatively short distance and at a transverse angle to both the general isobath pattern of the upper slope, and to Gulf Stream currents (Brooks and Bane, 1978). The Charleston Bump includes areas of nearly vertical, 100-200-m high rocky scarps with carbonate outcrops and overhangs; other complex bottom such as coral mounds (mostly dead coral); and flat hardbottom consisting of phosphorite-manganese pavement (Popenoe and Manheim 2001; Sedberry *et al.* 2001). The bottom relief is important to deep reef species and supports the Wreckfish (*Polyprion americanus*) (Sedberry *et al*. 1999) and pelagic longlining fisheries (Cramer 1996; Sedberry *et a*l. 2001; Cramer 2001).

The feature was first described by Brooks and Bane (1978), who noted that it deflected the Gulf Stream offshore. This deflection and the subsequent downstream eddies, gyres and upwellings may increase productivity and concentrate fishes and other organisms along thermal fronts downstream from the Charleston Bump (McGowan and Richards 1989; Bane et al. 2001; Haney 1986; Collins and Stender 1987; Lee et al. 1991) including the Charleston Gyre. The cyclonic Charleston Gyre is a permanent but highly variable oceanographic feature of the South Atlantic Bight induced by the deflection of rapidly moving Gulf Stream waters by the Charleston Bump. The gyre produces a large area of upwelling of nutrients, which contributes significantly to primary and secondary production within the SAB region. It is also important in retention and cross-shelf transport of larvae of reef fishes that spawn at the shelf edge (Sedberry et al. 2001). The size of the deflection and physical response in terms of replacement of surface waters with nutrient rich bottom waters from depths of 450 meters to near surface (less than 50 meters) vary with seasonal position and velocity of the Gulf Stream currents (Bane et al. 2001).

The nutritional contribution of the large upwelling area to productivity of the relatively nutrient poor SAB is significant. While emphasis has generally been placed on shallow habitats, the South Atlantic Fishery Management Council (SAFMC 1998) designated the Charleston Gyre as an essential nursery habitat for some offshore fish species with pelagic stages, such as reef fishes, because of increased productivity that is important to ichthyoplankton (Govoni and Hare 2001; Sedberry et al. 2001).

9. Artificial Reefs

In addition to the natural hard or live bottom reef habitats, wrecks and other manmade structures (artificial reefs) also provide substrate for the proliferation of live bottom. Although the areal coverage of artificial reefs and hardbottom in the South Atlantic region has been not been quantified, the combined area of artificial reefs is thought to be low compared to the area of hardbottom. As long noted by researchers, the physical characteristics of artificial reef habitat may result in differences in the observed behavior of fish species on or around such structures in contrast to behavior observed on equivalent areas of natural hard-bottoms (Bohnsack 1989; Lindberg et al 2006). Some reef structures, particularly those of higher relief, seem to yield generally higher densities of managed and non-managed pelagic and demersal species than a more widely spread lower relief, natural hard-bottom or reef (Rountree 1989; Collins et al 2016, Streich et al. 2017). However, many fishes in Gulf of Mexico studies have been documented as older and more fecund on natural reefs (Glenn et al. 2017; Karnauskas et al. 2017). The fishery management implications of these differences must be recognized and taken into consideration when planning, developing, and managing artificial reefs as EFH (Lindberg and Seaman 2011).

The Charleston Deep Artificial Reef MPA was established under Snapper Grouper Amendment 14 (SAFMC 2007) and adjusted in Snapper Grouper Amendment 36 to better match placement of artificial reef material (SAFMC 2016). Additionally, there are two artificial reef areas (Area 51 and Area 53) with regulations through Snapper Grouper Amendment 36.

There is limited literature on the results of artificial reef mitigation of dredge and fill burial of nearshore hardbottom (via beach renourishment projects) using artificial reefs. Reviews of various aspects are provided in CSA (2009; 2014). A detailed empirical comparison among nearshore hardbottom and mitigation reefs off Ft. Lauderdale, Florida (Kilfoyle et al. 2013), revealed that mitigation habitat had high species richness but differed dramatically in structure from impacted nearshore hardbottom, creating an environment unlike nearshore hardbottom. The study concluded that "mitigation reefs in general, and boulder reefs specifically, should not be relied upon to provide an equitable replacement to nearshore hardbottom habitat loss" (Kilfoyle et al. 2013). The impacts of elevated sedimentation from dredging are likely negative across many variables (e.g. coral abundance and condition (Miller et al. 2016 and Fournay and Figuardo 2017)) that indirectly and directly influence fishes (CSA, 2009, Jordan et al. 2010), yet are not addressed by reef mitigation.

10. Essential Fish Habitat

Live hardbottom habitat constitute essential fish habitat for a high number of species of warm-temperate and tropical species of snappers, groupers, and associated fishes (SAFMC, 1998, SAFMC 2009). Fautin et al. (2011) reported 1200 species of fish from the entire South Atlantic region, including the Florida Keys. Designations of live hardbottom as EFH or as EFH Habitat Areas of Particular Concern for Council managed species in various Fishery Management Plans are presented in the SAFMC EFH User Guide (https://safmc.net/documents/efh-user-guide/ .)

Detailed information on designation, spatial distribution, threats and SAFMC EFH Policy Statements can be viewed online (https://safmc.net/fishery-management-plans/habitat/ .)

Distinct faunal assemblages have been associated with at least four hardbottom habitats: live/hardbottom on the open shelf; the shelf edge reef; upper slope reef; and Blake Plateau/Charleston Bump. Exploratory surveys for reef fishes have yielded 119 species representing 47 families of predominantly tropical and subtropical fishes off the coasts of North Carolina and South Carolina (Grimes et al., 1982; Lindquist et al 1989; Table 3.3-2). Parker and Dixon (1998, 2002) identified 119 species of reef fish representing 46 families during underwater surveys 44 km off Beaufort, North Carolina (Table 2.18). Off South Carolina and Georgia, 54 families, 98 genera and 128 species were taken in 83 trawl collections during winter and summer, in depths from 16-67 m (Sedberry and Van Dolah 1983). Sedberry and Schobernd (2009) reported 25 families and 54 species seen during nine shelf-edge submersible dives off Florida, Georgia and South Carolina. Three upper-slope dives yielded seven families, and seven species.

During sampling for the fishery independent baseline assessment off southeast Florida, 1,238,951 fish representing 305 species from 70 families were recorded from 2012 to 2016. (Kilfoyle et al. 2018). Out of those 305 species, 184 were recorded every year. Of the 121 species that were seen less frequently, 50 were small cryptic or nocturnal species, 10 were solitarily occurring elasmobranchs, 10 were large sportfishes, 7 were temperate-associated species, and many of the rest are considered as uncommonly or infrequently encountered. By comparison, there were 347 species recorded in fishery independent reef fish surveys in the Florida Keys and 370 species in the Dry Tortugas during the same 2012-2016 time-frame (Kilfoyle et al. 2018).

A total of 181 fish species has been reported from Gray's Reef National Marine Sanctuary, an inner-shelf (18-20 m) live bottom reef off Georgia (Fautin et al. 2010; J. Hare, unpublished data). A study of South Atlantic Bight reef fish communities by Chester et al. (1984) confirmed that specific reef fish communities could be identified based on the type of habitat. Bottom topography and bottom water temperatures are the two most important factors which create habitats suitable for warm-temperate and tropical species. Hardbottom habitats off mainland southeast Florida and areas off the Carolinas are often centrally placed between mid-shelf reefs to the east and estuarine habitats within inlets to the west. Therefore, they may serve as settlement habitats for immigrating larvae or as intermediate nursery habitats for juveniles emigrating out of inlets (Vare 1991; Lindeman and Snyder 1999). This cross-shelf positioning, coupled with their role as the only natural structures in these areas, suggests nearshore hardbottom can represent important Essential Fish Habitat.

Section 600.815 (a) (9) of the final rule on essential fish habitat determinations recognizes that subunits of EFH can be of particular concern. Such areas, termed Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPCs), can be identified using four criteria from the rule: a) importance of ecological functions; b) sensitivity to human degradation; c) probability and extent of effects from development activities; and d) rarity of the habitat (SAFMC 2009). Applications of EFH and EFH-HAPCs in the management of the SAFMC snapper-grouper complex was examined in Lindeman et al (2000), with a focus on developmental variation and MPAs. Hardbottom habitat types which have been identified as EFH-HAPCs include the following areas.

Charleston Bump and Gyre

The South Atlantic Bight, the Charleston Bump and Gyre are described in greater detail in several research and review papers (e.g., Bane et al. 2001; Sedberry et al. 2001; Govoni and Hare 2001 and papers cited therein). The following synopsis is based on the review by Sedberry et al. (2001), Fautin et al. (2010) and O. Pashuk (unpublished MS).

In general, the Gulf Stream flows along the shelf break, with very little meandering, from Florida to about 32° N latitude where it encounters the Charleston Bump and is deflected seaward forming a large offshore meander. The cyclonic Charleston Gyre is formed, with a large upwelling of nutrient-rich deep water in its cold core. The Charleston Bump is the underwater ridge/trough feature located southeast of Charleston, South Carolina, where seafloor rises from 700 to 300 m within a relatively short distance and at a transverse angle to both the general isobaths pattern of the upper slope, and to Gulf Stream currents. Downstream of the Charleston Bump, enlarged wavelike meanders can displace the Gulf Stream front up to 150 km from the shelf break. These meanders can be easily seen in satellite images.

Although two to three large meanders and eddies can form downstream of the Bump, the Charleston Gyre is the largest and the most prominent feature. The consistent upwelling of nutrient-rich deep water from the depths over 450 m to the near-surface layer (less than 50 m) is the main steady source of nutrients near the shelf break within the entire South Atlantic Bight, and it contributes significantly to primary and secondary production in the region. The Charleston Gyre is considered an essential nursery habitat for some offshore fish species with pelagic stages. It is also implicated in retention of fish eggs and larvae and their transport onshore.

The Charleston Bump and the Gyre can also create suitable habitats for adult fish. For example, the highest relief of the Bump is the only known spawning location of the Wreckfish. The Charleston Gyre may be also beneficial to other demersal species of the Snapper-Grouper complex, as well as to pelagic migratory fishes, due to food availability and unique patterns of the currents in this area.

Ten Fathom Ledge and Big Rock

The Ten Fathom Ledge and Big Rock areas are hard-bottom habitats located south of Cape Lookout, North Carolina. The Ten Fathom Ledge is located at 34° 11' N. and 76° 07' W. in 95 to 120 meter depth on the Continental Shelf in Onslow Bay, North Carolina, beginning along the southern edge of Cape Lookout Shoals. This area encompasses numerous patch reefs of coral-algal-sponge growth on rock outcroppings distributed over 136 square miles of ocean floor. The substrate consists of oolithic calcarenites and coquina forming a thin veneer over the underlying Yorktown formation of silty sands, clays, and calcareous quartz sandstones.

The Big Rock area encompasses 36 square miles of deep drowned reef around the 50-100 meter isobath on the outer shelf and upper slope approximately 36 miles south of Cape Lookout. Hard substrates at the Big Rock area are predominately algal limestone and calcareous sandstone. Unique bottom topography at both sites produces oases of productive bottom relief with diverse and productive epifaunal and algal communities surrounded by a generally monotonous and relatively unproductive sand bottom. Approximately 150 species of reef-associated species have been documented from the two sites (R. Parker, unpublished data.).

Shelf Break Area from Florida to North Carolina

Although the area of bottom between 100 and 300 meters depths from Cape Hatteras to Cape Canaveral is small relative to the more inshore live bottom shelf habitat as a whole, it constitutes essential fish habitat for deep-water reef fish. A series of troughs and terraces are composed of bioeroded limestone and carbonate sandstone (Newton et al. 1971), and exhibit vertical relief ranging from less than half a meter to more than 10 meters. Ledge systems formed by rock outcrops and piles of irregularly sized boulders are common.

Overall, the deep-water reef fish community likely consists of fewer than 60 species; however, many fishery species spawn there (Sedberry et al. 2006). Parker and Ross (1986) observed 34 species of deep-water reef fishes representing 17 families from submersible operations off North Carolina in waters 98 to 152 meters deep. In another submersible operation in the Charleston Bump area off South Carolina, Gutherz et al. (1995) describe sightings of 27 species of deep-water reef fish in waters 185 to 220 meters in depth. Schobernd and Sedberry (2009) reported 25 families and 54 species seen during nine shelf-edge submersible dives off Florida, Georgia and South Carolina. Three upper-slope dives yielded seven families, and seven species.

Gray's Reef National Marine Sanctuary

Gray's Reef National Marine Sanctuary (GRNMS) is located 17.5 nautical miles east of Sapelo Island, Georgia, and 35 nautical miles northeast of Brunswick, Georgia. Gray's Reef encompasses nearly 32 km^2 at a depth of about 22 meters (Parker et al. 1994). The Sanctuary contains extensive, but patchy hardbottoms of moderate relief (up to 2 meters). Rock outcrops, in the form of ledges, are often separated by wide expanses of sand, and are subject to weathering, shifting sediments, and slumping, which create a complex habitat including caves, burrows, troughs, and overhangs (Hunt 1974). Parker et al. (1994) described the habitat preference of 66 species of reef fish distributed over five different habitat types. Numbers of species and fish densities were highest on the ledge habitat, intermediate on live bottom, and lowest over sand. Kendall et al. (2008) found that presence of dominant groupers, Gag and Scamp, was most strongly related to height of ledge undercut, whereas abundance of Black Sea Bass was best explained by percent cover of sessile biota. A designated research area was created within the sanctuary boundary in 2010 to potentially evaluate the effects of fishing, natural events and cycles, and climate change.

Nearshore Hardbottom of Mainland East Florida

Extending semi-continuously from at least St. Augustine Cape Canaveral to the Florida Keys, nearshore hardbottom was evaluated in terms of the four HAPC criteria in Section 600.815 of the final EFH interim rule: important ecological functions, sensitivity, probability of anthropogenic stressors, and rarity. In terms of ecological function, several lines of evidence suggest that nearshore hardbottom reefs may serve as nursery habitat ((Lindeman and Snyder 1999; Baron et al. 2004, Jordan et al. 2004, CSA, 2009, Kilfoyle et al. 2013, CSA 2014). Based on quantitative information available for Palm Beach County, Florida, (Lindeman and Snyder 1999, CSA, 2009): a) pooled early life stages consistently represented over 80% of the total individuals at all sites censused, b) eight of the top ten most abundant species were consistently represented by early stages, and c) use of hardbottom habitats was recorded for newly settled stages of more than 20 species.

The mere presence of more juvenile stages than adults does not guarantee a habitat is a valuable nursery. Rapid decays in the benthic or planktonic survival of early stages of marine fishes are common demographic patterns (Shulman and Ogden 1987; Richards and Lindeman 1986), ensuring that if distributions are homogeneous, all habitats will have more early stages than adults. The high numbers of early stages on nearshore reefs appear to reflect more than just larger initial numbers of young individuals. Newly settled stages of most species of grunts and eight of nine species of snappers of the southeast mainland Florida shelf have been recorded primarily in depths less than five meters, despite substantial sampling efforts in deeper waters, with several interesting exceptions (Jordan et al. 2012). Adults are infrequent or absent from the same shallow habitats. There is habitat segregation among life stages of many species, with the earliest stages using the shallowest habitats in many species of grunts and snappers (Starck 1970; Dennis 1992; Lindeman et al. 1998). Similar ontogenetic differences in both distribution and abundance exist for many other taxa which utilize nearshore hardbottom habitats. Based on this and other evidence, Lindeman and Snyder (1999) concluded that at least 35 species utilize nearshore hardbottom as a primary or secondary nursery area. At least ten of these species are managed under the Snapper/Grouper FMP.

Because nearshore areas are relatively featureless expanses of sand in the absence of hardbottom, such structures may also have substantial value as reference points for spawning activities of inshore fishes, a major aspect of EFH-HAPCs (SAFMC, 1998). Many species require three-dimensional structure as a reference point for coarse-scale aggregation and fine-scale behavior during spawning (Thresher 1984). Using information from the literature, personal observations, and discussions with commercial fishermen, at least 15 species were estimated to spawn on nearshore reefs (CSA 2009). An additional 20 species may also spawn on or near these reefs. Some are of substantial economic value; these include snook, pompano, and several herring species.

Based on the demonstrated or potential value of these areas as nurseries and spawning sites for many economically valuable species, nearshore hardbottom habitats were estimated to support highly important ecological functions, the first EFH-HAPC criterion for the SAFMC (SAFMC 1998). The second and third HAPC criteria, sensitivity and probability of anthropogenic stressors, are interrelated in terms of nearshore hardbottom. They are treated collectively here. Various stretches of nearshore hardbottom have been completely buried by dredging projects associated with beach management activities in this subregion. They may also be subjected to indirect stressors over both short and long time scales from such projects. For example, between 1995 and 1998, up to 19 acres of nearshore hardbottom reefs were buried by beach dredging projects at two sites in Palm Beach County. Such activities occur within other counties of this subregion as well. The 50-year planning document for beach management in southeast mainland Florida (ACOE 1996), includes beach dredge-fill projects for over fifteen areas, with renourishment intervals averaging 6-8 years. Given the past and projected future, it is concluded that both the sensitivity of these habitats and the probability of anthropogenic stressors is high.

In terms of the final EFH-HAPC criterion, rarity, nearshore hardbottom ranks high. In southeast mainland Florida, most shorelines between Dade and Broward Counties (25°30'-26°20' N) lack natural nearshore hardbottom with substantial three-dimensional structure (ACOE 1996). Although substantial stretches of nearshore hardbottom exist in portions of Palm Beach, Martin, St. Lucie, and Indian River Counties (Perkins et al. 1997) (26°20'-27°15' N) these reefs are often separated by kilometers of barren stretches of sand. Offshore, most mid-shelf areas (5-20 m) are also dominated by expanses of sand despite the variable occurrence of several mid-shelf reef lines. Therefore, there are no natural habitats in the same or adjacent nearshore areas that can support equivalent abundances of early life stages. Absences of nursery structure can logically result in increased predation and lowered growth. In newly settled and juvenile stages, such conditions could create demographic bottlenecks that ultimately result in lowered local population sizes.

Nursery usage of nearshore hardbottom reefs may be a bi-directional phenomenon. Many species utilize these habitats during both newly settled and older juvenile life stages. This suggests that nearshore hardbottom can facilitate both inshore and offshore migrations during differing ontogenetic stages of some species. Their limited availability does not necessarily decrease their value. When present, they may serve a primary nursery role as shelter for incoming early life stages which would undergo increased predation mortality without substantial habitat structure. In addition, some species use these structures as resident nurseries; settling, growing-out, and maturing sexually as permanent residents (e.g., pomacentrids, labrisomids). A secondary nursery role may result from increased growth because of higher food availabilities in structure-rich environments. Nearshore hardbottom may also serve as secondary nursery habitat for juveniles that emigrate out of inlets towards offshore reefs. This pattern is seen in gray snapper and blue striped grunt which typically settle inside inlets and primarily use nearshore hardbottom as older juveniles (Lindeman et al. 1998; CSA 2009).

In summary, nearshore hardbottom habitats of southeast Florida ranked high in terms of ecological function, sensitivity, probability of stressor introduction, and rarity. Based on the criteria in Section 600.815 (a) (9), it is concluded that they represent Essential Fish Habitat-Habitat Areas of Particular Concern for species managed under the Snapper/Grouper Fishery Management Plan and dozens of other species which co-occur with many species in this management unit. Many of these other species, not currently managed under the SAFMC are important prey items (Randall, 1967) for those species under management.

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Deepwater Coral Habitat

To review information on Deepwater Corral habitat please refer to Coral Amendment 8 : https://safmc.net/amendments/coral-amendment-8/

Sargassum Habitat (Link to FMP/CEBA2)

To review information on The Sargassum Habitat please refer to the Sargassum Fishery Management plan and associated amendments on the SAFMC webpage: https://safmc.net/fishery-management-plans/sargassum/

Additional Habitats

For the following Habitats please refer to FEP I on the SAFMC webpage: https://safmc.net/documents/combined-fep_toc-pdf/

Estuarine Emergent Marsh

Oyster Reef and Shell Banks Habitat

Mangrove Habitat

Seagrass SAV Habitat

Water Column Habitat

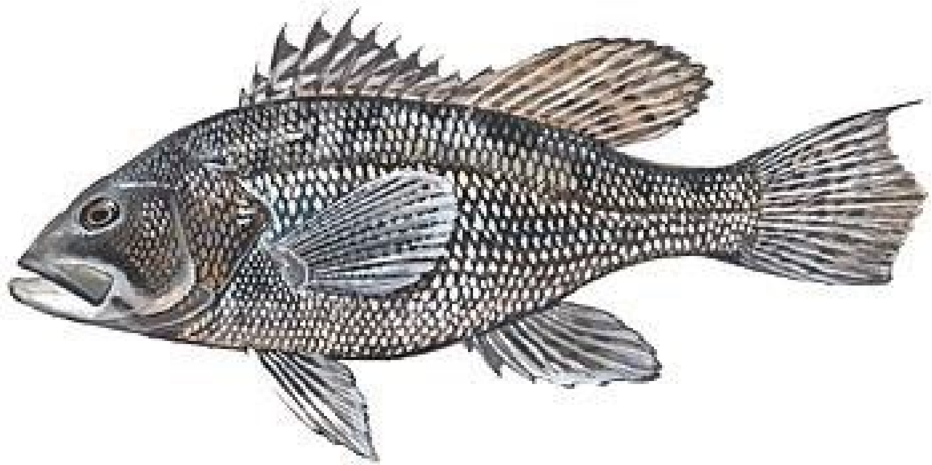
Softbottom/Subtidal Habitat

Section 3 Managed Species

SAFMC Managed Species Summaries

Seabasses: Family Serranidae

Black Sea Bass



Centropristis striata - Black Sea Bass (Blackfish, Pinbass, Rock bass).

Larger Black Sea Bass are black, while the smaller individuals are more of a dusky brown, with both having a belly that is only slightly lighter in color than the sides. The fins are dark, and the dorsal is marked with a series of white spots and bands. In larger fish, the upper portion of the caudal fin ends as a filament. During spawning, males may have a conspicuous blue nuchal hump. Black Sea Bass can be separated from their closest relatives, the Rock Sea Bass, *C. philadelphica* and the Bank Sea Bass, *C. ocyurus*, by color and morphology, body depth, and gill raker and fin ray counts.

Black Sea Bass is a temperate species with permanent reproducing populations from Cape Cod, Massachusetts, to Cape Canaveral, Florida, and in the northeastern Gulf of Mexico. Larval Black Sea Bass settle in coastal and estuarine waters often near structure and migrate to inshore and mid-shelf reefs when they grow larger and mature. Once settled on (offshore) reefs, site fidelity is very high. Black Sea Bass are opportunistic feeders eating whatever is available, preferring crabs, shrimp, worms, small fish and clams.

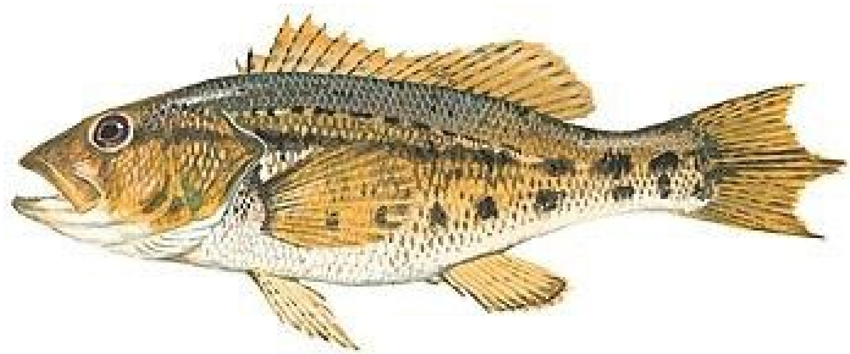
Black Sea Bass can reach a maximum age of about 11 years, but can live longer (up to 20 years) in others regions, and grow to 24 inches or 6 pounds.

Black Sea Bass are protogynous hermaphrodites, transitioning from female to male at about 4 years of age and a length of about 10 inches. Females can mature within their first year and around 6 inches in length (larger elsewhere). The spawning season extends from February through September, but peaks in the cooler months of February through April. Females spawn multiple times during the spawning season with the number of eggs produced during the spawning season ranging from 30,000 to 500,000 depending on fish size.

In the Atlantic waters off the southeastern U.S., Black Sea Bass is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Black Sea Bass has been under intense commercial and recreational fishing pressure at least since the late 1970s, being an important reef fish species targeted by both fisheries. It is caught in hook and line and trap fisheries.

Other vulnerabilities and sources of mortality include decline in estuarine water quality, harmful algal blooms, and predation by larger reef predators, potentially including invasive lionfish.

Bank Sea Bass



Centropristis ocyurus - Bank sea bass (Rock squirrel, Rockfish (misnomer))

Bank Sea Bass is a warm temperate, small demersal serranid with a tapering yellow- brown body with tri-lobed caudal fin. There are black markings which consist of three longitudinal rows of blotches on the sides in addition to spots on the dorsal and caudal fins. The head, fins, and front portion of the body often have blue and yellow spots and stripes. Bank Sea Bass are similar in appearance to Rock Sea Bass, but can be distinguished by the lack of dermal flaps above the dorsal fin spines.

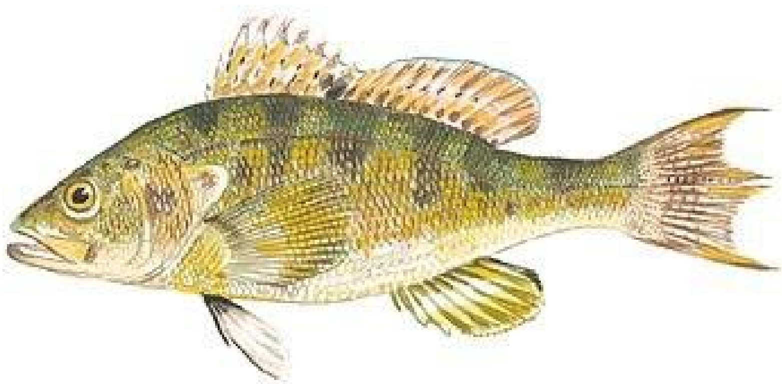
Bank Sea Bass occurs in reefs or rocky offshore habitats from Cape Lookout, North Carolina, to the Yucatan banks of the southern Gulf of Mexico. It is found in waters ranging from 50 - 500 feet and in the Atlantic waters off the southeastern U.S., it is more common in shelf edge habitats than the Black Sea Bass, which is found more on inner- and mid-shelf reefs. Bank Sea Bass is an opportunistic carnivore consuming crustaceans, mollusks, fishes, and echinoderms.

Little is known about the life history of Bank Sea Bass. They can grow to about 16 inches and nearly 2 lbs., and live to a maximum age of 7 to 8 years. Bank Sea Bass are protogynous hermaphrodites and transition from female to male generally between 5 and 7 inches of length. Females mature when they are 2 to 3 years old and spawning occurs offshore between January and November, but peak spawning occurs from February through April.

Female Bank Sea Bass can spawn multiple times during the spawning season and can spawn, depending on size, well over 30,000 eggs in a spawning season.

In the southeastern United States, Bank Sea Bass is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Bank Sea Bass is of limited direct economic value and is captured incidentally by anglers and commercial fishermen.

Rock Sea Bass



Centropristis philadelphica - Rock Sea Bass

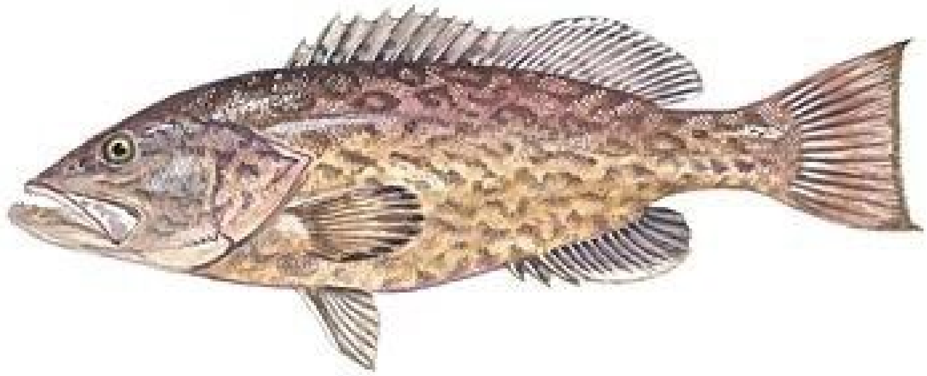
Rock Sea Bass is small demersal serranid with a tri-lobed caudal fin, an overall brown/greenish color with 5 to 7 darker bars (saddles) along the dorsal area, and long fleshy tabs on dorsal fin spines. The fins have diffuse light and darker brown bands. It can be confused with Bank sea bass which is similar in size and appearance, but Rock Sea Bass has a black blotch at the posterior end of the spinous dorsal fin that is continuous with one of the bars. Black Sea Bass grows to a larger size and is black in color.

Rock Sea Bass is a warm temperate species that occurs in the Western Atlantic from North Carolina to Palm Beach, Florida as well as the northern Gulf of Mexico. It prefers hard- bottom, rocks, jetties, and ledges. Rock Sea Bass is an opportunistic bottom feeder with a diet mostly consisting of crustaceans, small fish, polychaetes, and mollusks.

This species has a fast growth rate and reaches a maximum size of 12 inches and a maximum age of 3 years Rock Sea Bass is a protogynous hermaphrodite that matures at an early age (1 year) and undergoes sex transition at ages 1 to 2 years. Spawning occurs at offshore locations at depths greater than 36 ft during February through July, with a peak in April and May. The sex ratio is skewed toward females at younger ages, with the % females ranging from 100% at age 0 to 60% at age 2 to 0% at age 3.

In the Atlantic waters off the southeastern U.S., Rock Sea Bass is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Rock Sea Bass is of limited direct economic interest and is captured incidentally by anglers and commercial fishermen.

Gag



Mycteroperca microlepis - Gag, Gag grouper (Gray grouper, Charcoal belly (large males))

Gag is a large grouper with a compressed body. Coloration is highly variable and changes with the size of the fish but has some variation of a distinct reticulate body color pattern. Large Gag are dark brownish-gray above and paler below, with traces of dark wavy markings on the sides. Smaller fish are much lighter and have numerous dark brown or charcoal reticulate marks along the sides. Large males sometimes display a "blackbelly" and "black-back" phase that is mostly pale grey, with a network of faint dark markings below the soft dorsal fin; the belly and ventral part of the body above anal fin are black in this phase, as are edge of the soft dorsal fin, central rear part of the tail fin and rear margins of pectoral and pelvic fin. Gag resembles Black grouper, Scamp, and Yellowmouth grouper, but can de distinguished by its distinct reticulate body color pattern and caudal fin shape. The deeply notched preopercle further distinguish them from the most similar Black grouper.

Gag is a warm temperate species, from the Yucatan Peninsula throughout the Gulf of Mexico, around the Florida peninsula northward to Cape Hatteras, North Carolina. They are usually found shallower than 375 ft on sponge-coral habitat and rock ledges. Larvae and/or juveniles migrate to specific estuarine seagrass and oyster reef habitats at depths less than 3 ft and leave for shallow coastal shelf reefs in the fall and winter of their first year. They prey on crabs, shrimp, lobster, octopus, squid and fish that live close to reefs.

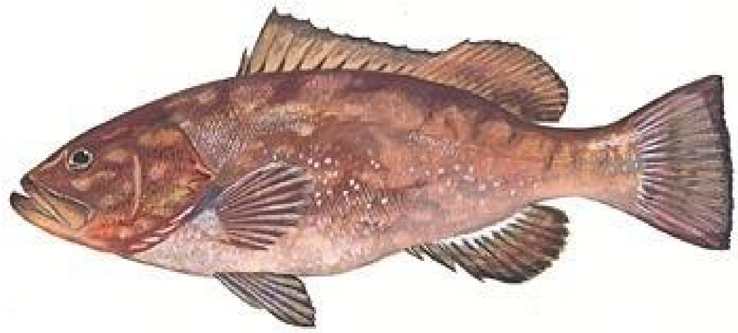
Gag can grow to over 5 feet in length and live over 30 years. Gag are protogynous, transitioning from females to male at an age of about 10 years and a length of about 39 inch Female Gag mature at an age of 3 to 4 years, when they are about 28 to 31 inches long. The sex ratio may have been changed from historical levels as a result of overfishing, skewing towards more females. Spawning occurs from December through May, with a peak between February and April, at which time they may make annual spawning migrations to specific locations where they may form spawning aggregations.

Adult spawning aggregations have been reported on shelf edge reefs at depths of 240 to 300 ft.

In the southeast, Gag is managed by the South Atlantic Fishery Management Council under the Snapper Grouper Fishery Management Plan and is subject to annual catch limits, size and bag limits, trip limits, gear restrictions, and a spawning season closure. Gag is a popular target by commercial and recreational fishermen using a variety of hook and line gear, including electric and snapper reels, power heads, and spear-guns.

Because Gag post-larvae and juveniles depend on specific estuarine micro-habitats, seagrass and oyster reefs, non-fishery mortality can be high with the loss of these habitats due to anthropogenic causes.

Red Grouper



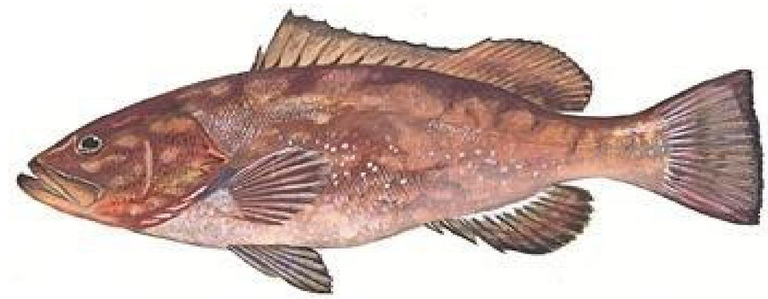
Epinephelus morio - The Red Grouper

Red Grouper are easily recognized by their deep brownish-red color and by the sloped, straight line of their spiny dorsal fin. The fin has a long second spine and an unnotched interspinous membrane, while other shallow-water *Epinephelus* groupers have a notched dorsal spine membrane and a third spine longer than the second. The body has occasional white spots on the sides, and there are often dark spots on the snout or cheeks. The inside of the mouth is bright red-orange. The Red Grouper is most closely related to the Nassau Grouper, which has several vertical bars and blotches, and is found more commonly on coral reefs in the West Indies. The Red Grouper is a protogynous serranid that is associated with reef habitat, especially the adults, in the Western Atlantic from Massachusetts through the Gulf of Mexico and south to Brazil, with a disjunct distribution off the Atlantic coast. They are commonly caught off North Carolina, northern South Carolina and southern Florida but are rare from southern South Carolina to northern Florida. Red Grouper are reported to occur at depths of 80 - 400 ft. Red Grouper inhabits ledges, crevices, and caverns of rocky limestone reefs, and also lower-profile, live-bottom areas. They are also known to be important ecosystem engineers due to their creation of large depressions in the sea floor which become habitat for various species.

Red grouper can live to over 25 years, with older fish reaching a size of 33 inches in length and 25 lbs. Red grouper are protogynous hermaphrodites transitioning from female to male at an age of about 8 years and a length of about 28 inches. Female Red Grouper mature at an age of about 3 years, when they are about 20 inches in length. Red Grouper spawning season is from February through June, with a peak in April. Females can spawn multiple times during the spawning season and can release over 1.5 million pelagic eggs in a season. The larvae remain at the surface for 30 - 40 days before settling to the bottom.

In the Atlantic waters off the southeastern U.S., Red Grouper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, gear restrictions, and a spawning season closure. It is targeted by recreational and commercial fishers using a variety of hook and line gear, including snapper reels and spear guns.

Scamp



Mycteroperca phenax - Scamp (Broomtail)

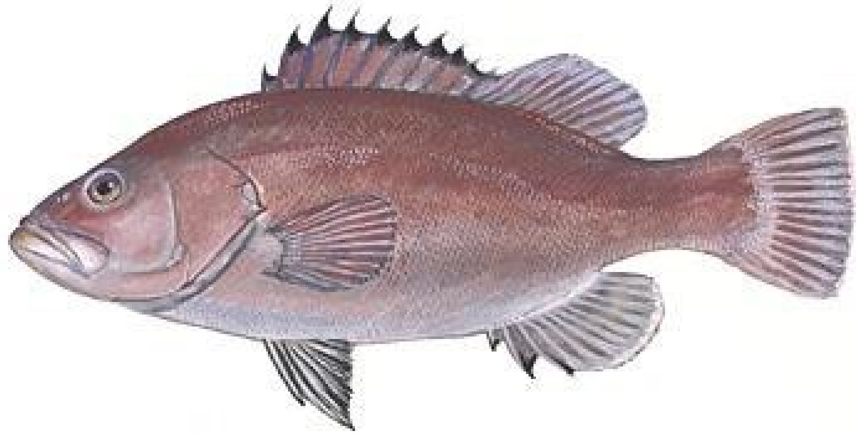
Scamp is a small to medium sized slender-bodied grouper. They are identified by their pronounced anal and soft dorsal ray extensions, a more concave profile of the head, and by their color. Scamp have a tan to grayish-brown body covered with sharply defined, well-separated dark spots, which are approximately an eighth of an inch in diameter. Yellowmouth Grouper can have a very similar appearance, but generally live in deeper waters. Coloration in Scamp is variable, as cat's paw and grey-head color phases have also been observed. Juvenile Scamp are not bi-colored as in Yellowmouth Grouper.

Scamp can be found along the Atlantic Coast of the U.S. from North Carolina to Key West, FL, in the Gulf of Mexico, and along the southern shores of the Caribbean. Scamp inhabit low-profile live-bottom areas, areas of living *Oculina* coral (off Florida east coast), and over ledges and high-relief rocky bottoms in waters between 75 to 300 feet deep. Scamp can be an aggressive ambush predators preying on crabs, shrimp, and fish.

Scamp can live up to 30 years and reach lengths to over 40 inches in length and weighing more than 35 lbs. Scamp are protogynous hermaphrodites transitioning from female to male at the age of 5 to 9 when they are 20 to 30 inches in length. Female Scamp mature at an age of 1 to 2 years, when they are about 14 inch length. Scamp spawn from February to August with a peak in March through May.

In the Atlantic waters off the southeastern U.S., Scamp is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, gear restrictions, and a spawning season closure. Scamp is highly prized and has been targeted by commercial and recreational fisheries. Scamp is caught using various hook and line gear, including snapper reels, and spearguns.

Snowy Grouper



Hyporthodus niveatus - Snowy Grouper (chocolate grouper)

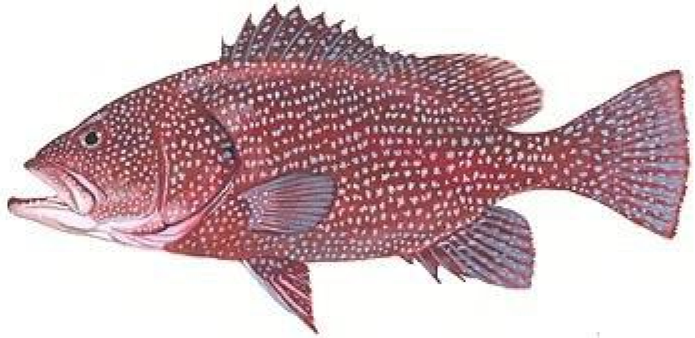
Snowy Grouper is a large deepwater reef-associated species. Although coloration varies with the size, smaller fish are dark brown overall, punctuated with pearly white spots on the sides that are not always visible on larger fish. A distinctive black, saddle occurs on the upper caudal peduncle and extends down below the lateral line. Larger Snowy Grouper usually lose the white spots and caudal saddle and become dark brown with a slight coppery tint. The spiny portion of the dorsal fin has a black margin. It is rarely confused with other species.

Snowy Grouper occurs in the western Atlantic from Massachusetts to Brazil, including Bermuda, Cuba, the Bahamas, and the Gulf of Mexico. Off the Atlantic waters off the southeastern U.S., Snowy Grouper can be found on the outer continental shelf and upper slope at depths greater than 150 feet in habitats characterized by ridges, terraces and precipitous cliffs; or on wrecks and artificial reefs. Snowy Grouper is a bottom fish that ambushes bottom-dwelling prey. The most common diet items are deepwater crabs, but finfish are eaten also.

Snowy Grouper is relatively long-lived and may reach a maximum age of 35 years and a weight of 70 lbs. Like many groupers, it is a protogynous hermaphrodite transitioning from female to male at the age of 10 to 17 when they are about three feet long. Female Snowy grouper mature at an age of 5 to 6 years, when they are about 24 inches in length. The spawning season is from April to September, with a peak in May to August.

In the Atlantic waters off the Southeast U.S., Snowy Grouper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, bag limits, trip limits, gear restrictions, and a seasonal closures. Snowy Grouper landings occur primarily in commercial fisheries using snapper reels, but some recreational hook and line catch occurs, particularly at the shallow end of the depth range (160 to 200 feet).

Speckled Hind



Epinephelus drummondhayi - Speckled Hind (Kitty Mitchell, Strawberry Grouper)

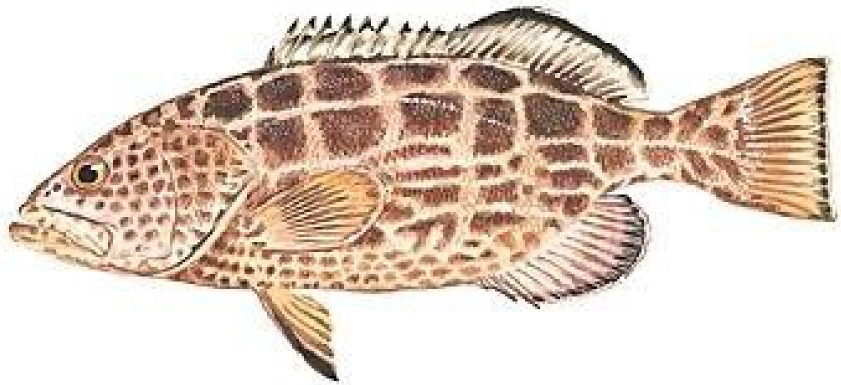
Speckled Hind is a distinctive grouper with a laterally-compressed body densely covered with small pearly white spots on a dark reddish-purple to brown background. Some juveniles undergo a “xanthic phase”, where white spots cover a light yellow background. Speckled Hind is a warm-temperate species, occurring from the Yucatan Peninsula throughout the Gulf of Mexico, around the Florida peninsula northward to Cape Hatteras, North Carolina and Bermuda. It is absent from the tropical continental and insular Caribbean Sea and Bahama Islands. They commonly inhabit mid-shelf to upper continental slope reef habitats at depths ranging from 65 to 600 feet. Speckled Hind is usually found inshore of more typical deepwater reef fish such as Tilefish, and Snowy, Warsaw, and Yellowedge groupers. Yellow (xanthic) phase juvenile Speckled Hind have been observed on shelf-edge *Oculina* coral reefs off east central Florida, and on shelf-edge hard-bottom reefs off South Carolina. Speckled Hind is considered piscivorous and generally engulf their prey whole.

Speckled Hind can reach a maximum age of 35 years, and can weigh over 50 pounds (the world record is 64 lbs. caught off North Carolina). Speckled Hind are protogynous hermaphrodites spawning over a prolonged period from April to October with a peak in May to August. Females transition to male at 6 years of age or older and at a length of 1.5 to 2.0 feet.

Female Speckled Hind mature at an age of 4 to 6 years, when they are about 1.5 feet long. In the Atlantic waters off the southeast U.S., Speckled Hind is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Speckled Hind are caught on shelf edge and continental slope reefs using hook-and-line gear including electric reels and bottom longlines.

Predation by larger groupers and snappers is highly likely in early developmental stages, and invasive lionfish have been documented to feed on juvenile *Epinephelus* groupers.

Black Grouper



Mycteroperca bonaci - Black grouper

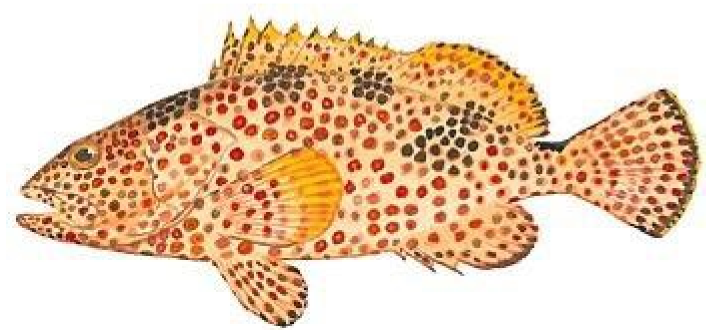
Black Grouper is a large reef fish that is grayish or dark brown, with irregular coppery spots (some spots join to form chain-like streaks). The pectoral fins are dusky brown, gradually becoming orange at the edge; the soft dorsal and anal fins and leading edges of pelvic fins have a dark margin. The preopercle (cheek) bone is evenly rounded, without a notch or projecting bony lobe at the corner. Black Grouper is often confused with Gag; however, the most noticeable color difference is the coppery spots on Black Grouper that do not occur on Gag. The tail of Gag is slightly concave, whereas the tail of a Black Grouper is squared off.

Black Grouper occur off North Carolina to Florida, around Bermuda, and in the Gulf of Mexico, West Indies, and from Central America to southern Brazil. Adults are found over hard- bottom such as coral reefs and rocky ledges. Black Grouper occur at depths of 30 to 100 ft.

Juveniles sometimes occur in estuarine seagrass and oyster habitat, or on shallow patch reefs. Black Grouper live for at least 33 years and attain sizes as great as five feet. Black Grouper change sex from female to male, and approximately 50% of females are sexually mature by 2.7 ft and 5.2 years of age. At a length of 4 ft and an age of 15.5 years, approximately 50% of the females have become males. Black grouper are in spawning condition throughout the year; however, peak spawning of females occurs from January to March.

In the southeast, Black Grouper are managed by the South Atlantic Fishery Management Council under the Snapper Grouper Fishery Management Plan and are subject to annual catch limits, size and bag limits, trip limits, gear restrictions, and a spawning season closure. Most of the landings are in the Florida Keys.

Rock Hind



Epinephelus adscensionis - Rock Hind

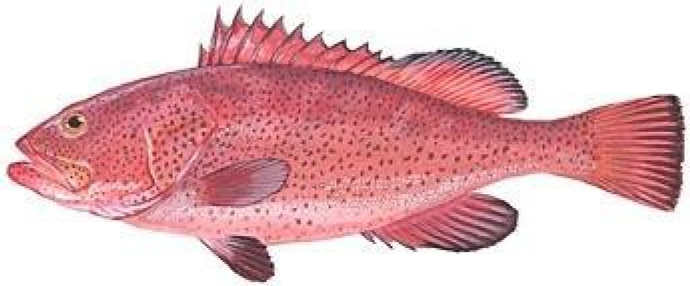
Rock Hind is a medium-sized grouper that is generally yellow-brown or pale greenish.

The body is covered with reddish-brown spots and scattered pale blotches; there is usually 3 to 5 dark brown blotches (groups of dark spots) at the base of the dorsal fin and a blackish brown blotch on top of the caudal peduncle. The maximum lengths is about 24 inches. Rock Hind occurs on rocky reefs in depths of 6 to 350 ft. It feeds mainly on crabs and fishes. Females mature at 12 inch (2 years old); ripe females (14 to 17 inches) were noted from January to June at the Florida Middle Grounds. Rock Hind has a large range and is known from both sides of the Atlantic Ocean and some of its islands. In the region, Rock Hind occurs in Bermuda and from North Carolina to Florida, the Gulf of Mexico, and in the Caribbean to southern Brazil.

Rock Hind has been observed to spawn in aggregations near insular shelf edges in depths of 66 to 98 ft, January through March. Off South Carolina, females in spawning condition have been collected during May through August. Rock Hind are reported to be protogynous. Crabs compose the majority of their diet, but Rock Hind have also been observed to feed on fishes and young sea turtles.

Rock Hind is of minor importance to commercial and sport fisheries in the region, as it is less abundant than other groupers. Rock Hind are managed by the South Atlantic Fishery Management Council. It is caught with hook-and-line and spear.

Red Hind



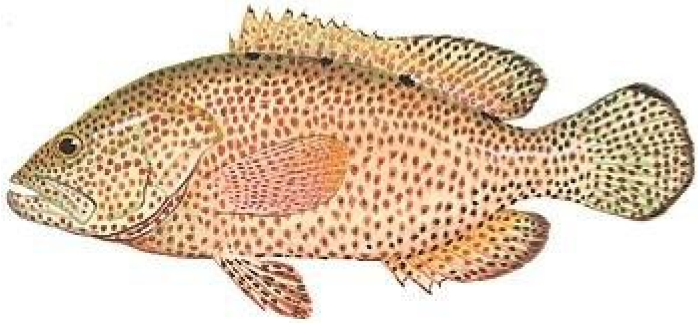
Epinephelus guttatus - Red hind

Red hind and Rock hind (*Epinephelus adscensionis*) are characterized by numerous dark spots on a lighter background. This color feature alone distinguishes the two species from Speckled Hind. Red Hind have pale pink bodies with uniform red spots. The back and the sides of Red Hind lack the large black blotches or saddles that are seen on Rock Hind, and the soft- rayed portions of the dorsal and anal fins as well as caudal fin of Red Hind are margined in black.

The species is found in tropical and subtropical waters as deep as 400 feet, from North Carolina to Brazil, including the southern part of the Gulf of Mexico and the Caribbean. It is most abundant off Bermuda and in the West Indies.

The species may live up to 17 years or longer. Maximum reported size is 30 inches in length (male) and 55 lbs. Red hind is protogynous. Spawning occurs from March to July in Atlantic waters off the southeastern U.S., and females release an average of 90 thousand to 3 million pelagic eggs. Annual spawning aggregations occur during the full moon in January and February off the southwest coast of Puerto Rico and during the summer in Bermuda with no relation to lunar periodicity. Red hind is managed by the South Atlantic Fishery Management Council in the Snapper Grouper FMP. Commercial and recreational landings are small.

Graysby



Cephalopholis cruentata - Graysby

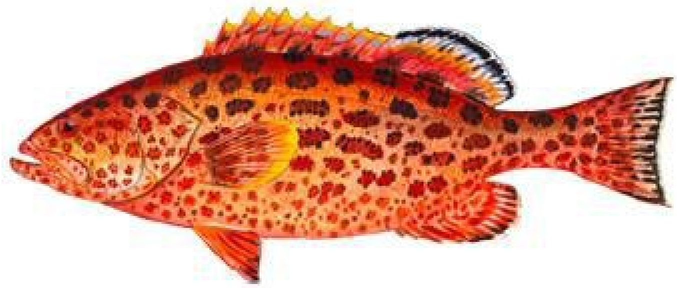
The Graysby is a smaller species of grouper that varies in color from pale gray to dark brown. It has many darker orangish to red-brown spots on its body, fins, and head, and 3-5 pale or dark spots that run along the base of the dorsal fin. A white line runs between the eyes from the nape to the lower lip. The tail is more rounded than in similar species. This species and the Coney have only 9 spines in their dorsal fins, whereas other groupers in the area have 10 or 11 spines.

Graysby occur from North Carolina to south Florida and in the Gulf of Mexico, Caribbean, and Bermuda. The Graysby inhabits live bottom habitat and is found as deep as 557 ft. It is sedentary, solitary, and secretive, usually hiding during the day and feeding at night.
Juveniles feed on shrimp, whereas adults eat primarily fishes. Adult Graysby eat bony fish, shrimp, stomatopods, crabs, and gastropods.

Maximum reported size is 17 inches and 2.4 lbs. In the Caribbean, individuals in spawning condition have been observed in March and from May to July, and spawning there occurs from July through October. Female Graysby approaching spawning condition have been found during summer off the southeastern U. S. Size and age at first maturity are estimated as 6 inches and 3.5 years. Sexual transition occurs at sizes ranging from 6 to 10 inches, with most transitional individuals occurring between the sizes of 8 and 9 inches and ages 4 to 5. Maximum reported age is 13 years, and maximum size is 17 inches.

Graysby is managed by the South Atlantic Fishery Management Council in the Snapper Grouper FMP. Commercial and recreational landings are small.

Yellowfin Grouper



Mycteroperca venenosa - Yellowfin grouper (Fireback)

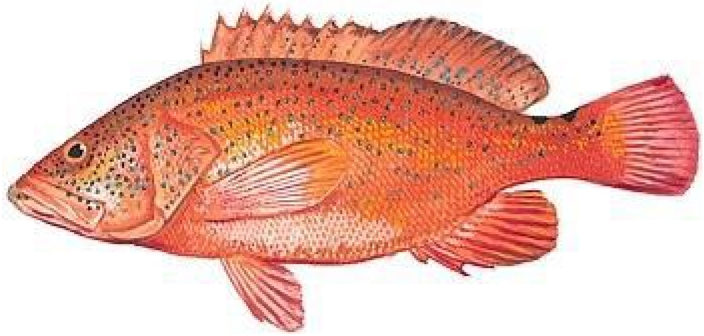
Yellowfin Grouper is a large grouper with a highly greenish olive or bright red color with longitudinal rows or darker black blotches over its entire body. The outer one-third of pectoral fins are bright yellow, while the lower parts of larger fish have small bright red spots. In shape, Scamp and Yellowmouth Grouper are similar, but the Yellowfin Grouper's coloration is distinctive enough to avoid misidentification.

Yellowfin Grouper occurs in the Western Atlantic, ranging from Bermuda to Brazil and the Guianas, including the Gulf of Mexico and Caribbean Sea at depths of 7 to 449 ft. Off the southeastern U.S., it is mostly found offshore on reefs off southern portions of Florida. The juveniles are commonly found in shallow seagrass beds, while adults occur over rocky areas and coral reefs. Yellowfin Grouper is primarily a piscivore, but includes squid in its diet.

Yellowfin Grouper can grow to 40 inches in length and 40 lbs., while reaching ages of 15 years. They are protogynous hermaphrodites, but data on maturity and transition from female to male is largely lacking. Spawning occurs from February to August, but off Florida most spawning activity is seen in May. Yellowfin Grouper seem to aggregate for spawning at some of the same sites utilized by Tiger Grouper, Nassau Grouper, and Black Grouper.

In the Atlantic waters off the southeast United States, Yellowfin Grouper are managed by the South Atlantic Fishery Management Council under the Snapper Grouper Fishery Management Plan and are subject to annual catch limits, size and bag limits, gear restrictions, and a spawning season closure.

Coney



Cephalopholis fulva - Coney

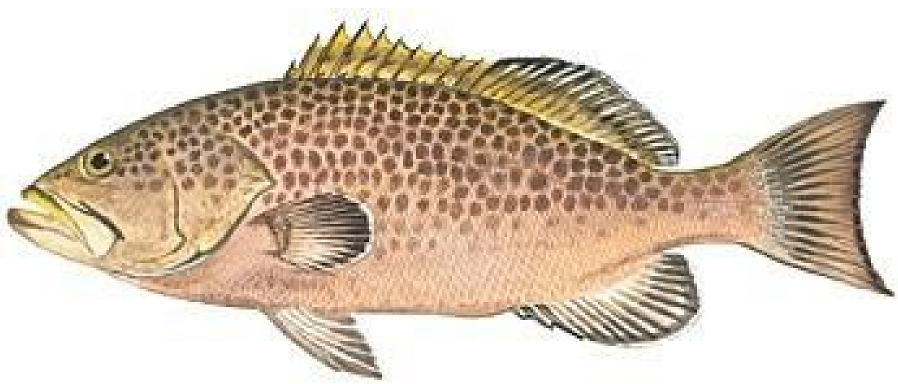
Coney is a small grouper with red fins, many small blue spots edged with black line scattered on the body, a caudal peduncle with two prominent black spots on the upper edge, and a pair of black blotches on the tip of the lower jaw. The overall body color is highly variable, from yellow or red to brown or bicolored.

Coney occurs in the Western Atlantic, ranging from South Carolina and Bermuda to southern Brazil. The Coney is a common species in shallow waters, and is a sedentary species that usually hides in caves or under ledges during the day. It is often seen in coral reefs and clear water, and can be found to depths as great as 492 ft. Coneys are predators, feeding mostly on crustaceans and small fish; they may also follow morays and snake eels to feed.

The maximum reported length for coneys is 16 inches and they can reach an age of 11 years. Coney is a protogynous hermaphrodite transitioning from female to male at a length of about 8 inches. Females mature at about 5 to 6 inches. Spawning occurs in small groups composed of one male and multiple females. Although ripe ovaries can be found in female Coney from November to March, spawning activity appears to be linked to particular moon phases (several days around the last quarter and new moon) in January and February.

In the Atlantic waters off the southeastern U.S., Coney is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. There is not much of a directed fishery for coney, which are most commonly caught off the southeast Florida and in the Caribbean. Most commercial landings of coney are often labeled as unclassified grouper. They are mostly caught by hook and line gear.

Yellowmouth Grouper



Mycteroperca interstitialis - Yellowmouth Grouper

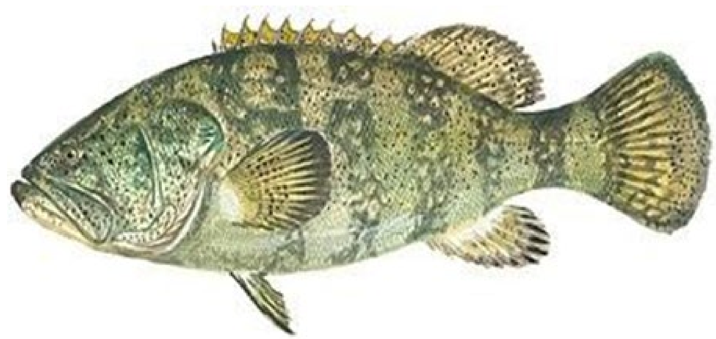
Yellowmouth Grouper is a tan or brown grouper with darker spots. It has spots, or a network of spots, fused into lines on the body, and a distinct yellow wash behind the jaws, yellow around the eyes and the outer edges of fins yellowish. Young fish are bi-colored, dark above with white below. It is very similar to Scamp, but adults generally occurs in deeper waters.

Yellowmouth Grouper occurs along the eastern U.S. coast, Bermuda, Bahamas, Gulf of Mexico, and in the Caribbean south to Brazil. Adults are found over rocky hard-bottom and coral reefs near the shoreline to depths of up to 500 ft. Young commonly occur in mangrove lined lagoons. Yellowmouth Grouper mostly eat fish, but also consumes crustaceans.

Yellowmouth Grouper can grow to about 33 inches, weighing over 22.5 lbs. The maximum age is reported to be between 28 to 41 years. Yellowmouth Grouper is a protogynous hermaphrodite transitioning from female to male at a length of about 20 to 25 inches at an age between 5 and 14 years. Females mature at about 16 to 18 inches and between the age of 2 and 4 years. Yellowmouth Grouper may spawn all year, but peak spawning (in the Gulf of Mexico) is in March to May. Spawning occurs in small groups composed of one male and multiple females.

In the Atlantic waters off the southeastern U.S., Yellowmouth Grouper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. There is not much of a directed fishery for Yellowmouth Grouper, but is generally caught with other deep water Snapper Grouper species by both commercial and recreational fishers. They are mostly caught by hook and line gear, including snapper reel.

Goliath Grouper



Epinephelus itajara - Goliath Grouper, jewfish, guasa

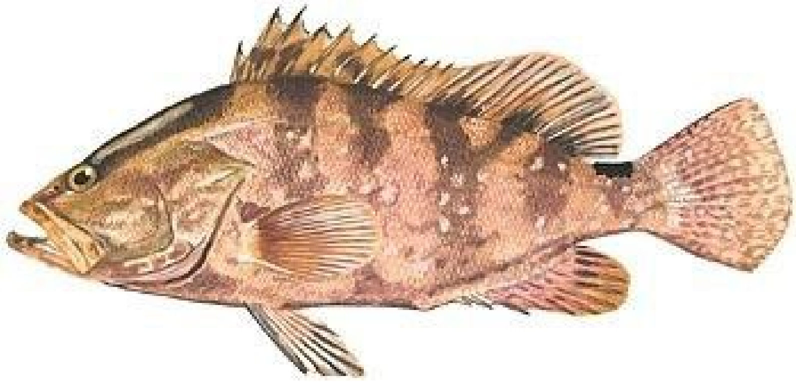
Goliath Grouper is one of the largest and most distinctive groupers in the Atlantic waters off the southeastern U.S. The first (spinous) dorsal consists of a series of short spines not seen in other regional groupers. Head and fins are covered with small black spots, and irregular dark vertical bars present on the sides of body. The pectoral and caudal fin are rounded, and the first dorsal fin is shorter than, and not separated from second dorsal.

Goliath Grouper occurs in estuaries as post-larvae, juveniles (in mangroves and seagrass) and adults with a center of abundance in shallow nearshore and mid-shelf reefs, rarely to depths of more than 330 ft. Goliath grouper feed primarily on crustaceans, particularly spiny lobsters, as well as turtles and fishes, including stingrays. It is a territorial species, and larger individuals have reportedly stalked and approached divers.

The maximum reported size is 100 inches (male) and over 1,000 lbs. The reported maximum age is 37 years. However, it is likely that this species could live much longer if left unexploited. There is some evidence that males may transform from immature females. Males exhibit a similar testicular structure to those of other serranids that are protogynous, however, some mature males are smaller than mature females. Males mature at 44 inch length and age 4, with all males being mature at 46 inches and age 7. Females mature at 47 inches in length and age 6, while all are mature at 53 inches in length and age 8. Goliath Grouper form consistent spawning aggregations. Spawning occurs during full moon from June through December, with a peak in July through September. Spawning locations are shipwrecks, rock ledges, and isolated, and reef habitat.

In the Atlantic waters off the southeastern U.S., Goliath Grouper are managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Goliath Groupers are typically captured by hook and line, mostly incidental to other bottom fisheries (Grouper Snapper and Snook). Because Goliath Grouper post-larvae and juveniles depend on specific estuarine micro-habitats, seagrass and mangrove forest, estuarine reefs, non-fishery mortality can be high with the loss of these habitats or major declines in water quality. Unfortunately the majority of estuarine seagrass and most mangrove habitat (over 90%) has been lost in estuaries of the southeastern U.S. due to coastal urbanization and impoundment for mosquito control. The fishery is closed to possession or harvest with any gear in all sectors.

Nassau Grouper



Epinephelus striatus - Nassau Grouper

The Nassau Grouper is easily distinguished from other shallow-water groupers by the five dark bars on the body and the black saddle on the tail, just before the tail fin. Nassau Grouper occurs on coral reefs and associated habitats in the tropical Western Atlantic, and range from Bermuda, the Bahamas, and Florida to southern Brazil, including the Gulf of Mexico. Juveniles are common in seagrass beds.

Nassau Grouper is a medium-sized grouper (maximum 48 inches and 30 lbs. maximum) that is famous for its large spawning aggregations that form at predictable times and places, primarily in winter. Unlike most other groupers, where some large females become males, Nassau Grouper have individuals that begin life as males, with some females having a potential for sex change. Male and female Nassau Grouper mature between 16 and 20 inches at ages between 4 to 8 years. The spawning season is associated with water temperature and the moon phase. At lower latitudes, spawning activity lasts for about one week per month during December through February.

In the Atlantic waters off the southeastern U.S., Nassau Grouper are managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Nassau Groupers typically are captured by hook and line, mostly incidental to other bottom fisheries. The fishery is closed to possession or harvest with any gear in all sectors.

Yellowedge Grouper

Hyporthodus flavolimbatus - Yellowedge Grouper

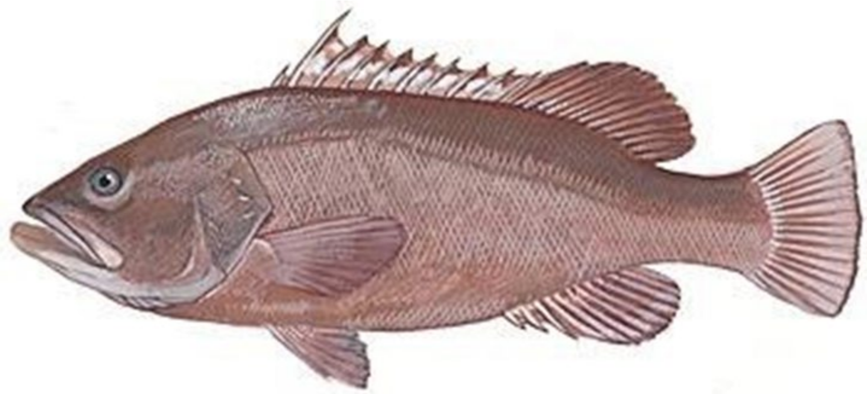
Yellowedge Grouper belongs to a complex of deepwater groupers that include the Warsaw, Snowy and Misty Groupers. The Yellowedge and Snowy Groupers lack the elongate second dorsal spine that is so obvious in the Warsaw Groupers. Yellowedge Grouper typically do not show the classical lateral spot pattern that the Snowy Grouper has.

Yellowedge Grouper is a warm-temperate species with spawning populations from Cape Hatteras North Carolina to Florida and the Gulf of Mexico to Brazil. It occurs on reefs and sand/mud bottom at depths ranging from 210 to 902 ft. On soft-bottom habitats it is often seen within or near trenches or burrow-like excavations. Yellowedge Grouper eat a wide variety of invertebrates (mainly brachyuran crabs) and fishes.

Yellowedge Grouper are one of the longest living groupers as are other members of this deepwater group, likely exceeding 85 years. The maximum reported size is 45 inches and 41 lbs. Yellowedge Groupers are protogynous hermaphrodites, reversing sex with over half the females having transformed into males at 32 inches. Spawning occurs from April through October in the South Atlantic. Yellowedge Grouper spawning aggregations have been observed around deep slope shipwrecks off east central Florida.

Yellowedge Grouper managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP, and are caught in shelf edge and deep continental slope hook and line fisheries, both in commercial and recreational fisheries. A variety of hook and line gear are used including electric reels and bottom multi-hook long lines. Non-fishery mortality sources are largely unknown as critical post-larvae and juvenile habitat for Yellowedge Grouper has not been documented.

Warsaw Grouper



Hyporthodus nigritus - Warsaw Grouper (jewfish, black jewfish, Warsaw, guasa)

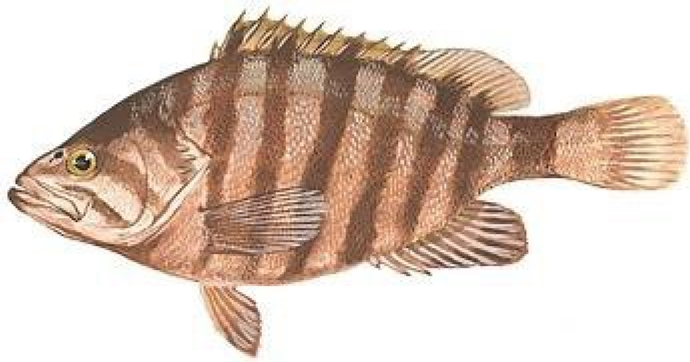
The Warsaw Grouper belongs to a complex of deep water groupers that include the Yellowedge, Snowy and Misty Groupers. Warsaw Grouper has 10 dorsal spines, the second of which is much longer than the third, which distinguishes it from all others in this complex. The color is a grayish brown to dark reddish-brown background with numerous small, irregular white blotches on the sides. The color appears much lighter around the nape and along the posterior margin of the operculum. All of the fins are dark brown, except the white-splotched spiny portion of the dorsal fin. The young are characterized by a yellow caudal fin; dark saddle on caudal peduncle; and some whitish spots on body.

Warsaw grouper is a warm-temperate cool water species with permanent breeding populations in deep reefs along the continental shelf edge and deep slope from Cape Hatteras, North Carolina to east central Florida and the Gulf of Mexico. The Warsaw Grouper has been consistently observed in small groups typically with a single very large (80 inches in length) individual around deep Oculina coral reefs and shipwrecks at depths from 180 to 1,722 ft on the east central coast of Florida. The warsaw's huge mouth enables it to engulf prey whole after capturing it.

Warsaw Grouper are protogynous hermaphrodites. Females mature 40 inches at 9 years**.** Female to male transition size is unknown, but the largest reported females were 45 inches. while the smallest male was 47 inches and 10 years old. The oldest and largest males are reported to be 41 years and 92 inches. The maximum age is estimated at 44 to 46 years. The Warsaw Grouper spawning activity has not been documented in the Atlantic waters off the southeastern U.S., but is estimated to occur from spring into summer based on post-larval collections and aging and is known to spawn August - October in the Gulf of Mexico, and during April and May off Cuba.

In Atlantic waters off the southeastern U.S. the Warsaw Grouper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Warsaw Grouper are caught in shelf edge and deep continental slope hook and line fisheries, both in commercial and recreational fisheries. A variety of hook and line gear are used including electric reels and bottom multi-hook long lines. Non-fishery mortality sources are largely unknown as critical post-larvae and juvenile habitat for Warsaw Grouper has not been documented.

Misty Grouper



Hyporthodus mystacinus - Misty Grouper

Misty Grouper have alternating light and dark bars from the nape to the base of the tail (usually 8 or 9 of each). Light and dark bars extend onto the dorsal and anal fins, and the two dark bars just before the tail may be joined into a broader and darker band around the caudal peduncle.

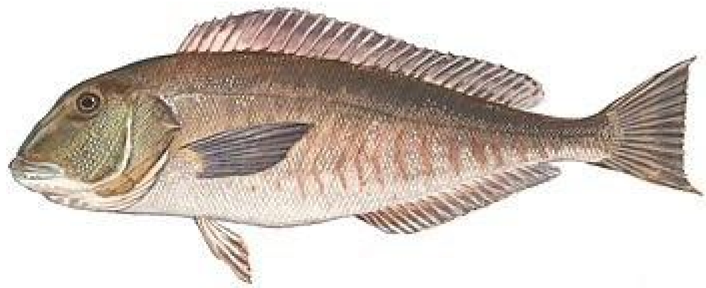
The range of Misty Grouper is limited to the Western North Atlantic from North Carolina and Bermuda to the West Indies and probably northern South America; this species also apparently occurs in the Eastern Pacific Ocean. It inhabits both hard-bottom and soft-bottom habits at depths from approximately 330 to 1,640 ft.

Maximum length of Misty Grouper is 62 inches and they can grow to 166 lbs. The age of two large specimens from Bermuda was estimated at 135 and 150 years. Like other groupers, Misty Groupers are probably protogynous hermaphrodites, but little is known about their biology. Misty Grouper are known to consume crabs, shrimps, squid, and fish.

Misty Grouper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP, however it has been rare in landings. It is caught mostly by hook and line.

Tilefishes

Blueline Tilefish



Caulolatilus microps - Blueline Tilefish (Gray Tilefish, Tilefish)

Blueline Tilefish has a dull olive-gray overall appearance with white below. It has elongate, continuous dorsal and anal fins more than half the length of body, and a long snout with narrow gold stripe underlined in blue from snout to the tip of the eye. The gill cover has a strong, flat spine. The lack of fleshy protuberance behind the head distinguishes it from (Golden) Tilefish (*Lopholatilus chamaeleonticeps*).

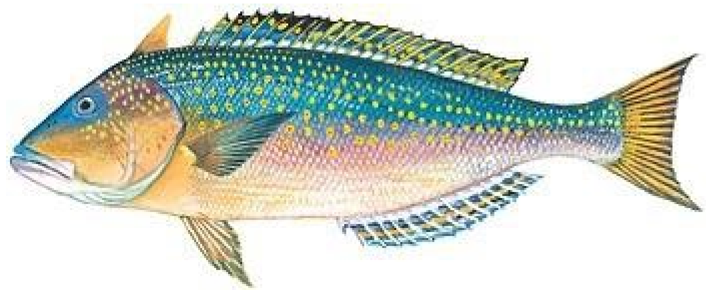
Blueline Tilefish is patchily distributed along the outer continental shelf of North America from Cape Lookout, NC, to Campeche Bank, Mexico. Adults appear to move little, inhabiting areas along the outer continental shelf, shelf break, and upper slope on irregular bottom. Usual adult habitats include ledges or crevices and around boulders or rubble piles at depths of 160 to 820 ft Individuals have been observed hovering near or entering burrows under rocks as observed in many other tilefishes (malacanthids). Blueline Tilefish feeds on bottom creatures, such as crabs, shrimp, snails, worms, sea urchins, and small fish.

Blueline Tilefish can live to at least 26 year but the expected maximum age may be closer to 45 years. There is dimorphic growth with males growing larger at age than females, with both sexes reaching over 32 inches.

Blueline Tilefish are gonochorists with an extended spawning season from February to November, with a peak March – September. Data suggests they are fully mature by 365mm FL. Females are prolific spawners and produce up to 94 batches of eggs during the spawning season producing over 3 million eggs during a season.

In the Atlantic waters off the southeastern U.S., Blueline Tilefish is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, bag limits, trip limits, and gear restrictions. They are caught by both commercial and recreational fishers. Hook and line is most commonly used by recreational fishers, snapper reels and longlines are the gear used most by commercial fishers to catch Blueline Tilefish.

Golden Tilefish



Lopholatilus chamaeleonticeps – Tilefish (Golden Tilefish)

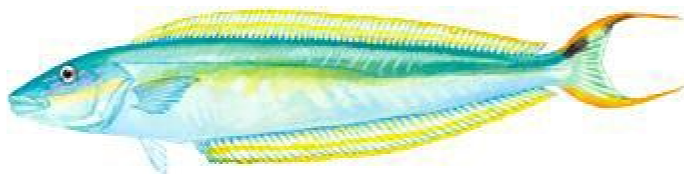
Tilefish is easily distinguishable from other members of the family Malacanthidae by the large adipose flap, or crest, on the head. The species is blue-green and iridescent on the back and sides, with numerous spots of bright yellow and gold, and a white belly.

Tilefish is a long-lived, slow-growing deepwater demersal member of the family Malacanthidae distributed along the outer continental shelf of North America from Nova Scotia to the northern shoreline to Campeche Bank, Mexico including the Gulf of Mexico. Golden Tilefish is also found throughout continental Caribbean. It is also off of South America from Venezuela to Surinam. Tilefish move little as adults and occupy burrows within clay bottoms or scour depressions around boulders or rubble piles in depths of 250 to 1,500 ft and water temperatures of about 50° to 60° F.

Tilefish can reach a length of 38 inches and 40 years of age. Females are smaller than males, although whether or not the species displays hermaphroditism is still under investigation. Sexual maturity is reached when fish are about 27 inches long, 3 years of age, and weigh about 9 lbs. Female Tilefish spawn from March through November with a spawning peak occurring between April and June. Male Tilefish was also in spawning condition from March through November, however, most spawning activity occurred from April through June.

Tilefish feed during the day on the bottom on crustaceans, clams, snails, worms, anemones and sea cucumbers. In the Atlantic waters off the southeastern U.S., Tilefish is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, bag limits, and gear restrictions. They are caught by both commercial and recreational fishers. Hook and line is most commonly used by recreational fishers, while snapper reels and longlines are the gear used most by commercial fishers.

Sand Tilefish



Malacanthus plumieri - Sand Tilefish

Sand Tilefish are elongate and slender pale gray fish that may have a bluish cast. They are reef-associated but are found over sand and coral or rock rubble from near shore to depths of about 150 ft, from Cape Lookout, NC, to Santos, Brazil, including Bermuda, Bahamas, Gulf of Mexico, and Caribbean (also around Ascension Island in South Atlantic).

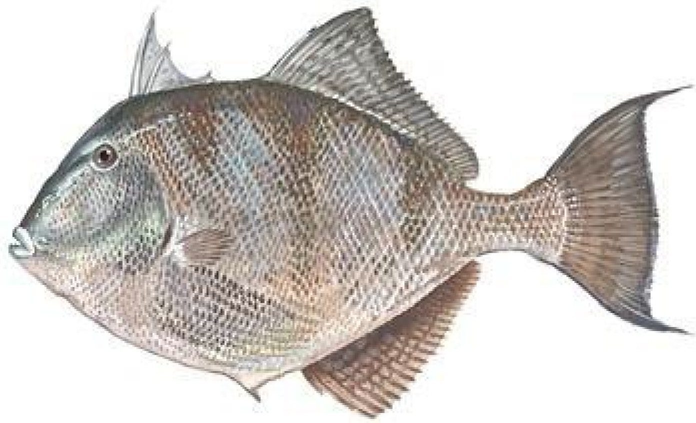
Sand Tilefish build burrows surrounded by mounds of rubble and shell fragments near reefs and grass beds. Prey items include shrimps (amphipods, stomatopods, decapods), fishes, polychaete worms, chitons, sea urchins and sea stars.

Males guard territories that include several haremic females. The maximum reported size is 28 inches and 2.4 lbs.; however the common average size is much smaller. There is little information on the life history of this species. Tilefishes that have been studied are not hermaphroditic, and it is likely that Sand Tilefish is also a gonochoristic.

Sand Tilefish is of minor economic importance, but is probably landed and sold as mixed unidentified tilefish or reef fish. This species is managed by the South Atlantic Fishery Management Council in the Snapper Grouper FMP.

Triggerfishes

Gray Triggerfish



Balistes capriscus - Gray Triggerfish (Taly, Leatherjacket, Leatherneck)

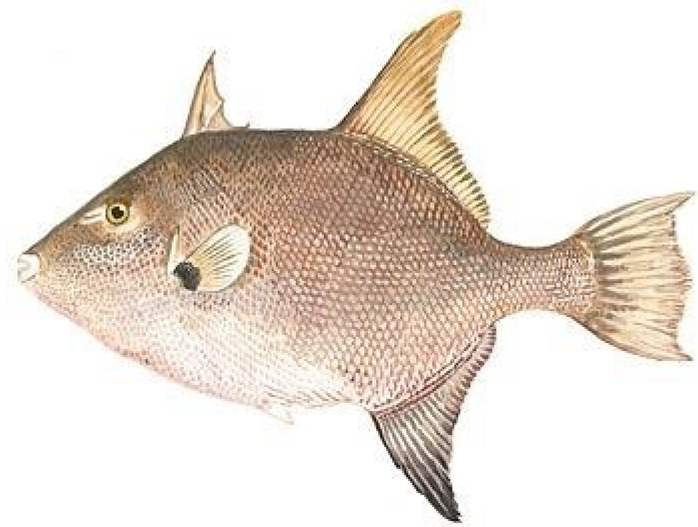
The Gray Triggerfish, has large incisor teeth and a deep laterally compressed body covered with tough, sandpaper-like skin. The Gray Triggerfish is easily distinguished from other triggerfishes in the Atlantic waters off the southeastern U.S., such as Queen Triggerfish, by its drab gray color. Triggerfish can be distinguished from filefish species by the presence of more than one dorsal spine.

Gray Triggerfish is a warm-temperate species in the family Balistidae that is found throughout the Atlantic Ocean, including the Mediterranean Sea. Gray Triggerfish occurs in coastal waters of the western Atlantic from Nova Scotia (Canada) to Argentina, including the Gulf of Mexico and Bermuda. Throughout this distribution they generally are found at depths to 330 ft, though they are commonly found between 40 and 140 ft among reefs and hard-bottom habitat, such as wrecks and rock outcroppings. The most common items in their diet are small mussels, sea urchins and barnacles, which they dislodge and crush with their teeth.

Gray Triggerfish is a gonochorist that can reach a maximum age of 15 years and length of 22 inches. Males grow larger and live longer than females. Female Gray Triggerfish begin maturing at or before 1 year of age and around 6 inches in length. Spawning occurs off-shore from April-September, with Gray Triggerfish having demersal eggs that are deposited in guarded nests. Typically a single male guards a territory that houses several nests belonging to several females in a harem-like system. Females can spawn up to 12 times a season.

In the Atlantic waters off the Atlantic waters off the southeastern U.S., Gray Triggerfish is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Ocean Triggerfish



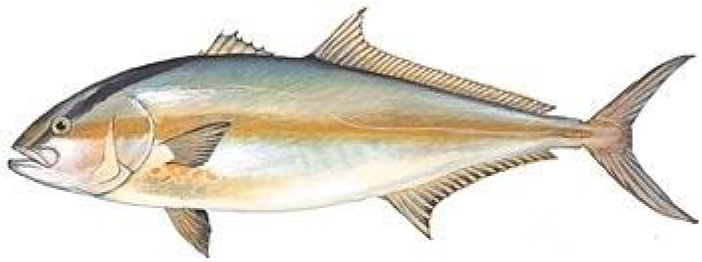
Canthidermis sufflamen - Ocean triggerfish,

The Ocean Triggerfish is grayish in color with a dark edge on the dorsal and anal fins. It occurs in both the Western and Eastern Atlantic. In the Western Atlantic, it ranges from Massachusetts to South America, including the Gulf of Mexico and Caribbean. The ocean triggerfish is found at depths of 16 to 197 ft in mid-water or at the surface associated with *Sargassum,* near drop-offs of seaward reefs, and occasionally in shallow waters. This species is sometimes solitary, but also is known to form small groups in open water of over 50 individuals. It is sometimes seen in association with the Black Durgon. This species feeds primarily on large zooplankton, but also eats benthic invertebrates.

Maximum reported length is 26 inches (male) and Ocean Triggerfish wan weigh up to
13.5 lbs. Spawning reportedly occurs year round with, but with a peak September.

Jacks

Greater Amberjack



Seriola dumerili – Greater Amberjack

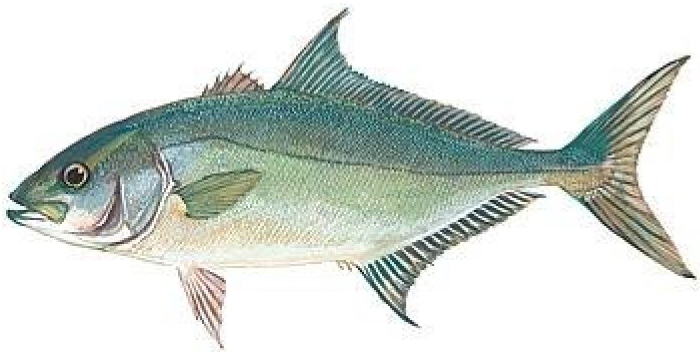
Greater Amberjack are large, silvery fish with a bluish grey or olivaceous dorsal surface, often a dark bar passing through the eye and ending at the base of the first dorsal fin, and a relatively long anal-fin base. A vertical line from the depressed lobe of the soft dorsal fin generally intersects the origin of the anal fin. They often have an amber stripe along mid-body. The dorsal fin usually has 7 spines, but it may appear to have only 6 because the last spine is small and may be covered by skin in larger specimens.

The Greater Amberjack, *Seriola dumerili*, is a pelagic and epibenthic warm-temperate species in the family Carangidae. This large jack is distributed from Nova Scotia to Brazil and throughout the Pacific, Indian, and Eastern Atlantic Oceans as well as the Gulf of Mexico, the Caribbean Sea, and the Mediterranean Sea. Greater Amberjack often are found near reefs, rocky outcrops, or wrecks off the southeastern United States, with a relatively broad depth range of 50 to 780 ft.

Greater Amberjack has a fast growth rate and reaches a maximum size of 74 inches, maximum weight of 178 pounds, and maximum age of 13 years. Females are generally larger at age than males. This species is gonochoristic with a spawning season from January to June with a peak in April and May. Spawning appears to be more prevalent off south Florida and the Florida Keys compared to locations further north along the Atlantic coast. They mature at 1 year of age and 29 inches in length.

Greater Amberjack are included in the Snapper Grouper FMP and are managed by the South Atlantic Fishery Management Council. Recreational fishing for Greater Amberjack began in the early 1950s, but there was no targeted fishery until the 1970s.

Almaco Jack



Seriola rivoliana - Almaco Jack

Almaco Jack is elongate, moderately deep-bodied and compressed, with the upper profile more convex than lower. This gives Almaco Jack a more oval shape than other species of *Seriola*. The scales are small and smooth, and there are no scutes on the tail as in many jacks.

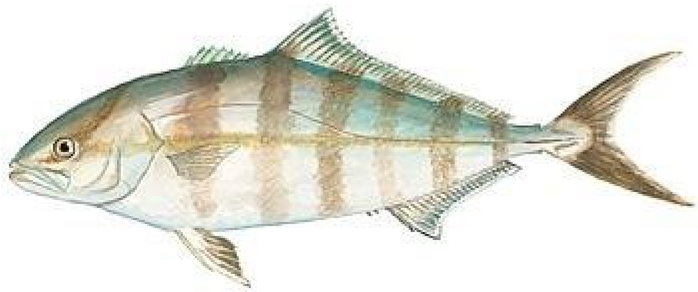
There are grooves present on the caudal peduncle. Almaco Jack are brown or olive to bluish- green above, with the sides and belly lighter. A darker band that is prominent in juveniles and often persistent in adults extends from the eye to the first dorsal fin. A faint amber lateral stripe extending backward from the eye is frequently present. Juveniles (to about 7 inches in length) have six dark vertical body bands, and a dark seventh band at the end of caudal peduncle.

Almaco Jack occurs in the Indo-West Pacific, in the Eastern Pacific, and in the Western Atlantic, where it occurs from Massachusetts to northern Argentina. It is pelagic and inhabits outer reef slopes and offshore hard-bottom banks, generally at depths from 49 to 525 ft.

Juveniles are often seen around floating objects. Almaco Jack feeds mainly on fish. Almaco Jack are usually seen between 22 and 32 inches and 3.5 to 6 lbs. Size at maturity is estimated at 32 inches. The all-tackle IGFA Atlantic world angling record is 78 lbs., but they have been reported up to 132 lbs. in other areas.

Almaco Jack are caught on hook and line gear. It is not targeted, but the flesh is regarded as good to very good. It has been implicated in ciguatera poisoning in the Caribbean. Almaco Jack are managed in the South Atlantic Fishery Management Council Snapper Grouper management unit and are included in the recreational aggregate bag limit with no size or seasonal limits. The recreational and commercial fisheries are open year round with no size limits, but with gear restrictions and an annual catch limit set by NMFS.

Banded Rudderfish



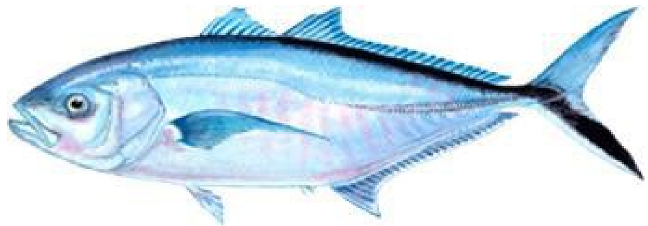
Seriola zonata - Banded Rudderfish

Banded Rudderfish less than 11 inches long have dark band from eye to first dorsal fin and six prominent bars on body, while larger fish are bluish, greenish, or brown. The soft dorsal base is about twice the length of the anal fin and the tail-lobe is white tipped. They can be differentiated from other amberjacks by having a shallower body.

Banded Rudderfish are typically found in the Western Atlantic from Nova Scotia, Canada to Santos, Brazil, including the Gulf of Mexico and the Caribbean Sea. They are absent from Bahamas and most islands. Adult Banded Rudderfish are pelagic or epibenthic and confined to coastal waters over the continental shelf. Young fish are associated with weed lines or floating debris and may follow sharks and other large fish. Banded Rudderfish feed on shrimp and fishes.

Banded Rudderfish is a relatively small carangid, reaching a maximum size of less than 30 inches and 11.5 lbs. Little is known about maturity and spawning.
In the Atlantic waters off the southeastern U.S., Banded Rudderfish is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits (in the jack complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Bar Jack



Caranx ruber - Bar Jack

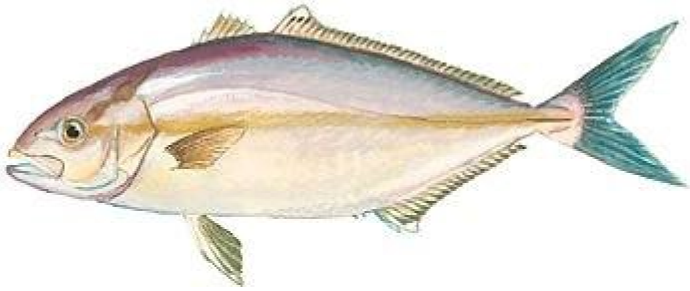
The Bar Jack, *Caranx ruber*, occurs in the Western Atlantic from New Jersey to southern Brazil, including the Gulf of Mexico and throughout the Caribbean Sea. Fish less than 11 inches long have dark band from eye to first dorsal fin and six prominent bars on body; larger fish are bluish, greenish, or brown; soft dorsal base about twice the length of the anal fin; tail-lobe white tipped.

It is commonly found in clear insular areas or coral reef habitats off mainland coasts, from depths of 10 to 115 ft. Juveniles frequent areas with *Sargassum* and appear to be common in shallow water (0 to 49 ft) reef habitats, but probably move to the outer margins of the shelf at or before maturity. Bar Jack are founds in nearshore and offshore waters over hard-bottom, generally in shallower water than other amberjacks. Young are associated with weed lines or floating debris and may follow sharks and other large fish. Bar Jack are sometimes solitary, but usually forms schools, possibly associated with spawning events. Prey items include fishes, shrimps, and other invertebrates.

Maximum reported size is 28 inches and 18.2 lbs. The minimum size of maturity for both males and females off Jamaica is 9 inches. The mean length at maturity is 10 inches for both sexes, and most fish are probably mature when they reach 10 inches in length. Spawning occurs during all year with peak spawning during April and October. Peak spawning off Cuba occurs during April and July.

In the Atlantic waters off the southeastern U.S., Bar Jack are managed by the South Atlantic Council under the Snapper Grouper FMP and are subject to annual catch limits (in the jacks complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Lesser Amberjack



Seriola fasciata - Lesser Amberjack

Lesser Amberjack has an olive green or brownish back and silversides, with a dark band (variably present) extending backward and upward from eye. Juveniles can have split or wavy bars on their sides. Lesser Amberjack has a proportionately larger eye and deeper body than the Greater Amberjack.

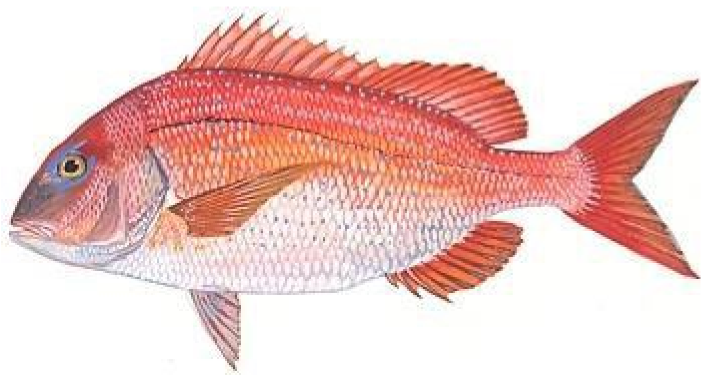
Lesser Amberjack occur in the Eastern and Western Atlantic Oceans. In the Western Atlantic, it is found from Massachusetts to Brazil. This is a benthopelagic species, primarily found in depths of 180 to 430 ft, with smaller juveniles being epipelagic in oceanic or offshore neritic waters. Lesser Amberjack feeds on squids and fishes.

Lesser Amberjack is a relatively small carangid, reaching a maximum reported size of 27 inches and over 10 lbs. Sexually dimorphic growth was observed in the Gulf of Mexico, with females attaining a larger size than males. Little is known about maturity and spawning.

In the Atlantic waters off the southeastern U.S., Lesser Amberjack is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits (in the jack complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Porgies

Red Porgy



Pagrus pagrus - Red Porgy (Pinky, Pink Porgy, Rose Porgy, Strawberry Porgy)

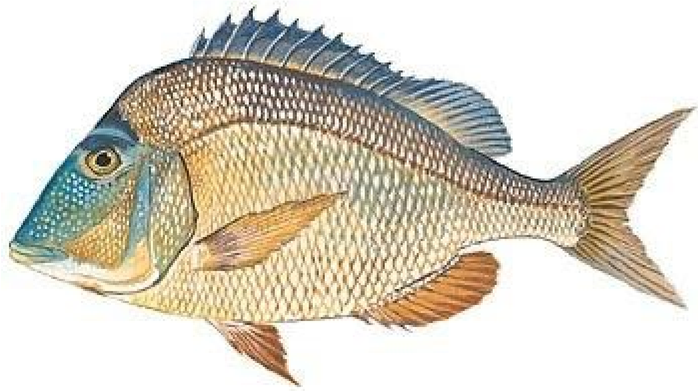
The Red Porgy is a sparid distributed throughout the Atlantic Ocean and Mediterranean Sea. In the western Atlantic, they range from New York, U.S., the Caribbean Sea, and through the Gulf of Mexico to Argentina. Their head and body are a silvery red, with many tiny blue spots. They are distinguished from other porgy species in the U.S. by having a rear nostril that is round (not slit-like).

In the Atlantic waters off the southeastern U.S,, Red Porgy inhabit reefs on the middle to outer continental shelf and shelf-break out to 920 ft in depth, but commonly found between 30 and 260 ft. They are found over rock, rubble, or sand bottom, with young frequently found on seagrass beds and the continental shelf. They feed on crustaceans, fishes, and mollusks. Red Porgy in the northwestern Atlantic are thought to constitute a single stock, but are separate from the northeastern and southwestern Atlantic.

Red Porgy are protogynous winter spawners (November to May), with the peak spawning season in November through March. Notable plasticity in the growth as well as reproductive parameters, such as size and age at female maturity and size and age at transition, has been documented. The oldest reported age is 14 years with sizes upwards of 20 inches.

In the Atlantic waters off the southeast U.S., Red Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, gear restrictions, and a spawning season closure. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Knobbed Porgy



Calamus nodosus - Knobbed porgy

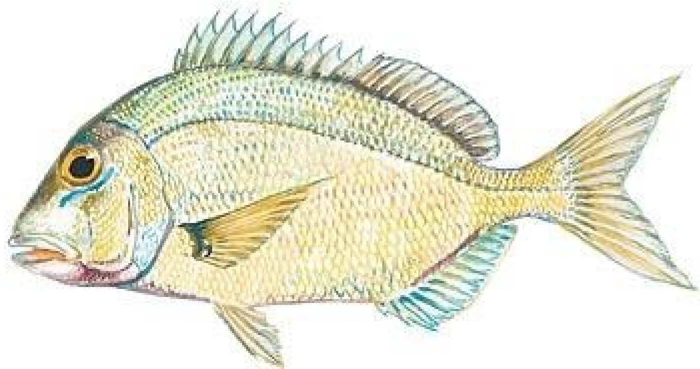
The Knobbed Porgy is deep-bodied, with a conspicuously steep forehead and bony protrusions just in front of the eyes. The body is iridescent silvery blue, and the snout is purplish with numerous yellow-bronze spots and a blue streak under the eyes.

Knobbed Porgy is a warm-temperate species that occurs in the Western Atlantic Ocean from North Carolina to the Florida Keys, and throughout most of the Gulf of Mexico. This fish is a demersal species, and typically occurs over hard-bottom habitat at depths from 25 to 300 ft. Knobbed porgy have large incisors and strong molars which enable them to crush and consume hard-bodied animals, such as clams, snails, crabs, urchins, starfish and barnacles. They are fast enough to catch small fish, but fishes are rarely a part of their diet.

Maximum reported size is 21 inches in length (male/unsexed) and 5.8 lb. The maximum reported age is 21 years off the southeastern United States. Growth rate is medium, as asymptotic length is reached in 6 to 10 years. Length and age at which 100% of sampled fish are mature is 12 inches and 6 years, respectively. Male to female sex ratios increase with increasing length and age, and histological evidence of protogyny was found. Females transition to males between 11 and 15 inches in length, and between 5 to 20 years, during any time of year. Females spawn during March to July at outer-shelf reefs with a peak during April and May, and an estimated spawning interval of 1.5 days.

In the Atlantic waters off the southeastern U.S., Knobbed Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits (porgy complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Jolthead Porgy



Calamus bajonado - Jolthead Porgy

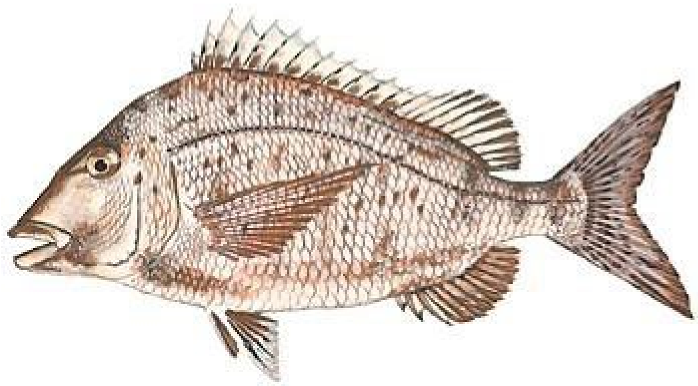
Jolthead Porgy are most recognizable by their long snout. They are generally silvery to brassy, with a bluish cast. The front of the head is brown, sometimes with a blue line along lower rim of eye. Live specimens under water display a whitish stripe below the eye and another between the eye and mouth; these marks are said to fade quickly upon death. The corner of the mouth is orange.

Jolthead Porgy occur in the Western Atlantic from Rhode Island and Bermuda, southward to Brazil, including the northern Gulf of Mexico. This species inhabits coastal waters from 10 to 650 ft in depth. It can be found on vegetated sand bottoms but occurs more frequently on coral and hard-bottom. Large adults are usually solitary. Crabs and mollusks constitute its primary prey items.

Maximum reported size is 30 inches and 23 lbs. Little is known about Jolthead Porgy reproduction in the Atlantic waters off the U.S., but size and age at maturity in the Gulf of Mexico ranges from 12 to 17 inches and 3 to 5 years.

In the Atlantic waters off the southeastern U.S., Jolthead Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits (porgy complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Whitebone Porgy



Calamus leucosteus - Whitebone porgy, Silver Porgy

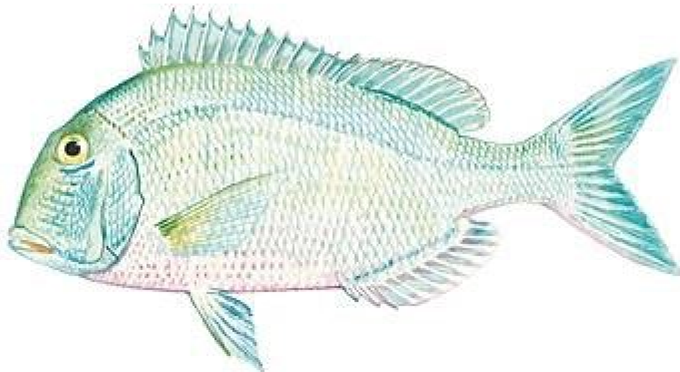
The Whitebone Porgy is silvery with faint brownish blotches on the sides. It has a rounded head and a pointed snout. The pectoral fin is relatively long. The caudal fin has dark edges. Note that many other porgies have 14 to 15 rays in the pectoral fins and markings between the eye and snout. Whitebone Porgy has 16 rays in the pectoral fin and evenly dusky cheeks with no marks.

Whitebone Porgy are found in the Western Atlantic from North Carolina to southern Florida in the U.S. and the entire Gulf of Mexico. They are most frequently encountered in or near sponge-coral habitats at depths of 33-328 ft. Off the southeastern United States, Whitebone Porgy feed mainly on small hard-shelled species of gastropods, pagurid decapods, and sipunculids. Polychaetes, pelecypods, barnacles, and fishes are also eaten. Larger individuals consume fishes and echinoderms.

Off the southeastern United States, maximum reported size is 16.5 inches and maximum reported age is 12 years. Whitebone Porgy are protogynous and approximately 60% of the females transition into males. Spawning occurs during April-August off the southeastern United States with a peak during May.

In the Atlantic waters off the southeastern U.S., Whitebone Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits (porgy complex), bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Saucereye Porgy



Calamus calamus - Saucereye Porgy

The Saucereye Porgy has a larger eye than the other porgies. Its color is silvery with bluish reflections, with golden scales forming longitudinal stripes and pearly-bluish interspaces. The cheeks and snout are purplish, with round brassy spots. Their fins are pale and blotched with orange. The iris of the eye is golden.

Saucereye Porgy is a reef-associated species that occurs from North Carolina and Bermuda to Brazil at depths of 3-246 ft. Adults are frequently found in coral areas, while the young prefer seagrass (e.g. *Thalassia*) and sandy bottoms. The diet of saucereye porgy includes polychaetes, echinoderms, mollusks, crabs, gastropods, and other benthic crustaceans.

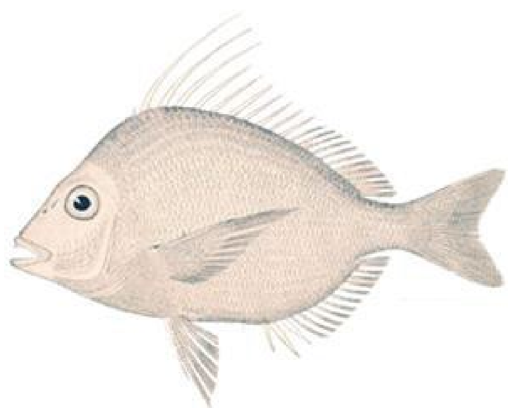
Not much is known about the life history of this species, but the reported maximum size is 22 inches in length (male/unsexed) and 1.5 lbs.

In the Atlantic waters off the southeastern U.S., Saucereye Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits in the Porgy complex, bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Scup / Longspine Porgy

Stenotomus caprinus - Longspine porgy, and Stenotomus chrysops - Scup

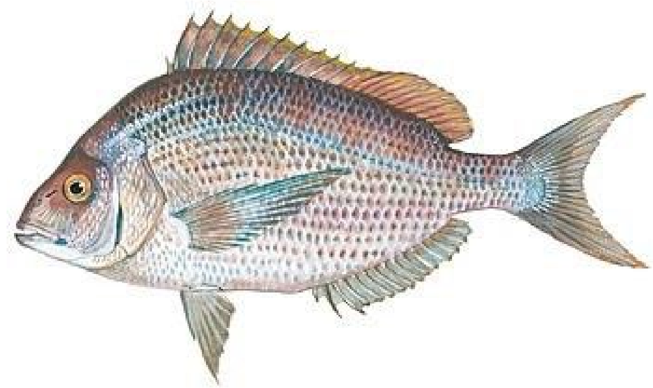
Longspine Porgy and Scup are very similar species with the Longspine Porgy having a significantly elongated first dorsal spine that can break off easily when caught. Note that juvenile Scup can also have an elongated first dorsal spine. They are deep-bodied species with very spiny fins. The front teeth are incisor-form and are very narrow, almost conical. There are two rows of molars in the upper jaw. The color is dusky brown with somewhat bright silvery reflections below. The fins are mottled with dark brown in the adults and the young may be faintly barred.



Stenotomus caprinus - Longspine Porgy

Longspine Porgy is found on mud bottom from North Carolina to Georgia in the U.S. and in the Gulf of Mexico from northern Florida to Yucatan, Mexico at depths of 16-607 ft. Their diet includes polychaetes, crabs, other benthic invertebrates, shrimps, prawns, fishes, stomatopods, and amphipods.

Not much is know about the life history of Longspine Porgy, but the maximum reported size is 12 inches in length and the maximum age is reported to be 3 years.
In the southeastern United States, Longspine Porgy is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits in the Porgy Complex, bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.



Stenotomus chrysops - Scup

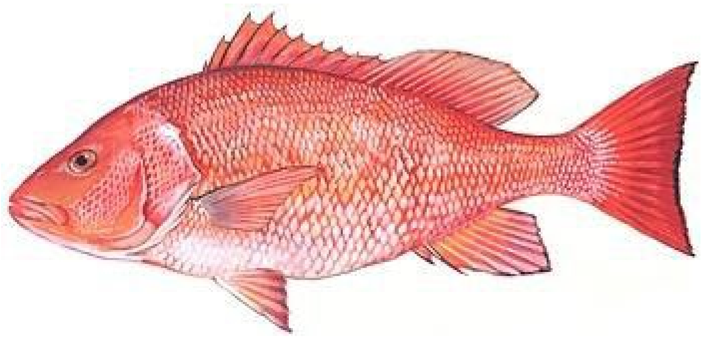
Scup is a schooling species that occur in the Western Atlantic from Nova Scotia in Canada to Florida and inhabit the nearshore region of the continental shelf from Nova Scotia to South Carolina. It is found over hard-bottom habitats, such as rock outcroppings and wrecks in waters of 45° F or warmer. Scup feed on squid, polychaetes, amphipods, and other benthic invertebrates.

Maximum reported size is 18 inches in length (male/unsexed) and 4.6 lbs. Length at 50% maturity is 6 inches in length. Spawning is reported to occur from May through August, peaking in June. It is a gonochoristic species and mature sexually at the age of 2 and about 8 inches in length. The eggs and larvae are pelagic and are carried by currents and winds before settling to the bottom. Scup may live to be 15 years old.

In the Atlantic waters off the southeastern U.S., Scup is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits in the Porgy Complex, bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Snappers

Red Snapper



Lutjanus campechanus - Red Snapper (Mules, Sow Snapper, Spot Snapper (small))

Red Snapper has a pinkish-red color over its entire body, with whitish color below. Red Snapper has red eyes, long triangular snout, and a sharply pointed anal fin. Red Snapper less than 1 ft in length have a large dark spot on the upper sides, below the anterior soft dorsal rays, that disappears as it gets larger.

Red Snapper is distributed in warm-temperate waters throughout the Gulf of Mexico south to the Yucatan Peninsula and in United States Atlantic waters north to North Carolina. Adult Red Snapper are associated with structured habitats such as coral reefs, wrecks, gas and oil platforms, rocky outcroppings, and live-bottom habitats in relatively shallow waters (typically <250 ft) in the Atlantic waters off the southeastern U.S. Juveniles occur in shallow waters over sandy or muddy bottom.

Red Snapper reach a maximum length of about 40 inches and maximum reported age over 50 years. They are gonochoristic and spawn May through October in the Atlantic, with a peak June through September. They begin to mature under 2 years of age for both sexes. Overall sex ratio appears to vary by age and size, with more females present at older ages and larger sizes.

Red Snapper has been under intense commercial and recreational fishing for decades. In the Atlantic waters off the southeastern U.S., Red Snapper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions when the fishery is open. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Vermilion Snapper

Rhomboplites aurorubens - Vermilion Snapper (Beeline(r) Snapper)

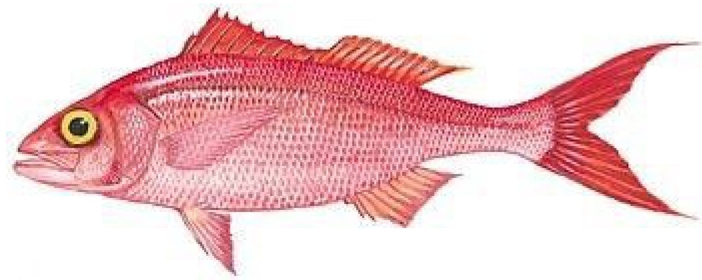
Vermilion Snapper have streamlined bodies which are pale to silver white below and vermilion/reddish above. Narrow yellow-gold streaks, some horizontal and others oblique, occur below the lateral line. The dorsal fin is rosy colored with a yellow margin. The caudal fin is red but has a faint black margin. Large canine teeth are absent and the orientation of the mouth and eye give it the appearance of looking upward. The Vermilion Snapper is the only Western Atlantic snapper with 12 dorsal-fin spines (other species usually have 10 spines and rarely have 9 or 11 spines).

The Vermilion Snapper is a warm-temperate and tropical lutjanid occurring from North Carolina and Bermuda, throughout the West Indies and Gulf of Mexico, and south to southeastern Brazil. Off the Atlantic waters of the southeastern U.S., Vermilion Snapper is a schooling fish that is commonly associated with patches of sponge/coral habitat, rocky outcrops, and rocky ledges on the continental shelf and shelf-break (85-180 ft), as well as the upper-slope reef habitats (~330 ft). Young fish occur in shallower waters than the adults (typically < 85 ft), where they also form large schools. They feed on fishes, shrimps, crabs, polychaetes, other benthic invertebrates, cephalopods, and planktonic organisms.

Vermilion Snapper is relatively small, reaching maximum lengths of 24 inches and maximum ages greater than 20 years old. They are gonochoristic and spawn off the Atlantic waters off the southeastern U.S. from April to September, with a peak between June and August. They mature at a young age (nearly all are mature at 1 year old) and small size (beginning around 6 inches in length). There is also a skewed sex ratio, with more females present than males.

This species has been targeted by commercial and recreational fishers for decades. In the Atlantic waters off the southeastern U.S., Vermilion Snapper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used gear.

Queen Snapper



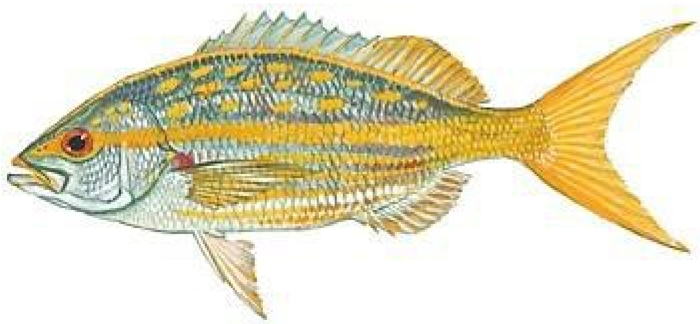
Etelis oculatus - Queen Snapper

The Queen Snapper is a moderately large snapper that occurs in the Western Atlantic, ranging from Bermuda and North Carolina to Brazil, including the Gulf of Mexico and Caribbean Sea. It is commonly found near oceanic islands, and is particularly abundant in the Bahamas and the Antilles. The back and upper sides of Queen Snapper is red; body is silvery, long and slender; dorsal fin distinctly notched; eyes are large; caudal fin deeply forked; and there is no dark lateral spot.

Queen Snapper is a bathydemersal species that moves offshore to deepwater reefs and rocky ledges as it grows and matures. It is primarily found over rocky bottom habitat, in depths of 327 to 1,475 ft. Maximum reported size is 39 inches (male) and 11.7 lbs. Limited information indicates the size at maturity and age at first maturity are estimated as 21 inches and 1 year, respectively. Spawning is reported to occur during April and May off St. Lucia.
Approximate life span is 4.7 years.

Queen Snapper is targeted by commercial and recreational fishers, but most landings are from the commercial sector. Off the Southeast United States, Queen Snapper is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. It is included in the Deepwater Complex along with Yellowedge Grouper, Silk Snapper, Misty Grouper, Sand Tilefish, and Blackfin Snapper, which is subject to annual catch limits, size and bag limits, and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Yellowtail Snapper



Ocyurus chrysurus - Yellowtail Snapper

Yellowtail Snapper are primarily silver with a prominent mid-lateral yellow band from the snout to the tail.

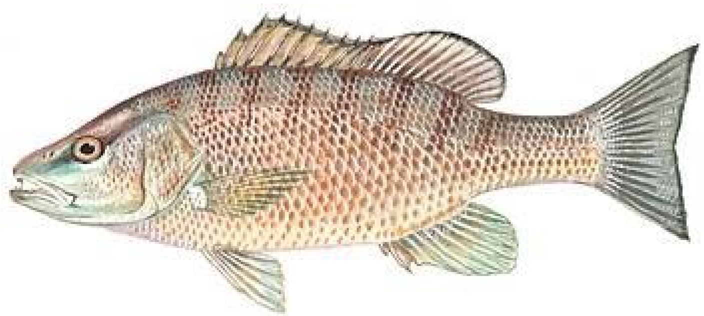
Yellowtail Snapper occurs in the Western Atlantic, ranging from Massachusetts to southeastern Brazil, including the Gulf of Mexico and Caribbean Sea, but is most common in the Bahamas, off south Florida, and throughout the Caribbean. The Yellowtail Snapper inhabits waters as deep as 590 ft, but are most abundant at depths of 66 to131 ft. Adults typically inhabit sandy areas near offshore reefs, and juveniles are usually found over back reefs and seagrass beds. Yellowtail snapper typically exhibit schooling behavior. Yellowtail Snapper are nocturnal predators; juveniles feed primarily on plankton, whereas adults eat a combination of planktonic and benthic organisms, including fishes, crustaceans, worms, gastropods, and cephalopods.

Maximum reported size is 34 inches in length (male) and 9 lbs. Maximum age is 17 years. There is a truncation in the size and age structure of Yellowtail Snapper near human population centers. Yellowtail Snapper have separate sexes throughout their lifetime. Size at 50% maturity is estimated as 9 inches in length (males) and 10 inches length (females).

Spawning occurs over a protracted period and peaks generally from late spring through summer. Spawning generally occurs in offshore waters during the new moon, and spawning often involves large spawning aggregations.

In the Atlantic waters off the southeastern U.S., Yellowtail Snapper are managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions. Most U.S. landings are from the Florida Keys and southeastern Florida.

Gray Snapper



Lutjanus griseus - Gray Snapper or Mangrove Snapper

Gray Snapper are among the species of Western Atlantic snappers with no dark spot below the soft dorsal fin, at any size, and a rounded anal fin. They are separated from the similar Cubera Snapper by having upper canines distinctly larger than lower and by having an anchor- shaped tooth patch on the roof of the mouth. Color is quite variable, ranging from reddish to olive to greyish. Young often have a dark diagonal bar from tip of snout through eye and may have a blue line below eye.

Gray Snapper occur in the Western Atlantic from Massachusetts to Brazil, including the Gulf of Mexico and Caribbean Sea. This species occupies a variety of habitats during its life history. It occurs at depths of 16 to 591 ft, in coral reefs, rocky areas, estuaries, mangrove areas, and in the lower reaches of rivers (especially the young). Gray Snapper often forms large aggregations. The gray snapper feeds mainly at night on small fishes, shrimps, crabs, gastropods, cephalopods, and some planktonic items.

Maximum reported size of Gray Snapper is 35 inches in length (male) and 44 lbs., and maximum reported age is 24 years. Gray Snapper are gonochorists. Length and age at first maturity is estimated as 9 inches and 2 years for females and 9 inches for males. Spawning occurs during summer near the time of the full moon. This species spawns from late May to early September in the Florida Keys. In the northeastern Caribbean, individuals in spawning condition have been observed in May, August, and September. Off Cuba, Gray Snapper spawn during June through September with a peak in July.

In the Atlantic waters off the southeastern U.S., Gray Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions. Most Gray Snapper landed in Atlantic waters off the southeastern U.S. are caught in Florida. Due to the use of various habitats during their life history, Gray Snapper are vulnerable to habitat degradation from tidal rivers to the continental shelf, with the loss of mangrove habitat being of special concern.

Mutton Snapper

Lutjanus analis - Mutton Snapper

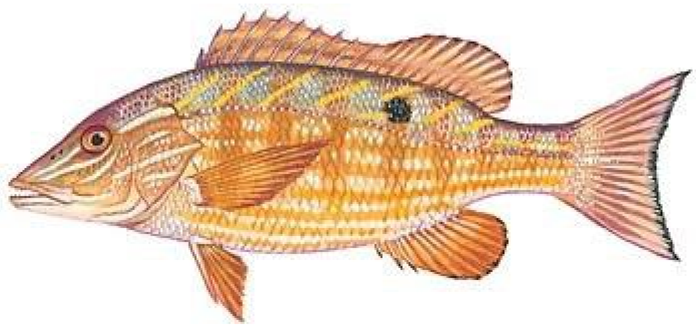
Mutton Snapper are among the snappers in the Western Atlantic with a dark spot under the soft dorsal fin and a pointed anal fin, although the lateral spot is progressively smaller in larger fish. Among this group of snappers the mutton is the only one with a roughly v-shaped patch of teeth in the front of the roof of the mouth (as opposed to an anchor-shaped patch with a posterior extension). The iris of the eye is red, and lateral coloration varies from uniform to barred with shades of red, olive, and whitish. The head has blue lines and spots.

Mutton Snapper are found in the Western Atlantic from Massachusetts to southeastern Brazil, including the Caribbean Sea and the Gulf of Mexico. It is most abundant around the Antilles, the Bahamas, and off southern Florida. Mutton snapper can typically be found in both brackish and marine waters at depths of 82 to 312 ft, although they have been captured on mud slopes at depths of 328 to 656 ft. Juveniles generally occur closer to shore, over sandy, vegetated bottom habitats, while large adults are commonly found offshore among rocks and coral habitat. Mutton snapper feed on fishes, shrimps, crabs, cephalopods, and gastropods.

Mutton Snapper have a reported maximum size of 37 inches in length (male) and 35 lbs. Maximum age of Mutton Snapper is 29 years. Mutton Snapper are gonochorists (separate sexes). Size at 50% maturity is 13 inches in length and 16 inches in length for males and females, respectively; all males and females are probably mature by 17 inches in length and 18 inches length, respectively. Spawning occurs in aggregations. Individuals have been observed in spawning condition February through July. Some spawning occurs during February to June, but spawning peaks during the week following the full moon in April and May. Spawning aggregations are known to occur north of St. Thomas, USVI, and south of St. Croix, USVI, in March, April, and May. Spawning at Riley's Hump off south Florida peaks in June.

In the Atlantic waters off the southeastern U.S., Mutton Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions.

Lane Snapper



Lutjanus synagris - Lane Snapper

The Lane Snapper is one of two species of snappers in the Western Atlantic with a large dark spot below the soft dorsal fin (usually) and a rounded anal fin. Most of the lateral spot is above the lateral line. In addition to the lateral spot, this species can usually be easily identified by the yellow lateral stripes below the lateral line and diagonal yellow stripes above the lateral line.

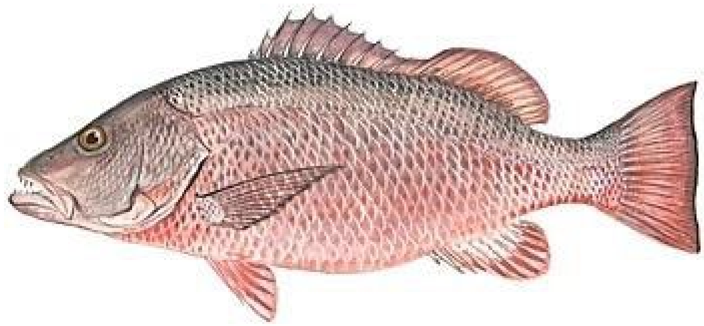
Lane Snapper occur in the Western Atlantic, ranging from North Carolina and Bermuda to southeastern Brazil, including the Gulf of Mexico and Caribbean Sea. It is most common near the Antilles, on the Campeche Bank, off Panama, and off the northern coast of South America.

This species occurs over all bottom types, but is usually encountered near vegetated areas as juveniles and coral reefs as adults. Lane Snapper feed primarily at night on small fishes, benthic crabs, shrimp, worms, gastropods, and cephalopods.

Maximum reported size is 24 inches (male), the world record weight is 8.3 lbs. Maximum age of Lane Snapper is 19 years. Size at 50% maturity is 6 inches for males and 7 inches in length for females. Lane Snapper first become sexually mature at age 1. They often form large aggregations, especially during the spawning season. Reproduction occurs over a protracted period, with some degree of reproductive activity occurring all year, although peak spawning occurs during April to July.

In the Atlantic waters off the southeastern U.S., Lane Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions.

Cubera Snapper



Lutjanus cyanopterus - Cubera Snapper (Cuban snapper)

Cubera Snapper is a dark brown or gray color that may have a reddish tinge, while the fins have only a slight hint of blue. It has a broad-based triangular tooth patch on roof of mouth without a posterior extension. Canine teeth in both jaws are very strong, with one pair of canines enlarged and visible even when mouth is closed.

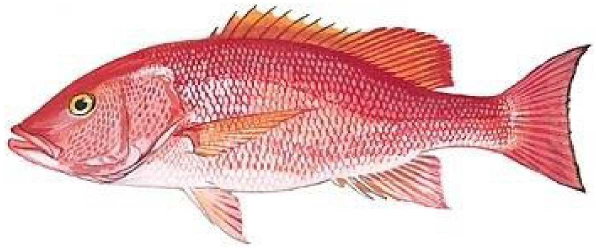
Cubera Snapper occurs in the Western Atlantic from Nova Scotia and Bermuda to Brazil.

It also occurs throughout the Bahamas and Caribbean, including Antilles. It is rare north of Florida and in the Gulf of Mexico. Adults are found mainly around ledges over rocky bottoms or around reefs, at depths of 59-180 ft. Juveniles are reef-associated but also occur in brackish marine waters, and sometimes inhabit mangrove areas.

Maximum reported sizes for Cubera Snapper are 64 inches (male/unsexed) and 127 lbs. There is little information regarding Cubera Snapper reproduction, though spawning has been observed during July-August off Cuba. Cubera snapper feed on fishes, crabs, and shrimp.

In Atlantic waters off the southeastern U.S., Cubera Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions.

Silk Snapper



Lutjanus vivanus - Silk Snapper (Silky Snapper or Yellow-Eyed Snapper)

Silk Snapper is red overall, darker above and lighter below with fine wavy longitudinal yellow lines. The caudal fin has a dusky margin. The yellow iris identifies the Silk Snapper from its close relatives, the Red Snapper and the Blackfin Snapper, both of which possess a red iris.

The Silk Snapper is a warm-temperate and tropical species that occurs in the Western Atlantic, from North Carolina to Brazil, including the Bahamas and the northern Gulf of Mexico. It commonly occurs along rocky ledges, in depths of 300 to 800 ft. Adults are generally found further offshore than juveniles and usually ascend to shallow water at night. However, juveniles are sometimes observed on deep reefs. Silk snapper form moving aggregations of similar-sized individuals. They eat primarily fishes, shrimps, crabs, gastropods, cephalopods, tunicates, and some pelagic items, including urochordates.

Maximum reported size is 33 inches and 18 lbs. Silk Snappers are gonochorists that begin maturing at 9 to 11 inches in length for females and males, respectively, which coincides with 5 to 6 years of age. Spawning occurs in June, July, and August in waters off North and South Carolina.

In the Atlantic waters off the southeastern U.S., Silk Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits (other snapper complex), size and bag limits (aggregate snapper bag limit), and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Blackfin Snapper

Lutjanus buccanella - Blackfin Snapper

Blackfin Snapper color is generally red, with yellowish caudal, anal, and pelvic fins. Blackfin Snapper also have a distinctive and prominent dark comma-shaped blotch at the base of the pectoral fins, which gives the fish its common name, and differentiates it from similar

species. It also has a rounded anal fin and the absence of the black spot on side underneath dorsal fin present in many other juvenile and/or adult snappers.

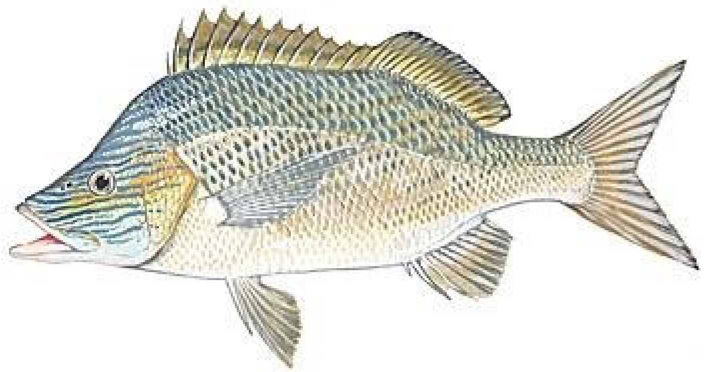
Blackfin Snapper is a warm-temperate and tropical species that occur in the Western Atlantic, generally ranging from North Carolina, south throughout the Bahamas, and the northern Gulf of Mexico, to southeast Brazil. This is a demersal species in which adults occur in deep waters over sandy or rocky bottoms, and near drop-offs and ledges, ranging from 165-300 ft in depth. Juveniles occur in shallower waters, often associated with reefs in depths of 115-164 ft.

Blackfin Snapper can reach sizes of 30 inches and excess of 30 lbs. Blackfin snapper is a gonochorist that begins maturing around 9 inches in length for both sexes. There is little information regarding spawning off the Atlantic coast of the Atlantic waters off the southeastern U.S., but in the Caribbean, Blackfin Snapper spawn year round, with peaks in April and September. Fishes are the primary prey item of Blackfin Snapper.

In the Atlantic waters off the southeastern U.S., Blackfin Snapper is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits (other snapper complex), size and bag limits (aggregate snapper bag limit), and gear restrictions. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Grunts

White Grunt



Haemulon plumieri- White Grunt (Ruby Red Lips, Red Mouth Grunt, or Common Grunt)

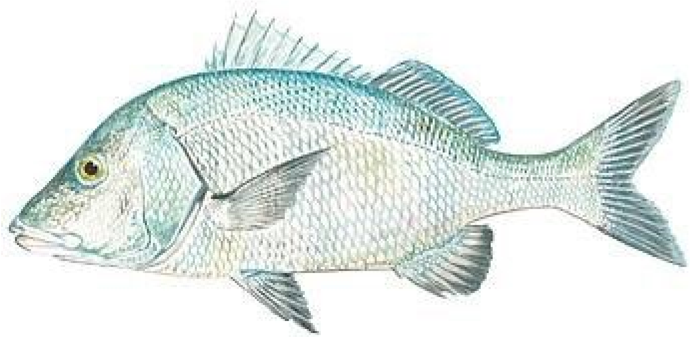
White Grunt is silver-gray, with numerous blue and yellow horizontal stripes on the body and head with a white underbelly. The mouth is large and bright orange. The lining of the body cavity, or peritoneum, is black.

White Grunt is a demersal reef fish found in warm-temperate and tropical waters of the western Atlantic from Virginia to Brazil. It has a disjunct distribution off the Atlantic waters off the Atlantic waters off the southeastern U.S., as it is typically absent from Cape Romain, SC, to Cape Canaveral, FL. White Grunt is typically associated with live-bottom and rocky outcrop habitats where it can be found in dense aggregations during the day at depths from 10 - 130 ft. Juveniles are common in seagrass beds. They are known to feed on crustaceans, small mollusks, and small fishes.

White Grunt reach a maximum reported size of 25 inches, 8 lbs., and live over 20 years of age. White Grunt is a gonochoristic species that begins maturing before 2 years of age and around 6 inches in length. It has a spawning season from May to September with a peak in April to June.

In the waters off the southeastern U.S., recreational fishermen are the primary source of White Grunt landings and this species managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits, size and bag limits, trip limits, and gear restrictions.

Margate



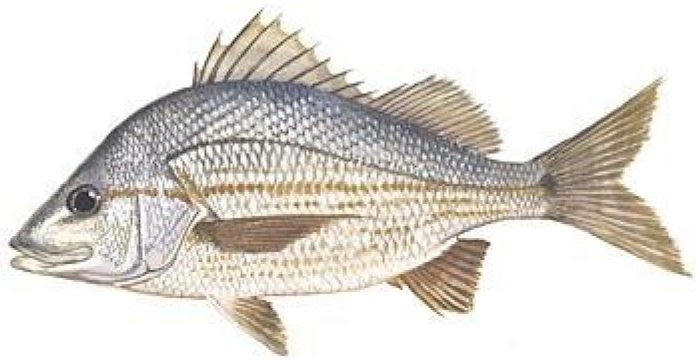
Haemulon album - Margate

Margate occurs in the Western Atlantic from the Florida Keys to Brazil, including the Caribbean Sea. The Margate is similar appearance and proportions to White Grunt (*Haemulon Plumieri*), but with a more elevated and arching back, and is more compressed. The teeth of Margate are in narrow bands, and are somewhat smaller than in the other grunts. Adult Margate is whitish, olivaceous on the back, with faint spots on the scales of back and sides. The inside of the mouth is orange; the lips and snout yellowish; the fins dusky greenish; a broad but indistinct band extends along the sides. Younger fish are bluish in coloration of body and fins, with dark parallel stripes below.

Margate are found in pairs or larger schools, over seagrass beds, sand flats, coral reefs, and wrecks in depths of 66 to 197 ft. Maximum reported size is 32 inches (male) and 2 lbs. The mean size at maturity off Jamaica is 10 inches in length. In the northeastern Caribbean, individuals in spawning condition have been observed in February, March, April, and September. Margate off Cuba are in spawning condition throughout the year with a peak during March and April.

Margate in the Atlantic waters off the Southeast United States is managed by the South Atlantic Fishery Marine Council in the Snapper Grouper FMP. It is included in the Grunts
Complex along with White Grunt, Sailor's Choice, and Tomtate. The Complex is subject to annual catch limits , size and bag limits (aggregate snapper bag limit), and gear restrictions. The magnitude of their landings is small. They are caught by both commercial and recreational fishers, with hook and line gear being the most commonly used.

Tomtate



Haemulon aurolineatum - Tomtate (Red Mouth, Blood Mouth)

Tomtate is silver white all over with a yellow-brown stripe running the length of the body and ending as a black blotch at the base of the caudal fin. This spot is also evident in most juvenile grunts, and may be lost by older fish. The inside of its mouth is bright red.

Tomtate occur in the Western Atlantic from Massachusetts to Brazil, including the Gulf of Mexico and Caribbean Sea. Tomtate inhabits seagrass beds, sand flats, patch reefs, rocky outcrops, and even muddy bottom habitat, to depths of 180 ft. They swim in schools and feed on small crustaceans, mollusks, other benthic invertebrates, plankton, and algae.

Along the Atlantic waters off the Atlantic waters off the southeastern U.S., maximum reported length of Tomtate is 10 inches in length and up to 1 lb., which is one of the smallest grunt species. It has a maximum reported age of 17 years. They are a gonochorist species with nearly all females being mature by 6 inches in length and two years old. Along the southeastern United States, female Tomtate are in spawning condition from March through July, with peak spawning occurring in April through June.

Tomtate are not highly regarded by fishermen due to their size. However, in the Atlantic waters off the Atlantic waters off the southeastern U.S., Tomtate is managed by the South Atlantic Fishery Marine Council under the Snapper Grouper FMP and is subject to annual catch limits (Grunt complex), and gear restrictions, but no size, bag limits, or trip limits.

Sailors Choice

Haemulon parra - Sailors Choice

Sailors Choice, *Haemulon parra*, is a large grunt, with an oblong compressed body. The head is blunt, with its upper profile moderately convex. The body is pale, with brown to grey spots forming broken stripes, often oblique, along the scale rows. The dorsal, caudal, anal, and pelvic fins are chalky and there is a black blotch usually present beneath free margin of preopercular bone on the lower cheek. As with many grunts, the mouth is red within. The outer margin of the eyes is often yellow.

Sailors Choice is a reef-associated species that occurs in the Western Atlantic including the Bahamas, Florida, northern Gulf of Mexico, throughout the Caribbean Sea, and Central and South American coasts. It occurs from the shore to outer reefs (to about 130 ft) in association with a variety of structured habitats. It feeds on crustaceans, annelid worms and echinoderms. Young occur on seagrass beds. Adults occur in schools in relatively open areas and the species is rare around oceanic islands.

Sailors Choice attain a maximum size of 16 inches and are common to about 12 inches.

Not much is know about life history aspects such as age, growth, and reproduction of this species.

Sailors Choice are not targeted, but are caught with traps, seines, and hook-and-line. Separate statistics are not reported for this species. They are managed in the South Atlantic Fishery Marine Council Snapper Grouper management unit and are included in the recreational aggregate bag limit (no size or season limit); there are no commercial catch limits, although the species is managed with an annual catch limit set by NMFS and gear restrictions.

Cottonwick

Haemulon melanuru - Cottonwick

Cottonwick is found in the Western Atlantic from Bermuda, southeastern Florida, and the Bahamas to Brazil. This reef-associated species occurs at depths ranging from 10 to 164 ft. Cottonwick feeds on benthic crustaceans and other benthic invertebrates.
Maximum reported size is 13 inches (male/unsexed) and 1.2 lbs. The length at 50% maturity is 8 inches off Jamaica .

Wrasses

Hogfish

Lachnolaimus maximus - Hogfish

Hogfish has a long, pig-like snout, and protrusible jaws with thick lips and strong canine teeth. The first three spines of the dorsal fin, as well as the upper and lower tips of the caudal fin, are extended into long filaments. Color is highly variable and changes with size. The scales on the back are often edged in yellow, and a dark spot is at the rear base of the dorsal fin. This spot disappears with age. Males possess a dark oblique band that covers the top portion of the head, extending to the tip of the snout. Juveniles are much lighter in color overall, usually of a pink or gray with white mottling along the sides.

Hogfish occur in the Western Atlantic from Nova Scotia (Canada) to northern South America, including the Gulf of Mexico and Caribbean Sea, although it is most commonly found in the Caribbean. Hogfish are primarily found in warm subtropical and tropical waters. Genetic analysis indicates there at three stock in U.S. waters, which include the Gulf of Mexico, Florida/Florida Keys, and Carolinas. In U.S. waters, hogfish are most commonly found in the Florida Keys. Hogfish are usually found in loose aggregations around hard-bottom areas, such as coral reefs, rocky ledges and wrecks. They occur at depths of 10 to 98 ft over open bottom or coral reef; however, hogfish have occasionally been captured by the MARMAP program at depths ranging from 75 to 174 ft and have been observed during submersible dives off South Carolina at depths of 171 ft. Hogfish primarily eat mollusks, but also feed on crabs and sea urchins.

Maximum reported size is 36 inches in length (male) and 22 lbs. Maximum reported age in the eastern Gulf of Mexico is 23 years and 13 years in the Florida Keys. Hogfish are protogynous. Spawning aggregations have been documented to occur in water deeper than 52 ft off La Parguera, Puerto Rico from December through April. It is reported that Hogfish spawn off Cuba during May through July. Peak spawning of Hogfish off Puerto Rico is during December through April. Off the Florida Keys, spawning occurs from September to April with a February and March peak. Off of the southern coast of NC, spawning occurs from April through July.

Hogfish in the Atlantic waters off the southeastern U.S. are managed by the South Atlantic Fishery Management Council in the Snapper Grouper FPM. They are primarily taken by spear and hook and line gear.

Spadefishes

Atlantic Spadefish

Chaetodipterus faber. Atlantic Spadefish, angelfish

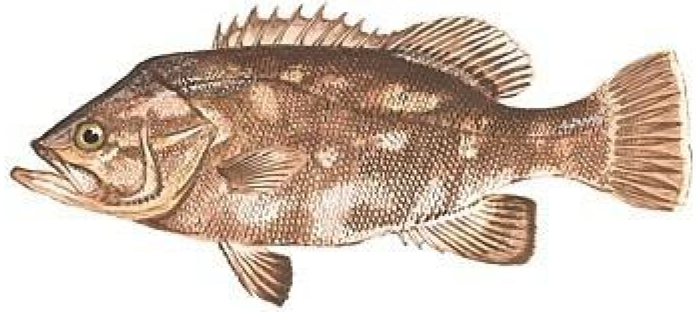
The Atlantic Spadefish is characterized by a deep and compressed body, extended dorsal and anal fin rays, and dark vertical bars on a light silvery background (bars may fade in large individuals). Its mouth is small and provided with bands of brush-like teeth. Young are entirely dark brown or blackish with white mottling.

Atlantic Spadefish are found from Massachusetts to southeastern Brazil, including the Gulf of Mexico. They have been Introduced to Bermuda. They inhabit a variety of different habitats in coastal waters (10 to 115 ft), including reefs, mangroves, sandy beaches, estuaries, around wrecks and pilings, and under bridges. They are often seen in large schools of hundreds of similarly-sized individuals. Juveniles are apt to be encountered around mangroves and in estuaries in their dark coloration with white mottling. Atlantic Spadefish feeds on a variety of invertebrates, both benthic and planktonic, as well as algae.

Maximum reported length is 39 inches, but they are commonly half that size. They live to be at least 8 years old off South Carolina. The sexes are separate and 64% of age 0 males are sexually mature and all males age 1 and older are mature. All age 0 females are immature, while all females age 1 and older are mature. Atlantic Spadefish are in spawning condition off South Carolina during May-September with peak spawning occurring during May. Adults readily take a baited hook and have a firm, well-flavored flesh. There is no extensive fishery for them. They are managed in the South Atlantic Fishery Marine Council Snapper Grouper management unit and are included in the recreational aggregate bag limit (no size or season limit); there are no commercial catch limits, although the species is managed with gear restrictions, a limited access permit requirement, and an annual catch limit that is set by NMFS.

Wreckfishes

Wreckfish



Polyprion americanus - Wreckfish

Wreckfish are a commercially-important, deepwater, demersal fish, occurring on both sides of the Atlantic Ocean. They are bluish grey on the back and paler with a silvery sheen on the belly. Their fins are blackish brown. Juveniles have black blotches on their head and body. Wreckfish have a relatively big head with a big mouth and a rough bony ridge across the upper part of the gill cover. Juveniles have black blotches on their head and body.

Wreckfish can be found in the eastern Atlantic from Norway to South Africa, including the Mediterranean, Canary Islands, Azores, Bermuda, and Madeira, and in the western Atlantic from Grand Banks, Newfoundland, to La Plata River, Argentina. Adult Wreckfish are found from depths of 130 to 2,625 ft, but most occur in waters deeper than 1,000 ft, with a maximum reported depth of 3,284 ft. At these depths, adult Wreckfish concentrate around steep, rocky bottoms and deep coral reefs, but they can be found in lower concentrations along flat, hard- bottom. Juveniles up to 24 inches in length are pelagic and are widely dispersed and are common in the surface waters of the eastern North Atlantic, but rare in the western North Atlantic. It mostly feeds on fishes and squids.

Wreckfish reach a maximum age of 80 years and maximum size of 6 ft. Juvenile pelagic phases grow quickly, but the adults are slow-growing. Females grow larger than males.

Wreckfish are gonochorists that mature at age 7 years and 31 inches in length. Spawning has been documented off of South Carolina and Georgia, but may be more widespread. Spawning season is December to April.

In Atlantic waters off the southeastern U.S., Wreckfish is managed by the South Atlantic Fishery Management Council under the Snapper Grouper FMP. Until the mid-1980s, Wreckfish were unexploited commercially in the western North Atlantic. The resource was discovered by pelagic longliners along the Charleston Bump on coral pinnacles. Currently, they are mostly caught by commercial fishers in deep waters (>1,000 ft) using a specialized modified snapper reel. It is managed under an individual transferable quota system, so there are no size or trip limit requirements, though there are gear and annual catch limit restrictions, with commercial and recreational allocations.

Coastal Migratory Pelagics

King Mackerel

Scomberomous cavalla - King Mackerel

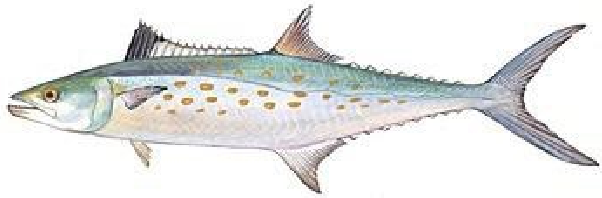
King Mackerel, (*Scomberomous cavalla*), is a coastal pelagic species that is found throughout the Gulf of Mexico and Caribbean Sea and along the western Atlantic from the Gulf of Maine to Brazil and from the shore to 2,000 ft depths. King mackerel have a streamlined body with tapered head, iridescent bluish green or iron-gray back, silvery sides and ventral surface, and pale to dusky fins. It is distinguished from Spanish mackerel by the lateral line, which dips sharply in Spanish mackerel. In addition, the anterior dorsal fin on a Spanish mackerel is gray in coloration.

Adult King Mackerel are known to spawn in areas of low turbidity, with salinity and temperatures of approximately 30 ppt and 80°F, respectively. There are major spawning areas off Louisiana and Texas in the Gulf; and off the Carolinas, Cape Canaveral, and Miami in the western Atlantic. Spawning occurs generally from May through October with peak spawning in September. Eggs are believed to be released and fertilized continuously during these months, with a peak between late May and early July with another between late July and early August.

King mackerel mature at approximately age 2 to 3 and have longevities of 24 to 26 years for females and 23 years for males. Maturity may first occur when the females are 18 to 20 inches in length and usually occurs by the time they are 35.4 inches in length. Stage five ovaries, which are the most mature, are found in females by about age 4 years. Males are usually sexually mature at age 3, at a length of 28 inches. Females in U.S. waters, between the sizes of 18 to 59 inches released 69,000-12,200,000 eggs. Because both the Atlantic and Gulf populations spawn while in the northernmost parts of their ranges, there is some thought that they are reproductively isolated groups.

Larvae of the king mackerel have been found in waters with temperatures between 79- 88°F. This stage of development does not last very long. Larvae of the king mackerel can grow as quickly as 0.02 to 0.05 inches per day. This shortened larval stage decreases the vulnerability of the larva, and is related to the increased metabolism of this fast-swimming species. Juveniles are generally found closer to shore at inshore to mid-shelf depths (to < 29 feet) and occasionally in estuaries. Adults are migratory, and the Coastal Migratory Pelagics FMP recognizes two migratory groups (Gulf and Atlantic). Typically, adult king mackerel are found in the southern climates (south Florida and extreme south Texas/Mexico) in the winter and in the northern Gulf in the summer. Food availability and water temperature are likely causes of these migratory patterns. Like other members of this genus, king mackerel feed primarily on fishes. They prefer to feed on schooling fish, but also eat crustaceans and occasionally mollusks. Some of the fish they eat include jack mackerels, snappers, grunts, and halfbeaks. King Mackerel are managed by the South Atlantic Fishery Management Council in Atlantic waters from the Florida Keys to Maine. They are primarily taken with hook and line.

Spanish Mackerel



Scomberomorus maculatus - Spanish Mackerel

Spanish Mackerel, (*Scomberomorus maculatus)* is a coastal pelagic species, occurring over depths to 246 ft throughout the coastal zones of the western Atlantic from southern New England to the Florida Keys and throughout the Gulf of Mexico. Spanish Mackerel are greenish dorsally with silver sides and belly. Yellow or olive oval spots traverse the body, which is covered with very tiny scales. The lateral line curves gently to base of tail, which distinguishes it from king mackerel. The Spanish Mackerel is much smaller than King Mackerel, averaging only 2 to 3 pounds in weight.

Adults Spanish Mackerel usually are found in neritic waters (area of ocean from the low- tide line to the edge of the continental shelf) and along coastal areas. They inhabit estuarine areas, especially the higher salinity areas, during seasonal migrations, but are considered rare and infrequent in many Gulf estuaries.

Spanish Mackerel generally mature at age 1 to 2 and have a maximum age of approximately 11 years. The size at 50% maturity is approximately 12 to 13 inches and 0.70 years. The size at 50% maturity for males is 8 to 9 inches. Spawning occurs along the inner continental shelf from April to September. Eggs and larvae occur most frequently offshore over the inner continental shelf at temperatures between 68°F to 90°F and salinities between 28 and 37 ppt. They are also most frequently found in water depths from 30 to about 275 ft, but are most common in depths less than 164 ft.

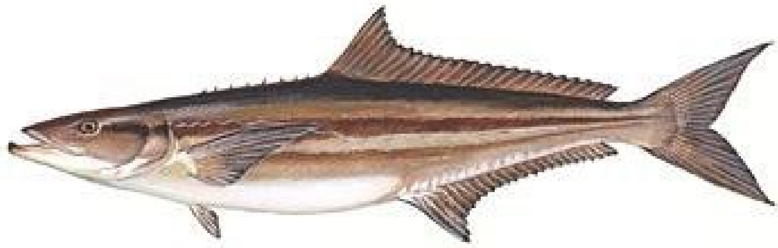
Juveniles are most often found in coastal and estuarine habitats and at temperatures >77°F and salinities >10 ppt. Although they occur in waters of varying salinity, juveniles appear to prefer marine salinity levels and generally are not considered estuarine dependent. Like King Mackerel, adult Spanish Mackerel are migratory, generally moving from wintering areas of south Florida and Mexico to more northern latitudes in spring and summer.

Like King Mackerel, Spanish Mackerel primarily eat other fish species (herring, sardines, and menhaden) and to a lesser extent crustaceans and squid at all life stages (larvae to adult).

They are eaten primarily by larger pelagic predators like sharks, tunas, and bottlenose dolphin. Spanish Mackerel are managed by the South Atlantic Fishery Management Council in Atlantic waters from the Florida Keys to Maine. They are primarily taken with hook and line.

Cobia

Rachycentron canadum - Cobia



Cobia is a large, fast growing pelagic species. The body is dark brown to silver, paler on the sides and grayish white to silvery below, with two narrow dark bands extending from the snout to base of caudal fin. Young cobia have pronounced dark lateral bands, which tend to become obscured in the adult fish. Most fins are deep brown, with gray markings on the anal and pelvic fins. The body is elongate and torpedo-shaped with a long, depressed head. The eyes are small and the snout is broad. The lower jaw projects past the upper jaw. The skin looks smooth with very small embedded scales.

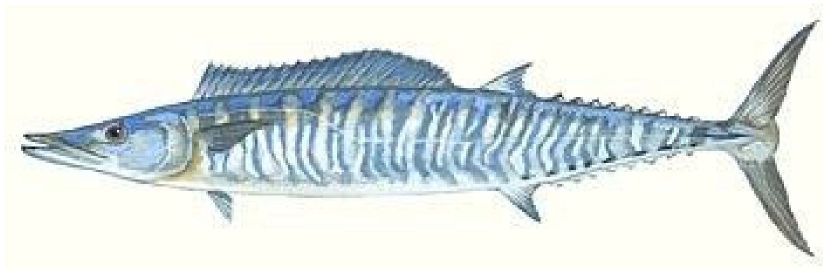
Cobia are distributed worldwide in tropical and subtropical waters, except for the eastern Pacific. They prefer water temperatures between 68° to 86°F and are abundant in the warm coastal waters of the U.S. from the Chesapeake Bay south and throughout the Gulf of Mexico.

Cobia are often found in harbors, estuaries, nearshore around wrecks and reefs and offshore along the continental shelf. Cobia are opportunistic feeders, their diet includes crustaceans, cephalopods, and fish. They have been seen in shallow coastal waters in schools of up to 100 fish. Additionally, cobia are known to follow larger sharks, rays, and turtles, taking advantage of prey items lost during their feeding activity.

Cobia grow quickly and can reach a maximum age of 14, reaching a length of 80 inches, and weighing 135 lbs. Females reach sexual maturity at 3 years while males mature at 2 years. Spawning occurs May through August in Atlantic waters off the southeastern U.S. and the spawning frequency is approximately once every 4 to 12 days and can occur as many as 15 to 36 times during the season. Inshore spawning of Cobia has been documented in some regions along Atlantic waters off the southeastern U.S. In the Western Central Atlantic, the Cobia population is divided into 2 regional stocks (Gulf and Atlantic). Mixing of the two stocks has been documented through tagging studies, and early genetic studies indicated that the 2 stocks were genetically similar . The Gulf of Mexico stock extends around the tip of Florida up to Brevard County, where some degree of overlap occurs with the Atlantic stock. The Atlantic stock ranges from the GA/FL border through New York. Currently, there is not enough resolution in the genetic or tagging studies to indicate exactly where the 2 stocks split. Genetic analysis indicates a mixing zone occurs somewhere to the north of the Brevard County Line . Due to the uncertainty regarding the boundaries of the mixing zone, it was decided for management purposes, that the stocks would be separated at the FL/GA line.

In the Atlantic waters off the southeastern U.S. Cobia is managed under the Coastal Migratory Pelagics FMP. It is mostly caught by recreational fishers using hook and line gear.

Wahoo



Acanthocybium solandri - Wahoo

Wahoo is a steel blue fish above and pale blue below. The body is slender and the elongate jaws form a pointed beak. It has a series of 25 to 30 irregular blackish-blue vertical bars on the sides. A distinguishing characteristic is that protrusions on the gills (gill rakers) are absent.

Wahoo is an oceanic pelagic fish found worldwide in tropical and subtropical waters. In the western Atlantic wahoo are found from New York through Colombia including Bermuda, the Bahamas, the Gulf of Mexico, and the Caribbean. Wahoo are present throughout the Caribbean area, especially along the north coast of western Cuba where it is abundant during the winter.

There is pronounced seasonal variation in abundance. They are caught off North and South Carolina primarily during the spring and summer (April-June and July-September), off
Florida's east coast year-round, off Puerto Rico and the U.S. Virgin Islands year-round with peak catches between September and March, in the Gulf of Mexico year-round, in the eastern Caribbean between December and June, and in Bermuda between April and September. Adult Wahoo in the Atlantic are pelagic in nature and generally associated with Sargassum. It is assumed that juveniles inhabit waters with temperatures of 72° to 86° F and are associated with Sargassum. Juvenile Wahoo are reported to travel in small schools.

Wahoo are short-lived fish (5 years) and grow rapidly, reaching lengths of up to 60.1 inches and weights of up to 45 pounds. Both sexes are capable of reproducing during the first year of life, with males maturing at 34 inches and females at 40 inches. Spawning in the United States takes place from June to August. Wahoo are voracious predators that feed primarily on fishes such as mackerels, butterfishes, porcupine fishes, round herrings, scads, jacks, pompanos, and flying fishes.

Wahoo are managed by the South Atlantic Fishery Management Council in the Atlantic waters from the Florida Keys to New York. They are primarily taken by trolling with hook and line gear.

Dolphin

Coryphaena hippurus - Dolphin, Dolphinfish, Mahi Mahi.

Dolphin has bright turquoise, green and yellow patterns, which fade almost immediately upon death. This species may be distinguished from the pompano dolphin by its 55-66 dorsal fin rays, and a very wide and square tooth patch on the tongue. The body tapers sharply from head to tail; irregular blue or golden blotches scattered over sides; anterior profile of head on adult males is nearly vertical; head of females more sloping; the single dark dorsal fin extends from just behind the head to the tail; anal fin margin concave and extending to tail.

Dolphin is an oceanic pelagic fish found worldwide in tropical and subtropical waters.

The range for dolphin in the western Atlantic is from Georges Bank, Nova Scotia to Rio de Janeiro, Brazil. They are also found seasonally throughout the Caribbean Sea and the Gulf of Mexico, and they are generally restricted to waters warmer than 68°F. There is pronounced seasonal variation in abundance. Dolphin are caught off North and South Carolina from May through July. Dolphin off Florida's East Coast are caught mainly between April and June.

February and March are the peak months off Puerto Rico's coast. Dolphin are caught in the Gulf of Mexico from April to September with peak catches in May through August. e pelagic often associated with structure such as Sargassum. Dolphin are fast growing, prolific and have a short lifespan (< 5 years). Average fork lengths for males and females ranges from 34 to 55 inches.

Males grow faster and usually live longer than females. Dolphin are batch spawners and have a protracted spawning season. The spawning season varies with latitude. Dolphin collected in the Florida Current spawned from November through July, and those collected from the Gulf Stream near North Carolina were reproductively active during June and July. Evidence for a continuous spawning season is attributed to the presence of several size classes of eggs found in the ovaries. Size at first maturity ranges from 14 inches in length in Florida to 21 inches in length (Gulf of Mexico) for sexes combined. Males first mature at a larger size than females. Females size at full maturity ranges from 20 inches in Florida, to 24 inches in Puerto Rico.

They eat a wide variety of fish species including: small oceanic pelagic species (e.g., Flying Fish, Halfbeaks, Man-o-war Fish, Sargassum Fish, and Rough Triggerfish); juveniles of large oceanic pelagic species (e.g., tunas, billfish, jacks, and dolphin); and pelagic larvae of neritic, benthic species (e.g., Flying Gurnards, triggerfish, pufferfish, and grunts). They also eat invertebrates (e.g., cephalopods, mysids, and scyphozoans) suggesting that they are essentially non-selective, opportunistic foragers. Dolphin are managed by the South Atlantic Council Atlantic waters from the Florida Keys to New York. They are primarily taken with hook and line, and longline gear.

Pompano Dolphin

Corypheana equiselis - Pompano Dolphin

Pompano Dolphin (*Coryphaena equiselis*), have been recorded off North Carolina, Florida, Bermuda, and in the central Atlantic, Gulf of Mexico, and Caribbean including off Puerto Rico. It is considered to be more of an open ocean species than the larger common Dolphin (*Coryphaena hippurus*), with Pompano Dolphin being found in water temperatures that exceed 75˚F. Pompano Dolphin have been shown to be common in the waters around Bermuda.

The species appears to be more abundant in the Florida Straits than anywhere else in United States territorial waters. Fishermen in the Florida Straits have documented pompano dolphin occurring in the same school with common Dolphin. The Pompano Dolphin's body coloration tends to be more silver and blue but can exhibit a somewhat muted green-yellow color pattern. Greatest body depth of Pompano Dolphin occurs just behind the head; whereas, greatest body depth of common Dolphin is mid-body. Pompano Dolphin has 55 to 65 dorsal rays compared to 48 to 55 dorsal rays for Dolphin. The pectoral fin of Pompano Dolphin is more than half the head length compared to being less than half the head length in Dolphin.

The Pompano Dolphin is small seldom reaching 30 inches and 9 lbs. in weight while the common Dolphin can reach lengths in excess of 60 inches and weights of 80 lbs. Little is known about the life history of Pompano Dolphin; however ripe Pompano Dolphin have been collected in the Atlantic at 8 inches SL.

The South Atlantic Fishery Management Council manages Pompano Dolphin from the east coast of Florida to Maine in the Dolphin Wahoo FMP. The Dolphin-Wahoo FMP refers to the common Dolphin (*Coryphaena hippurus*) and Pompano Dolphin (*Coryphaena equiselis*) as "dolphin." There are not separate management measures for the two species. Annual catch limits, minimum size limits, bag limits, and apply to both dolphin species.

Shrimp

The shrimp fishery in the South Atlantic includes six species: Brown Shrimp (*Farfantepeneaus aztecus*), Pink Shrimp (*Farfantepenaeus duorarum*), White Shrimp (*Litopenaeus setiferus*), Seabob Shrimp (*Xiphopenaeus kroyeri*), Rock Shrimp (*Sicyonia brevirostris*), and Royal Red Shrimp (*Pleoticus robustus*). The shrimp species in the Atlantic waters off the southeastern U.S. occupy similar habitats with the greatest differences being in optimal substrate and salinity.

The penaeid shrimps (White, Brown, and Pink) can be identified by examining the groove along either side of the rostrum. The groove extends less than half the length of the carapace in White Shrimp, and the entire length in Browns and Pinks. Pink Shrimp can be discerned from Browns by a light purplish-blue tail and usually a dark red spot on the side of the abdomen. Both Brown and Pink Shrimp have a groove on the top of the next to last tail segment: this grove is nearly closed in Pink Shrimp. Seabob Shrimp can be identified by the lack of spines, or teeth, on the lower side of the rostrum which is long and recurved. Males can be identified in all species by the presence of a petasma (male reproductive organ) clearly recognizable between the first set of walking legs on the abdomen.

Juvenile and adult penaeids are omnivores bottom feeders with food items consisting of polychaetes, amphipods, nematodes, caridean shrimps, mysids, copepods, isopods, amphipods, ostracods, mollusks, foraminiferans, chironomid larvae, and various types of organic debris.

Shrimp are preyed on by a wide variety of species at virtually all stages in their life history. Grass Shrimp, killifishes, and Blue Crab prey on young penaeid shrimp, and a wide variety of finfish are known to prey heavily on juvenile and adult penaeid shrimp.

White Shrimp

Litopenaeus setiferus – White Shrimp (Gray Shrimp, Lake Shrimp, Green Shrimp, Green-tailed Shrimp, Blue Tailed Shrimp, Rainbow Shrimp, Daytona Shrimp, Common Shrimp, and Southern Shrimp).

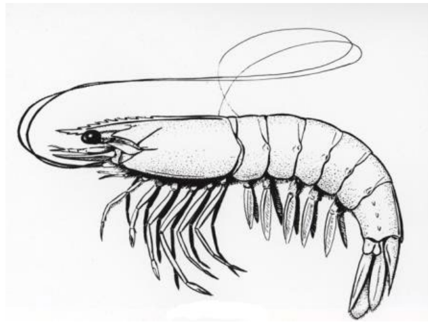
White Shrimp range from Fire Island, New York to St. Lucie Inlet on the Atlantic Coast of Florida. Along the Atlantic Coast of the U.S., the White Shrimp has centers of abundance in South Carolina, Georgia, and northeast Florida. White Shrimp are generally found on muddy bottoms concentrated in waters < 89 feet (27 meters). White Shrimp are more active during daylight hours.

All penaeid shrimp undergo 11 larval stages in coastal waters with the period for White Shrimp being 10 to 12 days. The mechanism for larval recruitment to the estuaries is not fully understood, but most likely involves nearshore tidal currents as early as April to July. Juveniles are typically found in small creeks of the estuaries with growth rates of up to 0.09 inches per day (South Atlantic Fishery Management Council 1996b). Sub-adults migrate to the sounds, with an offshore migration of mature adults (> 4.7 inches, 120 millimeters) typically occurring between April and June, with spawning occurring within a few miles of the coast at temperatures above 72ºF.

All penaeid shrimp have an annual life cycle. Their abundance is driven primarily by environmental conditions (water temperature) and can fluctuate seasonal. White Shrimp is the largest shrimp fishery in Atlantic waters off the southeastern U.S., with a roe season in the spring, the bulk of the harvest in the fall, and an overwintering fishery (usually in federal waters > 3nm). It is managed under the South Atlantic Fishery Management Council's Shrimp FMP as an annual crop. As such standard procedures to establish an overfishing threshold are difficult. Instead, the Council establishes targets and thresholds based on annual landings and CPUE data from the Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) to indicate relative abundance (health) of the stock.

Vulnerabilities and sources of mortality include predation, decline in estuarine water quality, environmental conditions (winter freeze kills, coastal flooding, etc.), and disease (black gill).

Brown Shrimp



*Farfantepeneaus aztecus – Brown Shrimp (B*rownie, Green Lake Shrimp, Red Shrimp, Redtail Shrimp, Golden Shrimp, Native Shrimp, and also the Summer Shrimp in North Carolina).

Brown Shrimp occur on the Atlantic Coast from Martha's Vineyard, Massachusetts to the Florida Keys. Breeding populations apparently do not range north of North Carolina. The species may occur in commercial quantities in waters as deep as 361 feet (110 meters), but they are most abundant in water less than 180 feet (55 meters), in areas of mud, sand, and shell bottom.

Brown Shrimp burrow into the sediment and are most active at night.

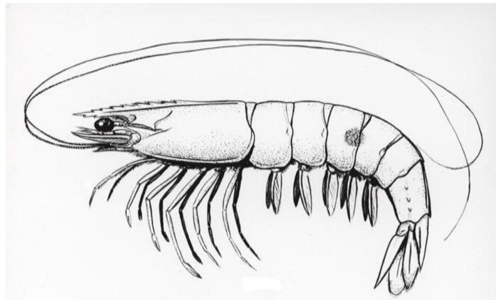
All penaeid shrimp undergo 11 larval stages in coastal waters with the period for Brown Shrimp being 11 to 17 days. Post larvae overwintering in offshore bottom sediments. The mechanism for larval recruitment to the estuaries is not fully understood with an influx of post larvae reported during February and March. Juveniles are typically found in small creeks of the estuaries with growth rates of up to 0.098 inches (2.5 millimeters) per day. Sub-adults migrate to the sounds, with an offshore migration of mature adults (> 5.5 inches, 140 millimeters) being reported off South Carolina during October and November. The precise spawning area is uncertain but believed to be further offshore (> 9nm).

All penaeid shrimp have an annual life cycle. Brown Shrimp is driven primarily by environmental conditions (water temperature and salinity) and can fluctuate seasonal. Brown Shrimp are primarily a summer (June to August) fishery in Atlantic waters off the southeastern U.S.. It is managed under the South Atlantic Fishery Management Council's Shrimp FMP as an annual crop. As such standard procedures to establish an overfishing threshold are difficult.

Instead, the Council establishes targets and thresholds based on annual landings and CPUE data from the Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) to indicate relative abundance (health) of the stock.

Vulnerabilities and sources of mortality include predation, decline in estuarine water quality, environmental conditions (coastal flooding), and disease (black gill).

Pink Shrimp



*Farfantepenaeus duorarum – Pink Shrimp (*Spotted Shrimp, Hopper, Pink Spotted Shrimp, Brown Spotted Shrimp, Grooved Shrimp, Green Shrimp, Pink Night Shrimp, Red Shrimp, Skipper, and Pushed Shrimp).

Along the Atlantic waters off the southeastern U.S., Pink Shrimp occur from southern Chesapeake Bay to the Florida Keys but are most common in Florida and North Carolina. Pink shrimp are most abundant in waters of 36 to 121 feet. They are common in the estuaries surrounding southern Florida and into deep water (approximately 328 ft) southeast of the Keys, and are the dominant species within the Dry Tortugas shrimping grounds and Florida Bay. Pink Shrimp prefer hard sand and calcareous shell bottom (Williams 1955, 1984). They burrow into the sediment by day and are most active at night.

All penaeid shrimp undergo 11 larval stages in coastal waters with the period for Pink Shrimp being 15 to 25 days. The larval transport mechanism for Pink Shrimp larvae to enter the estuaries is not well known but shoreward counter currents and favorable winds may enhance movement to the northeast Florida coast . Florida Pink Shrimp typically leave the estuaries two to six months after recruitment. Growth varies by region and season with a range of 0.010 to
0.067 inches per day (0.25 to 1.7 millimeters) . In Florida, shrimp growth faster in the winter than in the spring, while North Carolina growth rates peak during the summer. Offshore migration of mature adults (> 3.35 inches, 85 millimeters) occurs in April and May, and again during October and November in Florida, while small Pink Shrimp first occur in North Carolina commercial catches in August.

All penaeid shrimp have an annual life cycle. Their abundance is driven primarily by environmental conditions (water temperature) and can fluctuate seasonal. Pink Shrimp harvest occurs nearly exclusively in Florida - 67% and North Carolina - 33%. The fishery is managed under the South Atlantic Fishery Management Council's Shrimp FMP as an annual crop. As such standard procedures to establish an overfishing threshold are difficult. Instead, the Council establishes targets and thresholds based on annual landings and CPUE data from the Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) to indicate relative abundance (health) of the stock.

Vulnerabilities and sources of mortality include predation, decline in estuarine water quality, environmental conditions (cold water kills).

Sea Bob Shrimp

Xiphopenaeus kroyeri – Seabob Shrimp (Atlantic Seabob).

Seabob Shrimp range from North Carolina to Brazil, but it is not a common commercial species in the Atlantic waters off the southeastern U.S., with no reported landings the past ten years (2006 to 2015). Louisiana dominates the Gulf of Mexico commercial harvest with 90% of the report landing the past ten years. Seabobs inhabit offshore waters up to 230 ft, but are most common in depth less than 89 ft over mud or sand bottom across a large salinity gradient.
Abundance is highest from October to December in the Gulf.

All penaeid shrimp undergo 11 larval stages. Seabob shrimp are not estuarine dependent, spending their entire life in a narrow area along the coastline. Little is known of their life history but is it believed they can grow to 5.51 inches (140 millimeters) and ripe females have been found in Louisiana waters in July and August at 2.48 inches (63 millimeters).

Rock Shrimp

Sicyonia brevirostris – Rock Shrimp (Brown Rock Shrimp, Atlantic Rock Shrimp).

Rock Shrimp are very different in appearance from U.S. South Atlantic penaeid species. Their exoskeleton is thick, rigid, and stony, covered with short hair. The abdomen has deep transverse grooves and numerous tubercles.

Rock Shrimp are found in the Gulf of Mexico, Cuba, the Bahamas, and the Atlantic waters off the southeastern U.S. to Virginia. The center of abundance and the concentrated commercial fishery for Rock Shrimp in the south Atlantic region occurs off northeast Florida south to Jupiter Inlet. Their habitat is limited, usually associated with terrigenous and biogenic sand substrates and only sporadically on mud. Rock Shrimp also utilize hard-bottom and coral, more specifically Oculina, habitat areas. The largest concentrations are found between 82 to 213 feet (25 - 65 meters) but have been found to depths of 656 feet (200 meters).

Female Rock Shrimp attain sexual maturity at about 0.669 inches (17 millimeters) carapace length (CL), and all males are mature by 0.945 inches CL (24 millimeter). The spawning season for Rock Shrimp is variable with a peak beginning between November and January and lasting 3 months. Individual females may spawn three or more times in one season. The development from egg to postlarvae takes approximately one month, with subsequent development to the smallest mode of recruits occurring in two to three months. The major larval transport mechanism is the shelf current systems near Cape Canaveral, Florida with recruitment to the offshore waters of Cape Canaveral between April and August.

Rates of growth in Rock Shrimp are variable and depend on factors such as season, water temperature, shrimp density, size, and sex. Rock Shrimp grow between 0.079 and 0.118 inches CL per month (2 to 3 millimeters) as juveniles and 0.020 - 0.024 inches CL per month as adults (0.5 - 0.6 millimeters).

Rock Shrimp are bottom feeders, most active at night, with a diet primarily of mollusks, crustaceans, and polychaete worms .

Although Rock Shrimp are also found off North Carolina, South Carolina, and Georgia and are occasionally landed in these states, no sustainable commercially harvestable quantities comparable to the fishery prosecuted in the EEZ off Florida are being exploited. Rock Shrimp are included in the fishery management unit (FMU) of the Shrimp FMP of the South Atlantic Region.

Vulnerabilities and sources of mortality include fishing mortality in combination with high natural mortality and possibly poor environmental conditions.

Royal Red Shrimp

Pleoticus robustus – Royal Red Shrimp

Royal Red Shrimp are characterized by a body covered with short hair and a rostrum with the ventral margin toothless. A post-orbital spine is evident on the side of the carapace. Color can range from orange to milky white.

Royal Red Shrimp are found on the continental slope throughout the Gulf of Mexico and South Atlantic area from Cape Cod to French Guiana. In the Atlantic waters off the southeastern U.S. they are found in large concentrations primarily off northeast Florida. They inhabit the upper regions of the continental slope from 591 to 2395 ft, but concentrations are usually found at depths > 820 feet.

Males mature at 5 inches (127 millimeters) in length, while females mature at 7 inches (178 millimeters) in length. Spawning peaks off the east coast of Florida during winter and spring, although some spawning occurs throughout the year. Larval development of this species is unknown, but research suggests recruitment to the fishery at age two and they may live up to five years. Little is known on their growth rates and habitat preferences other than depth as described above.

The South Atlantic commercially fishery is almost exclusively in the EEZ off Florida with harvest averaging just over 100,000 lbs. the past ten years (2006 - 2015). Overfishing has been a concern given the long-lived nature of the species. Royal Red Shrimp are not included in the Fishery Management Unit for the Shrimp FMP of the South Atlantic because no management measures were being proposed for the species when the FMP was developed.

Vulnerabilities and sources of mortality include fishing mortality and loss of habitat.

Golden Crab

Chaceon fenneri - Golden Crab

The golden crab is a large gold or buff colored species with a hexagonal carapace. The carapace has five anterolateral teeth on each side, large well-developed frontal teeth, and shallow, rounded orbits. The chelipeds (claws) are unequal and the dactyli of the walking legs are laterally compressed.

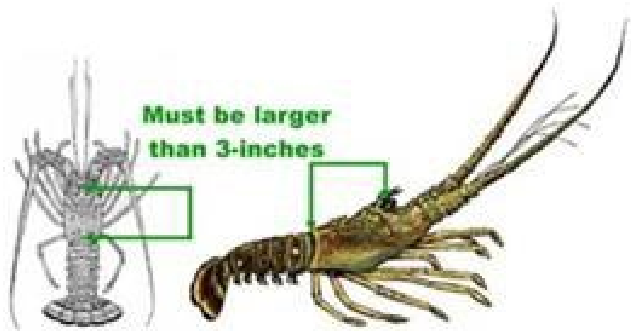
Golden crab inhabit the continental slope of Bermuda and the southeastern United States from the Chesapeake Bay through the Straits of Florida and into the eastern Gulf of Mexico. It is a deep water species reported from depths from 200 to 1000 meters. Maximum abundances occurs between 350 and 550 meters off the southeastern U.S. in areas with a bottom of silt-clay and foraminiferan shell. Feeding habits are poorly known, but they are assumed to be opportunistically scavengers, feeding on dead carcasses from the water column.

Males can grow larger than female and can measure a maximum of 6 inches in carapace length (CL), while the females can measure a maximum of 5 inches CL. Egg carrying females have been reported during September, October and November. They usually release larvae in depths less than 500 m from February to March. Females may undergo long-distance movements during their lifetimes.

Golden Crab is managed by the South Atlantic Fishery Management Council in the Golden Crab FMP. It is mostly caught by the commercial sector using crab traps. Given the deep water habitat in which the Golden Crabs occur, the primary non-fisheries threat may come from threats to these offshore areas such as disposal of materials and potential oil and other exploitation.

Lobsters

Spiny Lobster



Panulirus argus - Caribbean Spiny Lobster (crayfish, crawfish, langosta, and Florida lobster)

Caribbean Spiny Lobsters are by far the most abundant lobster off of the Atlantic waters off the southeast U.S. They vary from whitish to a dark red-orange. The two large, cream- colored spots on the top of the second segment of the tail. There are also two smaller cream- colored spots adjacent to the tail fan. Spiny lobsters lack the large, distinctive, crushing claws of their northern cousins, the American Lobster.

Caribbean Spiny Lobster occurs throughout the Caribbean Sea, along the shelf waters of the southeastern United States north to North Carolina, in Bermuda, and south to Brazil and the Gulf of Mexico. The origins of the Florida stock remain unknown as information on larval recruitment remains scarce. However, given the constant recruitment to the fishery despite the reduction in spawning potential of the Florida stock, recruitment is probably in large part exogenous. Caribbean Spiny Lobster is a highly migratory species with a complex life cycle in which distinctly different habitat types are occupied during ontogeny. There are both oceanic and inshore stages with preferential environments including open ocean during planktonic stages, stages utilizing dense vegetation such as seagrass meadows as juveniles, and crevice shelters provided by live and hard-bottom habitat as larger juveniles and adults . Large juvenile and adult lobsters are very mobile and capable of moving several miles during nocturnal foraging. They are nocturnal feeders and predominantly prey upon live mollusks and crustacea, including hermit crabs and conch.

Mating and spawning of eggs in Caribbean spiny lobster can occur throughout the range of mature adults. Spiny Lobster releases eggs principally from April through September. Mating and spawning behavior appear, in part, controlled by environmental factors, including day length and water temperatures. The onset of population-wide reproductive maturation of female lobsters occurs at about 3 inches carapace length (CL), though females as small as 2 inches. CL have been observed bearing eggs, with larger females spawning earlier in the reproductive season than smaller females. The onset of population-wide functional maturity in males has been estimated to occur at 4 inches CL. Growth rates are fastest at smallest sizes and decrease dramatically as lobsters attain sexual maturity.

In the Atlantic waters off the southeast U.S., Caribbean Spiny Lobster is managed by the South Atlantic Fishery Management Council and is subject to size and bag limits, gear restrictions, and fishing seasons. They are caught by both commercial and recreational fishers, with traps being the most commonly used gear along with diver harvest.

Coral

Corals are an important habitat for many species managed by the South Atlantic Fishery Management Council and are defined as essential fish habitat. Coral species in Atlantic waters off the southeast United States include but are not limited to fire coral and hydrocorals (Class Hydrozoa), stony corals (Order Scleractinai), black corals (Order Antipatharia), and octocoral (Subclass Octocorallia). Shallow-water corals are found typically in depths less than 160 ft and deep-water corals are defined as those found in depths greater than 160 ft. The shallow-water corals use symbiotic algae as an energy and nutrient source. The deep-water corals lack symbiotic algae and must extract nutrients and food from the water column. In addition to depth stratification, corals can be either reef forming (hermatypic) or non-reef forming (ahermatypic). Shallow-water hermatypic species typically are found south of St. Lucie Inlet but can be found as far north as St. John's Inlet. Deep-water hermatypic species can be found throughout the Atlantic waters off the southeast United States and Coral Habitat Areas of Particular Concern have been established to protect habitats for *Oculina varicosa* and *Lophelia pertusa*, two common hermatypic species.

Sargassum

Sargassum natans and *S. fluitans* - Pelagic brown algae

The pelagic species are golden to brownish in color and typically 8 to 31 in diameter.
Perhaps the most conspicuous features are the pneumatocysts. These small vesicles function as floats and keep the plants positively buoyant.

Most pelagic Sargassum circulates between 20°N and 40°N latitudes and 30°W longitude and the western edge of the Florida Current/Gulf Stream. The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea. Pelagic Sargassum contributes a small fraction to total primary production in the North Atlantic. However, within the oligotrophic waters of the Sargasso Sea it may constitute as much as 60% of total production in the upper meter of the water column. Large quantities of Sargassum frequently occur on the continental shelf off the southeastern United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore. Langmuir circulations, internal waves, and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows collectively termed "windrows". The algae sink in these convergence zones when downwelling velocities are high.

If buoyancy is lost, plants slowly sink to the sea floor and can reach 16,000 ft in about 2 days. Such sinking events contribute to the flux of carbon and other nutrients from the surface to the benthos.

Both species are sterile and propagation is by vegetative fragmentation and exhibit complex branching, lush foliage to linear serrate phyllodes and numerous berry-like pneumatocysts. Sargassum is concentrated as small patches, large rafts, or weed lines at the convergence of water masses in the coastal ocean, such as those found along tide lines near coastal inlets. The greatest concentrations of Sargassum patches are found in the Sargasso Sea and on the outer continental shelf of the South Atlantic, although they can be pushed into nearshore waters by winds and currents. Large pelagic adult fish such as dolphin and sailfish feed on the small prey in and around Sargassum. This behavior prompts sport fishermen to target Sargassum patches.

Pelagic brown algae form a dynamic structural habitat in the South Atlantic Region. Sargassum natans is much more abundant than S. fluitans, comprising up to 90% of the total drift macroalgae in the Sargasso Sea. Pelagic Sargassum supports a diverse assemblage of marine organisms including fungi, micro-and macro-epiphytes, at least 145 species of invertebrates over 100 species of fishes, four species of sea turtles, and numerous marine birds. Many of the organisms most closely associated with Sargassum have evolved adaptive coloration or mimic the algae in appearance.

In the Atlantic waters off the southeastern U.S., Pelagic Sargassum Habitat is managed by the South Atlantic Fishery Management Council under the Pelagic Sargassum FMP.

Other Managed Species in the Region

ASMFC (https://asmfc.org/habitat/program-overview)

MAFMC (https://www.mafmc.org/habitat)

NEFMC (https://www.nefmc.org/)

NMFS HMS (https://www.fisheries.noaa.gov/highly-migratory-species#by-species)

NMFS Protected Resources (https://www.fisheries.noaa.gov/about/office-protected-resources)

Section 4 Human Environment

Snapper Grouper Fishery –
Comprehensive Allowable Catch Limit Amendment for the South Atlantic Region
Regulatory Amendment 25 to the Fishery Management Plan for the Snapper Grouper Fishery of the South Atlantic Region
https://safmc.net/amendments/snapper-grouper-regulatory-amendment-25/

Coastal Migratory Pelagics Fishery -
King Mackerel Amendment 26 to the Fishery Management Plan for the Coastal Migratory Pelagics Fishery of the Gulf of Mexico and Atlantic Region
https://safmc.net/amendments/cmp-amendment-26/

Spanish Mackerel Framework Amendment 1 to the Fishery Management Plan for Coastal Migratory Pelagic Resources in the Gulf of Mexico and
South Atlantic Region
https://safmc.net/amendments/cmp-framework-amendment-1/

Cobia Framework Amendment 4 to the Fishery Management Plan for
Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region
https://safmc.net/amendments/cmp-framework-amendment-4/

Dolphin Wahoo Fishery - Regulatory Amendment 1 to the Fishery Management Plan for the Dolphin and Wahoo Fishery of the Atlantic
https://safmc.net/amendments/comprehensive-ecosystem-based-amendment-1/

South Atlantic Shrimp Fishery -
Penaeid Shrimp Fishery - Amendment 9 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region
https://safmc.net/amendments/shrimp-amendment-9/

Deepwater Shrimp Fishery - Amendment 8 to the Fishery Management Plan for Coral
https://safmc.net/amendments/comprehensive-dealer-reporting-amendment/

Golden Crab Fishery – Amendment 8 to the Fishery Management Plan for Coral
https://safmc.net/amendments/comprehensive-dealer-reporting-amendment/

Spiny Lobster Fishery - Final Amendment 11 to the Fishery Management Plan for Spiny Lobster in the Gulf of Mexico and South Atlantic Regions
https://safmc.net/amendments/spiny-lobster-amendment-11/

Fishing Communities Represented in FEP I - https://safmc.net/documents/combined-fep_toc-pdf/

Section 5 Essential Fish Habitat and Habitat Conservation

SAFMC EFH and EFH HAPC Designation Users Guide

Final November 2016 Revised August 2021

Purpose and Scope of this Guide

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) requires federal fishery management councils and NOAA's National Marine Fisheries Service (NMFS) to designate Essential Fish Habitat (EFH) for species managed under federal fishery management plans (FMPs). Federal regulations that implement the EFH program encourage fishery management councils and NMFS also to designate subsets of EFH as a way to highlight priority areas within EFH for conservation and management. These subsets of EFH are called EFH-Habitat Areas of Particular Concern (EFH-HAPCs or HAPCs) and are designated based on ecological importance, susceptibility to human-induced environmental degradation, susceptibility to stress from development, or rarity of the habitat type.

In 1998 through a single administrative action referred to as a "comprehensive amendment," the South Atlantic Fishery Management Council (SAFMC) amended nine FMPs under its jurisdiction or co-jurisdiction[1] to designate EFH (SAFMC 1998b). When SAFMC completed the FMP for dolphin and wahoo, EFH designations for those species were included in that FMP. In 2012, SAFMC used Comprehensive Ecosystem-Based Amendment 2 (CEBA-2) to designate new EFH-HAPCs for tilefish (managed under the FMP for the snapper/grouper complex), deepwater coral (managed under the FMP for coral, coral reef and live/hardbottom), and new EFH for the pelagic Sargassum (managed under the FMP for Sargassum). The supporting information for the initial EFH and HAPC designations is presented in a report commonly referred to by its abbreviated title *Habitat Plan for the South Atlantic Region* (SAFMC 1998a). Supporting information for designations made after 1998 appear in the respective FMP or in CEBA-2. More recently, *Fishery Ecosystem Plan of the South Atlantic Region* (SAFMC 2009) reviews and updates much of the supporting information[2].

[1] Red drum was managed by SAFMC at the time of these EFH designations. However, in 2008, management of Atlantic red drum was transferred from the Magnuson-Stevens Act to the Atlantic Coast Act, and with that transfer the EFH designations for red drum were no longer applicable; although NMFS may still use the Fish and Wildlife Coordination Act to comment on the affects of a project to Atlantic red drum.

[2] Specifically, Volume II of *Fishery Ecosystem Plan of the South Atlantic Region* (SAFMC 2009). This plan is available at *www.safmc.net/ecosystem/Home/EcosystemHome/tabid/435/Default.aspx.*

During development of the *Fishery Ecosystem Plan of the South Atlantic Region*, SAFMC's advisory panels and partners identified portions of EFH designations that were not clear and led to divergent EFH assessments. With one exception[3], while these differences did not significantly affect how SAFMC and the NMFS Southeast Regional Office, Habitat Conservation Division (SER HCD), evaluated impacts to EFH or developed EFH conservation recommendations, clarification would aid development of EFH assessments. For example, a more complete listing of state designated nursery habitats, which are an HAPC under three FMPs, would bring a sharper focus to EFH assessments.

This users guide provides the clarifications requested. As noted above, the information supporting the EFH designations appears in *Fishery Ecosystem Plan of the South Atlantic Region* (SAFMC 2009) and in individual FMPs. General information on the EFH provisions of the Magnuson-Stevens Act and its implementing regulations (50 CFR 900 Subparts J and K) can be found at *sero.nmfs.noaa.gov/hcd/efh.htm*; these sources should be reviewed for information on the components of EFH assessments, steps to EFH consultations, and other aspects of EFH program operation.

<u>Coral-HAPCs</u>: Please note that this users guide focuses on HAPCs designated under the EFH provisions of the Magnuson-Stevens Act. Under the FMP for Coral, Coral Reefs and Live/Hard Bottom Habitat, SAFMC can use its regulatory authority to designate coral-HAPCs to eliminate or reduce the impact of fishing on those habitats. By itself, the coral-HAPC designation carries no regulatory authority regarding impacts from non-fishing activities. In 1998, only one coral-HAPC existed, Oculina Bank, which SAFMC designated in 1984 and expanded in 2000 to include the Oculina Experimental Closed Area. The comprehensive amendment (SAFMC 1998b) designated each of these areas as EFH-HAPCs, which afforded them the protections from both designations. Similarly, in 2010, SAFMC designated five new coral-HAPCs (Cape Lookout Banks, Cape Fear Banks, Blake Ridge Diapir, Miami-Stetson Terrace, and Pourtales Terrace), and SAFMC added the EFH-HAPC designation to each of these areas in 2012 via CEBA-2. The only reason coral-HAPCs are discussed here is because some publicly available documents discuss non-fishing activities in coral-HAPCs, and these documents suggest coral-HAPCs are managed differently from EFH-HAPCs with respect to non-fishing activities that may impact the habitat. While that difference existed before CEBA-2 went into effect, that difference no longer exists.

[3] The exception is the HAPC designation for golden and blueline tilefish. These species managed within the fishery management plan for the snapper-grouper complex have a life history that differs markedly from other species within this complex.

Fishery Management Plan for the Shrimp Fishery

of the South Atlantic Region (1993)

EFH Designation Boundary

SAFMC's EFH designation for shrimp applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Penaeid Shrimp (SAFMC 1998b)

For penaeid shrimp, Essential Fish Habitat (EFH) includes inshore estuarine nursery areas, offshore marine habitats used for spawning and growth to maturity, and all interconnecting water bodies as described in the Habitat Plan. Inshore nursery areas include tidal freshwater (palustrine), estuarine, and marine emergent wetlands (e.g., intertidal marshes); tidal palustrine forested areas; mangroves tidal freshwater, estuarine, and marine submerged aquatic vegetation (e.g., seagrass); and subtidal and intertidal non-vegetated flats. This applies from North Carolina through the Florida Keys.

Areas which meet the criteria for EFH-Habitat Areas of Particular Concern (EFH-HAPCs) for penaeid shrimp include all coastal inlets, all state-designated nursery habitats of particular importance to shrimp (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas), and state-identified overwintering areas.

Clarifications to Designations for Penaeid Shrimp

1. The public and resource agencies have requested a complete list of the state-designated areas that may function as nursery habitats of species managed by the SAFMC. Appendix 1 contains a complete list of State protected areas with marine and or estuarine waters that function as nursery habitat and/or that are designated as EFH or EFH-HAPC for Council-managed species. No state-identified overwintering grounds have been identified for penaeid shrimp.

2. <u>Coastal inlets</u> include the throat of the inlet as well as shoal complexes associated with the inlets (Figure 2). Shoals formed by waters moving landward through the inlet are referred to as flood tidal shoals, and shoals formed by waters moving waterward through the inlet are referred to as ebb tidal shoals.

EFH Designations in the Comprehensive Amendment for Rock Shrimp (SAFMC 1998b)

For rock shrimp, Essential Fish Habitat (EFH) consists of offshore terrigenous and biogenic sand bottom habitats from 18 to 182 meters in depth with highest concentrations occurring between 34 and 55 meters. This applies for all areas from North Carolina through the Florida Keys. EFH includes the shelf current systems near Cape Canaveral, Florida which provide major transport mechanisms affecting planktonic larval rock shrimp. These currents keep larvae on the Florida Shelf and may transport them inshore in spring. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse rock shrimp larvae.

Clarifications to Designations for Rock Shrimp

No clarifications of these designations have been requested during EFH consultations.

EFH Designations in the Comprehensive Amendment for Royal Red Shrimp (SAFMC 1998b)

Essential Fish Habitat (EFH) for royal red shrimp include the upper regions of the continental slope from 180 meters (590 feet) to about 730 meters (2,395 feet), with concentrations found at depths of between 250 meters (820 feet) and 475 meters (1,558 feet) over blue/black mud, sand, muddy sand, or white calcareous mud. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse royal red shrimp larvae.

Clarifications to Designations for Royal Red Shrimp

No clarifications of these designations have been requested during EFH consultations.

Fishery Management Plan, Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region (1983)

EFH Designation Boundary

SAFMC's EFH designation for snapper grouper species applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Snapper Grouper (SAFMC 1998b)

Essential Fish Habitat (EFH) for snapper-grouper species includes coral reefs, live/hard bottom, submerged aquatic vegetation, artificial reefs and medium to high profile outcroppings on and around the shelf break zone from shore to at least 600 feet (but to at least 2000 feet for wreckfish) where the annual water temperature range is sufficiently warm to maintain adult populations of members of this largely tropical complex. EFH includes the spawning area in the water column above the adult habitat and the additional pelagic environment, including *Sargassum*, required for larval survival and growth up to and including settlement. In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse snapper grouper larvae.

For specific life stages of estuarine dependent and nearshore snapper-grouper species, EFH includes areas inshore of the 100-foot contour, such as attached macroalgae; submerged rooted vascular plants (seagrasses); estuarine emergent vegetated wetlands (saltmarshes, brackish marsh); tidal creeks; estuarine scrub/shrub (mangrove fringe); oyster reefs and shell banks; unconsolidated bottom (soft sediments); artificial reefs; and coral reefs and live/hard bottom.

Areas which meet the criteria for EFH-Habitat Areas of Particular Concern (EFH-HAPCs) for species in the snapper-grouper management unit include medium to high profile offshore hard bottoms where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hard bottom areas; The Point, The Ten Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump (South Carolina); mangrove habitat; seagrass habitat; oyster/shell habitat; all coastal inlets; all state-designated nursery habitats of particular importance to snapper grouper (e.g., Primary and Secondary Nursery Areas designated in North Carolina); pelagic and benthic *Sargassum*; Hoyt Hills for wreckfish; the Oculina Bank Habitat Area of Particular Concern; all hermatypic coral habitats and reefs; manganese outcroppings on the Blake Plateau; and Council-designated Artificial Reef Special Management Zones (SMZs).

EFH Designations in CEBA-2 for Snapper Grouper (SAFMC 2011)

EFH-HAPCs for golden tilefish includes irregular bottom comprised of troughs and terraces inter-mingled with sand, mud, or shell hash bottom. Mud-clay bottoms in depths of 150-300 meters are HAPC. Golden tilefish are generally found in 80-540 meters, but most commonly found in 200-meter depths.

EFH-HAPC for blueline tilefish includes irregular bottom habitats along the shelf edge in 45-65 meters depth; shelf break; or upper slope along the 100-fathom contour (150-225 meters); hardbottom habitats characterized as rock overhangs, rock outcrops, manganese-phosphorite rock slab formations, or rocky reefs in the South Atlantic Bight; and the Georgetown Hole (Charleston Lumps) off Georgetown, SC.

EFH-HAPCs for the snapper grouper complex include the following deepwater marine protected areas (MPAs) as designated in Snapper Grouper Amendment 14:

- Snowy Grouper Wreck MPA
- Northern South Carolina MPA
- Edisto MPA
- Charleston Deep Artificial Reef MPA
- Georgia MPA
- North Florida MPA
- St. Lucie Hump MPA
- East Hump MPA

Clarifications to the Designations for Snapper Grouper

1. The public and resource agencies have requested a complete list of the localities of known or likely periodic spawning aggregations. SAFMC intends to provide this list on its website as soon as practicable.

2. Coastal inlets include the throat of the inlet as well as shoal complexes associated with the inlets (Figure 2). Shoals formed by waters moving landward through the inlet are referred to as

flood tidal shoals, and shoals formed by waters moving waterward through the inlet are referred to as ebb tidal shoals.

3. Designated SMZ is EFH-HAPC: The Council has determined that a designated SMZ meets the criteria for an EFH-HAPC designation, and the Council intends that all SMZs designated under the Snapper Grouper FMP also be designated as EFH-HAPCs under the Snapper Grouper FMP.

The Council established the special management zone (SMZ) designation process in 1983 in the Snapper Grouper FMP, and SMZs have been designated in federal waters off North Carolina, South Carolina, Georgia, and Florida since that time. The purpose of the original SMZ designation process, and the subsequent specification of SMZs, was to protect snapper grouper populations at the relatively small, permitted artificial reef sites and "create fishing opportunities that would not otherwise exist." Thus, the SMZ designation process was centered around protecting the relatively small habitats, which are known to attract desirable snapper grouper species.

Similarly, in the Comprehensive Ecosystem-Based Amendment 1 (CE-BA1, 2010), the Council has designated essential fish habitat (EFH) areas and EFH habitat areas of particular concern (HAPC) under the Snapper Grouper FMP. Under the Magnuson-Stevens Act, FMPs are required to describe and identify EFH and to minimize the adverse effects of fishing on such habitat to the extent practicable. An EFH-HAPC designation adds an additional layer to the EFH designation. Under the Snapper Grouper FMP, EFH-HAPCs are designated based upon ecological importance, susceptibility to human-induced environmental degradation, susceptibility to stress from development, or rarity of habitat type. The Council determined in CE-BA 1 that the Council-designated SMZs met the criteria to be EFH-HAPCs for species included in the Snapper Grouper FMP. Since CE-BA 1, the Council has designated additional SMZs in the Snapper Grouper FMP. The SMZ and EFH-HAPC designations serve similar purposes in pursuit of identifying and protecting valuable and unique habitat for the benefit of fish populations, which are important to both fish and fishers.

4. The public and resource agencies have requested a complete list of the State protected areas with marine and or estuarine waters that function as nursery habitat and/or that are designated as EFH or EFH-HAPC for Council-managed species. Appendix 1 contains a complete list of protected areas which may function as nursery habitats of species managed by the SAFMC.

Fishery Management Plan (Including Regulatory Impact Review, Environmental Assessment, and Social Impact Statement) for the Golden Crab Fishery

of the South Atlantic Region (1995)

EFH Designation Boundary

SAFMC's EFH designation for golden crab applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Golden Crab (SAFMC 1998b)

Essential fish habitat (EFH) for golden crab includes the U.S. Continental Shelf from Chesapeake Bay south through the Florida Straits (and into the Gulf of Mexico). In addition, the Gulf Stream is an EFH because it provides a mechanism to disperse golden crab larvae. The detailed description of seven EFH types (a flat foraminferan ooze habitat; distinct mounds, primarily of dead coral; ripple habitat; dunes; black pebble habitat; low outcrop; and soft-bioturbated habitat) for golden crab is provided in Wenner et al. (1987).

There is insufficient knowledge of the biology of golden crabs to identify spawning and nursery areas and to identify EFH-Habitat Areas of Particular Concern (EFH-HAPCs) at this time. As information becomes available, the Council will evaluate such data and identify EFH-HAPCs as appropriate through the framework.

Clarifications to the Designations for Golden Crab

1. The Council views the first sentence as a general, introductory statement to the later specific areas designated as EFH. In addition to the Gulf Stream, seven habitat types provided in Wenner et al. (1987)[4] are EFH for golden crab; those seven habitat-by-depth combinations are:

- Flat foraminiferan ooze habitat (405 to 567 meters). This habitat type is characterized by pteropod-foraminiferan debris mixed with larger shell fragments, a sediment surface mostly covered with a black phosphorite precipitate.

[4] Wenner, EL, Ulrich, GF, and Wise, JB. 1987. Exploration for golden crab, *Geryon fenneri*, in the South Atlantic Bight: Distribution, population structure, and gear assessment. Fishery Bulletin. 85: 547-560

- Distinct mounds, primarily of dead coral at depths of 503 to 555 meters. Coral mounds rose approximately 15 to 23 meters in height above the surrounding sea floor and included several that were thinly veneered with a fine sediment and dead coral fragments, as well as a number that were thickly encrusted with live branching ahermatypic corals, sponges, pennatulids, and crinoids.
- Ripple habitat (320 to 539 meters)
- Dunes (389 to 472 meters)
- Black pebble habitat (446 to 564 meters)
- Low outcrop (466 to 512 meters)
- Soft-bioturbated habitat (293 to475 meters)

Fishery Management Plan, Environmental Impact Statement and Regulatory Impact Review for Spiny Lobster in the Gulf of Mexico and South Atlantic (1982)

EFH Designation Boundary

This FMP plan is administered by SAFMC and the Gulf of Mexico Management Council. SAFMC's EFH designation for spiny lobster applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border (although see below) to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Spiny Lobster (SAFMC 1998b)

Essential Fish Habitat (EFH) for spiny lobster includes nearshore shelf/oceanic waters; shallow subtidal bottom; seagrass habitat; unconsolidated bottom (soft sediments); coral and live/hard bottom habitat; sponges; algal communities (*Laurencia*); and mangrove habitat (prop roots). In addition the Gulf Stream is an EFH because it provides a mechanism to disperse spiny lobster larvae.

Areas which meet the criteria for EFH-Habitat Areas of Particular Concern (EFH-HAPCs) for spiny lobster include Florida Bay, Biscayne Bay, Card Sound, and coral/hard bottom habitat from Jupiter Inlet, Florida through the Dry Tortugas, Florida.

Clarifications to the Designations for Spiny Lobster

1. In practice, the northern limit for inshore benthic habitats designated EFH for spiny lobster is Sebastian Inlet, the northern extent of the offshore benthic habitats designated as EFH for spiny lobster is the area offshore of the St. Johns River.

Fishery Management Plan, Environmental Impact Statement, Regulatory Impact Review, Final Regulations for the Coastal Migratory Pelagic Resources (1983)[5]

EFH Designation Boundary

SAFMC's EFH designation for coastal migratory pelagic species applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border (although see below) to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Coastal Migratory Pelagic Species (SAFMC 1998b)

Essential Fish Habitat (EFH) for coastal migratory pelagic species includes sandy shoals of capes and offshore bars, high profile rocky bottom and barrier island ocean-side waters, from the surf to the shelf break zone, but from the Gulf Stream shoreward, including *Sargassum*. In addition, all coastal inlets, all state-designated nursery habitats of particular importance to coastal migratory pelagics (for example, in North Carolina this would include all Primary Nursery Areas and all Secondary Nursery Areas).

In addition, the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse coastal migratory pelagic larvae. For king and Spanish mackerel EFH occurs in the South Atlantic and Mid-Atlantic Bights.

Areas which meet the criteria for EFH-Habitat Areas of Particular Concern (EFH-HAPCs) include sandy shoals of Capes Lookout, Cape Fear, and Cape Hatteras from shore to the ends of the respective shoals, but shoreward of the Gulf stream; The Point, The Ten-Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump and Hurl Rocks (South Carolina); The Point off Jupiter Inlet (Florida); *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; nearshore hard bottom south of Cape Canaveral; The Hump off Islamorada, Florida; The Marathon Hump off Marathon, Florida; The "Wall" off of the Florida Keys; Pelagic *Sargassum*; and Atlantic coast estuaries with high numbers of Spanish mackerel based on abundance data from the ELMR Program. Estuaries meeting this criteria for Spanish mackerel include Bogue

[5] Amendment 31 to this FMP, effective March 21, 2019, transferred management of Atlantic Migratory Group Cobia (Georgia - New York) to the Atlantic States Marine Fisheries Commission. Accordingly, references germane to cobia EFH and EFH-HAPCs have been removed from the FMP sections described below.

Sound and New River, North Carolina; Bogue Sound, North Carolina (Adults May-September salinity >30 ppt); and New River, North Carolina (Adults May-October salinity >30 ppt).

Clarifications to the Designations for Coastal Migratory Pelagic Species

1. Coastal inlets include the throat of the inlet as well as shoal complexes associated with the inlets (Figure 2). Shoals formed by waters moving landward through the inlet are referred to as flood tidal shoals, and shoals formed by waters moving waterward through the inlet are referred to as ebb tidal shoals.

2. The public and resource agencies have requested a complete list of the State protected areas with marine and or estuarine waters that function as nursery habitat and/or that are designated as EFH or EFH-HAPC for Council-managed species. Appendix 1 contains a complete list of state protected areas which may function as nursery habitats of species managed by the SAFMC.

The Fishery Management Plan for Coral, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Region (1995)

EFH Designation Boundary

This FMP plan is administered by SAFMC. An earlier version of the FMP was jointly administered by SAFMC and the Gulf of Mexico Management Council. SAFMC's EFH designation for coral and coral reefs applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border (although see below) to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment for Coral, Coral Reefs, and Live/Hard Bottom Habitats (SAFMC 1998b)

A. Essential Fish Habitat (EFH) for hermatypic stony corals includes rough, hard, exposed, stable substrate from Palm Beach County south through the Florida reef tract in subtidal to 30 m depth, subtropical (15°-35° C), oligotrophic waters with high (30-35o/oo) salinity and turbidity levels sufficiently low enough to provide algal symbionts adequate sunlight penetration for photosynthesis. Ahermatypic stony corals are not light restricted and their essential fish habitat includes defined hard substrate in subtidal to outer shelf depths throughout the management area.

B. EFH for *Antipatharia* (black corals) includes rough, hard, exposed, stable substrate, offshore in high (30-35o/oo) salinity waters in depths exceeding 18 meters (54 feet), not restricted by light penetration on the outer shelf throughout the management area.

C. EFH for octocorals excepting the order Pennatulacea (sea pens and sea pansies) includes rough, hard, exposed, stable substrate in subtidal to outer shelf depths within a wide range of salinity and light penetration throughout the management area.

D. EFH for Pennatulacea (sea pens and sea pansies) includes muddy, silty bottoms in subtidal to outer shelf depths within a wide range of salinity and light penetration.

Areas which meet the criteria for EFH-Habitat Areas of Particular Concern (EFH-HAPCs) for coral, coral reefs, and live/hard bottom include The 10-Fathom Ledge, Big Rock, and The Point

(North Carolina); Hurl Rocks and The Charleston Bump (South Carolina); Gray's Reef National Marine Sanctuary (Georgia); The *Phragmatopoma* (worm reefs) reefs off the central east coast of Florida; Oculina Banks off the east coast of Florida from Ft. Pierce to Cape Canaveral; nearshore (0-4 meters; 0-12 feet) hard bottom off the east coast of Florida from Cape Canaveral to Broward County); offshore (5-30 meter; 15-90 feet) hard bottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary.

EFH Designations in CEBA-2 for Coral, Coral Reefs, and Live/Hard Bottom Habitats (SAFMC 2011)

The following Deepwater Coral HAPCs designated in Comprehensive Ecosystem-Based Amendment 1 are designated as EFH-HAPCs: Cape Lookout Coral HAPC, Cape Fear Coral HAPC, Blake Ridge Diapir Coral HAPC, Stetson-Miami Terrace Coral HAPC, and Pourtalés Terrace Coral HAPC.

Clarifications to the designations for Coral, Coral Reefs, and Live/Hard Bottom Habitats

1. Several fishery management plans refer in different ways to coral, coral reef, or hardbottom in their EFH designations. The public and resource agencies have requested a more uniform application of these terms in the designations. SAFMC's Coral Advisory Panel and Habitat and Environmental Protection Advisory Panel are developing terminology that will bring consistency to the wording of the EFH designations.

Fishery Management Plan for Pelagic *Sargassum* Habitat of the South Atlantic Region (2002)

EFH Designation Boundary

SAFMC's EFH designation for *Sargassum* applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in CEBA-2 for Coral, Coral Reefs, and Live/Hard Bottom Habitats (SAFMC 2011)

Essential Fish Habitat (EFH) for *Sargassum* is the top ten meters of the water column in the South Atlantic EEZ bounded by the Gulfstream.

Clarifications to the designation for Sargassum

No clarifications of this designation have been requested during EFH consultations.

Fishery Management Plan for the Dolphin and Wahoo Fishery of the Atlantic (2003)

EFH Designation Boundary

This fishery management plan is administered by SAFMC in cooperation with the New England Fishery Management Council and Mid-Atlantic Fishery Management Council. SAFMC's EFH designation for dolphin and wahoo applies to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border (although see below) to the Dry Tortugas in the Florida Keys (Figure 1). Within this area, the specific habitats and locations that are EFH are listed below.

EFH Designations in the Comprehensive Amendment (1998b) and the Fishery Management Plan for Dolphin and Wahoo (2003)

EFH for dolphin and wahoo is the Gulf Stream, Charleston Gyre, Florida Current, and pelagic *Sargassum.*

EFH-HAPCs for dolphin and wahoo in the Atlantic include The Point, The Ten-Fathom Ledge, and Big Rock (North Carolina); The Charleston Bump and The Georgetown Hole (South Carolina); The Point off Jupiter Inlet (Florida); The Hump off Islamorada, Florida; The Marathon Hump off Marathon, Florida; The "Wall" off of the Florida Keys; and Pelagic *Sargassum.*

Clarifications to the designation for Dolphin and Wahoo

No clarifications of this designation have been requested during EFH consultations.

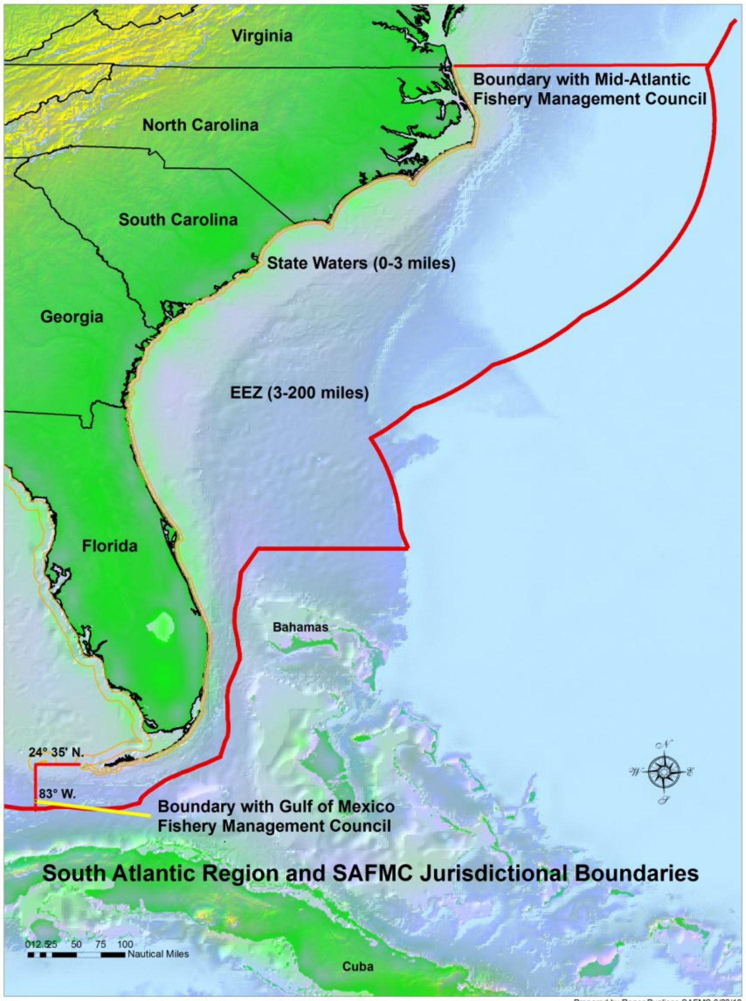


Figure 1. Unless otherwise specified in an EFH designation, SAFMC's EFH designations apply to all waters from the EEZ to the landward most influence of the tide, from the Virginia/North Carolina border to the Dry Tortugas in the Florida Keys.

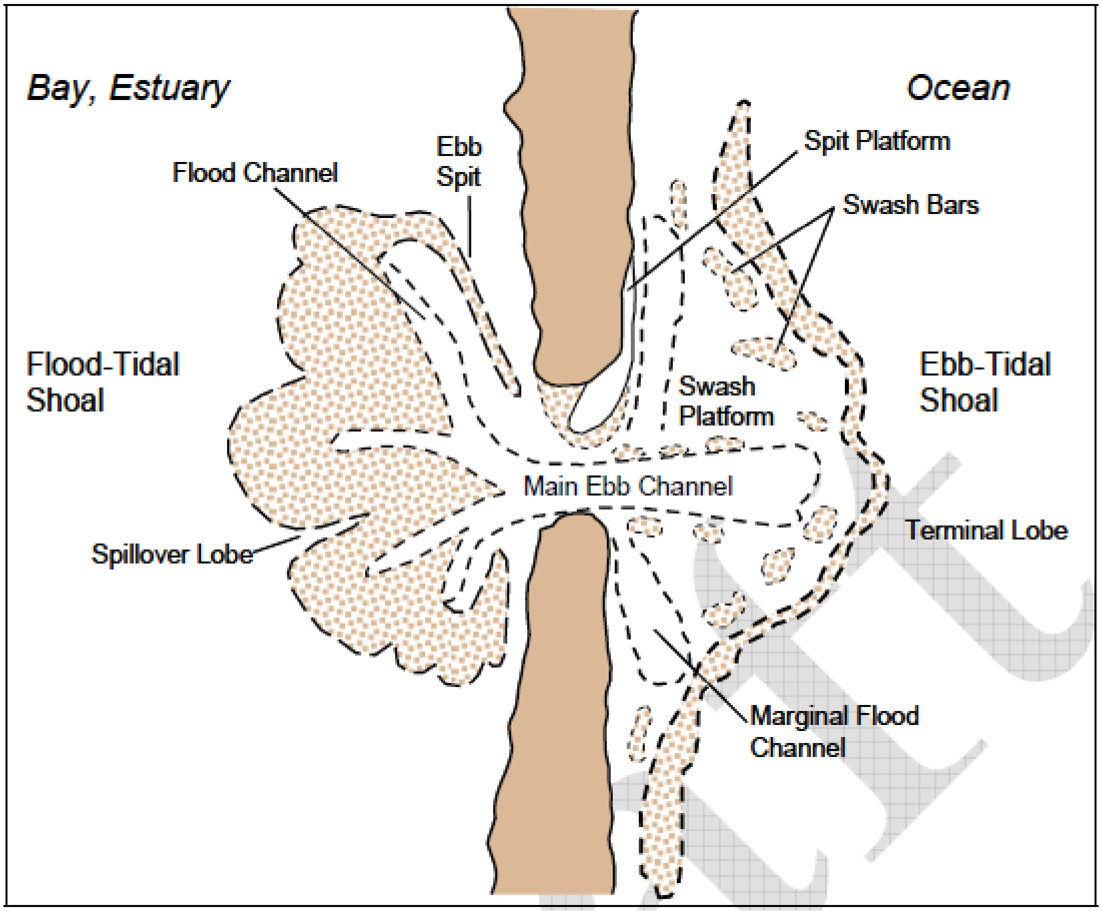


Figure 2. Components of a tidal inlet. (Source U.S. Army Corps of Engineers)

Appendix 1. State-Designated Areas.

The table below references the state regulations that present state-designated areas that warrant special protection under state law. These areas are "state-designated areas" which may function as nursery habitats of species managed by the SAFMC and under the EFH or EFH-HAPC designations for penaeid shrimp, snapper grouper species, and coastal migratory pelagic species.

Designation	Regulation	Comments
North Carolina		
Inland Primary Nursery Areas	15A NCAC 10C .0503	
Primary Nursery Areas	15A NCAC 03R .0103	
Permanent Secondary Nursery Areas	15A NCAC 03R .0104	
Secondary Nursery Areas	15A NCAC 03R .0105	
Strategic Habitat Areas and Critical Habitat Areas	15A NCAC 03H .0104 (4)(h)	None as of November 30, 2010
Crab Spawning Sanctuaries	15A NCAC 03R .0110	
Oyster Sanctuaries	15A NCAC 03R .0117	
Outstanding Resource Waters	15A NCAC 02B .0225	
South Carolina		
Outstanding Resource Waters	DHEC R. 61-69	Only coastal counties included as state designated nursery grounds
Outstanding National Resource Waters	DHEC R. 61-68	None coastal as of November 30, 2010
Georgia		
Outstanding National Resource Waters	391-3-6-.03	None as of November 30, 2010
Florida		
Aquatic Preserves and Outstanding Florida Waters	258.35, Florida Statutes (F.S.) and 62-302.700, Florida Administrative Code (F.A.C)	Only Preserves and Waters located on the Atlantic coast of Florida included

Appendix 1 (continued). State-Designated Areas —North Carolina.

In North Carolina, NC Marine Fisheries Rule 15A NCAC 03I .0101(4) defines "Fish Habitat Areas" as "The estuarine and marine areas that support juvenile and adult populations of fish species, as well as forage species utilized in the food chain. Fish habitats, as used in this definition, are vital for portions of the entire life cycle, including the early growth and development of fish species." Nursery areas are further defined in 15A NCAC 03I .0101(4)(f) as "areas that for reasons such as food, cover, bottom type, salinity, temperature, and other factors, young finfish and crustaceans spend the major portion of their initial growing season. Primary nursery areas are those areas in the estuarine system where initial post-larval development takes place. These are areas where populations are uniformly early juveniles. Secondary nursery areas are those areas in the estuarine system where later juvenile development takes place. Populations are composed of developing sub-adults of similar size that have migrated from an upstream primary nursery area to the secondary nursery area located in the middle portion of the estuarine system." Strategic Habitat Areas are defined in 15A NCAC 03H .0104 (4)(h) as "Locations of individual fish habitats or systems of habitats that provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity." All of these areas are managed by the NC Division of Marine Fisheries.

Maps of Primary Nursery Areas, Secondary Nursery Areas, and Special Secondary Nursery Areas have been combined into one map package on the NC Division of Marine Fisheries website at: http://portal.ncdenr.org/web/mf/primary-nursery-areas. Specific coordinates for the various resource area designations can be found at the following NC Marine Fisheries rule links:

Primary Nursery Areas 15A NCAC 03R .0103:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2003%20-%20marine%20fisheries/subchapter%20r/15a%20ncac%2003r%20.0103.pdf.

Permanent Secondary Nursery Areas 15A NCAC 03R .0104:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2003%20-%20marine%20fisheries/subchapter%20r/15a%20ncac%2003r%20.0104.pdf

Special Secondary Nursery Areas 15A NCAC 03R .0105:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2003%20-%20marine%20fisheries/subchapter%20r/15a%20ncac%2003r%20.0105.pdf

Maps of Crab Spawning Sanctuaries can be found on the NC Division of Marine Fisheries website at:

http://portal.ncdenr.org/web/mf/crab-spawning-sanctuaries. Specific coordinates for Crab Spawning Sanctuaries can be found in NC Marine Fisheries Rule 15A NCAC 03R .0110:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2003%20-%20marine%20fisheries/subchapter%20r/15a%20ncac%2003r%20.0110.pdf

Maps of Oyster Sanctuaries can be found on the NC Division of Marine Fisheries website at: http://portal.ncdenr.org/web/mf/habitat/enhancement/oyster-sanctuaries

Specific coordinates for Oyster Sanctuaries can be found in NC Marine Fisheries Rule 15A NCAC 03R .0117:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2003%20-%20marine%20fisheries/subchapter%20r/15a%20ncac%2003r%20.0117.pdf

Inland Primary Nursery Areas are managed by the NC Wildlife Resources Commission and are defined in rule 15A NCAC 10C .0502 as "those areas inhabited by the embryonic, larval or juvenile life stages of marine or estuarine fish or crustacean species due to favorable physical, chemical or biological factors." Specific coordinates for Inland Primary Nursery Areas are found in NC Wildlife Resources Rule 15A 10C .0503:

http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2010%20-%20wildlife%20resources%20and%20water%20safety/subchapter%20c/15a%20ncac%2010c%20.0503.pdf

Outstanding Resource Waters are managed by the NC Division of Water Resources and are defined in rule 15A NCAC 02B .0225 as waters that are "of exceptional state or national recreational or ecological significance and that the waters have exceptional water quality" and that meet certain criteria. Both criteria and specific water body designations can be found in 15A NCAC 02B .0225 and at the following link: http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/15a%20ncac%2002b%20.0225.pdf

A link to an interactive map for Strategic Habitat Areas (SHAs) follows:

http://portal.ncdenr.org/web/mf/habitat/SHAs

Note: Region 3 SHAs are not yet included and Region 4 SHA designation is underway.

Offshore Areas

Coordinates of artificial reefs are included in the link below for an interactive map/reef guide: http://portal.ncdenr.org/web/mf/artificial-reefs-program

Appendix 1 (continued). State-Designated Areas—South Carolina.

In South Carolina, DHEC R. 61-69 designates Outstanding Resources Waters. Those estuarine Outstanding Resources Waters within coastal counties are state-designated areas that may function as nursery habitats of species managed by the SAFMC; the table below lists those estuarine Outstanding Resources Waters.

Waterbody	County	Description
Bass Creek	Beaufort	The entire creek tributary to May River
Bull Creek	Beaufort	The entire creek tributary to the Cooper River and May River
Callawassie Creek	Beaufort	The entire creek tributary to the Colleton River
Chechessee Creek	Beaufort	The entire creek tributary to the Colleton River and the Chechessee River
Colleton River	Beaufort	The entire stream tributary to the Chechessee River
Cooper River	Beaufort	The river form New River to Ramshorn Creek
May River	Beaufort	The entire stream tributary to Calibogue Sound
Okatie River	Beaufort	The entire river tributary to Colleton River
Sawmill Creek	Beaufort	The entire creek tributary to Colleton River
Adams Creek	Charleston	The entire creek tributary to Bohicket Creek
Bailey Creek	Charleston	The entire creek tributary to St. Pierre Creek
Big bay Creek	Charleston	The entire creek tributary to the South Edisto River
Bohicket Creek	Charleston	The entire creek tributary from North Edisto River to Church Creek
Bull's Bay	Charleston	The entire Bay
Bullyard Sound	Charleston	The entire Sound
Cape Romain Harbor	Charleston	The entire Harbor
Caper's Inlet	Charleston	The entire stream tributary to the Atlantic Ocean
Church Creek	Charleston	That portion of the creek from Wadmalaw Sound to Ravens Point
Copahee Sound	Charleston	The entire Sound
Dawhoo River	Charleston	The entire river from The South Edisto River to the North Edisto River
Fishing Creek	Charleston	From its headwaters to a point 2 miles from its mouth
Fishing Creek	Charleston	From a point 2 miles from its mouth to its confluence with St. Pierre Creek
Fishing Creek	Charleston	The entire creek tributary to Dawhoo River
Frampton Creek	Charleston	The entire creek tributary to Frampton Inlet
Frampton Inlet	Charleston	The entire inlet tributary to the Atlantic Ocean
Garden Creek	Charleston	The entire creek tributary to Toogoodoo Creek
Gibson Creek	Charleston	The entire creek tributary to Wadmalaw River
Intracoastal Waterway	Charleston	That portion of the waterway from Gibson Creek to the confluence of Wadmalaw Sound and Stono River
Intracoastal Waterway	Charleston	From Dawho River to Gibson Creek
Jeremy Inlet	Charleston	The entire inlet tributary to the Atlantic Ocean

Waterbody	County	Description
Leadenwah Creek	Charleston	The entire creek tributary to the North Edisto River
Long Creek	Charleston	The entire creek tributary to Steamboat Creek
Lower Toogoodoo Creek	Charleston	From a point 3 miles from its mouth to its confluence with Toogoodoo Creek
Mark Bay	Charleston	The entire Bay
Mcleod Creek	Charleston	The entire creek tributary to the North Edisto River (Also called Tom Point Creek)
Milton Creek	Charleston	The entire creek tributary to St. Pierre Creek
Mud Creek	Charleston	The entire creek tributary to the South Edisto River
North Edisto River	Charleston	From its headwaters to the Intracoastal Waterway
North Edisto River	Charleston	From Steamboat Creek to the Atlantic Ocean
Ocella Creek	Charleston	The entire creek tributary to the North Edisto River
Oyster House Creek	Charleston	The entire stream tributary to Wadmalaw River
Price Inlet	Charleston	The entire stream tributary to the Atlantic Ocean
Privateer Creek	Charleston	The entire creek tributary to the North Edisto River
Russell Creek	Charleston	The entire creek tributary to Dawho River
Sand Creek	Charleston	The entire creek tributary to Steamboat Creek
Scott Creek	Charleston	The entire creek from Big Bay Creek to Jeremy Inlet
Shingle Creek	Charleston	The entire creek tributary to St. Pierre Creek
South Creek	Charleston	The entire creek tributary to Ocella Creek
St. Pierre Creek	Charleston	The entire creek tributary to the South Edisto River
Steamoat Creek	Charleston	The entire creek tributary to the North Edisto River
Store Creek	Charleston	The entire creek tributary to St. Pierre Creek
Swinton Creek	Charleston	The entire creek tributary to Lower Toogoodoo Creek
Tom Point Creek	Charleston	The entire creek tributary to the North Edisto River (Also Called McLeod Creek)
Toogoodoo Creek	Charleston	The entire creek tributary to the North Edisto River
Townsend River	Charleston	The entire river tributary to Frampton Inlet
Wadmalaw River	Charleston	The entire river from Wadmalaw Sound to the North Edisto River
Wadmalaw Sound	Charleston	The entire sound
Westbank Creek	Charleston	The entire creek tributary to the North Edisto River
Whooping Island Creek	Charleston	The entire creek tributary to Steamboat Creek
Edisto River	Charleston, Colleton	From U.S. 17 to its confluence with the Dawhoo River and the South Edisto River
South Edisto River	Charleston, Colleton	From Dawhoo River to Mud Creek
Alligator Creek	Colleton	The entire creek tributary to the South Edisto River
Mosquito Creek	Colleton	That portion of the creek from Bull Cut to the South Edisto River

Waterbody	County	Description
Sampson Island Creek	Colleton	The entire creek tributary to the South Edisto River
Bass Hole Bay	Georgetown	The entire bay between Old Man Creek and Debidue Creek
Bly Creek	Georgetown	The entire creek tributary to Old Man Creek
Bob's Garden Creek	Georgetown	The entire creek tributary to Jones Creek
Boor Creek	Georgetown	The entire creek between Jones Creek and Wood Creek
Bread and Butter Creek	Georgetown	The entire creek tributary to Town Creek
Clambank Creek	Georgetown	The entire creek tributary to Town Creek
Cooks Creek	Georgetown	The entire creek between Old Man Creek and Debidue Creek
Crabhaul Creek	Georgetown	The entire creek tributary to Old Man Creek
Debidue Creek	Georgetown	That portion of the ck from confluence with Cooks Creek to North Inlet and all tidal creeks including those on western shore between Bass Hole Bay & Cooks Ck
Duck Creek	Georgetown	The entire creek tributary to Jones Creek
Jones Creek	Georgetown	That portion of the creek from a point midway between its confluence with Duck Creek and Noble Slough to North Inlet
North Inlet	Georgetown	The entire inlet tributary to the Atlantic Ocean
North Santee River	Georgetown	From 1000 feet below the Intracoastal Waterway to the Atlantic Ocean
Old Man Creek	Georgetown	The entire creek tributary to Town Creek
Sea Creek Bay	Georgetown	The entire bay tributary to Old Man Creek
Sixty Bass Creek	Georgetown	That portion of the creek from a point 0.4 mile from its confluence with Town Creek to North Inlet
South Santee River	Georgetown	From 1000 feet below the Intracoastal Waterway to the Atlantic Ocean
Town Creek	Georgetown	That portion of the creek from its eastern confluence with Clambank Creek to North Inlet
Wood Creek	Georgetown	The entire creek between Boor Creek and Jones Creek
Little Pee Dee River	Horry, Marion	That portion from the confluence with Lumber River to the confluence with Great Pee Dee River

Appendix 1 (continued). State-Designated Areas—Florida.

In 1975, the Florida Legislature set aside state-owned submerged lands in areas which have exceptional biological, aesthetic, and scientific value, as Aquatic Preserves or Sanctuaries to be maintained in their natural or existing condition (258.35-37, F.S.). Aquatic Preserves are also designated as Outstanding Florida Waters (62-302.700, F.A.C.), which are "waters designated by the Environmental Regulation Commission as worthy of special protection because of their natural attributes" (62-302.200(26), F.A.C.). The Aquatic Preserves that have estuarine and marine attributes and are located on the Atlantic coast of Florida function as nursery habitat and include EFH and EFH-HAPCs for species managed by the South Atlantic Fishery Management Council. The table below lists Aquatic Preserves designated by the State of Florida with estuarine and marine waters located on the Atlantic coast of Florida. The Florida Department of Environmental Protection provides GIS data to show precise boundaries at: *ocean.floridamarine.org/mrgis/Description_Layers_Marine.htm#management*

Aquatic Preserves and Outstanding Florida Waters in Monroe County and along Florida's East Coast	**County**
Banana River (as mod. 8-8-94)	Brevard
Biscayne Bay (Cape Florida)	Dade/Monroe
Biscayne Bay (Card Sound) (12-1-82)	Dade/Monroe
Coupon Bight	Monroe
Fort Clinch State Park Sound-Charlotte Harbor(as mod. 10-4-90)	Nassau
Guana River Marsh(8-8-94)	St. Johns
Indian River Malabar to Vero Beach	Brevard/Indian River
Indian River Malabar to Vero Beach(additions), except those Indian River portions of Sebastian Creek and Turkey Creek upstream of U.S. Highway 1 (1-26-88)	Brevard/Indian River
Indian River Vero Beach to Ft. Pierce (as mod. 10-4-90)	Indian River/St. Lucie
Jensen Beach to Jupiter Inlet (as mod. 10-4-90)	Martin/Palm Beach/St. Lucie
Lignumvitae Key	Monroe
Loxahatchee River-Lake Worth Creek (as mod. 8-8-94)	Martin/Palm Beach
Mosquito Lagoon	Volusia/Brevard
Nassau River-St. Johns River Marshes	Nassau/Duval
North Fork, St. Lucie	St. Lucie/Martin
Pellicer Creek	St. Johns/Flagler
Tomoka Marsh	Volusia/Flagler

Essential Fish Habitat Viewer

The EFH viewer was created in collaboration with FWC to create a visual representation of the EFH designations and HAPC designations for each SAFMC FMP.

https://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=961f8908250a404ba99fac3aa37ac723

Fishery Ecosystem Plan 1

To review the original Fishery Ecosystem plan please refer to the SAFMC webpage:

https://safmc.net/documents/combined-fep_toc-pdf/

SAFMC Habitat Fishery Management Plans

Coral FMP

To view the Coral FMP please refer to the SAFMC webpage: https://safmc.net/fishery-management-plans/coral/

Sargassum FMP

To view the Sargassum FMP please refer to the SAFMC webpage: https://safmc.net/fishery-management-plans/sargassum/

SAFMC EFH Policy Statements

South Atlantic Food Webs and Connectivity Policy – December 2016

Introduction

This document provides guidance from the South Atlantic Fishery Management Council (SAFMC) regarding South Atlantic Food Webs and Connectivity and the protection of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (EFH-HAPCs) supporting the Council move to Ecosystem Based Fishery Management. The guidance is consistent with the overall habitat protection policies of the SAFMC as formulated and adopted in the Habitat Plan (SAFMC 1998a), the Comprehensive EFH Amendment (SAFMC 1998b), the Fishery Ecosystem Plan of the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Amendment 1 (SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011), and the various Fishery Management Plans (FMPs) of the Council.

For the purposes of policy, the findings assess potential threats and impacts to managed species EFH and EFH-HAPCs and the South Atlantic ecosystem associated with changes in food webs and connectivity and processes that could improve those resources or place them at risk. The policies and recommendations established in this document are designed to address such impacts in accordance with the habitat policies of the SAFMC as mandated by law. The SAMFC may revise this guidance in response to 1) changes in conditions in the South Atlantic region, 2) applicable laws and regulatory guidelines, 3) new knowledge about the impacts or 4) as deemed as appropriate by the Council.

Policy Considerations

A key tenet of ecosystem-based fisheries management (EBFM) is the consideration of potential indirect effects of fisheries on food web linkages when developing harvest strategies and management plans. Examples of unintended consequences include the over exploitation of predators, an increase in abundance of their prey, and a decline of organisms two trophic levels below them, a phenomenon known as a trophic cascade (Carpenter et al. 1985). Alternatively, fishing on lower trophic level species, planktivorous "forage" fishes for example, may ultimately lead to predator population declines due to food limitation (e.g. Okey et al. 2014; Walters and Martell 2004). Food web linkages connect different components of the larger ecosystem, such as pelagic forage fishes and their piscivorous predators or demersal carnivores. This connectivity between food webs over space, time, and depth creates multiple energy pathways that

enhance ecosystem stability and resilience. Food web models are increasingly being utilized by fisheries managers as ecological prediction tools because they provide the capability to simulate the entire ecosystem from primary producers to top predators to fisheries. Food web models can serve to inform single species assessment and management and are capable of generating reference points (Walters et al. 2005) and ecosystem-level indicators (Coll et al. 2006; Fulton et al. 2005).

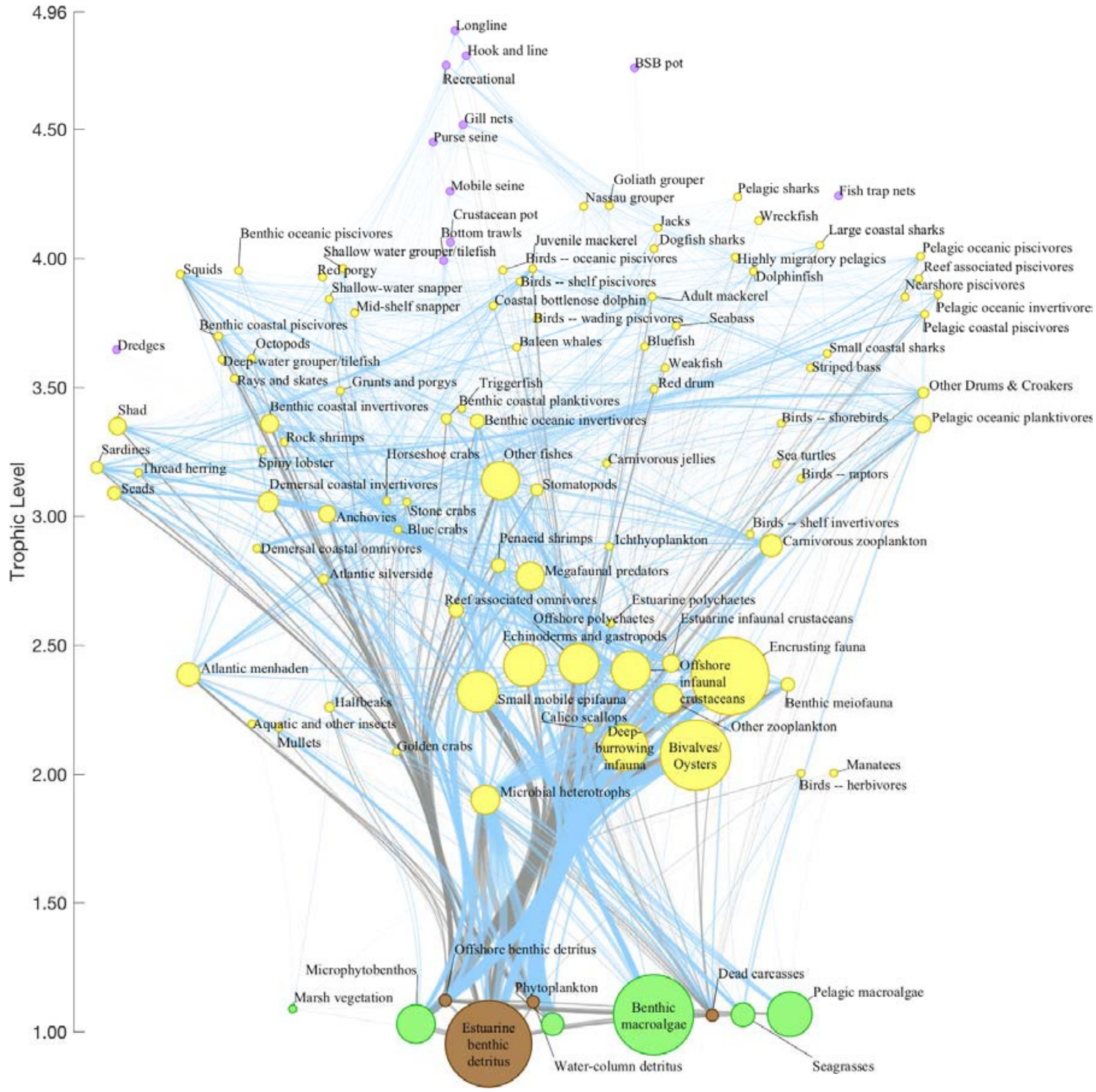


Figure 1-1. The marine food web of the South Atlantic Bight, based on the latest iteration of the SAB Ecopath model as described in Okey et al (2014), based originally on a preliminary model by Okey and Pugliese (2001). Nodes are colored based on type (green = producer, brown = detritus, yellow = consumer, purple = fleet). Blue for all edges except flows to detritus, which are gray. Diagram produced by Kelly Kearney, UW Joint Institute for the Study of the Atmosphere and Ocean and NOAA Alaska Fisheries Science Center, April 2015.

Threats to EFH and EFH-HAPCs from Changes in South Atlantic Food Web and Connectivity

The SAFMC finds that negative impacts to EFH and EFH-HAPCs can change South Atlantic food webs and connectivity for managed species. Table 1 following food webs and connectivity policy and research recommendations, presents a summary of South Atlantic fisheries and their designated EFH and EFH-HAPCs as presented in the SAFMC EFH User Guide (http://safmc.net/download/SAFMCEFHUsersGuideFinalNov16.pdf).

SAFMC Policies Addressing South Atlantic Food Webs and Connectivity

The SAFMC establishes the following policies to address South Atlantic food webs and connectivity, and to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment and Fishery Ecosystem Plan (SAFMC 1998a; SAFMC 1998b; SAFMC 2009a).

General Policies:

1. **Forage Fisheries** – Managers should consider forage fish stock abundances and dynamics, and their impacts on predator productivity, when setting catch limits to promote ecosystem sustainability. To do so, more science and monitoring information are needed to improve our understanding of the role of forage fish in the ecosystem. This information should be included in stock assessments, ecosystem models, and other fishery management tools and processes in order to support the development of sustainable harvest strategies that incorporate ecosystem considerations and trade-offs.
    i. Note: Initial preliminary definition and potential list of forage fish species presented in Appendix A.

2. **Food Web Connectivity** – Separate food webs exist in the South Atlantic, for example inshore-offshore, north-south, and benthic-pelagic, but they are connected by species that migrate between them such that loss of connectivity could have impacts on other components of the ecosystem that would otherwise appear unrelated and must be accounted for.

3. **Trophic Pathways** – Managers should aim to understand how fisheries production is driven either by bottom-up or top-down forcing and attempt to maintain diverse energy pathways to promote overall food web stability.

4. **Food Web Models** – Food web models can provide useful information to inform stock assessments, screen policy options for unintended consequences, examine ecological and economic trade-offs, and evaluate performance of management actions under alternative ecosystem states.
5. **Food Web Indicators** – Food web indicators have been employed to summarize the state of knowledge of an ecosystem or food web and could serve as ecological

benchmarks to inform future actions.

6. **Invasive Species** – Invasive species, most notably lionfish, are known to have negative effects on ecologically and economically important reef fish species through predation and competition and those effects should be accounted for in management actions.

7. **Contaminants** – Bioaccumulation of contaminants in food webs can have sub-lethal effects on marine fish, mammals, and birds and is also a concern for human seafood consumption.

Research and Information Needs Addressing South Atlantic Food Webs and Connectivity

1. Scientific research and collection of data to further understand the impacts of climate variability on the South Atlantic ecosystem and fish productivity must be prioritized. This includes research on species distribution, habitat, reproduction, recruitment, growth, survival, predator-prey interactions and vulnerability.

2. Characterization of offshore ocean habitats used by estuarine dependent species, which can be useful in developing ecosystem models.

3. Scientific research and monitoring to improve our understanding of the role of forage fish in the ecosystem, in particular abundance dynamics and habitat use.

4. Basic data are the foundation of ecosystem-based fisheries management thus, fixing existing data gaps in the South Atlantic must be addressed first in order to build a successful framework for this approach in the South Atlantic.

5. NOAA in cooperation with regional partners develop and evaluate an initial suite of products at an ecosystem level to help prioritize the management and scientific needs in the South Atlantic region taking a systemic approach to identify overarching, common risks across all habitats, taxa, ecosystem functions, fishery participants and dependent coastal communities.
6. NOAA in cooperation with regional partners develop risk assessments to evaluate the vulnerability of South Atlantic species with respect to their exposure and sensitivity to ecological and environmental factors affecting their populations.
7. NOAA coordinate with ongoing regional modeling and management tool development efforts to ensure that ecosystem management strategy evaluations (MSEs) link to multispecies and single species MSEs, inclusive of economic, socio-cultural, and habitat conservation measures.

8. NOAA develop ecosystem-level reference points (ELRPs) and thresholds as an important step to informing statutorily required reference points and identifying key dynamics, emergent ecosystem properties, or major ecosystem-wide issues that impact multiple species, stocks, and fisheries. Addressing basic data collection gaps is critical to successful development of ELRPs.
9. Continued support of South Atlantic efforts to refine EFH and HAPCs is essential to protect important ecological functions for multiple species and species groups in the face of climate change.
    a. Habitats designated as EFH and EFH-HAPCs by the SAFMC (Table 1), if negatively impacted, can change South Atlantic food webs and connectivity for managed species.

Table 1. Habitats designated as Essential Fish Habitat (EFH), their associated managed fisheries/species, and EFH-HAPCs (Source: SAFMC EFH Users Guide 2016).

Essential Fish Habitat	Fisheries/Species	EFH- Habitat Areas of Particular Concern
Wetlands		
Estuarine and marine emergent wetlands	Shrimp, Snapper Grouper	Shrimp: State designated nursery habitats Mangrove wetlands
Tidal palustrine forested wetlands	Shrimp	
Submerged Aquatic Vegetation		
Estuarine and marine submerged aquatic vegetation	Shrimp, Snapper Grouper, Spiny lobster	Snapper Grouper, Shrimp
Shell bottom		
Oyster reefs and shell banks	Snapper Grouper	Snapper Grouper
Coral and Hardbottom		
Coral reefs, live/hardbottom, medium to high rock outcroppings from shore to at least 600 ft where the annual water temperature range is sufficient.	Snapper Grouper, Spiny lobster, Coral, Coral Reefs and Live Hard/bottom Habitat	The Point, Ten Fathom Ledge, Big Rock, MPAs; The *Phragmatopoma* (worm reefs) off central east coast of Florida and nearshore hardbottom; coral and hardbottom habitat from Jupiter through the Dry Tortugas, FL; Deepwater CHAPCs
rock overhangs, rock outcrops, manganese- phosphorite rock slab formations, and rocky reefs		Snapper-grouper [blueline tilefish]
Artificial reefs	Snapper Grouper	Special Management Zones
Soft bottom		
Subtidal, intertidal non-vegetated flats	Shrimp	
Offshore marine habitats used for spawning and growth to maturity	Shrimp	
Sandy shoals of capes and offshore bars	Coastal Migratory Pelagics	Sandy shoals; Capes Lookout, Fear, Hatteras, NC; Hurl Rocks, SC;
troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters		Snapper-grouper [golden tilefish]
Water column		
Ocean-side waters, from the surf to the shelf break zone, including Sargassum	Coastal Migratory Pelagics	
All coastal inlets	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
All state-designated nursery habitats of particular importance (e.g., PNA, SNA)	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
High salinity bays, estuaries	Cobia in Coastal Migratory Pelagics	Spanish mackerel: Bogue Sound, New River, NC; Broad River, SC
Pelagic Sargassum	Dolphin	
Gulf Stream	Shrimp, Snapper-grouper, Coastal Migratory Pelagics, Spiny lobster, Dolphin-wahoo	
Spawning area in the water column above the adult habitat and the additional pelagic environment	Snapper-grouper	

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Appendix A. Potential list of potential forage species and definition.

Note: Species highlighted constitute a preliminary list of non-managed forage fish species.

Final Report SEAMAP-SA		Period 05/01/2006 - 04/30/2011,									
Table 2.5											
Abundance, biomass, and occurrence by species. Values are for 2006-2010 calendar years. Ranking is by total number of individuals. Top 50 species of 215											
CommonName	Species	Number Rank	Total Number	% of Total Abundance	Biomass (kg)	%of Total BioMass	Number of Occurrences	% of Occurences	CumPct Number	Rank Biomass	CumPct Biomasss
Atl bumper	Chloroscombrus chrysurus	1	1368597	35.34	18645.26	6.76	979	61.57	35.34	5	46.21
Atl croaker	Micropogonias undulatus	2	467821	12.08	24544	8.89	871	54.78	47.42	2	25.33
spot	Leiostomus xanthurus	3	342689	8.85	19807.84	7.18	1121	70.5	56.27	3	32.51
white shrimp	Litopenaeus setiferus	4	141041	3.64	3779.69	1.37	809	50.88	59.91	14	64.34
striped anchovy	Anchoa hepsetus	5	140732	3.63	1244.2	0.45	961	60.44	63.54	27	73.97
moonfish	Selene setapinnis	6	128782	3.33	2173.18	0.79	1001	62.96	66.87	20	69.92
cannonball jellyfish	Stomolophus meleagris	7	127957	3.3	45368.66	16.44	723	45.47	70.17	1	16.44
scup/porgy	Stenotomus sp.	8	120165	3.1	4249.36	1.54	505	31.76	73.27	11	59.99
pinfish	Lagodon rhomboides	9	87700	2.26	4134.76	1.5	623	39.18	75.53	12	61.49
banded drum	Larimus fasciatus	10	68273	1.76	5041.15	1.83	775	48.74	77.29	9	56.81
butterfish	Peprilus triacanthus	11	68083	1.76	1801.7	0.65	852	53.58	79.05	22	71.34
star drum	Stellifer lanceolatus	12	67465	1.74	1279.21	0.46	462	29.06	80.79	26	73.52
Southern kingfish	Menticirrhus americanus	13	63683	1.64	6310.79	2.29	1181	74.28	82.43	7	52.86
harvestfish	Peprilus paru	14	61621	1.59	2706.34	0.98	986	62.01	84.02	16	66.41
Atl thread herring	Opisthonema oglinum	15	56675	1.46	1427.48	0.52	977	61.45	85.48	25	73.06
brown shrimp	Farfantepenaeus aztecus	16	49209	1.27	759.13	0.28	548	34.47	86.75	32	75.62
brief squid	Lolliguncula brevis	17	48151	1.24	555.35	0.2	1263	79.43	87.99	33	75.82
Atl cutlassfish	Trichiurus lepturus	18	46126	1.19	2442.13	0.88	599	37.67	89.18	19	69.13
silver seatrout	Cynoscion nothus	19	43987	1.14	2448.59	0.89	659	41.45	90.32	18	68.25
northern searobin	Prionotus carolinus	20	38652	1	430.23	0.16	712	44.78	91.32	34	75.98
weakfish	Cynoscion regalis	21	35781	0.92	3000.54	1.09	670	42.14	92.24	15	65.43
Atl menhaden	Brevoortia tyrannus	22	27118	0.7	842.86	0.31	206	12.96	92.94	30	75.04
spider crab	Libinia dubia	23	23998	0.62	74.19	0.03	496	31.19	93.56	44	76.6
squid sp	Loligo spp.	24	21515	0.56	316.24	0.11	485	30.5	94.12	36	76.22
bay anchovy	Anchoa mitchilli	25	20415	0.53	31.27	0.01	442	27.8	94.65	49	76.69
bluefish	Pomatomus saltatrix	26	20169	0.52	1763.96	0.64	531	33.4	95.17	23	71.98
silver perch	Bairdiella chrysoura	27	19695	0.51	826.85	0.3	292	18.36	95.68	31	75.34
inshore lizardfish	Synodus foetens	28	19482	0.5	1537	0.56	830	52.2	96.18	24	72.54
pigfish	Orthopristis chrysoptera	29	14141	0.37	1086.03	0.39	418	26.29	96.55	28	74.36
spadefish	Chaetodipterus faber	30	7942	0.21	369.7	0.13	416	26.16	96.76	35	76.11
Spanish mackerel	Scomberomorus maculatus	31	7906	0.2	1008.44	0.37	781	49.12	96.96	29	74.73
Atl sharpnose shark	Rhizoprionodon terraenovae	32	7778	0.2	4522.38	1.64	973	61.19	97.16	10	58.45
lady crab	Ovalipes stephensoni	33	5630	0.15	45.44	0.02	421	26.48	97.31	47	76.66
shortfinger anchovy	Anchoa lyolepis	34	5515	0.14	19.94	0.01	225	14.15	97.45	50	76.7
iridescent swimming crab	Portunus gibbesii	35	5165	0.13	47.12	0.02	462	29.06	97.58	46	76.64
Atl lookdown	Selene vomer	36	5078	0.13	183.14	0.07	408	25.66	97.71	38	76.37
hogchocker	Trinectes maculatus	37	4903	0.13	161.57	0.06	296	18.62	97.84	39	76.43
windowpane	Scophthalmus aquosus	38	4137	0.11	100.84	0.04	410	25.79	97.95	41	76.51
bullnose ray	Myliobatis freminvillei	39	3844	0.1	12041.15	4.36	330	20.75	98.05	6	50.57
lesser blue crab	Callinectes similis	40	3774	0.1	45.23	0.02	375	23.58	98.15	48	76.68
bonnethead shark	Sphyrna tiburo	41	3670	0.09	4091.41	1.48	561	35.28	98.24	13	62.97
butterfly ray	Gymnura micrura	42	3561	0.09	2626.05	0.95	470	29.56	98.33	17	67.36
fringed flounder	Etropus crossotus	43	3514	0.09	80.22	0.03	575	36.16	98.42	42	76.54
cownose ray	Rhinoptera bonasus	44	3437	0.09	19154.01	6.94	196	12.33	98.51	4	39.45
king mackerel	Scomberomorus cavalla	45	3216	0.08	218.23	0.08	280	17.61	98.59	37	76.3
bluntnose stingray	Dasyatis sayi	46	2896	0.07	5847.42	2.12	490	30.82	98.66	8	54.98
spotted hake	Urophycis regius	47	2827	0.07	76.87	0.03	189	11.89	98.73	43	76.57
ocellated flounder	Ancylopsetta quadrocellata	48	2599	0.07	102.39	0.04	414	26.04	98.8	40	76.47
leopard sea robin	Prionotus scitulus	49	2498	0.06	62.75	0.02	284	17.86	98.86	45	76.62
clearnose skate	Raja eglanteria	50	2410	0.06	2138.9	0.77	300	18.87	98.92	21	70.69

(Source: SEAMAP-SA Report Project: NA06NMF435002: September 2012)

Forage species: fish—small, short-lived and fast growing mid-trophic level species—are primary energy pathways in many marine food webs, and that they support other valuable fish stocks and many species of marine birds and mammals. Forage fish are presumed to be important in the SAB because they are food for valuable commercial and recreational species in this ecosystem, in addition to supporting other species in the broader biological community. SAB forage fish groups include Atlantic menhaden(*Brevoortia tyrannus*), halfbeaks (*Hemiramphus spp., Hyporhamphus unifasciatus*), anchovies (*Anchoa spp., A. mitchilli, A. hepsetus, Engraulis eurystole*), sardines (*Harengula jaguana*, *Sardinella aurita*), Atlantic silverside (*Menidia menidia*), scads (*Decapterus punctatus*, *Trachurus lathami*, *Selar crumenophthalmus*), shad (*Alosa spp.*), Atlantic thread herring (*Opisthonema oglinum),* mullets (*Mugil spp.*), and other pelagic oceanic planktivores such as lanternfish (*Diaphus spp.*), antenna codlet (*Bregmaceros atlanticus*), striated argentine (*Argentina striata*), chub mackerel (*Scomber japonicus*), and flyingfish (Exocoetidae).

Note: Squids (*Illex illecebrosus*, *Loligo pealei*) and shrimps (rock shrimps and penaeid shrimps) in this system also serve as forage (Pauly 1998, Anderson and Piatt 1999, Okey 2006), as do krill (Euphausiacea). These forage groups exhibit widely varying importance, *e.g*., interaction strengths, in the presently modelled context. (Source: Exploring the Trophodynamic Signatures of Forage Species in the U.S. South Atlantic Bight Ecosystem to Maximize System-Wide Values. Thomas A. Okey, Andrés M. Cisneros-Montemayor, Roger Pugliese, Ussif R. Sumaila)

South Atlantic Climate Variability and Connectivity Policy – December 2016

Introduction

This document provides guidance from the South Atlantic Fishery Management Council (SAFMC) regarding South Atlantic Climate Variability and Fisheries and the protection of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (EFH-HAPCs) supporting the Council move to Ecosystem Based Fishery Management. The guidance is consistent with the overall habitat protection policies of the SAFMC as formulated and adopted in the Habitat Plan (SAFMC 1998a), the Comprehensive EFH Amendment (SAFMC 1998b), the Fishery Ecosystem Plan of the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Amendment 1 (SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011), and the various Fishery Management Plans (FMPs) of the Council.

For the purposes of policy, the findings assess potential threats and impacts to managed species EFH and EFH-HAPCs and the South Atlantic ecosystem associated with climate variability or change and processes that could improve those resources or place them at risk. The policies and recommendations established in this document are designed to address such impacts in accordance with the habitat policies of the SAFMC as mandated by law. The SAMFC may revise this guidance in response to 1) changes in conditions in the South Atlantic region, 2) applicable laws and regulatory guidelines, 3) new knowledge about the impacts or 4) as deemed as appropriate by the Council.

Policy Considerations

The marine environment is constantly in flux and today, many parts of the ocean are changing quickly due to such factors as varying temperatures and salinities, fluctuating productivity, rising sea levels, ocean acidification and growing coastal populations.

While the extent and types of changes occurring vary from region to region, these changes are a major driver of ecosystem dynamics and the impacts are already being observed by scientists, managers, and fishermen in the South Atlantic.

Fish populations can react to changing ocean conditions. For example, as the ocean warms, many fish species are expanding their range or shifting their distributions toward the poles or into deep areas to find cooler waters[6,7]. Changes in spawning location and timing could have cascading effects, such as changes in population size, stock structure and population connectivity[8]. Research indicates that winter severity is also emerging as an important factor shaping fish assemblages and distribution patterns in this region[9]. In the South Atlantic, black sea bass are being caught further south off Florida and Walker (2016) documented an increase in probability of occurrence in recent years around Cape Canaveral Florida which could be related to cooler near surface water resulting from more frequent upwelling events in recent years. Such events need to be investigated comprehensively. Scientists are also observing changes in the distribution of cobia which are shifting northwards during their spring migration[10]. As conditions change and fluctuate, other South Atlantic fish populations could follow suit. Changing ranges are particularly important as fish movements into other jurisdictions can affect existing management plans and perhaps require modification of the existing management strategies.

Along with north-south (latitudinal) changes in distribution, vertical (depth) changes in the distribution of fish are affecting the catchability of the resources in terms of availability and vulnerability. These changes are particularly important for fishermen and the stock assessment process, for which changes in catch rates are assumed to be linearly related to changes in abundance. The effects of environment on stock dynamics need to be parsed into those which affect catchability – which tend to obscure true abundance signals – and those factors which actually lead to change stock abundance.

Differentiating between these effects involves the changes in development of quantitative catchability coefficients derived from environmental data, and is becoming increasingly important with climate change.

Changing ocean conditions have the potential to alter existing fisheries and create opportunities for new fisheries in different regions and in the South Atlantic region. Sometimes this can happen before managers have an opportunity to assess impacts of the new fishery on the ecosystem and legislate appropriate management measures. For example, there is a developing fishery for cannonball jellyfish off the South Atlantic coast but there is little information on the

[6] M. C. Jones, W. W. L. Cheung. 2014. Multi-model ensemble projections of climate change effects on global marine biodiversity *ICES Journal of Marine Science*,DOI: 10.1093/icesjms/fsu172
[7] Hare J., Alexander M., Fogarty M., Williams E., Scott J. 2010. Forecasting the dynamics of a coastal fishery species using a coupled climate-population model. Ecological Applications. 20(2):452-464
[8] H.J. Walsh, D.E. Richardson, K.E. Marancik, and J.A. Hare. 2015. Long-term changes in the distributions of larval and adult fish in the Northeast U.S. shelf ecosystem. PLOS One. DOI:10.1371/journal.pone.0137382.
[9] J.W. Morley, R. D. Batt, and M. L. Pinsky (in review). Marine assemblages respond rapidly to winter climate variability have a cascading effect on other fish species and habitats, highlighting the need for a precautionary approach.
[10] Pinsky, M. L., B. Worm, M. J. Fogarty, J. L. Sarmiento, and S. A. Levin. 2013. Marine taxa track local climate velocities. Science 341: 1239-1242 doi: 10.1126/science.1239352

possible ecosystem impacts of these fisheries[11]. As climate variability leads to range expansions and distribution shifts, new opportunities may develop and exploiting these opportunities could.

Changing ocean chemistry, in particular the impact of ocean acidification, has the potential to change food webs in the region. Ocean acidification appears likely to have significant consequences because many species which depend on calcium metabolism serve as prey or provide habitat, including mollusks, diatoms, soft and hard corals, and crustacean larvae; indeed direct impacts in other regions have already included shellfish mortality.

Around the nation, scientists and managers are formulating management strategies for changing ocean conditions[12]. In 2009, the North Pacific Fishery Management Council banned all commercial fishing in the changing Arctic until more scientific information is available and the Council is able to evaluate potential impacts. In 2014, the Mid-Atlantic Fishery Management Council, in coordination with the South Atlantic Fishery Management Council, New England Fishery Management Council, and Atlantic States Marine Fisheries Council, held a workshop to examine the potential impacts of climate change and the associated management implications. They underscored the importance of fostering ecological resilience to develop “climate-ready” fisheries, fishing communities, stock assessment, and management strategies[13]. The 2015 National Science and Statistical Committee meeting also focused on incorporating climate variability into stock assessments and fisheries management as one of its meeting themes[14]. Currently, NOAA is developing Regional Action Plans (RAPs) to guide and increase the use of climate-related information necessary to manage marine resources[15]. The extent and degree of changes expected in the South Atlantic are not fully known and the consequences of these changes cannot always be predicted. Such changes have implications for both stock assessments and fisheries management decisions.

Threats to EFH and EFH-HAPCs from Climate Variability

The SAFMC finds that climate variability in the South Atlantic impacts EFH and EFH- HAPCs and fisheries for managed species. Table 1 following climate variability policy and research recommendations, presents a summary of fisheries and habitat designations potentially affected by climate variability in the South Atlantic as presented in the SAFMC EFH User Guide.

[11] http://coastalgadnr.org/sites/uploads/crd/pdf/FMPs/CannonballFMP.pdf

[12] M. L. Pinsky and N. J. Mantua, 2014. Emerging Adaptation Approaches for Climate-Ready Fisheries. Oceanography 27(4): 147- 159.

[13] MAFMC 2014. A Workshop Report: East Coast Climate Change and Governance Workshop Report. March 19-21, 2014. Washington, DC.

[14] http://www.wpcouncil.org/wp-content/uploads/2015/01/DRAFT-2015-National-SSC-Workshop-Timed-Agenda.pdf

[15] https://www.st.nmfs.noaa.gov/ecosystems/climate/rap/index

<u>SAFMC Policies Addressing South Atlantic Climate Variability and Fisheries</u>

The SAFMC establishes the following policies to address South Atlantic climate variability and fisheries, and to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment and Fishery Ecosystem Plan (SAFMC 1998a; SAFMC 1998b; SAFMC 2009a).

General Policies:

1. As species expand/shift their distributions due to changing ocean conditions and/or market demands, it is the Council's policy that the SAFMC will proactively work with:

a. State agencies, other Councils, Atlantic State Fishery Commission, NOAA Fisheries to manage species that span multiple jurisdictions.

b. South Atlantic LCC, NOAA RISAs, Southeast Climate Science Center, and other multi-organizational partnerships.

c. The fishing industries, fishing communities, and other interested civil stakeholders.

2. A priority list of climate indicators should be developed by NOAA or regional partners or selected that likely track ecological, social, and economic trends and status. The Council requests annual summaries of these indicators, species likely to be influenced, and fisheries trends that appear to be due to changing ocean environmental conditions in the South Atlantic ecosystem.

3. Climate change requires the consideration of tradeoffs. Changing ocean conditions necessitate responses ranging from increasing buffers due to a higher level of uncertainty to adjusting quotas upward or downward to account for predicted and realized increases or decreases in productivity.

4. Given the uncertainty of climate impacts, the precautionary principle should be invoked as possible for future management decisions on issues that can be influenced by climate change.

5. Careful scientific and management evaluation should be undertaken as new fisheries develop, including consideration of how to avoid harmful impacts on essential fish habitat.

Research Needs Addressing Climate Variability

1. Scientific research and collection of data to further understand the impacts of climate variability on the South Atlantic ecosystem and fish productivity must be prioritized. This includes research on species vulnerabilities in terms of distribution, habitat, reproduction, recruitment, growth, survival, and predator-prey interactions.

2. As appropriate, climate data and the effects of climate variability should be integrated into stock assessments. Climate impacts could also be a focus of the new proposed stock assessment research cycle.
3. More three dimensional ocean observations of ocean conditions are needed to characterize the coastal- estuarine – ocean habitats.
4. Management Strategy Evaluations are desired to allow the Council to analyze potential regional climate scenarios and determine whether current harvest strategies are robust to future changes.
5. Greater understanding of the socio-economic impacts and fisheries responses to climate variability is needed.
6. Characterization of offshore ocean habitats used by estuarine dependent species which may be useful in developing ecosystem models.

Many habitats in the South Atlantic Region that are susceptible to the effects of climate variability have been designated as EFH and EFH-HAPCs by the SAFMC (Table 1).

Table 1. Habitats designated as Essential Fish Habitat (EFH), their associated managed fisheries/species, and EFH-HAPCs (Source: SAFMC EFH Users Guide 2016).

Essential Fish Habitat	**Fisheries/Species**	**EFH- Habitat Areas of Particular Concern**
Wetlands		
Estuarine and marine emergent wetlands	Shrimp, Snapper Grouper	Shrimp: State designated nursery habitats Mangrove wetlands
Tidal palustrine forested wetlands	Shrimp	
Submerged Aquatic Vegetation		
Estuarine and marine submerged aquatic vegetation	Shrimp, Snapper Grouper, Spiny lobster	Snapper Grouper, Shrimp
Shell bottom		
Oyster reefs and shell banks	Snapper Grouper	Snapper Grouper
Coral and Hardbottom		
Coral reefs, live/hardbottom, medium to high rock outcroppings from shore to at least 600 ft where the annual water temperature range is sufficient.	Snapper Grouper, Spiny lobster, Coral, Coral Reefs and Live Hard/bottom Habitat	The Point, Ten Fathom Ledge, Big Rock, MPAs; The *Phragmatopoma* (worm reefs) off central east coast of Florida and nearshore hardbottom; coral and hardbottom habitat from Jupiter through the Dry Tortugas, FL; Deepwater CHAPCs
rock overhangs, rock outcrops, manganese- phosphorite rock slab formations, and rocky reefs		Snapper-grouper [blueline tilefish]
Artificial reefs	Snapper Grouper	Special Management Zones
Soft bottom		
Subtidal, intertidal non-vegetated flats	Shrimp	
Offshore marine habitats used for spawning and growth to maturity	Shrimp	
Sandy shoals of capes and offshore bars	Coastal Migratory Pelagics	Sandy shoals; Capes Lookout, Fear, Hatteras, NC; Hurl Rocks, SC;

Essential Fish Habitat	**Fisheries/Species**	**EFH- Habitat Areas of Particular Concern**
troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters		Snapper-grouper [golden tilefish]
Water column		
Ocean-side waters, from the surf to the shelf break zone, including Sargassum	Coastal Migratory Pelagics	
All coastal inlets	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
All state-designated nursery habitats of particular importance (e.g., PNA, SNA)	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
High salinity bays, estuaries	Cobia in Coastal Migratory Pelagics	Spanish mackerel: Bogue Sound, New River, NC; Broad River, SC
Pelagic Sargassum	Dolphin	
Gulf Stream	Shrimp, Snapper-grouper, Coastal Migratory Pelagics, Spiny lobster, Dolphin-wahoo	
Spawning area in the water column above the adult habitat and the additional pelagic environment	Snapper-grouper	

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Energy Exploration and Development Policy - June 2014

Introduction

This document provides guidance from the South Atlantic Fishery Management Council (SAFMC) regarding the protection of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (EFH-HAPCs) from impacts associated with energy exploration and development activities as described in the "Threats to Marine and Estuarine Resources" section of this policy. This document also provides guidance regarding mitigation of those impacts, including avoidance, minimization and compensatory mitigation. The guidance is consistent with the overall habitat protection policies of the SAFMC as formulated and adopted in the Habitat Plan (SAFMC 1998a), the Comprehensive EFH Amendment (SAFMC 1998b), the Fishery Ecosystem Plan of the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Amendment 1 (SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011), and the various Fishery Management Plans (FMPs) of the Council.

For the purposes of policy development, the types of activities within the scope of this document include wind; oil and gas; methane hydrate mining; estuarine and marine hydrokinetic; liquefied natural gas (LNG) regasification, pipelines, and offshore and on- shore facilities; and onshore power plants. The findings assess potential impacts to EFH and EFH-HAPCs posed by activities related to energy exploration and development in offshore and coastal waters, riverine systems and adjacent wetland habitats, and the processes that could improve those resources or place them at risk. The policies and recommendations established in this document are designed to avoid and minimize impacts and optimize benefits from these activities, in accordance with the general habitat policies of the SAFMC as mandated by law. The SAMFC may revise this guidance in response to changes in the types and location of energy exploration and development activities in the South Atlantic region, applicable laws and regulatory guidelines, and knowledge about the impacts of energy exploration and development on habitat.

EFH At Risk from Energy Exploration and Development Activities

The SAFMC finds that:

1. Energy exploration or development has the potential to occur within or in proximity to EFH including – but not limited to – coral, coral reefs, and live/hardbottom habitat at all depths in the Exclusive Economic Zone (EEZ); EFH-HAPCs; or other special biological resources essential to commercial and recreational fisheries under SAFMC jurisdiction.

2. Energy development activities have the potential to cause impacts to a variety of habitats across the shelf and to nearshore, estuarine, and riverine systems and wetlands, including:
    a) waters and benthic habitats in or near drilling and disposal sites, including those potentially affected by sediment movement and by physical disturbance associated with drilling activities and site development;
    b) waters and benthic habitats in or near LNG processing facilities or other energy development sites,
    c) exposed hardbottom (e.g. reefs, live bottom, deepwater *Lophelia* mounds) in shallow and deep waters,

d) coastal wetlands
e) coastal inlets and
f) riverine systems and associated wetlands; and
g) Intertidal oyster reefs

3. Certain offshore, nearshore, and riverine habitats are particularly important to the long-term viability of commercial and recreational fisheries under SAFMC management, and potentially threatened by oil, gas, wind and other energy exploration and development activities:
    a) coral, coral reef and live/hardbottom habitat, including deepwater coral communities,
    b) marine and estuarine water column habitat,
    c) estuarine wetlands, including mangroves and marshes,
    d) submerged aquatic vegetation (including seagrass),
    e) waters that support diadromous fishes, and their spawning habitats
    f) waters hydrologically and ecologically connected to waters that support EFH.

4. Siting and design of onshore receiving, holding, and transport facilities could have impacts on wetlands, shallow habitats such as oyster reefs and submerged aquatic vegetation, and endangered species' habitats if they are not properly located.

5. Sections of South Atlantic waters potentially affected by these projects, both individually and collectively, have been identified as EFH or EFH-HAPC by the SAFMC. Potentially affected species and their EFH under federal management include (SAFMC, 1998b):
    a) Summer Flounder (various nearshore waters, including the surf zone and inlets; certain offshore waters),
    b) Bluefish (various nearshore waters, including the surf zone and inlets),
    c) many snapper and grouper species (live/hardbottom from shore to 600 feet, and – for estuarine-dependent species such as gag grouper and gray snapper – unconsolidated bottoms and live/hard bottoms in the estuaries,
    d) Black Sea Bass (various nearshore waters, including unconsolidated bottom and live/hardbottom to 600 feet),
    e) penaeid shrimp (estuarine emergent habitat, offshore habitats used for spawning and growth to maturity, and waters connecting to inshore nursery areas, including the surf zone and inlets, live/hardbottom),
    f) coastal migratory pelagics (e.g., King Mackerel, Spanish mackerel) (sandy shoals of capes and bars, barrier island ocean-side waters from the surf zone to the shelf break inshore of the Gulf Stream; all coastal inlets),
    g) corals of various types and associated organisms (on hard substrates in shallow, mid-shelf, and deepwater),
    h) royal red shrimp (upper regions of the continental slope from 180 meters (590 feet) to about 730 meters (2,395 feet), with concentrations found at depths of between 250 meters (820 feet) and 475 meters (1,558 feet) over blue/black mud, sand, muddy sand, or white calcareous mud),
    i) rock shrimp (offshore terrigenous and biogenic sand bottom habitats from 18 to 182 meters in depth with highest concentrations occurring between 34 and 55 meters. This

applies for all areas from North Carolina through the Florida Keys. Essential fish habitat includes the shelf current systems near Cape Canaveral, Florida which provide major transport mechanisms affecting planktonic larval rock shrimp),

j) golden crab (a flat foraminferan ooze habitat; distinct mounds, primarily of dead coral; ripple habitat; dunes; black pebble habitat; low outcrop; and soft- bioturbated habitat),

k) Pennatulacea (sea pens and sea pansies) muddy, silt bottoms from the subtidal to the shelf break, and deepwater corals and associated communities,

l) Highly Migratory Species (areas identified as EFH for managed by the Secretary of Commerce (e.g., inlets and nearshore waters, including shark pupping and nursery grounds), and

m) Diadromous species (riverine and offshore areas that support, including important prey species such as shad, herring and other alosines in addition to Shortnose and Atlantic sturgeon).

6. Many of the habitats potentially affected by these activities have been identified as EFH-HAPCs by the SAFMC. Each EFH-HAPC, type of activity posing a potential threat and FMP is provided as follows:

EFH-HAPC	Activity	FMP
Nearshore hardbottom	LNG regasification, pipelines and power plants	Snapper Grouper
Coastal inlets	estuarine hydrokinetic; LNG regasification, pipelines,	Shrimp, Snapper Grouper
Spawning sites	estuarine hydrokinetic; LNG regasification and pipelines; and power plants	Shrimp, Snapper Grouper
Manganese outcroppings on the Blake Plateau	oil and gas; methane hydrate mining; marine hydrokinetic; LNG regasification and pipelines	Snapper Grouper, Golden Crab
Pelagic and benthic *Sargassum*	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Snapper Grouper, Dolphin Wahoo
Inshore and nearshore areas to the ends of the sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras, North Carolina; Hurl Rocks, South Carolina; and *Phragmatopoma* (worm reefs) reefs off the central coast of Florida and near shore hardbottom south of Cape Canaveral	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Coastal Migratory Pelagics
Atlantic coast estuaries with high numbers of Spanish mackerel and cobia from ELMR, to include Bogue Sound, New River, North Carolina; Broad River, South Carolina	estuarine hydrokinetic; LNG on- shore facilities; and power plants	Coastal Migratory Pelagics
Florida Bay, Biscayne Bay, Card Sound, and coral hardbottom habitat from Jupiter Inlet through the Dry Tortugas, Florida	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Spiny Lobster
Hurl Rocks (South Carolina); The *Phragmatopoma* (worm reefs) off central east coast of Florida; nearshore (0-4 meters; 0-12 feet) hardbottom off the east coast of Florida from Cape Canaveral to Broward County; offshore (5-30 meters; 15-90 feet) hardbottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Coral, Coral Reef, and Live Hard/bottom
Council-designated Artificial Reef Special Management Zones (SMZs)	wind; oil and gas; methane hydrate mining; marine hydrokinetic; LNG regasification and pipelines	Snapper Grouper, Coastal Migratory Pelagics, Coral, Coral Reef, and Live Hard/bottom Habitat
Troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Snapper-grouper [golden tilefish]
Rock overhangs, rock outcrops, manganese-phosphorite rock slab formations, and rocky reefs	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Snapper-grouper [blueline tilefish]
HAPCs designated for HMS species (e.g., sharks) in the South Atlantic region – exploration and development	wind; oil and gas; marine hydrokinetic; LNG regasification and pipelines	Highly Migratory Species (NMFS FMP)

EFH-HAPC	Activity	FMP
Deepwater Coral HAPCs are designated as Snapper Grouper EFH-HAPCs: Cape Lookout Coral HAPC, Cape Fear Coral HAPC, Blake Ridge Diapir Coral HAPC, Stetson-Miami Terrace Coral HAPC, and Pourtalés Terrace Coral HAPC	wind; oil and gas; marine hydrokinetic; methane hydrate mining, LNG regasification and pipelines	Coral, Coral Reef, and Live Hard/bottom Habitat
Estuarine emergent and mangrove wetlands	estuarine hydrokinetic; LNG on- shore facilities; and power plants	Shrimp, Snapper Grouper
Seagrass	estuarine hydrokinetic; LNG on- shore facilities; and power plants	Shrimp, Snapper Grouper
State-designated nursery habitats (e.g., Florida Aquatic Preserves)	estuarine hydrokinetic; LNG on- shore facilities; and power plants	Shrimp, Snapper Grouper

7. Habitats likely to be affected by energy activities include many recognized in state level fishery management plans. Examples of these habitats include Strategic Habitat Areas (SHAs) such as those established by the State Marine Fisheries Commissions via FMPs, coastal habitat protection plans, or other management provisions. North Carolina SHAs, are a "subset of the overall system that includes a representative portion of each unique habitat so that overall biodiversity and ecological functions are maintained." NCMFC has established 20 units for Region 1; 67 units for Region 2; and 48 units for Region 3.

Threats to Marine and Estuarine Resources from Energy Exploration and Development Activities

The SAFMC finds that energy exploration and development activities threaten or potentially threaten EFH through the following mechanisms:

1. Direct mortality and displacement of organisms at and near dredging (Clarke et al. 2000), drilling or trenching sites , in addition to the installation of facilities and operation of such facilities .

2. Deposition of fine sediments (sedimentation) and drilling muds down-current from drilling, dredging, trenching, and/or backfilling sites. In a review of over 77 published studies that examine the effects of sedimentation and turbidity with 89 coral species, Erftemeijer et al. (2012) concluded increased sedimentation cause smothering and burial of coral polyps, shading, tissue necrosis, and unhealthy high concentrations of bacteria in coral mucus. Turbidity and sedimentation also reduce the recruitment, survival, and settlement of coral larvae.

3. Chronic elevated turbidity in and near drilling, dredging, trenching, and/or backfilling sites, which can interfere with foraging by fish and shrimp and abrade their gills and other soft tissues (Lindeman and Snyder 1999).

4. Direct mortality of eggs and larvae of marine organisms from water intake (Gallaway et al. 2007); post-larvae, juveniles and adults of marine and estuarine organisms due to spills

from pipelines, or from vessels in transit near or close to inlet areas.

5. Alteration of long-term shoreline migration patterns with complex ecological consequences due to the placement of facilities (nearshore/offshore.)

6. One of the risks associated with horizontal directional drilling (HDD) is the escape of drilling mud into the environment as a result of a spill, collapse of the drill hole or the rupture of mud to the surface, which is commonly known as a “frac-out”. A frac-out is caused when excessive drilling pressure results in drilling mud leaching vertically toward the surface. Because HDD activities occur in proximity to sensitive habitats (e.g., seagrass, coral), burial of habitat could result from “frac-outs” associated with HDD.

7. Permanent conversion of soft bottom habitat to artificial hardbottom habitat through installing a hard linear structure (i.e., a pipe covered in articulated concrete mats) can occur and the ecological effects of this habitat conversion are not well-understood.

8. Impacts to benthic resources from placement and shifting of anchors (Rogers and Garrison 2001), cables (Messing 2011; Gilliam and Walker 2012), pipelines, and other types of direct mechanical damage such as damage from deployment of instrumentation (e.g., Acoustic Doppler Current Profiles).

9. Alterations in amount and timing of river flow and significant blockage or reduction in area of critical spawning habitat resulting from damming or diverting rivers

10. Alteration of community diversity, composition, food webs and energy flow due to addition of structure (Sammarco, Paul W. 2014; Claisse et al. 2014).

11. Fish behaviour and health may be negatively impacted by anthropogenic sound depending on sound pressure levels and the duration of the sound producing activity (Popper et al 2014).

12. Operation of power plants can alter water quality The greatest risk to aquatic and estuarine ecosystems posed by power plant cooling systems is continuous exposure to sublethal stressors, such as changes in water quality, rather than the abrupt mortality of large numbers of organisms due to impingement and entrainment (Clark and Brownell 1973; Laws 2000; Kulkarni et al. 2011). Water quality (inclusive of temperature and salinity) is known to be a driver of fine scale spatial variation in nearshore fish communities, e.g., in Biscayne Bay (Serafy et al. 1997; 2003; 2005; Faunce and Serafy 2007).

13. The interactions among all effects (including lethal and sub-lethal; direct and indirect; short-term, long-term, and cumulative) affect the magnitude of the overall impacts. Such interactions may result in a scale of effect that is multiplicative rather than additive. The effects of those interactions are largely unstudied and almost completely unknown.

SAFMC Policies for Energy Exploration and Development Activities

The SAFMC establishes the following policies and best management practices (BMPs) related to energy exploration and development activities and related projects, to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment (SAFMC 1998a; SAFMC 1998b; SAFMC 2009a). The following is intended to include existing relevant guidance documents (e.g., *Alternative Energy Environmental Information Needs* (USDOI, MMS 2007a):

General Policies:

1. Projects should avoid, minimize, and – where possible – offset damage to EFH, EFH-HAPCs, and SHAs. This should be accomplished, in part, by integrating the best available and least damaging technologies into the project design.

2. Projects should avoid intersection or overlap with Allowable Fishing Areas within the Deepwater Coral HAPCs.

3. All facilities associated with energy exploration and development, should be designed to avoid or minimize to the maximum extent practicable impacts on coastal ecosystems and sand sharing systems.

4. Projects should comply with existing standards and requirements regulating domestic and international transportation of energy products including regulated waste disposal and emissions which are intended to minimize negative impacts on and preserve the quality of the marine environment.

5. Open-loop LNG processing facilities should be avoided in favor of closed-loop systems. Water intake associated with closed-loop should be minimized and the effects to fishery resources should be determined through baseline studies and project monitoring.

6. Pilot scale projects should not occur in areas where full-scale efforts are predicted to be environmentally unacceptable (e.g., MPAs, CHAPCs, and Spawning SMZs).

EFH Review, Administrative Policies, Licensing Policies and Best Management Practices:

1. EFH Assessments prepared for energy-related projects include the mandatory components set forth in 50 CFR Part 600, Subpart K:
    - A description of the proposed action;
    - An analysis of the effects, including cumulative effects, of the action on EFH, the managed species, and associated species by life history stage;
    - The Federal agency's views regarding the effects of the action on EFH; and
    - Proposed mitigation

2. Projects requiring expanded EFH consultation should provide a full range of alternatives, along with assessments of the relative impacts of each on each type of EFH, EFH-HAPC, and SHAs. Expanded EFH consultations allow NMFS and a Federal action agency the maximum opportunity to work together in the review of an activity's impact on EFH and the development of EFH conservation recommendations. Expanded consultation procedures must be used for Federal actions that would result in substantial adverse effects to EFH. Federal action agencies are encouraged to contact NMFS at the earliest opportunity to discuss whether the adverse effect of a proposed action makes expanded consultation appropriate.

3. Impact evaluations should include quantitative assessments for each habitat based on recent scientific studies, habitat characterizations, and the best available information. All EFH assessments should be based upon the best available science, be conservative, and follow precautionary principles as developed for various Federal and State policies. EFH Assessments are produced with information gathered from the best available technologies to map and characterize project sites (e.g., see Vinick et al. 2012). The methods used for habitat mapping and characterization work should reflect input from resource trustees and be performed with experienced personnel.

4. Existing transportation infrastructure (e.g., existing cables or pipelines) should be utilized wherever practicable in order to avoid or minimize environmental impacts.

5. The effects of sound from proposed projects on fish behaviour and health should be considered in EFH Assessments.

6. Compensatory mitigation should not be considered until avoidance and minimization measures have been duly demonstrated. Compensatory mitigation should be required to offset losses to EFH, including losses associated with temporary impacts, and should take into account uncertainty and the risk of the chosen mitigation measures inadequately offsetting the impacts. Mitigation should be local, "up-front," and "in-kind," and include long-term monitoring to assess and ensure the efficacy of the mitigation program selected.

7. Modelling efforts should fully characterize assumptions applied and disclose any potential biases that may affect results

8. Determination of the physical and chemical oceanographic and meteorological characteristics of the area should be done through field studies by lead action agencies, cooperating agencies, academics, or the applicant. These characteristics include but are not limited to, on-site direction and velocity of currents and tides, sea states, temperature, salinity, water quality, wind storms frequencies, and intensities and icing conditions. Studies should also include a detailed characterization of seasonal surface currents and likely spill trajectories. Such studies must be conducted prior to approval of any Exploration Plan or Development and Production Plan in order to have adequate information upon which to base decisions related to site-specific proposed activities.

9. The Environmental Impact Statement (EIS), Environmental Assessment (EA) or EFH Assessment for any outer continental shelf oil and gas lease sale should address impacts, if any, from activities specifically related to natural gas production, safety precautions required in the event of the discovery of "sour gas" or hydrogen sulfide reserves and the potential for cross-shelf transport of hydrocarbons to nearshore and inshore estuarine habitats by Gulf Stream spin-off eddies. The EIS, EA, or EFH Assessment should also address the development of contingency plans to be implemented if problems arise due to oceanographic conditions or bottom topography, the need for and availability of onshore support facilities in coastal areas, and an analysis of existing facilities and community services in light of existing major coastal developments.

10. License or permit decisions for construction projects that penetrate or attach to the seabed should be based on geotechnical studies completed to ensure that the geology of the area is appropriate for the construction method and that geological risks are appropriately mitigated.

11. Adequate spill containment and clean-up equipment should be maintained for all development facilities, and, the equipment shall be available on-site or located so as to be on-site within the landing time trajectory.

12. Bonds must be required and must be adequate to assure that resources will be available for unanticipated environmental impacts, spill response, clean-up and environmental impact assessment.

13. Exploration and development activities should not disrupt or impede known migratory patterns of endangered and threated species, nor shall they disrupt or impede the breeding or nesting seasons of endangered and threatened species. This may necessitate the imposition of seasonal, spatial, or other constraints on exploration and development activities.

14. Licenses and permits clearly should describe required monitoring before, during and after the project in sufficient detail to document pre-project conditions and the initial, long-term, and cumulative impacts of the project on EFH. Monitoring and, if necessary, for adaptive management shall be required for the life of the project. The monitoring methods should reflect input from resource trustees and be conducted by experienced personnel.

15. Third party environmental inspectors shall be required on all projects to provide for independent monitoring and permit compliance.

16. Hydrotest chemicals that may be harmful to fish and wildlife resources should not be discharged into waters of the United States.

17. Licenses or permits should require all project-related work vessels that traverse any reef system or sensitive habitat to be equipped with standard navigation aids, safety lighting and communication equipment. Equipment, such as tow lines, that could drag along the bottom and impact benthic habitat should be secured during transit. U.S. Coast Guard automated identification system (AIS) requirements must be followed.

18. Any anchor placement should completely avoid corals and be visually verified by diver or remote camera. In addition, measures to avoid anchor sweep should be developed and implemented.

19. Appropriate buffers should be designated around sensitive marine habitats.

20. A contingency plan should be required to address catastrophic blowouts or more chronic material losses from LNG facilities, including trajectory and other impact analyses and remediation measures and responsibilities.

21. Licenses and permits should require the development of resource sensitivity training modules specific to each project, construction procedures, and habitat types found within the project impact area. This training should be provided to all contractors and sub-contractors that are anticipated to work in or adjacent to areas that support sensitive habitats.

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Interactions Between Essential Fish Habitats And Marine Aquaculture Policy – June 2014

Introduction

This document provides the South Atlantic Fishery Management Council (SAFMC) guidance regarding interactions of marine aquaculture with Essential Fish Habitat (EFH) and Essential Fish Habitat - Habitat Areas of Particular Concern (EFH-HAPCs). This guidance is consistent with the overall habitat protection policies of the SAFMC as formulated in the Habitat Plan (SAFMC 1998a) and adopted in the Comprehensive EFH Amendment (SAFMC 1998b), Fishery Ecosystem Plan for the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Management Amendment 1(SAFMC 2009b),Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011) and the various Fishery Management Plans (FMPs) of the Council.

For the purposes of policy development, aquaculture is defined as the propagation and rearing of aquatic marine organisms for commercial, recreational, or public purposes. This definition covers all authorized production of marine finfish, shellfish, plants, algae, and other aquatic organisms for 1) food and other commercial products; 2) wild stock replenishment and enhancement for commercial and recreational fisheries; 3) rebuilding populations of threatened or endangered species under species recovery and conservation plans; and 4) restoration and conservation of aquatic habitat (DOC Aquaculture Policy 2011; NOAA Aquaculture Policy 2011). This guidance addresses concerns related to the production of seafood and other non- seafood related products (*e.g.*, biofuels, ornamentals, bait, pharmaceuticals, and gemstones) by aquaculture, but does not specifically address issues related to stock enhancement. The findings assess potential impacts, negative and positive, to EFH and EFH- HAPCs posed by activities related to marine aquaculture in offshore and coastal waters, riverine systems and adjacent wetland habitats, and the processes that could improve or place those resources at risk. The policies and recommendations established in this document are designed to avoid and minimize impacts and optimize benefits from these activities, in accordance with the general habitat policies of the SAFMC as mandated by law. The SAFMC may revise this guidance in response to changes in the types and locations of marine aquaculture projects in the South Atlantic region, applicable laws and regulatory guidelines, and knowledge about the impacts of aquaculture on habitat.

The recommendations presented apply to aquaculture activities that may impact EFH and EFH-HAPCs. Aquaculture activities have the potential to interact both positively and negatively with EFH and EFH-HAPCs when conducted in onshore, nearshore, and offshore environments. Current federal and state laws, regulations and policies differ for each of these environments. Additionally, aquaculture activities in nearshore and onshore environments may fall under multiple jurisdictions.

These recommendations should be factored into the FMPs in the region, either newly developed or amended to address offshore aquaculture as "fishing" under the Magnuson-Stevens Fishery and

Conservation Management Act (MSFCMA).[16] In those cases where aquaculture activities remain outside of the jurisdiction of federal management, EFH protection mechanisms for "non-fishing" activities should be used to protect EFH, wherever possible.[17][18]

Habitats and species that could be impacted by marine aquaculture activities include those managed by state-level as well as interstate (*e.g.*, ASMFC) FMPs (see Appendices A and B). Examples of affected habitats could include state-designated Critical Habitat Areas (CHAs) or Strategic Habitat Areas (SHAs) such as those established by the State Marine Fisheries Commissions via FMPs, coastal habitat protection plans, or other management provisions.

Overview of Marine Aquaculture and EFH Interactions

The environmental effects of marine aquaculture can vary widely depending on the species and genetic stock selected for culture, the location and scale of the aquaculture operation, the experience level of the operators, the culture system and facility design, biosecurity procedures, and the production methods. The use of modern production technologies, proper siting protocols, standardized operating procedures, and best management practices (BMPs) can help reduce or eliminate the risk of environmental degradation from aquaculture activities. In recent years, marine aquaculture has been used to bolster EFH (*e.g.*, oyster cultch planting to rebuild oyster reefs) and in some instances, aquaculture has been used to mitigate eutrophication by sequestering nutrients in coastal waters (*e.g.*, shellfish and algae culture).

The following summary provides information on the types of environmental effects resulting from marine aquaculture activities that have been documented and includes references to various BMPs and other existing regulatory frameworks used to safeguard coastal resources. This summary is not an exhaustive literature review of scientific information on this complex topic, rather it is a synthesis of relevant information intended to provide managers with a better understanding of the environmental impacts of marine aquaculture.

The SAFMC recognizes that there are several types of environmental risks associated with marine aquaculture both in terms of probability of occurrence and magnitude of effects. Federal, state, and local regulatory agencies should evaluate these risks as they develop and implement permitting and monitoring processes for the aquaculture industry. The SAFMC specifically recognizes the following potential interactions between marine aquaculture and EFH:

Escapement

Unintentional introductions and accidental releases of cultured organisms may have wide ranging positive or negative effects on EFH. Ecological damage caused by organisms that have escaped or been displaced, in the case of shellfish or algae, from aquaculture may occur in riverine,

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[16] Based on a legal opinion by NOAA General Counsel, landings or possession of fish in the exclusive economic zone from commercial marine aquaculture production of species managed under FMPs constitutes "fishing" as defined in the MSFCMA [Sec. 3(16)]. Fishing includes activities and operations related to the taking, catching, or harvesting of fish

[17] The reference to non-fishing activities is meant to clarify SAFMC's role to comment on aquaculture activities similar to the process that the SAFMC uses for "non-fishing" activities.

[18] While the MSFCMA currently defines aquaculture as "fishing", the Council applies the same EFH standards to both "fishing" and "non-fishing" activities.

estuarine, and marine habitats (Waples et al. 2012). The potential for adverse effects on the biological and physical properties of EFH include: (1) introduction of invasive species, (2) habitat alteration, (3) trophic alteration, (4) gene pool alteration, (5) spatial alteration, and (6) introduction of pathogens and parasites that cause disease.

Aquaculture is recognized as a pathway for both purposeful and inadvertent introduction of non-native species in aquatic ecosystems. Most introduced species do not become invasive; however, naturalization of introduced non-native species that results in invasion and competition with native fauna and flora has emerged as one of the major threats to natural biodiversity (Wilcove et al. 1998; Bax et al. 2001; D'Antonio et al. 2001; Olenin et al. 2007). Some non-native species alter the physical characteristics of coastal habitats and constitute a force of change affecting population, community, and ecosystem processes (Grosholz 2002). In the southeast United States, the culture of non-native species is primarily confined to ornamental plant and fish species grown in inland productions systems such as ponds, greenhouses, and indoor facilities. There is limited culture of non-native species for food with notable exceptions including inland production of tilapia (Ciclidae) and shrimp (*Litopenaeus vannamei*).

Even through use of native species, escapees have the potential to alter community structure, disrupt important ecosystem processes, and affect biodiversity. Environmental impacts are augmented by competition for food and space, introduction or spread of pathogens and parasites, and breeding or interbreeding with wild populations. Excessive colonization by shellfish or other sessile organisms may lead to alterations of physical habitat and preclude the growth of less abundant species with ecological significance. Similarly, escapees that colonize specific habitats and exhibit territorial behavior may compete with and displace local species to segregated habitats.

Culture of native species presents genetic risk from escapees interbreeding with individuals in the wild. The magnitude of the genetic impact on the fitness of wild stock is somewhat unclear. Genetic introgression of cultured escapees into wild populations is strongly density- dependent and appears linked to the population size and health of native populations relative to the magnitude of the escapes. To make a genetic impact, escapees must survive and reproduce successfully in the wild and contribute offspring with sufficient reproductive fitness to contribute to the gene pool. The capability of escaped fish to do so can vary widely based on a multitude of environmental and biological factors (*e.g.*, predation, competition, disease). In general, fitness of captive-reared individuals in the wild decreases with domestication (*i.e.*, the number of generations in captivity). Some genetic risks are inversely correlated, such that reducing one risk simultaneously increases another. For example, creating an aquaculture population that is genetically divergent from the wild stock may reduce the chances that escapees can survive and reproduce. Still, under this scenario aquacultured organisms that do survive could potentially pass on maladapted genes to the wild population.

The likelihood of escapes from aquaculture operations will vary depending on the species being cultured, siting guidelines, structural engineering and operational design, management practices (including probability for human error), adequacy of biosecurity and contingency plans, frequency of extreme weather events, and direct interactions with predators such as sharks, marine mammals, and birds. While a certain level of escape may not be avoidable in all cases, risk assessments should be used to make informed regulatory decisions in an effort to account for potential impacts on EFH. Risk assessment tools are available and have been used to identify and evaluate risks of farmed escapes on wild populations (Waples et al. 2012). Many empirical models have been used to inform policy (ICF 2012; RIST 2009), and are readily available for use in permitting and project planning.

Good practices for monitoring, surveillance, and maintenance of the aquaculture operation are critical to minimizing the likelihood of escapes. An escape prevention and mitigation plan should be developed for each farm. Plans should contain a rationale for approaches taken and any recapture or mitigation activities that should be initiated when an escape occurs.

Disease in aquaculture

As with all animal production systems, disease is a considerable risk for production, development, and expansion of the aquaculture industry. The industry has experienced diseases caused by both infectious (bacteria, virus, fungi, parasites) and non-infectious (nutritional, environmental, pollution, stress) agents. In addition to mortality and morbidity, disease causes reduction in market value, growth performance, reproductive capacity, and feed conversion. An accredited health professional should regularly inspect stocks and perform detailed diagnostic procedures to determine if disease is present, to identify risks, and to assess the overall health of the aquacultured species.

Veterinarians with expertise in fish culture, or qualified aquatic animal health experts, can assist with development of a biosecurity plan to minimize, prevent, or control the spread of pathogens within a farm site, between aquaculture operations, or to wild populations. Culture facilities should be required to report disease and mortality incidents to the proper state and federal agencies so that authorities can assess risk to wild stocks and habitats and determine if control or other management measures should be put in place.

The spread of pathogens from cultured organisms to wild populations is a risk to fisheries, natural resources, and EFH. There are documented cases of mortality in wild populations caused by both endemic and exotic diseases transferred from aquaculture stocks (Glibert et al. 2002, NAAHP 2008). The prevalence of disease in intensive aquaculture operations is influenced by many factors, including immune status, stress level, pathogen load, environmental conditions, water quality, nutritional health, life history stage, and feeding management. The type and level of husbandry practices and disease surveillance will also influence the potential spread of pathogens to wild stocks. International trade in live fish and shellfish and aquaculture products (e.g., discard of seafood processing waste) has led to the introduction of diseases to new areas. Once a pathogen or disease is introduced and becomes established in the natural environment, there is little possibility of eradication. However, increased awareness of disease risks, health control legislation, and better diagnostic methods, which have increased the ability to detect diseases and pathogens, are helping to reduce the frequency of introduction and the spread of diseases (NAAHP 2008). Improved facility design engineering and buffer zones between aquaculture facilities and natural stocks could also reduce the risk of disease transfer.

In some cases, the expansion and diversification of the marine aquaculture industry has resulted in parasite translocations (Shumway 2011). Because of this, many countries and regions have created compacts and agreements to include pathogen screening guidelines and certification programs for movement of germplasm, embryos, larvae, juveniles, and broodstock associated with marine aquaculture operations. In the United States, import and export certifications and testing for certain types of diseases falls under the jurisdiction of the USDA Animal and Plant and Health Inspection Service (APHIS). Most states have specific protocols that must be followed when transplanting cultured species into wild environments to minimize the incidence of disease transfer. In the case of aquaculture operations in federal waters, the Gulf of Mexico Fishery Management Council specified in their Fishery Management Plan for Regulating Offshore Marine Aquaculture that prior to stocking animals in an aquaculture system in federal waters of the Gulf, the permittee must provide NOAA Fisheries a copy of a health certificate signed by an aquatic animal health expert certifying cultured animals were inspected and determined to be free of World Organization of Animal Health reportable pathogens (OIE 2003,) or additional pathogens that are identified as reportable pathogens in the National Aquatic Animal Health Plan (GMFMC 2012).

The dynamics of communicable disease in aquaculture and the level of risk to the environment vary substantially with hydrography and the presence, concentration, and proximity of wild organisms susceptible to infection by introduced pathogens or that may serve as vectors or reservoir hosts. The operational categories onshore, nearshore, and offshore are useful in discussion of this topic:

1) Closed onshore systems: These systems have the least potential for transfer of pathogens between cultured and wild organisms and generally pose low risk to the environment. However, they may internally super-concentrate parasites or pathogens with direct life cycles and as such, can be a human health concern and management challenge. Generally effluent volume is minimal but periodic draining for maintenance or pathogen control may be expected and should be considered for development of regulations and BMPs.

2) Flow-through onshore systems: Effluent from such systems has the potential to contain exotic pathogens or high concentrations of native parasites or pathogens with direct life cycles. So these facilities pose at least some environmental risk. Of greatest concern is the introduction of non-native pathogens, which could have catastrophic effects on regional fisheries and aquaculture operations. Increased prevalence and intensity of infection by native pathogens near the facility is also a concern, particularly if the water body is poorly mixed with little flushing. However, high concentrations of wild pathogens are not likely present in influent water and parasites or pathogens with indirect life cycles are generally not able to proliferate inside the facility.

3) Inshore and nearshore cages and net pens: These operations have the greatest potential for exchange of pathogens between cultured and wild organisms. They bring cultured organisms into close contact with their wild cohorts, predators, prey, and a diverse community of potential intermediate hosts to parasites or pathogens, most importantly benthic invertebrates such as mollusks and polychaetes. These conditions provide an opportunity for parasites or pathogens with direct and indirect life cycles to proliferate in and near the pen where they may become major causes of disease in both wild and cultured hosts. Water depth and rate of flushing will vary greatly by location, but shallow embayments with poor mixing are generally the least suitable areas.

4) Offshore cages and net pens: Open ocean aquaculture operations benefit from high rates of water exchange and by extension rapid dilution of pathogens. Another hypothetical advantage, at least for fish culture, is that wild nektonic organisms and their pathogens are generally widely dispersed in offshore environments. However, wild fish and marine

mammals congregate around cages and nets where they find refuge, graze on fouling organisms, consume uneaten culture food, or sometimes successfully prey on cultured stock. So, although the benthos is far removed and dilution is rapid, there is still some opportunity for pathogen exchange, particularly of those infectious agents with direct life cycles.

Climate change has been implicated in increasing the prevalence and severity of infectious pathogens that may cause disease originating from cultured or transplanted aquaculture stocks (Hoegu-Guldberg and Bruno 2010). The emergence of these diseases is likely a consequence of several factors, including shifting of pathogen ranges in response to warming, changes to host susceptibility as a result of increasing environmental stress, and the expansion of potential vectors. Classical examples are outbreaks of oysters infected with MSX (*Haplosporidium nelsoni*), Dermo (*Perkinsus marinus*), and *Bonamia* spp. (Ford and Smolowitz 2007, Soniat et al. 2009, Shumway 2011). In most cases, pathogens have undergone rapid ecological and genetic adaptation in response to climate change. Guidelines for management of these diseases are well-developed for shellfish and other aquatic species. Managing for disease outbreaks is a key aspect of climate adaptation to prevent adverse impact to EFH. Management guidelines include record keeping, isolation and quarantine, and strict regulations on stocking or transplanting species from infected areas. Following these management recommendations should yield protection and conservation benefits for EFH.

Use of drugs, biologics, and other chemicals

Disease control by prevention is preferable to prophylactic measures and curative medical treatment. However, aquaculture drugs, biologics, and other chemicals play an important role in the integrated management of aquatic species health. Aquaculture operations in the United States use these products for: (1) disinfectants as part of biosecurity protocols, (2) herbicides and pesticides used in pond maintenance, (3) spawning aids, (4) vaccines used in disease prevention, or (5) marking agents used in resource management (AFS 2011). Additionally, some chemicals may be used as antifouling biocides for nets, cages, and platforms. Despite the best efforts of aquaculture producers to avoid pathogen introductions, therapeutic drugs are occasionally needed to control mortality, infestations, or infections. The availability and use of legally approved pharmaceutical drugs, biologics and other chemicals is quite limited in marine aquaculture (FDA 2012). A list of FDA approved drugs for use in marine aquaculture is provided in Appendix C.

Just as in the case of biological pathogens, the potential environmental impact of chemicals used in aquaculture, and those occurring as normal byproducts of stock physiology, varies greatly with hydrology and the proximity of other susceptible organisms:

1) Closed onshore systems: Water is infrequently discharged from these systems, so they generally pose low risk to the environment. However, improper application of chemicals and failure to comply with requirements for withdrawal periods can more easily harm stock and in the case of food fish may pose some risk to human health.
2) Flow-through onshore systems: Discharge of chemicals from these systems will typically occur in shallow coastal waters or wetlands. The potential for downstream concentration of anthropogenic contaminants, nitrogenous waste products, therapeutics,

etc. is relatively high. Further such coastal areas are frequently sensitive to insult and of high conservation priority.

3) Inshore and nearshore cages and net pens: These operations share most attributes of concern with Flow-through onshore systems but add the possibility of wild organisms coming into direct contact with medicated feed. Further, some mitigating practices such as detention ponds and effluent treatment are not options. Antifouling biocides may be employed. Shallow, low energy areas with poor mixing represent the least desirable locations.
4) Offshore cages and net pens: Rapid dilution of chemicals in these operations is a major advantage and concentrated aquaculture byproducts are unlikely to reach the benthos. One caveat is that external therapeutics may need to be administered in greater concentration and volume to be effective. Wild, nektonic organisms congregate around cages and so can come into direct contact with medicated feed. Additionally, antifouling biocides are likely to be needed to maintain functionality of offshore nets and cages.

While antibiotics are a commonly cited chemical therapeutant, the use of antibiotics in U.S. aquaculture is not common and strictly limited, and global use in aquaculture of antibiotics has declined in recent years, up to 95% in the culture of salmon and other species. This decline is largely attributed to improved husbandry and use of vaccines (Asche and Bjorndal 2011; Forster 2010; Rico et al. 2012). Antibiotics are characterized by low toxicity to non-bacterial organisms. The environmental risks of antibiotic use are minimal, especially with regards to impacts to fisheries and EFH. The transference of antimicrobial drug resistance among marine fish and shellfish pathogens is theoretically possible but has not yet been demonstrated. In a comprehensive review of the salmon aquaculture industry, no direct evidence of negative impact to wild fish health resulting from antibiotic use in salmon farming has been found (Burridge et al. 2010). With farms that use medicated feeds, some antibiotic compounds can persist in sediments around fish farms and therefore affect the microbial community. Laboratory and field studies have found that antibiotic persistence in sediment ranges from a few days to years depending on the drug in question and the geophysical properties of the water or sediment (Scott 2004, Armstrong et al. 2005, Rigos and Troisi 2005). At present, there are no approved antibiotics for use with marine aquatic species in the South Atlantic. A limited number of broad spectrum antibiotics and feed additives (*i.e*., florfenicol and oxytetracycline) are allowed as part of the National Investigational New Animal Drug Program, which is regulated by FDA and managed through partnership with the U.S. Fish and Wildlife Service. Antibiotics like other medicines should be used sparingly with prescription and in accordance with approved protocol to minimize environmental interactions.

Cultured fish are susceptible to parasitic diseases. For example, protozoa, monogenetic trematodes and arthropod parasites such as copepods, caligids, and isopods are naturally present and relatively harmless in wild fish populations, but under culture conditions they may dramatically proliferate and cause major stock losses with the potential for more frequent and intense infections in wild fish populations. Effective mitigation, management, and control of parasitic infections requires good husbandry. Chemicals used in the treatment of most parasitic infections in net pen operations are subsequently released to the aquatic environment. These compounds have varying degrees of environmental impact, but many are lethal to non-targeted aquatic invertebrates. The use of large quantities of drugs and chemicals for parasite control has the potential to be detrimental to fish health and EFH. Also there is evidence that repeated use of chemotherapeutants has led to resistant strain of ectoparasites such as “sea lice”

(*Lepeophtheirus*). Excessive use of parasiticides is of concern to the aquaculture industry and its regulators.

The most common biologics used for aquatic organisms are vaccines. A vaccine is any biologically based preparation intended to establish or improve immunity to a particular pathogen or group of pathogens. Vaccines have been used for many years in humans and agricultural livestock. They are considered the safest prophylactic approach to management of aquatic animal health and pose no risk to the environment or EFH. In aquaculture, the use of vaccines for disease prevention has expanded both with regard to the number of aquatic species and number of targeted pathogens. Vaccination has become a basis for good health for most finfish operations. Commercial vaccines can be administered by injection or immersion. Oral vaccines remain experimental. Vaccines have been successfully used to prevent a variety of bacterial diseases in finfish. Few viral vaccines are commercially available and vaccines for fungal and parasitic diseases do not exist. All vaccines for use on fish destined for human consumption must be approved by the USDA APHIS, the federal agency responsible for regulating all veterinary biologics, including vaccines, bacterins, antisera, and other products of biological origin.

Water quality impacts

Water quality is a key factor in any aquaculture operation, affecting both success and environmental sustainability. Extensive aquaculture operations should be sited in areas with an abundant and reliable supply of good water quality, and intensive operations face logistical husbandry and engineering challenges. The primary risks to water quality from marine aquaculture operations are increased organic loading, nutrient enrichment, and harmful algal blooms. Excess nitrogenous waste products and suspended organic solids in finfish aquaculture effluents can cause eutrophication in receiving water bodies when nutrient inputs exceed the capacity of natural dispersal and assimilative processes. Elevated nutrients and declines in dissolved oxygen are sometimes observed in areas near the discharge of high-density operations. These conditions rarely persist or present long-term risk to water quality; however acute damage to sensitive ecosystems may be dramatic and in the worst cases irreparable.

At some farm sites, a phytoplankton response to nutrient loading has been reported (Anderson et al. 2002) but generally this is a low risk. Because a change in primary productivity linked to fish farm effluents would have to be detected against the background of natural variability, it is difficult to discern effects unless they are of great magnitude and duration. Small, dispersed operations are probably of less consequence, but where large scale established aquaculture industry is concentrated in an area, anthropogenically derived nutrients could be of concern. However, contingency planning for harmful algal blooms and other natural perturbations should be considered, particularly in areas with known and frequent bloom events. Examples of mitigating practices include contingency planning for net pen relocation and development of a coordinated early warning system designed to detect early blooms, minimize economic loss and environmental impact.

Environmental impacts will vary by location (*i.e.*, on-shore, near-shore, and offshore); therefore, careful selection of sites is the most important tool for risk management. Operations appropriately sited in well-flushed, non-depositional areas may have little to no impact on water quality. The approach to limiting impacts to water quality will also vary by production format. For example, closed systems located onshore are able to directly control their discharges while production systems located offshore rely on best management practices, including siting aquaculture operations outside of nutrient sensitive habitats (*e.g.*, EFH), using responsible cleaning practices, integrating feed management strategies, using optimally formulated diets.

Aquaculture operations are regulated under the Clean Water Act, by the National Pollutant Discharge Elimination System (NPDES), a permitting system administered by the EPA for wastewater discharges into navigable waters.[19] NPDES permits contain industry-specific, technology and water-quality-based limits, and establish pollutant monitoring and reporting requirements.[20] Aquaculture operations that qualify as concentrated aquatic animal production facilities (*i.e.*, produce more than 45,454 harvest weight kilograms of fish and feed) must obtain a permit before discharging wastes. A permit applicant must provide quantitative analytical data identifying the types of pollutants present in wastewater effluents. The permit will set forth the conditions and effluent limitations under which an aquaculture operation may make a discharge. NPDES permit limitations are based on best professional judgment when national effluent limitations guidelines have not been issued pertaining to an industrial category or process.

Benthic sediment and community impacts

Benthic impacts can result from deposition of organic wastes, chemicals, therapeutics, and biocides from aquaculture operations. These impacts can affect EFH if aquaculture operations are not properly sited or managed. Excess feed and feces are the predominant sources of particulate wastes from fish farms. Shellfish operations release pseudofeces, a byproduct of mollusks filtering food from the water column. If allowed to accumulate, particulate waste products may alter biogeochemical processes of decomposition and nutrient assimilation. At sites with poor circulation, waste accumulation can alter the bottom sediment and perturbate infaunal communities if wastes are released in excess of the aerobic assimilative capacity of the bottom. Under such conditions, sediments will turn anoxic and the benthic community will decline in species diversity.

Common indicators used to assess benthic condition include total organic carbon, redox potential, total sulfides, and abundance and diversity of marine life. Electro-chemical and image analysis methods are used to quantify video-recorded observations of benthic condition. These indicators guide BMPs for grading and stocking fish, fallowing, or adjusting feed rates. Fallowing is the practice of temporarily relocating or suspending aquaculture operations to allow the benthic community and sediments to undergo natural recovery from the impacts of nutrient loading. Under ideal conditions, farms should not require a fallowing period for the purpose of sediment recovery; however, this practice is widely and successfully implemented around the world as a management practice for preventing damage to the benthic environment and EFH (Tucker and Hargreaves 2008). Fallowing times range from a few months to several years depending on local hydrology and the level of accumulation (Brooks et al. 2003, Brooks et al. 2004, Lin and Bailey-

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[19]Pursuant to the provisions of Section 402(a)(1); 40 CFR 122.44(k) of the Federal Water Pollution Control Act (Clean Water Act).

[20] EPA issues effluent guidelines for categories of existing sources and sources under Title III of the Clean Water Act. The standards are technology-based (*i.e.*, they are based on the performance of treatment and control technologies); they are not based on risk or impacts upon receiving waters

Brock 2008).

Benthic accumulation of organic wastes can be reduced by siting aquaculture operations in well-flushed areas, or in areas where net erosional sediments can decrease or eliminate accumulation of wastes, thereby minimizing benthic effects. Benthic monitoring plans should be designed to allow for early detection of enrichment and deterioration of benthic community structure. Additionally, nearby control sites should be established in order to collect baseline data for natural variability.

Location Specific Interactions with EFH

Onshore Aquaculture

Onshore aquaculture activities occur on-land in ponds, raceways, and tank-based systems. These systems can be used for multiple phases of aquaculture including broodstock holding, hatchery production, nursery production, grow-out, and quarantine. Water demand and usage varies from conventional pond systems to intensive recirculating aquaculture systems, which may employ sophisticated filtration components for water reuse. Onshore marine aquaculture operations have the potential to impact a variety of EFHs including:

a) waters and benthic habitats in or near marine aquaculture sites
b) exposed hard bottom (*e.g.*, reefs and live bottom) in shallow waters
c) submerged aquatic vegetation beds
d) shellfish beds
e) spawning and nursery areas
f) coastal wetlands
g) riverine systems and associated wetlands

The greatest impacts to EFH by onshore aquaculture involve escape of non-native species and nutrient discharge and its impact on water quality and bottom sediments. Onshore aquaculture activities affecting EFH are regulated by existing state and federal laws and requirements specified by EPA's National Pollutant Discharge Elimination System and coastal habitat protection plans.

Nearshore Aquaculture

Nearshore aquaculture activities are those that occur in rivers, sounds, estuaries and other areas that extend through the coastal zone.[21] Currently in the South Atlantic region, nearshore aquaculture is characterized primarily as shellfish aquaculture with hard clams *Mercenaria mercenaria* and oysters *Crassostrea virginica* comprising the most commonly cultured species.

While the relative risk of nearshore shellfish aquaculture to various EFHs is uncertain, the ranges of possible interactions include:

[21] The term "coastal zone" means the coastal waters strongly influenced by each other and in proximity to the shorelines of several coastal states, and includes islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. The zone extends seaward to the outer limit of State title and ownership under the Submerged Lands Act (43 U.S.C. 1301 et seq.)

a) coral, coral reef and live/hard bottom habitat
b) marine and estuarine waters
c) estuarine wetlands, including mangroves and marshes
d) submerged aquatic vegetation
e) waters that support diadromous fishes, and their spawning and nursery habitats
f) waters hydrologically and ecologically connected to waters that support EFH

The environmental effects of shellfish and finfish aquaculture in coastal waters are well-documented (Naylor et al. 2006; Nash 2005; Tucker and Hargreaves 2008). Poorly sited and managed aquaculture activities can have significant impact on benthic communities, water quality, and associated marine life. While there are case studies documenting environmental impacts of practices used several decades ago, regulatory and management practices are reducing the likelihood of negative environmental effects (Price and Morris 2013).

In the case of cage culture, water quality and benthic effects are sometimes observed; however, these are typically episodic and restricted to within 30 m of the cages (Nash 2003). Long-term risks to water quality from offshore aquaculture activities are unlikely when operations are sited in well-flushed waters.

The most studied environmental benefit from marine aquaculture operations is as fish attractants. Wild fish use aquaculture cages for refuge and for foraging on biofouling organisms and uneaten feed. Wild fish can help distribute organic waste away from the cages and re-suspend organic compounds in sediments. As a result, overall fish abundance may increase in areas with aquaculture operations. Recreational and commercial fishers may benefit from increased fishing opportunities around marine aquaculture operations. Conversely, interactions with marine mammals that are attracted to the forage fish around cages are identified as potential long-term concern for management of protected species.

Potential interactions of nearshore shellfish aquaculture with EFH are changes to benthic habitat as a result of pseudofeces, the effects of mechanical harvesting, conversion of soft sediment habitat to hard bottom shellfish reef, displacement of cultured organisms, potential genetic transfer, sedimentation and loading of organic waste to the water column and benthic sediments, and disruption of the benthic community. Some changes could potentially impact SAV located near shellfish aquaculture operations, although this impact likely varies with species and production type.

In general, shellfish and algae aquaculture has positive impacts on EFH, providing ecosystem services and habitat related benefits in the estuary including mitigation of land-based nutrients and increased habitat for fish, shellfish, and crustaceans (Shumway 2011). Therefore, the positive and negative effects of shellfish culture activities to EFH need to be considered. The risk of nearshore aquaculture impacts to EFH can be minimized by including terms and conditions designed to protect sensitive habitats in permits issued under state and federal laws and regulations. Best management practices are now in place for shellfish aquaculture along the U.S. East Coast (Flimlin 2010).

Offshore Aquaculture

Offshore aquaculture activities occur in areas of the open ocean that extend from the seaward edge of the coastal zone through the exclusive economic zone.[22] In the South Atlantic region, offshore aquaculture may include the cultivation of macrophytic algae, molluscan shellfish, shrimp, or finfish. With exception of a few live rock aquaculture operations, there are currently no offshore aquaculture activities occurring in the South Atlantic region. It is feasible that co- siting aquaculture facilities with other offshore industries such as wind energy could facilitate offshore aquaculture development.[23] Over 25 laws exist to provide regulatory oversight of aquaculture in federal waters. Some examples include the Clean Water Act and the Coastal Zone Management Act.

While the relative threat of offshore aquaculture to EFHs varies widely depending on siting and management considerations, the ranges of possible interactions include:

a) coral, coral reef and live/hardbottom habitat, including deepwater coral communities
b) marine and estuarine waters
c) waters that support diadromous fishes and their spawning and nursery habitats
d) waters hydrologically and ecologically connected to waters that support EFH

The environmental effects of offshore shellfish and finfish aquaculture are not as well- documented for inshore waters. The information gleaned from coastal production sites, especially those with conditions similar to federal waters, provide some indications as to the potential effects of offshore aquaculture (see section on nearshore aquaculture).

Live Rock Aquaculture

Live rock is defined as living marine organisms or an assemblage thereof attached to a hard calcareous substrate, including dead coral or rock. In 1994, the SAFMC and GMFMC established a live rock aquaculture permitting system for state and federal waters off the coast of Florida under Amendment 2 to the Fishery Management Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic. The SAFMC further amended this program under Amendment 3 to the Coral FMP (1995), during which time the SAFMC received extensive public comment. This permitting system allows deposition and harvest of material for purposes of live rock aquaculture while maximizing protection of bottom habitat, EFH, and HAPC in federal waters of the South Atlantic.

[22] The term 'offshore aquaculture' is often used to refer to aquaculture in waters under federal jurisdiction, which typically extend from 3-200 nautical miles from the shoreline

[23] A notable exception is Live Rock Aquaculture, managed under Amendment 3 to the Coral Fishery Management Plan (1995)

SAFMC Policy for Marine Aquaculture in Federal Waters – June 2014

The SAFMC supports the establishment and enforcement of the following general requirements for marine aquaculture projects authorized under the Magnuson-Steven Fishery Conservation Act (MSA) or other federal authorities, to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment (SAFMC 1998a; SAFMC 1998b):

1. Marine aquaculture activities in federal waters of the South Atlantic require thorough public review and effective regulation under MSA and other applicable federal statutes.

2. Aquaculture permits should be for at least a 10-year duration (or the maximum allowed if the applicable law or regulation sets a maximum less than 10 years) with annual reporting requirements (activity reports). Permits of 10 years or more should undergo a 5-year comprehensive operational review with the option for revocation at any time in the event there is no prolonged activity or there are documented adverse impacts that pose a substantial threat to marine resources.

3. Only drugs, biologics, and other chemicals approved for aquaculture by the FDA, EPA, or USDA should be used, in compliance with applicable laws and regulations (see Appendix for current list of approvals).

4. Only native (populations) species should be used for aquaculture in federal waters of the South Atlantic.

5. Genetically modified organisms should only be used for aquaculture in federal waters of the South Atlantic, pending FDA and/or other Federal approval, following a rigorous and documented biological assessment which concludes there is no reasonable possibility for genetic exchange with natural organisms or other irreversible form of ecological impact. Further, aquaculture of genetically modified organisms should be prohibited in federal waters of the South Atlantic when there exists a reasonable opportunity for escapement and dispersal into waters of any state in which their culture and/or commerce are prohibited by state rule or policy.

6. Given the critical nature of proper siting, the permitting agency should require the applicant to provide all information necessary to thoroughly evaluate the suitability of potential aquaculture sites. If sufficient information is not provided in the time allotted by existing application review processes, the permitting agency should either deny the permit or hold the permit in abeyance until the required information is available.

7. Environmental monitoring plans for projects authorized under MSA should be developed by the applicant/permit holder and approved by NOAA Fisheries with input from the Council.

8. Fishery management plans for aquaculture should require permittees to have adequate funds (*e.g.*, assurance bond) committed to ensure removal of organisms and decommissioning of facilities that are abandoned, obsolete, or storm-damaged or have had their permit revoked. The plans should also require that the amount of these funds be determined by NOAA Fisheries with input from the Council and that the funds be held in

trust.

9. When issuing permits for aquaculture in federal waters, NOAA Fisheries should specify conditions of use and outline the process to repeal permits in order to prevent negative impacts to EFH. NOAA should take the appropriate steps to modify or revoke permits using its authority if permit conditions are not being met.

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Appendix A.

<u>List of Potentially Affected Species Currently Identified by SAFMC and their EFH in the South Atlantic</u>

Sections of South Atlantic waters potentially affected by these projects, both individually and collectively, have been identified as EFH or EFH-HAPC by the SAFMC. Potentially affected species and their EFH under federal management include (SAFMC, 1998b):

a) Summer flounder (various nearshore waters; certain offshore waters);
b) Bluefish (various nearshore waters);
c) Many snapper and grouper species (live hardbottom from shore to 600 feet, and – for estuarine-dependent species (*e.g.*, gag grouper and gray snapper) – unconsolidated bottoms and live hardbottoms to the 100 foot contour);
d) Black sea bass (various nearshore waters, including unconsolidated bottom and live hardbottom to 100 feet, and hardbottoms to 600 feet);
e) Penaeid shrimp (offshore habitats used for spawning and growth to maturity, and waters connecting to inshore nursery areas);
f) Coastal migratory pelagics (*e.g.*, king mackerel, Spanish mackerel; sandy shoals of capes and bars, barrier island ocean-side waters from the surf zone to the shelf break inshore of the Gulf Stream);
g) Corals of various types and associated organisms (on hard substrates in shallow, mid-shelf, and deep water);
h) Muddy, silt bottoms from the subtidal to the shelf break, deep water corals and associated communities;
i) Areas identified as EFH for Highly Migratory Species managed by the Secretary of Commerce (*e.g.*, for sharks this includes inlets and nearshore waters, including pupping and nursery grounds), and
j) Federal or state protected species.

Appendix B.

List of Potentially Affected Habitats Currently Identified by the SAFMC

Many of the habitats potentially affected by these activities have been identified as EFH- HAPCs by the SAFMC. Each habitat and FMP is provided as follows:

a) All hardbottom areas (SAFMC snapper grouper);
b) Nearshore spawning and nursery sites (SAFMC penaeid shrimps);
c) Benthic Sargassum (SAFMC snapper grouper);
d) From shore to the ends of the sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras, North Carolina; Hurl Rocks, South Carolina; and Phragmatopoma (worm reefs) reefs off the central coast of Florida and near shore hardbottom south of Cape Canaveral (SAFMC coastal migratory pelagics);
e) Hurl Rocks (South Carolina); the Phragmatopoma (worm reefs) off central east coast of Florida; nearshore (0-4 meters; 0-12 feet) hardbottom off the east coast of Florida from Cape Canaveral to Broward County; offshore (5-30 meters; 15-90 feet) hardbottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary (SAFMC coral, coral reefs and live hardbottom Habitat);
f) EFH-HAPCs designated for HMS species (e.g., sharks) in the South Atlantic region (NMFS Highly Migratory Species).
g) Oculina Bank HAPC and proposed deepwater coral HAPCs (SAFMC coral, coral reefs, and live hardbottom habitat), and
h) HAPCs for diadromous species adopted by the Atlantic States Marine Fisheries Commission (ASMFC).

Appendix C.

Regulation of Drugs, Biologics, and Other Chemicals

Several federal agencies are involved in regulating drugs, biologics, and chemicals used in aquaculture. Each federal agency has specific, congressionally mandated responsibilities to regulate the products under their jurisdictions. In the case of aquaculture, there is some overlap between these federal agencies, as well as with state and local regulatory bodies.

The U.S. Food and Drug Administration (FDA) regulates the use of animal drugs and animal feed in aquaculture, ensuring their safety and efficacy. The FDA is responsible for ensuring that drugs used in food-producing animals, including cultured seafood, are safe and effective and that foods derived from treated animals are free from potentially harmful drug residues.

The EPA regulates disinfectants, sanitizers, and aquatic treatments used solely for control of algae, biofilm or pest control (excluding pathogens in or on fish). As authorized by the Clean Water Act, EPA also administers NPDES permits, which regulates discharge of pollutants that include drugs and chemicals from aquaculture operations into U.S. waters.

The USDA Animal and Plant Health Inspection Service (APHIS) regulates all veterinary biologics, including vaccines, bacterins, antisera, diagnostic kits, and other products of biological origin. APHIS is responsible for testing, licensing, and monitoring of vaccines used in aquaculture. They insure that all veterinary biologics used for diagnosis, prevention, and treatment of aquatic diseases are pure, safe, potent, and effective.

The Federal Food, Drug, and Cosmetic Act (FFDCA) defines the term “drug” broadly to include articles intended for use in the diagnosis, cure, mitigation, and treatment or prevention of disease. In aquaculture, this includes compounds such as antibiotics, sedatives and anesthetics, gender manipulators, and spawning aids. Common household compounds are also considered drugs (*e.g.*, hydrogen peroxide, salt, ice). These products cannot be used on aquatic species unless they have been approved by FDA for the intended purpose.

- Disinfectants are compounds, which have antimicrobial properties that are generally applied to equipment and structures and are not intended to have a therapeutic effect on cultured animals.
- Pesticides are not widely used in aquaculture; however, herbicides can be an important part of aquatic weed management in pond production.
- Biologics include a range of products of biologic origin used in the diagnosis, prevention, and treatment of diseases. In aquaculture, the most commonly used biologics are vaccines used to immunize animals and prevent infections from occurring.

It is illegal to use (1) unapproved drugs for any purpose or (2) approved drugs in a manner other than that specified on the product label unless the drugs are being used under the strict conditions of an investigational new animal drug (INAD) exemption or an extra-label prescription issued by a licensed veterinarian. Some aquaculture producers may use drugs that are not approved for aquaculture, but considered to be of low regulatory priority (LRP) for purposes of enforcement. Examples include acetic acid, carbon dioxide, sodium bicarbonate, sodium chloride, and ice.

For more information visit:

US FDA Animal and Veterinary Drugs for Aquaculture

http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.h tm

A Quick Reference Guide to: Approved Drugs for Use in Aquaculture

http://www.fda.gov/downloads/AnimalVeterinary/ResourcesforYou/AnimalHealthLiteracy/UC M109808.pdf

Guide to Using Drugs, Biologics, and Other Chemicals in Aquaculture

http://www.fws.gov/fisheries/aadap/AFS-FCS%20documents/GUIDE_OCT_2011.pdf

Table 1. Approved and conditionally approved drugs for use in marine aquaculture.

Active Ingredient	Tradename	Indication(s)
Chorionic gonadotropin	Chorulon®	Aid to improve spawning function in broodstock
Formalin	Parasite-S®, Formalin-F®, Formacide-B®, Paracide-F®	Control of fungi and external parasites in all finfish and penaeid shrimp
Oxytetracycline hydrochloride	Pennox® 343, Tetroxy®	Mark skeletal tissues for tagging finfish
Oxytetracycline dihydrate	Terramycin® 200	Broad spectrum antibiotic to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, enteric red mouth, pseudomonas disease, and other gram negative systemic bacteria in marine fish, Mark skeletal tissues for tagging finfish
Tricaine methanesulfonate	Finquel®, Tricaine-S®	Anesthesia and immobilization of finfish and other aquatic poikilotherms

Table 2. Low regulatory priority aquaculture drugs for use in marine aquaculture.

Active Ingredient	Indication(s)
Acetic acid	Parasiticide for finfish
Calcium chloride	Used to aid in egg hardening, Used to aid in maintaining osmotic balance during holding and transport of aquatic animals
Calcium oxide	External protozoacide for finfish
Carbon dioxide gas	Anesthesia and immobilization of finfish and other aquatic poikilotherms
Fuller's Earth	Use to reduce the adhesiveness of fish eggs
Garlic (whole form)	Use to control helminth and sea lice infestations of marine finfish
Ice	Use to reduce the metabolic rate of aquatic poikilotherms during transport
Magnesium sulfate	Used to treat external parasites (monogenic trematodes and crustaceans) in finfish
Onion (whole form)	Used to treat external parasites (sea lice and other crustaceans) in finfish
Papain	Used to reduce the adhesiveness of fish eggs
Potassium chloride	Used to aid in maintaining osmotic balance during holding and transport of aquatic animals
Povidone iodine	Used to disinfect fish eggs
Sodium bicarbonate	Used to introduce carbon dioxide into water for anesthetizing aquatic animals
Sodium chloride (salt)	Used to aid in maintaining osmotic balance during holding and transport of aquatic animals; Parasiticide for aquatic animals
Sodium sulfite	Used to reduce the adhesiveness of fish eggs
Thiamine hydrochloride	Used to prevent or treat thiamine deficiency in finfish
Urea and tannic acid	Used to reduce the adhesiveness of fish eggs

Table 3. Investigational new animal drug exemptions for use in marine aquaculture. Permits held by the U.S. Fish and Wildlife Service as part of the National INAD Program.

Active Ingredient	Tradename	Indication(s)
Common carp pituitary	-	Aid to improve spawning function in broodstock
Catfish pituitary	-	Aid to improve spawning function in broodstock
Chloramine-T	Halamid®, Actamide®	Control of bacterial gill disease and external flavobacteriosis in certain species of marine finfish
Florfenicol	Aquaflor®	Broad spectrum antibiotic to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, and pseudomonas disease in marine aquatic animals
Hydrogen peroxide	Perox-Aid®	Use to treat external parasites in marine finfish
Luteinizing hormone releasing hormone analogue (LHRHa)	-	Aid to improve spawning function in broodstock
Oxytetracycline hydrochloride	Pennox® 343	Broad spectrum antibiotic to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, enteric red mouth, pseudomonas disease, and other gram negative systemic bacteria in marine fish, Mark skeletal tissues for tagging finfish
Oxytetracycline dihydrate	Terramycin® 200	Broad spectrum antibiotic to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, enteric red mouth, pseudomonas disease, and other gram negative systemic bacteria in marine fish, Mark skeletal tissues for tagging finfish
Calcein	Se-Mark®	Mark skeletal tissues for tagging finfish

Table 3 continued. Investigational new animal drug exemptions for use in marine aquaculture. Permits held by the U.S. Fish and Wildlife Service as part of the National INAD Program.

Active Ingredient	Tradename	Indication(s)
Salmon ganadotropin releasing hormone analogue (sGnRHa)	Ovaprim®, Ovaplant®	Aid to improve spawning function in broodstock
Benzocaine	Benzoak®	Anesthesia and immobilization of finfish and other aquatic poikilotherms
Eugenol	Aqui-S® 20E	Anesthesia and immobilization of finfish and other aquatic poikilotherms
Emamectin benzoate	Slice®	Use to control sea lice and other external parasite infestations of marine finfish
Methyl testosterone	-	Use to produce populations comprising over 90% phenotypically male finfish

Appendix D.

Examples of Existing Federal Laws Designed to Minimize Environmental Risks Associated with Marine Aquaculture.

Coastal Zone Management Act
Endangered Species Act
Rivers and Harbors Act of 1899
Clean Water Act
National Marine Sanctuaries Act
National Invasive Species Act
National Aquaculture Act
Outer Continental Shelf Lands Act
National Sea Grant College and Program Act Fish
and Wildlife Coordination Act
E.O. 11987: Exotic Organisms
E.O. 12630: Takings
E.O. 13089: Coral Reef Protection
E.O. 13112: Invasive Species
E.O. 13158: Marine Protected Areas
Marine Mammal Protection Act
Magnuson-Stevens Fishery Conservation and Management Act Animal
Health Act of 2002

Marine Submerged Aquatic Vegetation (SAV) Habitat Policy – June 14

The South Atlantic Fishery Management Council (SAFMC) and the Habitat Advisory Panel have considered the issue of the decline of Estuarine and Marine Submerged Aquatic Vegetation (SAV) or seagrass habitat in Florida and North Carolina as it relates to Council habitat policy. Subsequently, the Council's Habitat Committee requested that the Habitat Advisory Panel develop the following policy statement to support Council efforts to protect and enhance habitat for managed species.

Description and Function:

In the South Atlantic region, SAV is found primarily in the states of Florida and North Carolina

where environmental conditions are more favorable than in South Carolina and Georgia . The distribution of SAV habitat is indicative of its importance to economically important fisheries: in North Carolina, total coverage is estimated to be 130,000 acres (Deaton et al. 2010); in Florida, the nearshore seagrass coverage is estimated to be 2.2 million acres with an additional 2-3 million acres offshore in the Gulf of Mexico (Yarbro and Carlson, 2013).

SAV is designated through Fishery Management Plans as Essential Fish Habitat for several federally managed species, including Penaeid shrimp, spiny lobster, snapper-grouper species, and cobia. It is also designated as Habitat Area of Particular Concern for snapper-grouper species and juvenile summer flounder. SAV is critically important to numerous state managed species, and a diverse assemblage of fauna that are prey to federally managed species; SAV provides valuable ecological and economic functions. Food and shelter afforded by SAV result in a complex and dynamic system that provides a primary nursery habitat for various organisms important both to the overall system ecology, to commercial and recreational fisheries, and to non-harvested fish, shellfish, manatees, and sea turtles. Using ecological services valuations of Costanza et al. (1997) and Orth et al. (2006), Florida seagrass ecosystems alone provide services worth more than $20 billion a year. For more detailed discussion, please see Appendix 1.

Threats and Status:

Natural events, human activities, and global climate change influence the distribution and quality of SAV habitat. Natural events may include regional shifts in salinity or light availability because of drought or excessive rainfall, animal foraging, storm events, cold temperatures, or disease. Human- related activities can affect SAV through physical disturbance or alteration of habitat or water quality degradation. SAV is extremely susceptible to physical disturbance because of its vulnerable location in shallow, nearshore waters. Activities such as dredging for navigational channels or marinas, propeller scarring, bottom-disturbing fishing activities, and shoreline alteration can inflict damage or mortality on SAV directly. SAV is also vulnerable to water quality degradation and in particular to suspended sediment and eutrophication, due to its relatively high light requirements. Changing land use and increasing population threaten water quality in the coastal zone. The most recent syntheses of research describe a global crisis for SAV ecosystems (Orth et al. 2006; Waycott et al. 2009). Climate change and sea level rise could cause large-scale losses of SAV habitat due to rising water levels and temperatures, changing weather patterns, and a collapse of barrier islands. The major anthropogenic threats include:

(1) light limitation due to

  (a) increased particles and colored dissolved organic matter (CDOM) in runoff from land;

  (b) increased phytoplankton in coastal waters due to elevated nutrient inputs from runoff;

  (c) sediment resuspension from wind, wave, or boat action.

(2) mechanical damage due to:

  (a) propeller damage from boats;

  (b) bottom-disturbing fish-harvesting techniques;

  (c) dredging and filling.

SAV habitat in both Florida and North Carolina has experienced significant losses over the last 65 years. However, conservation measures taken by regional, state and federal agencies have slowed, and in some areas reversed, the decline. For example, in both North Carolina and Florida, progress has been made to map, monitor, and assess change in seagrass distribution so that appropriate management actions can be taken. In Florida, several National Estuary Programs have worked collaboratively with local governments and industry to reduce nutrient inputs, especially nitrogen, to estuarine and coastal waters. These efforts have resulted in significant increases in SAV acreage. Other advancements in seagrass protection and enhancement have been made, such as prop scar restoration, establishment of no motorized vessel zones around shallow grass beds, and implementation of more stringent stormwater runoff rules. The threats to this habitat and the potential for successful conservation measures highlight the need to continue to address the causes of SAV decline. Therefore, the SAFMC recommends immediate and direct action be taken to stem the loss of this essential habitat and to restore SAV beds where feasible. For more detailed discussion, please see Appendix 2.

SAV POLICY

Because of the economic and ecological value of SAV ecosystems, the SAFMC considers it imperative to take directed and purposeful action to protect remaining habitat and to support actions to restore SAV in locations where they have occurred in the past. The SAFMC strongly recommends that a comprehensive adaptive management strategy be developed to address the decline in SAV habitat in the South Atlantic region, including the Indian River Lagoon which has suffered more than a 50% decline in SAV in since 2011 due to a large and persistent phytoplankton bloom. Furthermore, as a stepping stone to such a long- term protection strategy, the SAFMC recommends the adoption of a reliable status and trend survey methodology (mapping and monitoring) to verify the location, health, and coverage of SAV at sub-regional and/or local scales (e.g., Florida's Seagrass Integrated Monitoring and Mapping Program and/or Virginia Institute of Marine Sciences' annual mapping of Chesapeake Bay).

The SAFMC will encourage the South Atlantic states to assess the status and trends in SAV ecosystems and will consider establishing specific plans for protecting and revitalizing, where necessary, the SAV resources of the South Atlantic region. This action can be achieved by the following four integrated components:

Monitoring and Research:

Periodic mapping and monitoring of SAV in the region are required to determine how distribution has changed spatially over time, the progress toward the goal of a net resource gain, and what management actions are needed to reach established goals.

The SAFMC supports efforts to:

- Develop and standardize imagery acquisition and resource mapping protocols, with regional modification as necessary to achieve effective results (Yarbro and Carlson 2013).
- Develop and maintain a Geographic Information System database for essential habitat including

SAV and use that information for assessment of trends in SAV extent (e.g., SIMM or OBIS-SEAMAP).

- Evaluate water quality criteria needed to support SAV survival and growth and support policy making to manage quality and quantity of surface runoff.
- Research and document causes and effects of SAV losses, including cumulative impacts, watershed runoff, shoreline development, shading associated with pier and

dock, development, invasive species, and extreme weather conditions (drought, tropical storms, algal blooms, etc.).

- Encourage states to minimize impacts to SAV by developing design criteria for docks and piers which establish minimum height, maximum width and materials.
- Investigate effective restoration techniques, including ecological function and cost/benefit.
- Research potential effect of climate change on SAV habitat.

Planning:

Establishing goals, objectives, and measures of success is essential to evaluate progress and to provide a framework to direct future actions. The SAFMC supports:

- Watershed planning which incorporates SAV as an integral part of a healthy ecological system and utilizes change in SAV distribution as an indicator of system health.
- The regulatory definition of SAV habitat as: shallow water habitat with appropriate sediment, depth, light penetration and wave energy, including areas without existing SAV.
- Comprehensive planning initiatives as well as interagency coordination, partnerships, and planning to protect SAV habitat and increase awareness.
- The establishment of standardized SAV survey protocols for reviewing coastal development permit applications. This action includes survey windows, survey methods, and in-water work windows.
- The Habitat Advisory Panel members in actively seeking to involve the SAFMC in the review of projects which will impact, directly or indirectly, SAV habitat resources.

Management:

Based on assessment of monitoring data, research results and planning, management actions should be developed or modified as necessary to address primary issues affecting SAV habitat. Conservation and expansion of SAV habitat are critical to the maintenance of the living resources that depend on these systems. A number of federal and state laws and regulations apply to activities that eliminate or modify SAV habitat, either directly or indirectly (Appendix 3). However, state and federal regulatory processes have been uneven in their effectiveness to prevent or slow the loss of SAV acreage. While restoration results through repair of bottom topography and planting of SAV have improved, these efforts are extremely costly and unsustainable if the causes of SAV loss are not corrected (e.g. Insufficient water clarity, continued prop scarring). Efforts to improve water clarity in areas where SAV was once abundant have resulted in the expansion and creation of SAV habitat on a much larger scale than is feasible through bottom recontouring and plantings alone. Declines in SAV acreage continue in a number of localities in the South Atlantic region (Yarbro and Carlson 2013) and it has often been difficult to implement effective resource management initiatives due to: the lack of adequate documentation of losses and specific cause/effect relationships, public resistance to additional coastal development regulations, and insufficient funding (for more detailed discussion, please see Appendix 3).

SAFMC supports:

- Review and modification of state and federal rules to ensure protection of SAV from impacts such as dredging, propeller scarring, marina and pier construction, and bottom-disturbing fishing activity.
- Review of state water quality standards and rules to determine if changes are needed to protect and enhance SAV.
- Development of SAV restoration guidelines for both high and low salinity SAV to accelerate successful, cost-effective SAV restoration.

Education and Enforcement:

Educating and engaging the public on the value of SAV habitat will aid in the protection of existing SAV habitat and garnish support for additional management measures that may be needed. Enforcing existing regulations to sustain SAV health minimizes the need for additional regulatory actions.

SAFMC supports:

- Design of education programs to heighten the public's awareness of the importance of SAV. An informed public will provide a firm foundation of support for protection and restoration efforts.
- Review of existing regulations and enforcement to determine their effectiveness.

- Coordination with state resource and regulatory agencies to ensure that existing regulations are being enforced.
- Development of economic analyses on the economic benefits of protecting and enhancing SAV habitat.

SAFMC SAV Policy Statement- Appendix 1

ECOSYSTEM SERVICES

Worldwide, submerged aquatic vegetation (SAV) constitutes a common shallow-water habitat type. These angiosperms have successfully colonized standing and flowing fresh, brackish, and marine waters in all climatic zones, and most are rooted in the sediment. Estuarine and marine SAV beds, or seagrasses, occur in the low intertidal and subtidal zones and may exhibit a wide range of habitat forms, from extensive collections of isolated patches to unbroken continuous beds. The bed is defined by the

presence of either aboveground vegetation, its associated root and rhizome system (with living meristem), or the presence of a seed bank in the sediments, as well as the sediment upon which the plant grows or in which the seed back resides. In the case of patch beds, the unvegetated sediment among the patches is considered SAV habitat as well.

There are seven species of marine SAV or seagrass in Florida's shallow coastal areas: turtle grass (*Thalassia testudium*); manatee grass (*Syringodium filiforme*); shoal grass (*Halodule wrightii*); widgeon grass (*Ruppia maritima*); star grass (*Halophila engelmannii*); paddle grass (*Halophila decipiens*); and Johnson's seagrass (*Halophila johnsonii*) (See distribution maps in Appendix 4). *H. johnsonii* is listed by the National Marine Fisheries Service as a threatened plant species. Areas of seagrass concentration along Florida's east coast begin south of Daytona Beach and include Mosquito Lagoon, Banana River, Indian River Lagoon, Lake Worth and Biscayne Bay. In 2010, seagrasses in these estuaries covered about 241,000 acres; an additional 159,000 acres of seagrass occur on the Atlantic side of Key Biscayne (Yarbro and Carlson 2013). Florida Bay, located between the Florida Keys and the Everglades, also has an abundance of seagrasses (145,000 acres), and seagrasses in the Florida Keys National Marine Sanctuary, west and south of the Florida Keys, comprise 856,000 acres. Large-scale losses (47,000 acres) of seagrasses have occurred in the Banana River since 2011. Seagrass acreage in the Southern Indian River Lagoon, Florida Bay and Biscayne Bay are likely stable, but trends in acreage of beds on the ocean side of south Florida are unclear because current estimates date to 1992.

The three dominant SAV species found in North Carolina are shoal grass (*Halodule wrightii*), eelgrass (*Zostera marina*), and widgeon grass (*Ruppia maritima*). Shoalgrass, a subtropical species, has its northernmost distribution at Oregon Inlet, North Carolina. Eelgrass, a temperate species, has its southernmost distribution in North Carolina. Areas of seagrass concentration in North Carolina are in southern and eastern Pamlico Sound, Core Sound, Back Sound, Bogue Sound and the numerous small southern sounds located behind the beaches in Onslow, Pender, Brunswick, and New Hanover Counties (See distribution maps in Appendix 4).

In addition meso- and oligohaline SAV species occur in shallow waters along the western shoreline of Pamlico Sound and the Neuse and Pamlico river tributaries. Widgeon grass is the dominant species in western Pamlico Sound due to its large tolerance to fluctuating salinity and water clarity conditions. In river tributaries, horned pondweed (*Zannichellia palustris*) is often the first species to emerge in the spring, and is replaced by widgeon grass or other species as water temperatures increase (NCDWQ 2007). Other species that occur in western Pamlico Sound and its tributaries include eelgrass, shoal grass, wild celery (*Vallsineria americana*), redhead pondweed (*Potamogeton perfoliatus*), and southern naiad (*Najas guadalupensis*). Many of the tributaries and shallow waters supporting lower salinity grass species are important nursery grounds for Penaeid shrimp, are designated Primary or Secondary Nursery Areas, and thus, are Essential Fish Habitat.

Marine SAV serve several valuable ecological functions in the marine estuarine systems where they occur. Food and shelter afforded by seagrasses result in a complex and dynamic system that provides a primary nursery habitat for various organisms that are important both ecologically and to commercial and recreational fisheries. Organic matter produced by seagrasses is transferred to secondary consumers through three pathways: herbivores that consume living plant matter; detritivores that exploit dead matter; and

microorganisms that use seagrass-derived particulate and dissolved organic compounds. The living leaves of these submerged plants also provide a substrate for the attachment of detritus and epiphytic organisms, including bacteria, fungi, meiofauna, micro- and macroalgae, and macroinvertebrates. Within the seagrass system, phytoplankton are present in the water column, and macroalgae and microalgae are associated with the sediment. No less important is the protection afforded by the variety of living spaces in the tangled leaf canopy of the grass bed itself, and this is especially critical to the juvenile stages of many important fish.

The structure of the beds can also provide a refuge from acoustic stressors in the adjoining water column, including dolphin whistles and boat noise (Wilson et al. 2013). In addition to biological benefits, seagrasses also cycle nutrients and heavy metals in the water and sediments, and dissipate wave energy (which reduces shoreline erosion and sediment resuspension).

Fish may associate with seagrass beds in several ways. Resident species typically breed and carry out much of their life history within the meadow (e.g., gobiids and syngnathids). Seasonal residents typically breed elsewhere, but predictably utilize seagrasses during a portion of their life cycle, most often as a juvenile nursery ground (e.g., sparids and lutjanids). Transient species can be categorized as those that feed or otherwise utilize seagrasses only for a portion of their daily activity, but in a systematic or predictable manner (e.g., haemulids).

In Florida, many economically important species utilize seagrass beds as nursery and/or spawning habitat: spotted seatrout (*Cynoscion nebulosus*), grunts (Heaemulids), snook (*Centropomus* spp.), bonefish (*Albulu vulpes*), tarpon (*Megalops atlanticus*) and several species of snapper (Lutianids) and grouper (Serranids). Densities of invertebrate organisms are many times greater in seagrass beds than in bare sand habitat.

Penaeid shrimp, spiny lobster (*Panulirus argus*), bay scallops (*Argopecten irradians*), green sea turtles (*Chelonia mydas*) and manatees also depend on seagrass beds.

In North Carolina, 40 species of fish and invertebrates have been captured in seagrass beds. Larval and juvenile fish and shellfish including gray trout (*Cynoscion regalis*), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), mullet (*Mugil cephalus*), spot (*Leiostomus xanthurus*), pinfish (*Orthopristis chrysoptera*), gag (*Mycteroperca microlepis*), white grunt (*Haemulon plumieri*), silver perch (*Bairdiella chrysoura*), summer flounder (*Paralichthys dentatus*), southern flounder (*P. lethostigma*), blue crabs (*Callinectes sapidus*), hard shell clams (*Mercenaria mercenaria*), and bay scallops (*Argopecten irradains*) utilize seagrass beds as nursery areas. Seagrasses are the sole nursery ground for

bay scallops in North Carolina. Seagrass meadows are also frequented by adult spot, spotted seatrout, bluefish (*Pomatomus saltatrix*), menhaden (*Brevortia tyrannus*), summer and southern flounder, pink and brown shrimp, hard shell clams, and blue crabs. Offshore reef fishes, including black sea bass (*Centropristis striata*), gag (*Mycteroperca microlepis*), gray snapper (*Lutianus griseus*), lane snapper (*Lutjanus synagris*), mutton snapper (*Lutianus annalis*), and spottail pinfish (*Displodus holbrooki*), also spend a portion of their life cycles in seagrass beds. Ospreys, egrets, herons, gulls and terns feed on fauna in seagrass beds, while swans, geese, and ducks feed directly on SAV itself. Green sea turtles (*Chelonia mydas*) also utilize seagrass beds, and juveniles may feed directly on the seagrasses.

SAFMC SAV Policy Statement- Appendix 2

STATUS

SAV habitat is a valuable natural resource which is now threatened by overpopulation in coastal areas and nearby watersheds. Worldwide, SAV has declined in area since the mid-twentieth century, and light limitation is the primary factor limiting SAV distribution (Orth et al. 2006; Waycott et al. 2009).

Several processes contribute to decreases in water clarity in estuarine and coastal regions; heightened nutrient inputs from coastal watersheds (due to development) fuel the growth of phytoplankton, which in turn reduce light available to benthic vegetation. Higher nutrient levels may also increase the biomass of epiphytes on SAV blades, reducing the light available for photosynthesis. Groundwater enriched by septic systems also may infiltrate the sediments, water column, and near-shore SAV beds with the same effect. Increases in the turbidity of overlying waters, resulting from sediment in runoff, dredging, channelization, boat traffic, and resuspension of bottom sediments, also may reduce the amount of light available to SAV. Changes in the timing and volume of river runoff due to climate change may also result in reduced light availability to coastal SAV. For example, increased and prolonged runoff from highly polluted/colored rivers, especially during spring and summer, appear to reduce light levels in Florida's Indian River Lagoon and jeopardize the survival of SAV. With excessive water column productivity, lowered dissolved oxygen concentrations may result and are detrimental to invertebrate and vertebrate grazers. Loss of these grazers may result in overgrowth by epiphytes and loss of food for predators. SAV losses resulting from reduced light availability can be more subtle and are often difficult to assess in the short term (months).

Although not caused by humans, disease ("wasting disease" of eelgrass in North Carolina) has historically impacted SAV beds. Activities that directly damage SAV beds, such as dredging and filling, bottom- disturbing fishing gear, propeller scarring and boat wakes are readily observed and are subject to regulations (See Appendix 3). Other indirect causes of SAV loss or change in SAV species may be ascribed to changing hydrology which may in turn affect salinity levels and circulation; reduction in flushing can cause an increase in salinity and the ambient temperature of a water body, stressing plants and ultimately changing the dominant SAV to more salt-tolerant species. Increases in flushing can mean decreased salinity, with possible species changes, and increased turbidity and near-bottom mechanical stresses which damage or uproot plants.

Large areas of Florida where SAV was once abundant have experienced significant losses since the mid- twentieth century. In some areas, SAV occurs at a fraction of historical areas. One of these depleted areas is Lake Worth in Palm Beach County where dredge and fill activities, sewage disposal, and stormwater runoff have almost eliminated this resource. Historically, North Biscayne Bay lost most of its SAV from urbanization and small losses continue. The Indian River Lagoon lost many SAV beds due to stormwater runoff directly and indirectly (via phytoplankton blooms) from reduced water clarity. Recent gains in the Northern Indian River Lagoon, due to concerted efforts to reduce nutrient and particle inputs, improved SAV acreage and brought a few locations close to historical levels; however, 47,000 acres of seagrass have recently disappeared due to a massive and recurring phytoplankton bloom. Many seagrass beds in Florida have been scarred from boat propellers disrupting the physical integrity of the beds. Florida's assessment of dredging/propeller scar damage indicates that Dade, Lee, Monroe, and Pinellas Counties have the most heavily damaged seagrass beds. Vessel registrations, both commercial and recreational, tripled from 1970-71 (235, 293) to 1992-93 (715,516). More people are engaged in marine activities, which affects the limited resources of fisheries and benthic communities.

In North Carolina, distribution and abundance of SAV vary seasonally and inter-annually. Growing seasons vary by species with peak abundance of high salinity species between April and October, and low salinity species between May and June. In North Carolina, total SAV coverage is conservatively estimated at 130,000 acres. This figure is based on an interagency coastwide mapping effort from 2006-2008 that identified 130,000 acres of seagrass. However, field ground truthing verified that the delineation based on aerial imagery underestimated SAV occurrence in the meso- and oligohaline estuaries due to lower water

clarity. However that mapping provided a baseline for future mapping events so that trends can be determined. Prior to that, SAV had not been remapped in comparable methodology to evaluate trends. NC Division of Marine Fisheries (NCDMF) now maintains an inventory of SAV mapping on the coast and the SAV Partnership, an interagency group of federal, state, and NGO representatives with interest in managing SAV, developed a monitoring plan that includes repeat mapping on 5 year cycles, staggered regionally. In 2012-2013, most of the marine SAV in high salinity waters were remapped (Currituck, eastern Pamlico, Core, and Bogue sounds) and the results are pending.

While quantified trends are not available, anecdotal information from resource agency staff on long term trends is available for some regions. Compared to North Carolina's low-moderate salinity SAV community, the high salinity seagrasses appear relatively stable. Mapping results of core areas of seagrass, such as behind the Outer Banks in Pamlico Sound and Core Sound, indicate there has not been a large change in coverage since the 1980s (D. Field/NOAA, pers. com, 2010). However, seagrass in Bogue Sound appears to have become less dense and patchier. In areas where SAV occurs to a lesser extent (Albemarle Sound, Neuse and Pamlico rivers, and waters south of Bogue Sound) SAV was reported to be more abundant in the 1970s, declined in the 1980s, and has been increasing since the early 2000s. These latter areas are located in closer proximity to riverine discharge and stormwater runoff. Under conditions of low rainfall and runoff, such as during droughts, improved water clarity and higher and less fluctuating salinity could be allowing expansion of distribution in these waters with less optimal water clarity conditions (Deaton et al. 2010). It is unclear how much influence sediment and nutrient loading from stormwater runoff or wastewater treatment effluent has on these fluctuations. In addition to weather related changes, seagrass habitat continues to be impacted by individually small, but cumulative, coastal development activities, such as dredging for navigational channels, marinas, and docks. Impacts from private projects are often reduced, but not always avoided. Several past and proposed North Carolina Department of Transportation projects related to ferry channels or bridges have impacted or will impact much larger areas of seagrass. Projects with a public benefit are allowed to have unavoidable SAV impacts, but mitigation is required. Bottom disturbing fishing activities, such as mechanical clam harvest, crab dredging, or shrimp trawling can damage SAV. A recommendation of the NC Coastal Habitat Protection Plan (CHPP) requires that habitat be protected from fishing gear damage through modifications to fishing boundaries and improved enforcement. The Division of Marine Fisheries, through the Fishery Management Plan process and rule changes, has moved shrimp trawling and oyster dredging boundaries to avoid impacting SAV.

SAFMC SAV Policy Statement- Appendix 3 PAST MANAGEMENT EFFORTS

Conservation of existing SAV habitat is critical to the maintenance of the organisms depending on these systems. A number of federal and state laws require permits for modification and/or development in SAV- bearing waters. These include Section 10 of the Rivers and Harbors Act (1899), Section 404 of the Clean Water Act (1977), and the states' coastal area management programs. Section 404 prohibits deposition of dredged or fill material in waters of the United States without a permit from the U.S. Army Corps of Engineers. The Fish and Wildlife Coordination Act gives federal and state resource agencies the authority to review and comment on permits, while the National Environmental Policy Act requires the development and review of Environmental Impact Statements. In addition to federal guidelines, states have rules related to development activities and SAV (Table 1). The Magnuson-Stevens Fisheries Conservation and Management Act was amended to require that each fishery management plan include a habitat section. The SAFMC's habitat subcommittee may comment on permit requests submitted to the Corps of Engineers when the proposed activity relates to habitat essential to managed species. State and federal regulatory processes have accomplished little to slow the decline of SAV habitat. Many of the impacts, especially those affecting water clarity, cannot be easily controlled by the regulations as enforced. For example, water quality standards are written so as to allow a specified deviation from background concentration; in this manner, standards allow a certain amount of degradation. An example of this is Florida's Class III water transparency standard, which defines the compensation depth to be where 1% of the incident light remains. The compensation depth for SAV is in well in excess of 10% and for some species is between 20 and 25%. The standard allows a deviation of 10% in the compensation depth which translates into 0.9% incident light or an order of magnitude less than what the plants require. Large-scale, direct mitigative measures to restore or enhance impacted areas have met with little success. Management of nutrient loads, especially nitrogen, from surface and ground waters is essential to restore the water clarity necessary to support SAV ecosystems. Where efforts have been successful, it has resulted from collaborative partnerships among industry, local and regional governments, and National Estuary Programs. Some of the approaches to minimize propeller scar damage to SAV beds include: education, improved channel marking, restricted access zones (complete closure to combustion engines, pole or troll areas), and improved enforcement. When SAV restoration and mitigation are undertaken, the SAFMC understands the need for extended monitoring, not only to determine success from plant's standpoint but also to assess the recovery of faunal populations and the functional attributes of the ecosystem as a whole. The SAFMC also encourages

long-term trend analysis of SAV distribution and abundance, using appropriate protocols and Geographic

Information System approaches, to inform management and permitting decisions.

Table 1. Summary of guidelines for SAV protection used by the federal regulatory and commenting agencies, as well as the state agencies of Maryland and Virginia (Source: Orth et al. 2002; NC Department of Environment and Natural Resources; Fl Department of Environmental Protection)

Categories	**North Carolina**	**Florida**	**Maryland**	**Virginia**	**US Army Corps of Engineers (Baltimore District)**	**US Environmental Protection Agency**	**US Fish and Wildlife Service**	**National Marine Fisheries Service**
Dredging of new Channels	Allowed if no significant adverse impact to SAV, PNAs, oyster beds, wetlands. Can seek variance.	Regulatory – allowed after impacts are avoided and minimized, and appropriate compensatory mitigation is provided for any remaining impacts that cannot be avoided or minimized. Proprietary - allowed if not contrary to public interest and appropriate compensatory mitigation is provided.	Not allowed in water □ 3 ft. at MLW.	Limit channels to minimum dimensions necessary; avoid SAV.	Not allowed in waters □ 2 ft. MLW in main channel. □ 1.5 ft. MLW in spurs; presence of SAV overrides these parameters	Generally, no new dredging except in historic channels.	Avoid shallow water habitats; not recommended in areas without piers & historical deepwater access.	Not recommended within existing SAV beds or adjacent shallows with potential for bed expansion
Dredging in SAV beds	No new dredging in SAV allowed. Can seek variance. Maintenance dredging is allowed.	Regulatory – allowed after impacts are avoided and minimized, and appropriate compensatory mitigation is provided for any remaining impacts that cannot be avoided or minimized. Proprietary - shall not be approved unless there is no reasonable alternative, project is not contrary to public interest and appropriate compensatory mitigation is provided for impacts.	Allowed in areas where there were historic channels	Usually not allowed.	Prohibited upstream of 1.5-2 ft. contour and in existing beds (see text for exceptions); channel dimensions may be restricted where slumping occurs.	Allowed in channels or historic channels only; not recommended otherwise.	Not recommended.	Not recommended.
Timing restrictions on dredging	Dredging moratoriums requested by resource agencies.	Dredging restrictions required by resource commenting agencies (e.g., presence of listed species).	Prohibited within 500 yards of SAV beds, April 15- October 15.	Restrictions may be placed if in proximity to living resources.	April 1- June 30; April 15- October 15 (species with two growing seasons).	March 31-June 15.	March-June	Species-dependent; April-October 15 for most species; April 1- June 30 for horned pondweed.

Categories	North Carolina	Florida	Maryland	Virginia	US Army Corps of Engineers (Baltimore District)	US Environmental Protection Agency	US Fish and Wildlife Service	National Marine Fisheries Service
Dredging in areas that historically supported SAV	Not allowed if SAV habitat. DMF defines that to include areas documented to have SAV within past 10 years.	Considered during the application review process.	Not recommended where SAV occurred during the previous growing season.	Considered during the application review process.	Depends on depths and why SAV disappeared. Check soils.	Not recommended	Not recommended	Not recommended where SAV has been documented during the past 2-3 growing seasons.
Dredging near SAV beds/buffer zones	Reviewing agencies would consider on case by case basis .	Considered during the application review process. Addressed as part of the Secondary Impact Analysis.	See timing restrictions on dredging above.	Considered during the application review process.	3 ft. buffer/1 ft. dredged below existing bottom; 15 ft. buffer from MHW & for SAV w. dense tuber mats.	3 ft. buffer/1 ft. dredged	3 ft. buffer/1 ft. dredged below existing bottom.	Recommend buffers around existing beds; no dredging in areas with potential bed expansion.
Depositing dredged material on SAV	Not allowed. Can seek variance.	Proprietary – prohibited, beach compatible dredge material must be placed on beaches or within the nearshore sand systems.	Prohibited	Locate to minimize impacts	Recommend against		Recommend against	Recommend against
Pier Construction	Not allowed through GP process if water < 2 ft MLW. Could be permitted through major process – case by case	Minimal sized structures are exempt from permitting. Larger structures require full permit review (Regulatory – allowed after impacts are avoided and minimized, and appropriate compensatory mitigation is provided for any remaining impacts that cannot be avoided or minimized. Proprietary - allowed if not contrary to public interest and appropriate compensatory mitigation is provided.)	Pier out to avoid dredging of SAV beds; minimize pier dimensions.	Limit to minimum necessary for water access, locate to avoid SAV.	Pier out, construct community piers or mooring piles to avoid dredging of SAV beds; maintain suitable pier height above SAV.		Pier out to avoid dredging of SAV beds; construct community rather than multiple individual piers.	Maintain 1:1 ratio of deck width to deck height above MLW.

Categories	North Carolina	Florida	Maryland	Virginia	US Army Corps of Engineers (Baltimore District)	US Environmental Protection Agency	US Fish and Wildlife Service	National Marine Fisheries Service
Marina development near SAV	Allowed if no significant adverse impact to SAV.	Regulatory – allowed after impacts are avoided and minimized, and appropriate compensatory mitigation is provided for any remaining impacts that cannot be avoided or minimized. Proprietary - allowed if not contrary to public interest and appropriate compensatory mitigation is provided.	Prohibited in areas □ 4.5 ft. unless dredged from upland and adverse impacts to SAV are minimized.	Undesirable near SAV, or in waters less than 3 ft. at MLW.	Avoid historical SAV beds for new marina construction; maintain buffer for marina expansion.	Avoidance of SAV recommended	Avoid	Recommend against new marinas or expansion in existing beds or adjacent shallows with potential for bed expansion.
SAV harvest	Permit required.	Permit required.	Permit required.	Permit required.				Limited harvest of hydrilla in the Potomac.
Fishing activity	Mechanical harvest of shellfish and trawling not allowed over SAV- through rule boundaries.	Mechanical harvest of shellfish limited to open shellfish harvesting areas, and prohibited over SAV through permit conditions. Shrimp trawling is prohibited in areas of Florida that are of high conservation value for SAV (e.g., Big Bend Region closed Areas).	No hydraulic clam dredging in existing SAV.	No clamming in water depths< 4 ft.				
Aquaculture activities	No new permits in existing SAV. Can renew if its grown into lease.	By rule, aquaculture activities on sovereignty submerged lands shall be designed to minimize or eliminate adverse impacts on sea grasses. In practice, aquaculture leases have not been historically authorized		No new permits in existing SAV.				

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SAFMC SAV Policy Statement- Appendix 4

Maps of SAV as EFH or EFH-HAPC for managed species are viewable through:

Links from the SAFMC Digital Dashboard: http://ocean.floridamarine.org/safmc_dashboard/ to The SAFMC EFH Viewer: http://ocean.floridamarine.org/sa_efh/

The SAFMC Habitat and Ecosystem Atlas: http://ocean.floridamarine.org/safmc_atlas/

Alteration of Riverine, Estuarine and Nearshore Flows Policy – June 2014

Policy Context

This document establishes the policies of the South Atlantic Fishery Management Council (SAFMC) regarding protection of the essential fish habitats (EFH) and habitat areas of particular concern (EFH-HAPCs) associated with alterations of riverine, estuarine and nearshore flows. Such hydrologic alterations occur through activities such as dam operations, water supply and irrigation withdrawals, and other modifications to the normative hydrograph. The policies are designed to be consistent with the overall habitat protection policies of the SAFMC as formulated and adopted in the Habitat Plan (October 1998) and the Comprehensive EFH Amendment (October 1998), Fishery Ecosystem Plan for the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Management Amendment 1(SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011) and the various Fishery Management Plans (FMPs) of the Council.

The findings presented below assess the threats to EFH potentially posed by activities related to the alteration of flows in southeast rivers, estuaries and nearshore ocean habitats, and the processes whereby those resources are placed at risk. The policies established in this document are designed to avoid, minimize and offset damage caused by these activities, in accordance with the general habitat policies of the SAFMC as mandated by law.

EFH At Risk from Flow-Altering Activities

The SAFMC finds:

1) In general, the array of existing and proposed flow-altering projects being considered for the Southeastern United States for states with river systems that drain into the SAFMC area of jurisdiction together constitutes a real and significant threat to EFH under the jurisdiction of the SAFMC.
2) The cumulative effects of these projects have not been adequately assessed, including impacts on public trust marine and estuarine resources (especially diadromous species), use of public trust waters, public access, state and federally protected species, state critical habitat, SAFMC-designated EFH and EFH-HAPCs.

3) Individual proposals resulting in hydrologic alterations rarely provide adequate assessments or consideration of potential damage to fishery resources under state and federal management. Historically, emphasis has been placed on the need for human water supply, hydropower generation, agricultural irrigation, flood control and other human uses. Environmental considerations are dominated by compliance with limitations imparted by the Endangered Species Act for shortnose and Atlantic sturgeon, and/or through provisions of Section 18 of the Federal Power Act, as administered by the Federal Energy Regulatory Commission, which applies to the provision of passage for diadromous species, as well as the provisions of the Fish and Wildlife Coordination Act.

4) Hydrologic alterations have caused impacts to a variety of habitats including:

    a. waters, wetlands and benthic habitats near the discharge and withdrawal points, especially where such waters are used for spawning by anadromous species
    b. waters, wetlands and benthic habitats in the area downstream of discharge or withdrawal points
    c. waters, wetlands and benthic habitats in receiving estuaries of southeast rivers and
    d. waters and benthic habitats of nearshore ocean habitats receiving estuarine discharge.

5) Certain riverine, estuarine and nearshore habitats are particularly important to the long-term viability of commercial and recreational fisheries under SAFMC management, and threatened by large-scale, long-term or frequent hydrologic alterations:
    a. freshwater riverine reaches and/or wetlands used for anadromous spawning and foraging
    b. downstream freshwater, brackish and mid-salinity portions of rivers and estuaries serving as nursery areas for anadromous and estuarine-dependent species
    c. nearshore oceanic habitats off estuary mouths- and
    d. areas supporting submerged aquatic vegetation (please see SAFMC's SAV Policy for further information).

6) Large sections of South Atlantic waters potentially affected by these projects, both individually and collectively, have been identified as EFH or EFH-HAPC by the

SAFMC, as well as the Mid-Atlantic Fishery Management Council (MAFMC) in the case of North Carolina. Potentially affected species and their EFH under federal management include, but are not limited to (SAFMC, 1998):

a. summer flounder (various nearshore waters, including the surf zone and inlets; certain offshore waters)

b. bluefish (various nearshore waters, including the surf zone and inlets)

c. many snapper and grouper species (live hardbottom from shore to 600 feet, and – for estuarine-dependent species [e.g., gag grouper and gray snapper] – unconsolidated bottoms and live hardbottoms to the 100 foot contour).

d. black sea bass (various nearshore waters, including unconsolidated bottom and live hardbottom to 100 feet, and hardbottoms to 600 feet)

e. penaeid shrimp (offshore habitats used for spawning and growth to maturity, and waters connecting to inshore nursery areas, including the surf zone and inlets)

f. coastal migratory pelagics (e.g., king mackerel, Spanish mackerel) (sandy shoals of capes and bars, barrier island ocean-side waters from the surf zone to the shelf break inshore of the Gulf Stream; all coastal inlets)

g. corals of various types (hard substrates and muddy, silt bottoms from the subtidal to the shelf break)

h. areas identified as EFH for Highly Migratory Species managed by the Secretary of Commerce (inlets and nearshore waters are important pupping and nursery grounds for sharks)

7) Projects which entail hydrologic alterations also threaten important fish habitats for diadromous species under federal, interstate and state management (in particular, riverine spawning habitats, riverine and estuarine habitats, including state designated areas - e.g. Primary and Secondary Nursery Areas of North Carolina), as well as essential overwintering grounds in nearshore and offshore waters. All diadromous species are under management by the Atlantic States Marine Fisheries Commission and the states. The SAFMC also identified essential habitats of anadromous and catadromous species in the region (inlets and nearshore waters).

8) Numerous habitats that have been impacted by these projects causing hydrologic alterations have been identified as EFH-HAPCs by the SAFMC. The specific fishery management plan is provided in parentheses:

   a. all nearshore hardbottom areas (SAFMC, snapper grouper).

   b. all coastal inlets (SAFMC, penaeid shrimps, and snapper grouper).

   c. nearshore spawning sites (SAFMC and penaeid shrimps).

   d. benthic *Sargassum* (SAFMC, snapper grouper).

   e. from shore to the ends of the sandy shoals of Cape Lookout, Cape Fear, and Cape Hatteras, North Carolina; Hurl Rocks, South Carolina; *Phragmatopora* (worm reefs) reefs off the central coast of Florida and nearshore hardbottom south of Cape Canaveral (SAFMC, coastal migratory pelagics).

   f. Atlantic coast estuaries with high numbers of Spanish mackerel and cobia from ELMR, to include Bogue Sound, New River, North Carolina; Broad River, South Carolina (SAFMC, coastal migratory pelagics).

   g. Florida Bay, Biscayne Bay, Card Sound, and coral hardbottom habitat from Jupiter Inlet through the Dry Tortugas, Florida (SAFMC, Spiny Lobster)

   h. Hurl Rocks (South Carolina), The *Phragmatopoma* (worm reefs) off central east coast of Florida, nearshore (0-4 meters; 0-12 feet) hardbottom off the east coast of Florida from Cape Canaveral top Broward County); offshore (5-30 meters; 15-90 feet) hardbottom off the east coast of Florida from Palm Beach County to Fowey Rocks; Biscayne Bay, Florida; Biscayne National Park, Florida; and the Florida Keys National Marine Sanctuary (SAFMC, Coral, Coral Reefs and Live Hardbottom Habitat).

      a) EFH-HAPCs designated for HMS species (e.g., sharks) in the South Atlantic region (NMFS, Highly Migratory Species).

9) Habitats likely to be affected by projects which alter hydrologic regimes include many recognized in state level fishery management plans. Examples of these habitats include Critical Habitat Areas (CHAs) established by the North Carolina Marine Fisheries Commission, either in FMPs or in Coastal Habitat Protection Plans.

Threats to Riverine, Marine and Estuarine Resources from Hydrologically-Altering Activities

The SAFMC finds that activities which alter normative hydrologic regimes of rivers, estuaries, inlets and nearshore oceanic habitats may include projects such as dam operations and water withdrawals. These actions may pose a threat to EFH, EFH- HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs through the following mechanisms:

Water withdrawals:

Impacts to aquatic species and habitats from water withdrawals for municipal, industrial, and agricultural purposes could potentially include impingement, entrainment, temporary and permanent alterations to habitat from construction activities, decreased downstream flows, and degradation of downstream water quality due to decreased downstream flows. Minimizing impingement and entrainment requires knowledge of the life history and behavioral traits of sensitive species in the project area, their sustained swimming speeds, and the sizes of their vulnerable life stages. In addition, projected approach and sweeping velocities at multiple flow scenarios need to be calculated during the project design phase. Approach velocity is the vector component perpendicular to the screen face as water passes through the screen mesh, measured approximately 3 inches from the screen surface. Sweeping velocity is the vector component parallel and adjacent to the screen face.

The most vulnerable life stages to water withdrawals are typically eggs, larvae, and juveniles. Protection devices need to prevent entrainment, prevent impingement, and guide sensitive species away from the facility. The first consideration is to separate the fish spatially and temporally from the intake. If intakes cannot be located away from habitats supporting sensitive species, reducing or eliminating withdrawals during the period these species are present can be an effective protection strategy.

Providing fish egress from the intake is important because without it they can eventually fatigue and become impinged. The preferred configuration is for the intake to be placed in open water, especially with a suitable sweeping velocity, because a bypass is therefore not required. However, when intakes are set into the bank, a bypass system with an entrance at the downstream end of the screen becomes necessary. Velocities at the bypass entrance should be high enough to provide efficient guidance for out-migrating fish.

Keeping the screen surface clean of debris is critically important for maintaining proper approach velocities because clogged screens tend to develop hot spots composed of higher velocities, significantly increasing rates of impingement.

Dam operations:

Impacts to aquatic species and habitats caused by flow alterations from dam operations include temporary and permanent alterations to habitat from construction activities, salinity changes that can alter emergent vegetation, reduce habitat suitability and growth rates of sensitive species, and increase the colonization of predators, degradation of downstream water quality, and altered downstream flows. Degraded downstream water quality associated with dam operations may include reduced dissolved oxygen, altered water temperature, increases in algal blooms, and reduced wastewater assimilation.

Flow modifications of natural hydrologic regimes caused by dams can greatly alter aquatic systems. The current environmental flows paradigm emphasizes the importance of the natural variability of flows and the concept that biota have evolved in response to critical components of variable flows. Components of natural river flows provide ecological functions and include baseflows, high pulse flows, and floods. For example, seasonal and annual variability in baseflows creates habitat diversity that results in diverse aquatic communities. Higher baseflows provide adequate habitat for aquatic organisms, maintain suitable water quality, keep fish eggs suspended, and enable fishes to move to feeding and spawning areas. Periodic naturally low baseflows can purge invasive species and concentrate prey into limited areas to benefit predators. High pulse flows shape physical habitat of river channels, determine the size of substrate, prevent riparian vegetation from encroaching into the channel, restore normal water quality conditions after prolonged low flows and flush away waste products and pollutants, aerate eggs, prevent siltation, and maintain suitable salinity in estuaries. Floods provide migration and spawning cues for fishes, enable fishes to access the floodplain for spawning and feeding and provide a nursery area for juvenile fishes, maintain the balance of species in aquatic communities, deposit gravel and cobbles in spawning areas, flush organic materials that serve as food and habitat structures into the channel, and purge invasive species.

Five critical components of flow regimes that regulate ecological processes in river ecosystems are recognized: magnitude, frequency, duration, timing, and rate of change. Alterations to each of these components of the natural flow regime can cause a wide range of detrimental ecological responses. As an example, the magnitude and frequency of high and low flows are common flow alterations as a result of dam operations. The extreme daily variations below peaking power hydroelectric dams represent an extremely harsh environment of frequent, unpredictable flow disturbance. Aquatic species living in these environments can suffer physiological stress, washout during high flows, and stranding during rapid dewatering. Frequent exposure can result in mortality of bottom- dwelling organisms and reductions in biological productivity. Many small fishes and early life stages are found in shallow shoreline or backwater areas, which can be impaired by frequent flow fluctuations. These flow modifications can lead to reductions in diversity and abundance of many fishes and invertebrates. Conversely, flow stabilization can also occur below dams, such as water supply reservoirs, that can result in artificially constant environments that lack natural extremes, decreased diversity, and reduced floodplain connectivity. Therefore, mimicking or ensuring the natural magnitude, frequency, duration, timing, and rate of change of baseflows, high pulse flows, and floods is preferable.

Methods of Instream Flow Protection:

Three types of approaches have been typically employed for setting environmental flow standards: minimum flow thresholds, statistically-based standards, and per cent of flow approaches. The most commonly applied approach has been to set a minimum flow to be maintained or minimum flows that vary seasonally. More recently, statistically-based standards have been used to maintain select characteristics of flow regimes. Increasingly, per cent of flow approaches are being used. Expanding upon the per cent of flow approach, bands of allowable alteration called sustainability boundaries can be placed around natural flow conditions as a means of expressing environmental flow needs. To do this, natural flow conditions are estimated on a daily basis at the points of interest, representing flows that would have existed in the absence of current flow alterations.

Sustainable boundary limits can be set on the basis of allowable perturbations from the natural condition. Richter et al. (2011), citing well-supported case studies and regional analyses, suggest a high level of ecological protection will be provided when daily flow alterations are no greater than 10%, a moderate level of protection when daily flows are altered 11-20%, and alterations greater than 20% will likely result in moderate to major changes in natural structure and ecosystem functions, with greater risk associated with greater levels of daily flow alteration. It is recommended that when a single threshold value or standard is needed, a presumptive standard of protecting 80% of daily flows will maintain ecological integrity in most rivers and 90% may be needed to protect rivers with at-risk species and exceptional biodiversity. When local ecological knowledge indicates that more protective standards may be needed, adjustments to values should be considered. In addition, when applying this standard to hydropower-regulated rivers, the standard applied to daily flow averages may be insufficient to protect ecological integrity because of peaking power operations, which cause considerable fluctuation within a day.

Current State Policies:

North Carolina: Surface and groundwater withdrawers who meet conditions established by the General Assembly register and annually report their water withdrawals and surface water transfers with the State. Registrations are updated at least every five years. Water withdrawal permits contain conditions to meet site-specific instream flow

requirements. Specifics of each project are used by the Division of Water Resources of North Carolina Department of Environment and Natural Resources to determine the appropriate instream flow recommendation. Some of these specifics include if the project is proposed or existing, presence or absence of a dam, purpose of the withdrawal, etc.

Some flow recommendations may be a percentage of a low flow value while others may be variable, seasonally dependent flows based on fieldwork and consensus among numerous stakeholders.

South Carolina: Surface water withdrawals are regulated by the South Carolina Department of Health and Environmental Control (SCDHEC) under the Surface Water Permitting, Withdrawal, and Reporting Act, which was signed into law in June, 2010. Most facilities that have a dam and withdraw surface waters must abide by the regulations provided in this Act. However, hydropower is exempted from the permitting requirements, including the minimum flow requirements, identified in this Act. Dams, whether for hydropower or other purposes, typically require federal permits or licenses to be constructed and operated. Minimum flows at dam projects can be required by the 401 Water Quality Certification administered by SCDHEC. In the development of 401 certifications, SCDHEC will consider recommendations from other State Agencies, such as the South Carolina Department of Natural Resources (SCDNR). SCDNR flow recommendations are guided by policies of the South Carolina Water Plan, which includes an established 1989 instream flow policy for protection of fish and wildlife habitats, which says:

In the absence of a site-specific instream flow study, recommended minimum flows are as follows:

Piedmont Streams:

July-November = 20% of mean annual daily streamflow January-April = 40% of mean annual daily streamflow

May, June, December = 30% of mean annual daily streamflow

Coastal Plain Streams:

July-November = 20% of mean annual daily streamflow January-April = 60% of mean annual daily streamflow

May, June, December = 40% of mean annual daily streamflow

Georgia: A centralized permitting process is in place under the Georgia Department of Natural Resources- Environmental Protection Division (GDNR-EPD), which issues surface and groundwater withdrawal permits for any use greater than 100,000 gallons per day. GDNR-EPD implements its 2001 Interim Instream Flow Protection Strategy through provisions in surface water withdrawal permits. It is applicable to new, post-2001, non- farm surface water allocations of water and is applicable to any non-federal impoundment. Therefore exceptions to this policy are agricultural projects, Federal reservoirs, and withdrawals from highly regulated streams, such as the Savannah River, in which flows are significantly determined by the operation of Federal reservoirs.

GDNR will work to identify a consensus approach to address minimum flow requirements for those seeking to withdraw water from highly regulated streams.

Pre-2001 withdrawal permit holders seeking increases in permit quantities are required to comply with the policy for the increased allocation only, not for the previously permitted withdrawal amount. Low flow protection for those projects using previous withdrawal amounts are governed by an annual 7Q10 or, if using pre-1977 withdrawal amounts, no minimum flow requirements. Under the 2001 Interim Instream Flow Protection Strategy, the permit applicant is able to select from one of three minimum stream flow options, outlined below:

1) Monthly 7Q10 Minimum Flow Option: The applicant is required to release the lesser of the monthly 7Q10 or inflow. The monthly 7Q10 is a statistical figure that reflects the lowest seven-day running average of a stream's flow for each calendar month with a recurrence frequency of once in ten years.

2) Site-Specific Instream Flow Study Option: A site-specific instream flow study may be performed to determine what minimum flow conditions must be maintained for protection of aquatic habitat.

3) Mean Annual Flow Options:

    a. 30% Mean Average Annual Flow for direct withdrawals, or inflow, whichever is less.

b. 30/60/40% Mean Annual Flow for water supply reservoirs, or inflow, whichever is less. This translates to the lesser of 30% of the mean annual flow or inflow during July through November, 60% of the mean annual flow or inflow during January through April, and 40% of the mean annual flow or inflow during May, June, and December.

Florida: The five state Water Management Districts or the Florida Department of Environmental Protection (FDEP) are required to establish minimum flows and levels (MFLs) for aquifers, surface watercourses, and other surface waterbodies to identify the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area (Chapter 373.042, Florida Statutes). FDEP is given general supervisory authority over the districts and delegates water resources programs to the districts where possible. Minimum levels are developed for lakes, wetlands and aquifers, whereas minimum flows are developed for rivers, streams, estuaries and springs. MFLs are adopted into Water Management District rules (Chapter 40D-8, Florida Administrative Code) and used in each District's water use permitting program to ensure that withdrawals do not cause significant harm to water resources or the environment.

Each District identifies waterbodies with adopted MFLs and those that they are currently targeting or planning to work on in the future.

The Districts collect and analyze a variety of data for each waterbody for application of methods that are used to develop specific MFL recommendations and to help define significant harm. If actual flows or levels are below established MFLs, or are expected to be below established MFLs within the next twenty years, the Districts develop and implement a recovery or prevention strategy (Chapter 40D-80, F.A.C.), in accordance with state law (Chapter 373.0421, Florida Statutes). The St. Johns River Water Management District and South Florida Water Management District are the two districts in Florida that drain into the South Atlantic region. These Districts often express MFLs as statistics of long-term hydrology incorporating return interval (years), duration (days), and magnitude (flow or level).

SAFMC Policies for Flow-altering Projects

The SAFMC establishes the following general policies related to projects resulting in hydrologic alterations, to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment (SAFMC 1998a; SAFMC 1998b):

1) Projects should avoid, minimize and where possible offset damage to EFH and EFH-HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and State Critical Habitat Areas (CHAs).

2) Projects should provide detailed analyses of possible impacts to EFH, EFH-HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs. This should include careful and detailed analyses of possible impacts, including short-term, long-term, population, and ecosystem-scale effects. Agencies with oversight authority should require expanded EFH consultation.

3) Projects should provide a full range of alternatives, along with assessments of the relative impacts of each on each type of EFH, EFH-HAPC, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs.

4) Projects should avoid impacts on EFH, EFH-HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs that are shown to be avoidable through the alternatives analysis, and minimize impacts that are not.

5) Projects should include assessments of potential unavoidable damage to EFH and other marine resources.

6) Projects should be conditioned on the avoidance of impacts, and the minimization of unavoidable impacts. Compensatory mitigation should be required for all unavoidable impacts to EFH, EFH-HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs, taking into account uncertainty about these effects. Mitigation should be local, up-front and in-kind, and should be adequately monitored.

7) Projects should include baseline and project-related monitoring adequate to document pre-project conditions and impacts of the projects on EFH, EFH-HAPCs, diadromous fishes, state and federally-listed species, Federal critical habitat, and CHAs.

8) All assessments should be based upon the best available science.

9) All assessments should take into account the cumulative impacts associated with other projects in the same southeast watershed.

10) Projects should meet state and Federal water quality standards. For instance operational or structural modifications may be employed, if necessary, to improve downstream dissolved oxygen and/or water temperature.

11) To the extent that it is reasonably practicable, construction activities should not be scheduled to coincide with the spawning migrations or early development of sensitive species that are present in the proposed project areas.

12) Impingement and entrainment of sensitive species at water intakes should be avoided. Water intakes should not be placed in areas that would negatively affect EFH's, EFH-

HAPCs, CHAs, Federal critical habitat, diadromous fishes, and state and federally-listed species.

13) When developing the intake design, intake screens in rivers and streams should be constructed away from the banks and within the flowing stream. If on the bank, the face should be continuous with the adjacent bank line to ensure a smooth transition to prevent eddies around the screen and a fish bypass system that returns fish to the main channel should be incorporated. Screens should be oriented so the angle between the face of the screen and the approaching flow is not more than 45 degrees off parallel. Anticipated sweeping and approach velocities of proposed projects should be compared to the known swimming speeds of sensitive species in the project area, egg size of sensitive species should be considered when deciding on mesh size, and the vertical distribution of sensitive species should be considered when deciding on the elevation of the intake. Approach velocities must be set lower than the sustained swimming speed of sensitive species. Sweeping velocities should be greater than the approach velocities. Using a non-withdrawal period or installing removable screens with reduced mesh size during the spawning and early development periods may also be options to avoid impingement and entrainment. Where possible, locate intakes where sufficient sweeping velocity exists to minimize sediment accumulation, facilitate debris removal, and encourage fish movement away from the screen face.

14) An on-going maintenance and repair program is necessary to ensure water intake facilities are kept free from debris and that screen mesh and other components are functioning correctly. Adequate facilities need to be in place for handling floating and submerged debris large enough to damage the screen.

15) Multiple years of post-construction monitoring should be used to study impingement and entrainment rates of sensitive species, and if a bypass system is included, for monitoring mortality through the bypass. Monitoring results need to confirm that the design criteria were met and that unexpectedly high mortality rates are not occurring. Monitoring results can then be used to improve the water intake structure, if needed.

16) Components of the natural flow regime should be altered as little as possible. Although achieving a natural hydrograph in its entirety may not be possible, restoration of some of the natural flow regime components can restore ecosystem elements that would be lost or reduced as a consequence of flow regulation.

17) For hydropower peaking projects, consider the implementation of ramping rate restrictions before and after the peaking operation and a non-peaking window during the critical reproductive and rearing periods of sensitive species.

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Marine and Estuarine Non-Native and Invasive Species Policy – June 2014

Policy Context

This document establishes the policies of the South Atlantic Fishery Management Council (SAFMC) regarding protection of South Atlantic estuarine ecosystems from potential impacts associated with invasive species. The policies are designed to be consistent with the overall habitat protection policies of the SAFMC as formulated in the Habitat Plan (SAFMC 1998a) and adopted in the Comprehensive EFH Amendment (SAFMC 1998b), Fishery Ecosystem Plan for the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Management Amendment 1(SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011) and the various Fishery Management Plans (FMPs) of the Council.

The findings presented below assess potential impacts to the South Atlantic's marine and estuarine ecosystems posed by invasion of non-native species and the processes which could place those resources at risk. In adhering to a precautionary approach to management, the SAFMC establishes in this document policies and recommendations designed to avoid, minimize, and offset potential impacts to South Atlantic estuarine ecosystems.

According to Pimentel et al. (2000, 2005), the United States spends $137 billion annually on issues related to invasive species, including development of control strategies and removal as well as loss of revenue. Research indicates that non-native organisms may compete with native organisms, alter habitats (Mack et al. 2000; Kolar and Lodge 2001; Rahel 2002; Olden et al. 2004) and reduce biodiversity (Olden et al. 2004).

While the number of introduced non-native marine organisms is small compared to that of terrestrial and freshwater species, introductions have accelerated in recent decades mainly due to increase in coastal development and shipping (Morris & Whitfield 2009). According to the United States Geological Survey (2010), more than 27 estuarine species, including those that occupy estuarine waters during at least one life-history stage, have been introduced in North Carolina (18), South Carolina (17), Georgia (16) and Florida (17). Of these, the majority comprises fishes (63%), with crustaceans and mollusks accounting for an additional 15%. Invasions by fishes and invertebrates is considered highly significant, with the potential to displace native species and impact community structure and biodiversity of marine and estuarine ecosystems (e.g., Grozholz et al. 2000; Streftaris et al. 2005; Goren & Galil 2005; Dierking 2007; Albins & Hixon 2008; Rilov & Crooks 2009).

Non-native plants also pose a threat to South Atlantic estuarine ecosystems. Recently, it has been found that two exotic mangrove species, introduced at a botanical garden, have spread and pose a threat to natural mangrove forests in south Florida (Fourqurean et al. 2010).

In marine waters, the United States Geological Survey (2010), found more than 72 marine species, including those that occupy marine waters for at least one life-history stage, have been introduced in North Carolina (27), South Carolina (48), Georgia (23) and the Atlantic coast of Florida to Key West (22). Of these, the majority comprises marine crustaceans (29%), with fishes and mollusks accounting for an additional 49%.

Invasions by fishes and invertebrates is considered highly significant, with the potential to displace native species and impact community structure and biodiversity of marine and estuarine ecosystems (e.g., Grozholz et al. 2000; Streftaris et al. 2005; Goren & Galil 2005; Dierking 2007; Albins & Hixon 2008; Rilov & Crooks 2009).

The SAFMC finds that:

1. Invasive organisms have the potential to cause adverse impacts to marine and estuarine habitats including:
    a. submerged aquatic vegetation;
    b. estuarine emergent vegetation, including mangroves;
    c. shellfish beds;
    d. spawning and nursery areas; and
    e. exposed hard bottom (e.g. reef and live bottom) in shallow and deep waters.
2. Certain estuarine and marine ecosystems are particularly important to the long-term viability of commercial and recreational fisheries under SAFMC management, and are potentially threatened by invasive species, including:
    a. estuarine waters;
    b. estuarine wetlands, including mangroves and marshes;
    c. submerged aquatic vegetation;
    d. coral, coral reefs, and live/hard bottom habitat; and
    e. marine waters.
3. Portions of the South Atlantic ecosystem potentially affected by invasive species, both individually and collectively, have been identified as EFH or EFH-HAPC by the SAFMC. Potentially affected species and their EFH under federal management include (SAFMC 1998b, SAFMC 2009a, SAFMC 2009b and SAFMC 2011):

a. for estuarine-dependent species (e.g., gag grouper and gray snapper) – unconsolidated bottoms and live hard bottoms to the 100 foot contour;

b. penaeid shrimp (waters connecting to inshore nursery areas);

c. muddy, silt bottoms from the subtidal to the shelf break, deepwater corals and associated communities; and

d. areas identified as EFH for Highly Migratory Species managed by the Secretary of Commerce (e.g., sharks: inlets and nearshore waters, including pupping and nursery grounds).

4. Scientists have documented important habitat values for East coast Florida nearshore hard bottom used by over 500 species of fishes and invertebrates, including juveniles of many reef fishes. On the continental shelf off Georgia and South Carolina, 598 species of invertebrates have been collected in trawls and dredge tows over hard bottom habitats, and 845 unique invertebrate taxa were found in benthic suction and grab samples in the same area (Wenner et al. 1984).

5. Invasive species present an unacceptable risk to the biological integrity of South Atlantic ecosystems and must be addressed. Moreover, South Atlantic ecosystems have been shown to be vulnerable to the establishment of non-indigenous species: 61% of the 104 marine or estuarine species reported as having been introduced into the SAFMC area of jurisdiction are considered to be established there (USGS 2010).

6. Stakeholder opposition and uncertainty about potential ecological effects were major considerations in a decision by the USACOE and the states of Maryland and Virginia to reject the idea of using the Asian oyster *Crassostrea ariakensis* in aquaculture or in efforts to revive wild oyster populations in the Chesapeake Bay.

7. The addition of invasive lionfish (*Pterois volitans* and *P. miles*), the nonindigenous orange cup coral (*Tubastraea coccinea*), and the invasive, bloom-forming macroalga *Caulerpa brachypus,* and cyanobacteria of the genus *Lyngbya* (Kuffner et al. 2005; Paul et al., 2005) could cause negative changes in coral reef ecosystems of the South Atlantic region.

8. The risk of transmission of viral diseases from introduced Asian tiger shrimp (*Penaeus monodon*) to native species of penaeid shrimp remains unknown, as does the source of their introduction.

Threats from Invasive Marine and Estuarine Organisms

The SAFMC finds the following to constitute potential threats to South Atlantic estuarine ecosystems:

1. In addition to lionfish, 37 species of non-native marine fish have been documented along Florida's Atlantic coast in the last decade. These species represent a "watch list" of potential

future invaders. It is thought that most of these species are aquarium trade releases, similar to lionfish.

2. Potential impacts of the invasion of Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) in South Atlantic waters include:
    a. reduction of forage fish biomass;
    b. increase in algal growth due to herbivore removal;
    c. competition with native reef fish;
    d. cascading trophic impacts on economically important species under SAFMC management;
    e. competition with native species could hamper stock rebuilding efforts for the Snapper Grouper Complex;
    f. impacts on commercial and recreational fisheries, the aquarium trade, and coastal tourism industry; and
    g. increase in frequency of envenomations of recreational swimmers, fishermen, and divers
3. The orange cup coral, *Tubastraea coccinea*, is a stony coral not native to the South Atlantic region.
    a. Artificial structures are their preferred habitat in the South Atlantic region and *T. coccinea* is prolific on some artificial structures in the Caribbean, Gulf of Mexico, and off Florida.
    b. While there have been no reports of orange cup coral on natural substrate in Florida, it has been observed in the northern Bahamas reefs and it may eventually colonize natural reef/hard bottom in the region.
4. The invasive, bloom-forming macroalga *Caulerpa brachypus* and cyanobacteria of the genus *Lyngbya* directly overgrow reefs, are generally unpalatable to herbivores, and can also physically and chemically inhibit coral recruitment (Kuffner et al. 2006; Paul et al. 2005).
5. In general, non-native estuarine organisms have the potential to cause cascading trophic impacts on economically important species under SAFMC management.
6. The apparent increase in the incidence of infection of American eels by the introduced parasitic nematode *Anguillicoloides crassus* may present an increased threat to an already declining population of American eels in the southeastern US, where *A. crassus* has been documented to have significant negative impacts (ASMFC 2002, 2008). This non-native

swim bladder parasite may decrease the American eel's ability to swim and to reach its spawning grounds in the Sargasso Sea (ASMFC, 2011)

7. Studies describe high rates of survival and growth of *Crassostrea ariakensis* in subtidal habitats spanning a wide range of temperatures and salinities (see Kingsley-Smith et al., 2009). Most of its biological characteristics make *C. ariakensis* a strong candidate to become invasive, thus it is not advisable for use in aquaculture or in restoration activities in South Atlantic estuaries.

8. Invasive aquatic plants, such as hydrilla (*Hydrilla verticillata*) and non-native phragmites (*Phragmites australis*), can develop large, dense populations that displace desirable native vegetation.

9. The Eurasian watermilfoil (*Myriophyllum spicatum*) is known to out-compete *Vallisneria americana* beds (Hauxwell et al. 2004), which is EFH for white shrimp.

10. At least two species of Indo-Pacific mangroves (*Bruguiera gymnorrhiza* and *Lumnitzera racemosa*) have naturalized and spread in the mangrove forests of South Florida, showing that Atlantic mangrove forests are indeed susceptible to invasion. Given the importance of the mangroves of the tropical Atlantic to the functioning of the coastal seascape, the ecosystem functioning of the region's mangrove forests may change as a consequence of invasive species (Fourqurean et al., 2010).

11. The large tropical Eastern Pacific barnacle, *Megabalanus coccopoma*, also known as the titan acorn barnacle, is a gregarious settler, and since it reaches a much larger size than native species of barnacles in the region, it may require greater maintenance efforts on surfaces exposed to coastal and high salinity estuarine areas if it becomes established.

12. The isopod *Synidotea laevidorsalis*, now successfully established on the US South Atlantic, is generally found fouling buoy and crab pot lines and floating docks in mesohaline to polyhaline reaches of coastal waters.

13. The green porcelain crab, *Petrolisthes armatus,* is well-established in the Indian River system, Florida, and on rocky rubble, oyster reefs, and other shallow subtidal and intertidal habitats throughout Georgia and South Carolina.

14. The spiny hands crab, *Charybdis hellerii,* has been collected occasionally from shallow coastal waters of the South Atlantic Bight between Crescent Beach, Florida, and Core Banks, North Carolina. The greatest number of specimens in that region has been found in the Winyah Bay estuary of South Carolina and in shallow waters off Core Banks, North Carolina.

15. The Asian green mussel, *Perna viridis*, is a nuisance even within its native range in the

Indo-Pacific. Impacts from this species have the potential to be severe. In addition to hampering the effectiveness of cooling systems, it is also notorious for fouling navigation buoys, floating docks, piers, and pilings. Ecological studies in Florida have shown that *P. viridis* is also detrimental to intertidal oyster reefs, where it displaces adult oysters and reduces the density of juvenile oysters.

1. The Charrua mussel, *Mytella charruana*, belongs to the same family as the invasive green mussel and several native marine mussels. *M. charruana* poses the potential problem of fouling structures submerged in seawater. Potential impacts include economic hardship due to its fouling ability, and ecological alteration due to competition with native shellfish species.
2. Two visually identical species of lionfish (*Pterois volitans* and *P. miles)* were introduced into the northwest Atlantic Ocean, Caribbean Sea and the Gulf of Mexico, probably through the US aquarium trade, in the 1980's. Lionfish have been established from Miami to North Carolina since 2002, and in the Florida Keys since 2009. On heavily invaded sites, lionfish have reduced fish prey densities by up to 90% and continue to consume native coral-reef fishes and crustaceans at unsustainable rates. More recently, lionfish have been reported in increasing numbers from inshore and estuarine waters as far north as Narragansett Bay, RI (Schofield et al., 2013)
3. Introductions of the Asian tiger shrimp (*Penaeus monodon*) into the southeastern US may be due to escapement from aquaculture facilities following flooding by storms and hurricanes; larvae released from Caribbean shrimp farms and transported north via the Gulf Stream; and/or migration from areas where tiger shrimp had previously become established in the wild. Evidence suggests that there has been an increase in abundance along the southeastern US coast over the past five years, indicating the likely presence of a breeding population. (Knott et al., 2013). The extent to which tiger shrimp are transmitting viral diseases or displacing native shrimp species through predation or competition for prey remains unknown.

SAFMC Policies Addressing Marine and Estuarine Invasive Species

The SAFMC establishes the following general policies related to invasive organisms:

1. In instances where an invasive species belongs to a group of organisms included in the Fishery Management Unit, the species would need to be excluded from the FMU via a plan amendment (or an existing framework) before a control or eradication strategy could be implemented

2. The Council encourages NOAA Fisheries Habitat Conservation Division (HCD) to consider recommending removal of invasive species as a compensatory mitigation measure. When removal of an invasive species is proposed in designated EFH, EFH-HAPCs or CHAPCs, the Council and HCD will work together to evaluate proposed removal techniques to ensure the method selected will avoid or minimize environmental damage.

3. Regarding compensatory mitigation projects or restoration activities that have a planting component, a requirement that plant materials be obtained through local nurseries within a certain radius around the estuary should be considered. Studies have shown different growth patterns of *Spartina* reared from nurseries located on the east coast of Florida versus the west coast of Florida.

4. The Council supports the availability of grant funding to promote research targeting invasive species-- including prevention of introductions, evaluation of impacts, expansion control and removal -- through existing partnerships (*i.e.*, SARP) and in cooperation with state and federal agencies including NOAA's Invasive Species Program, the National Invasive Species Council and the Gulf and South Atlantic Regional Panel of the National Aquatic Nuisance Species Task Force.

5. The Council supports the availability of grant funding to promote education and outreach efforts targeting invasive species.

6. The Council will recommend to the National Aquatic Nuisance Species Task Force, as appropriate, that management plans be developed for potentially invasive species in South Atlantic waters (this does not imply plans developed by the Council).

7. The Council encourages the development of novel gears (other than those prohibited by the Council, such as fish traps) that effectively remove invasive species but do not compromise the integrity of South Atlantic habitats and ecosystems. The Council encourages consulting with appropriate law enforcement agencies to ensure compliance with existing regulations and to address possible enforceability challenges.

8. The Council strongly supports integrating monitoring of invasive species into existing fishery-independent and dependent programs.

9. The Council strongly suggests that permits for offshore placement of infrastructure for energy generation (e.g. oil platforms, windmills) include provisions for monitoring the settlement and dispersal of non-indigenous species on and among such structures and in potentially affected natural habitats.

10. The Council strongly suggests inspection and thorough cleaning of surfaces prior to placement of Fish Attracting Devices (FAD). The potential risk of inadvertently

expanding the range of a non-native species through transport or establishment of new habitats should be carefully considered.

11. The Council supports programs to control invasive species' populations in areas of high ecological/economic importance. The Council supports harvest, eradication, and/or removal strategies that do not impact populations of managed species or their habitats.

12. The Council strongly discourages the use of any non-indigenous species in aquaculture operations in the South Atlantic region.

13. The Council supports its regional partners in their endeavor to promulgate regulations for ballast water and their efforts toward research and development to advance treatment technology for ballast water.

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Artificial Reef Habitat Policy Threats to EFH – September 2017

Introduction

This document provides the South Atlantic Fishery Management Council (SAFMC) guidance regarding protection and mitigation (avoidance, minimization, and compensatory mitigation) of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (EFH-HAPCs) related to artificial reef development, placement, and maintenance. Artificial reefs, sometimes called "manmade reefs", " fish havens", or "constructed reefs", are broadly defined as any structure placed on the seabed, either deliberately or accidentally (e.g., shipwrecks), that acts similar to natural hard-bottom reefs and enhances fish habitat (Seaman 2000; Seaman and Sprague 1991). Properly sited artificial reefs can provide habitat for a wide variety of invertebrates and finfish, improve survival for species that are hard-bottom limited (Broughton 2012), serve as memorials, or stabilize coastlines (Harris,L 2006). They can also enhance existing ecosystems or create new ones to fill in gaps where EFH has been damaged or lost (Ambrose 1994; Koenig 2001; Dupont 2008). The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Seaman 2000; Baine 2001). Artificial reefs may provide essential habitat while simultaneously acting to deflect pressure from surrounding natural hard bottom (e.g., Streich et al., 2017), including specially managed areas (e.g., Harmelin 2000); however, increased productivity may be offset by increased fishing pressure (Seaman 2000, Powers et al. 2003). For these reasons, permitted artificial reef sites are considered EFH by the SAFMC.

In addition to serving as EFH, this policy highlights that the Council has designated artificial reefs Special Management Zones (SMZs) as EFH-HAPCs. As a whole, the guidance is consistent with the overall habitat protection policies of the SAFMC as formulated and adopted in the Habitat Plan (SAFMC 1998a), the Comprehensive EFH Amendment (SAFMC 1998b), the Fishery Ecosystem Plan of the South Atlantic Region (SAFMC 2009a), Comprehensive Ecosystem-Based Amendment 1 (SAFMC 2009b), Comprehensive Ecosystem-Based Amendment 2 (SAFMC 2011), and the various Fishery Management Plans (FMPs) of the Council.

For the purposes of policy, the findings assess potential threats and impacts to managed species EFH and EFH-HAPCs and the South Atlantic ecosystem associated with artificial reefs and processes that could improve those resources or place them at risk. The policies and recommendations established in this document are designed to address such impacts in accordance with the habitat policies of the SAFMC as mandated by law. The SAFMC may revise this guidance in response to 1) changes in conditions in the South Atlantic region, 2) applicable laws and regulatory guidelines, 3) new knowledge about the impacts or 4) as deemed as appropriate by the Council.

Policy Considerations

Artificial reefs have the effect of changing habitats from a soft substrate to a hard substrate system or of adding higher relief to low relief (< 1m) hard substrate systems. Historically, fishermen created artificial reefs as fish attractants (Lindberg and Seaman 2011). An ongoing debate within the scientific community exists as to whether artificial reefs simply aggregate current individuals or actually enhance production (e.g., Bohnsack 1989, Pickering and Whitmarsh 1997; Lindberg 1997, Osenberg et al. 2002; Powers et al. 2003; Brickhill et al. 2005). The answer to that question can only be determined by viewing individual artificial reefs in a broader ecological context. For example, are fisheries habitat-limited (production) or recruitment-limited (aggregation) (Lindberg and Seaman 2001)? When well sited, the augmentation of species composition and local abundance of important species in a specific area are often seen as the primary benefits of reef deployment activities. Demersal reef-dwelling finfish, pelagic planktivores, and pelagic predators can use natural and artificial hard substrates in similar ways and often interchangeably (Arena et al 2007). In addition to location, temporal variation exists: elevated fish densities occur quickly after deployment (Bohnsack 1989), but substantial uncertainty remains about estimating overall fish production long-term (Powers et al. 2003, Lindberg et al. 2006). Finally, artificial reefs may affect species and life history stages differently: many reef-associated species occur on both natural and artificial reef habitats, with significant differences in the fish communities (Patterson et al. 2014; Streich et al. 2017).

As long noted by researchers, the physical characteristics of artificial reef habitat may result in differences in the observed behavior of fish species on or around such structures in contrast to behavior observed on equivalent areas of natural hard-bottoms (Bohnsack 1989; Lindberg et al 2006). Some reef structures, particularly those of higher relief, seem to yield generally higher densities of managed and non-managed pelagic and demersal species than a more widely spread lower relief, natural hard-bottom or reef (Rountree 1989; Collins et al 2016, Streich et al. 2017). However, many fishes in Gulf of Mexico studies have been documented as older and more fecund on natural reefs (Glenn et al. 2017; Karnauskas et al. 2017). The fishery management implications of these differences must be recognized and taken into consideration when planning, developing, and managing artificial reefs as EFH (Lindberg and Seaman 2011).

The proper placement of artificial materials in the marine environment can provide for the development of a healthy reef ecosystem, including intensive invertebrate communities and fish assemblages of value to both recreational and commercial fishermen. The effectiveness of an artificial reef in the enhancement of fishing varies and is dictated by geographical location, species targeted, stock health, and design and construction of the reef (Bohnsack 1989; Strelcheck et al. 2007). Artificial reefs have developed an impressive track record of providing beneficial results, as estimated in recent models and measured by fishing success for a wide range of finfish species (e.g., Pitcher et al. 2002, Gallaway et al. 2009). To date, artificial reefs have been chiefly employed to create specific, reliable, and more accessible opportunities for recreational anglers. They have been used to a lesser extent to enhance commercial fishing probably because artificial reef total area is small compared to much larger, traditionally relied-upon, natural commercial fishing grounds.

Threats to EFH and EFH-HAPCs in Regards to Artificial Reefs

The SAFMC finds that properly-sited artificial reefs in the South Atlantic can enhance EFH for managed species, but can also negatively impact EFH and EFH-HAPCs and managed fisheries if not deployed properly (e.g. Osborne Reef Project[1]). Table 1 presents a summary of fisheries and habitat designations potentially affected by artificial reef development in the South Atlantic as presented in the SAFMC EFH User Guide (https://safmc.net/documents/efh-user-guide/).

[1] http://www.dep.state.fl.us/waste/categories/tires/pages/osborneproject.htm

SAFMC Policies Addressing South Atlantic Artificial Reefs

The SAFMC establishes the following policies to address development of South Atlantic artificial reefs, and to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment and Fishery Ecosystem Plan (SAFMC 1998a; SAFMC 1998b; SAFMC 2009a).

***General Policies*:**

Uses	Artificial reefs can serve a variety of purposes beyond recreational and commercial activities. These potential purposes include areas for spawning, breeding, feeding, and refuge for growth to maturity of numerous marine organisms including Council-managed species.
	The Council supports state requests to designate specific artificial reefs as SMZs for research and production in an effort to prevent overexploitation of specific artificial reef sites.
Siting	Artificial reefs can be used to support fisheries management by providing a more standardized comparison for scientific investigations.
	Artificial reef managers should consult with all stakeholders (e.g., commercial trawlers, seismic surveyors) prior to siting in order to reduce user conflict and maximize the value of artificial reefs as EFH (Paxton et al. 2017).
	Artificial reefs should be sited in a manner that connects the various life history stages of the target species (i.e., reduces habitat bottlenecks at specific life stages) or enhances a bottlenecked life history stage
	Properly sited artificial reefs are EFH and are not detrimental to migratory species such as right whales or Atlantic sturgeon
	Properly sited artificial reefs are not hazards to navigation; they are charted and deployed with navigation as part of the design
Construction	The SAFMC requires the use of environmentally-safe, long-lasting materials for reef construction, which are stable in their location and avoid any potential danger to other species (e.g., sea turtles) and habitats (Lindberg & Seaman 2011; Barnette 2017).
	Managers should use proper design and placement (e.g., relief, distance from shore, proximity to other habitats) to target specific life stages and species.
	The impacts of decommissioning structures such as oil or gas platforms, offshore wind foundations, tactical aircrew combat training system (TACTS) towers, or navigational aids, should be considered on a case-by-case basis.
Mitigation	There should be mitigation measures specified if the function of an artificial reef is lost. Artificial reefs can be used to mitigate for damage to natural reefs and for damage to artificial reefs. However, natural (and to an extent artificial) reef habitat is not perfectly replaceable, so caution should be taken to reduce damage to natural and artificial reefs when possible
	Investigation on the potential of artificial reef construction to compensate fishers (as in "buy-back") for any future expansion of those SMZ areas designated as ‘no harvest’ should be conducted

Habitat and Species Research Associated with Artificial Reef Development The SAFMC encourages the funding of scientific research on the following topics:

Biological

1. Long-term 'no take' experiments on artificial reefs to statistically demonstrate any potential production of snapper and grouper through strict protection of spawning and juvenile growth.
2. Site selection and spatial habitat utilization by life stages and species life histories (e.g., nursery, spawning, etc.).
3. Community dynamics on artificial reefs and how they interact with communities on adjacent habitats.
4. Understanding the application of small scale scientific results to large scale regional fisheries management. E.g., how to apply results from local or specific individual artificial reef sites to a state or regional basis.
5. The feasibility of incorporating artificial reef habitat into ecosystem management and understanding the potential role of artificial reefs in fisheries management.
6. The role of artificial reefs in the recruitment and expansion of invasive species.
7. The connectivity of the designated reef areas regionally, relative to migration between and residence time on, specific sites (e.g., acoustic tagging studies).

Socioeconomics

8. The socioeconomic impacts of artificial reefs relative to the fishing and diving communities, in addition to the economic impact to local coastal municipalities.

Physical

9. The stability, durability, sedimentation, and subsidence of various reef structure metrics and placement in order to maximize ecological benefits and reduce entrapment or secondary effects and debris.

The SAFMC also encourages:

10. Long-term, multi-year standardized monitoring of artificial reefs and their communities, with the necessary long-term funding, to provide multi-year

trends in reef fish productivity and allow valid future comparisons of temporal and spatial data.

11. Inter-state and/or national collaboration by developing similar data collections with regional or national data access.

12. Development and application of new innovations and techniques to ensure that regulations established for artificial reefs, especially no harvest areas, are enforced and violators are apprehended and prosecuted for illegal use of gears and/or poaching to the fullest extent of the law.

13. Conducting regional public education and outreach regarding the benefits of artificial and human made reefs for special purposes, including no harvest production (MPA and SMZ) areas and disposing of mono-filament fishing lines on shore, away from reefs.

14. Increasing public awareness and collaboration with regional recreational divers to remove debris, document fish species and maintain healthy reef function.

Many habitats in the South Atlantic Region susceptible to the effects of artificial reef development have been designated as EFH and EFH-HAPCs by the SAFMC (Table 1).

Table 1. Habitats designated as Essential Fish Habitat (EFH), their associated managed fisheries/species, and EFH-HAPCs (Source: SAFMC EFH Users Guide 2016).

Essential Fish Habitat	**Fisheries/Species**	**EFH- Habitat Areas of Particular Concern**
Wetlands		
Estuarine and marine emergent wetlands	Shrimp, Snapper Grouper	Shrimp: State designated nursery habitats Mangrove wetlands
Tidal palustrine forested wetlands	Shrimp	
Submerged Aquatic Vegetation		
Estuarine and marine submerged aquatic vegetation	Shrimp, Snapper Grouper, Spiny lobster	Snapper Grouper, Shrimp
Shell bottom		
Oyster reefs and shell banks	Snapper Grouper	Snapper Grouper
Coral and Hardbottom		
Coral reefs, live/hardbottom, medium to high rock outcroppings from shore to at least 600 ft where the annual water temperature range is sufficient for a particular species.	Snapper Grouper, Spiny lobster, Coral, Coral Reefs and Live Hard/bottom Habitat	The Point, Ten Fathom Ledge, Big Rock, MPAs; The *Phragmatopoma* (worm reefs) off central east coast of Florida and nearshore hardbottom; coral and hardbottom habitat from Jupiter through the Dry Tortugas, FL; Deepwater CHAPCs
rock overhangs, rock outcrops, manganese- phosphorite rock slab formations, and rocky reefs		Snapper Grouper [blueline tilefish]
Artificial reefs	Snapper Grouper	Special Management Zones

Essential Fish Habitat	**Fisheries/Species**	**EFH- Habitat Areas of Particular Concern**
Soft bottom		
Subtidal, intertidal non- vegetated flats	Shrimp	
Offshore marine habitats used for spawning and growth to maturity	Shrimp	
Sandy shoals of capes and offshore bars	Coastal Migratory Pelagics	Sandy shoals; Capes Lookout, Fear, Hatteras, NC; Hurl Rocks, SC;
troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters		Snapper Grouper [golden tilefish]
Water column		
Ocean-side waters, from the surf to the shelf break zone, including Sargassum	Coastal Migratory Pelagics	
All coastal inlets	Coastal Migratory Pelagics	Shrimp, Snapper Grouper
All state-designated nursery habitats of particular importance (e.g., PNA, SNA)	Coastal Migratory Pelagics	Shrimp, Snapper Grouper
High salinity bays, estuaries	Cobia in Coastal Migratory Pelagics	Spanish mackerel: Bogue Sound, New River, NC; Broad River, SC
Pelagic Sargassum	Dolphin	

Essential Fish Habitat	Fisheries/Species	EFH- Habitat Areas of Particular Concern
Gulf Stream	Shrimp, Snapper Grouper, Coastal Migratory Pelagics, Spiny lobster, Dolphin Wahoo	
Spawning area in the water column above the adult habitat and the additional pelagic environment	Snapper Grouper	

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Threats Addressed by Policies Matrix – March 2021

	SAFMC EFH Policy Statements									
	Food Web Connectivity	Climate Variability	Marine Aquaculture	SAV	Beach Nourishment	Energy Exploration	Flows	Invasive	Artificial Reefs	Total Number Policies Addressing Threat
Navigation	X		X	X	X	X	X	X	X	8
Hydrologic Alterations	X		X	X	X		X	X	X	7
Natural Events and Climate Change	X	X	X	X			X	X	X	7
Urban/Suburban Development	X			X	X	X	X	X	X	7
Offshore Mining, Beach Dredge and Fill	X		X		X			X	X	5
Oil and Gas			X		X	X		X	X	5
Transportation (roadways and bridges)	X			X	X		X	X		5
Alternative Energy Technologies			X		X	X		X		4
Dredged Material Disposal	X			X	X			X		4
Industrial/ Commercial Activities			X			X		X	X	4
Non-native or nuisance species			X	X				X	X	4
Agriculture	X			X			X			3
Aquaculture			X	X				X		3
Artificial Reefs			X					X	X	3
Dams, Impoundments, Barriers to Passage	X						X	X		3
Inshore Mining			X		X			X		3
Marine Debris			X					X	X	3
Nonpoint-source Pollution			X	X						2
Silviculture										0

Section 6 Managed Areas

To view the Story Map for SAFMC Managed Areas visit the following link:
https://storymaps.arcgis.com/stories/74f471a916b242cda8f9a51ce82efaff

Managed Areas Web Application

https://safmc.net/managed-areas/

This webpage provides users an opportunity to view managed areas in the SAFMC's jurisdiction including but not limited to Deepwater Marine Protected Areas, Deepwater Coral HAPCs, Special Management Zones, Allowable Golden Crab Fishery Areas, Shrimp Fishery Access Areas, Oculina Bank CHAPC, SAFMC Gear and Area Restrictions, Danger Zones, and other Federal Marine Managed Areas.

Deepwater Marine Protected Areas

To view details and maps about the Deepwater MPAs visit the following link:
https://safmc.net/managed-areas/marine-protected-areas/

Special Management Zones

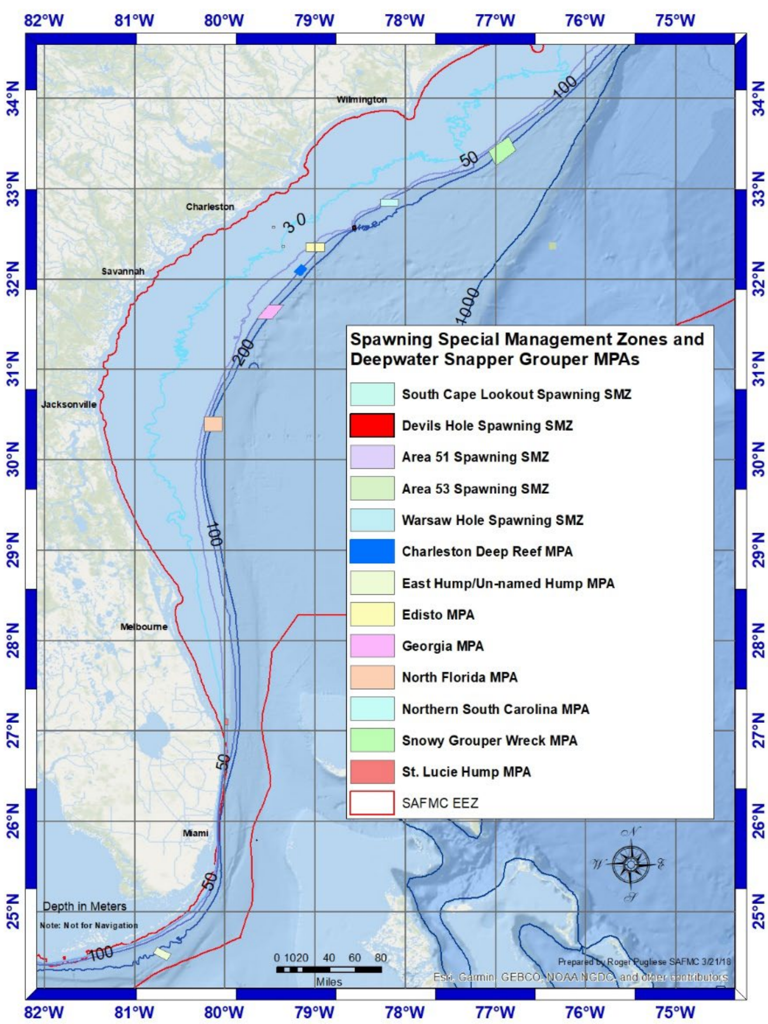
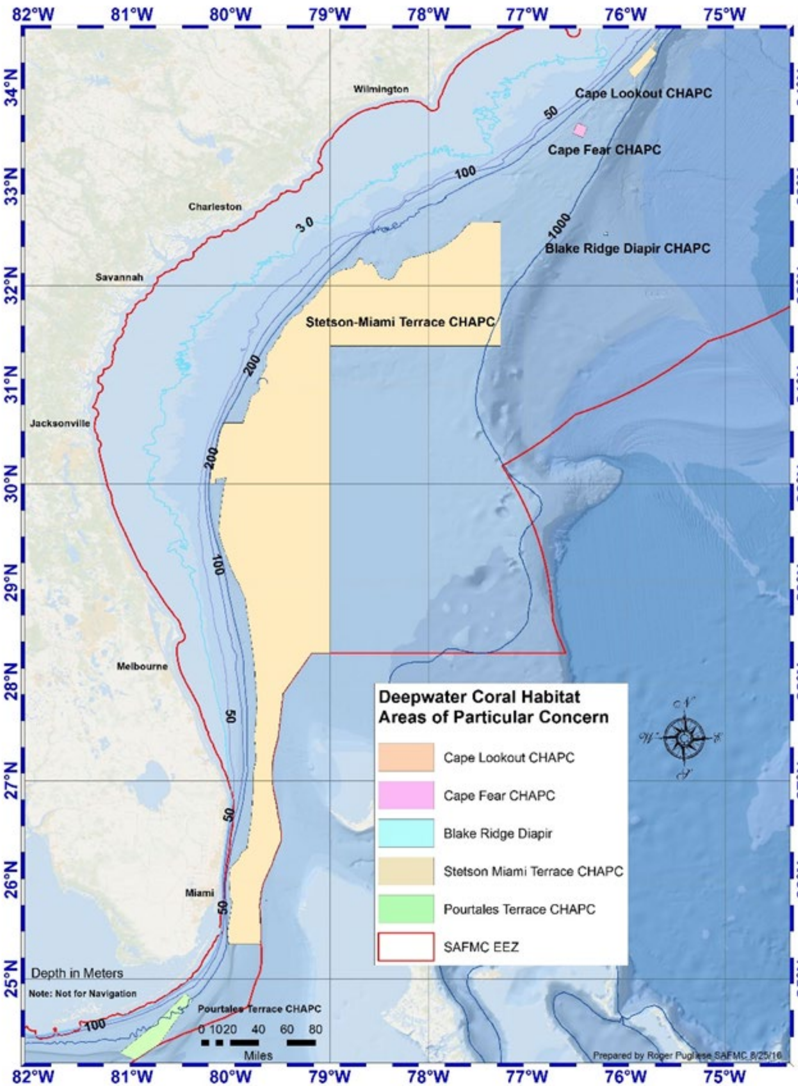
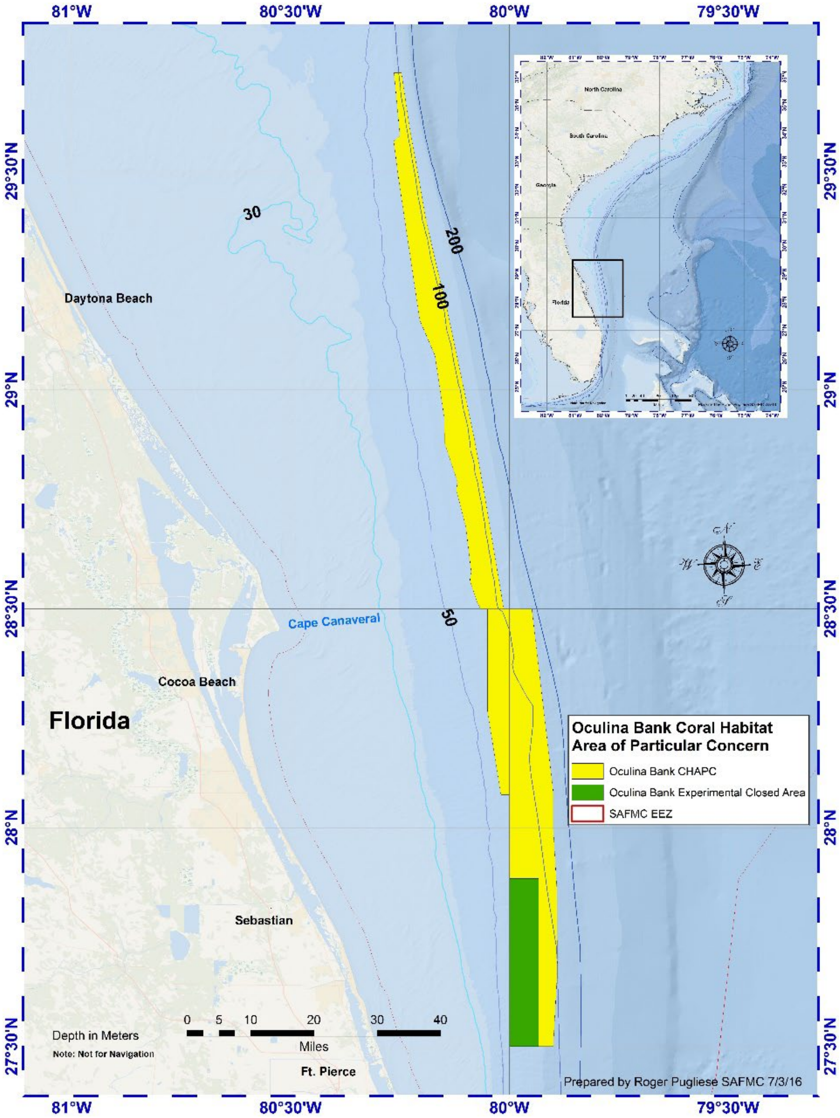


Image above for Spawning Special Management zones
To view all Special Management Zones – https://safmc.net/managed-areas/special-management-zones/

<u>Deepwater Coral HAPCs</u>



To view more information on Deepwater Coral HAPCs visit the following website:
https://safmc.net/safmc-managed-areas/deep-water-corals/



The map above visualizes the Oculina Bank CHAPC. For more information visit the following site. - https://safmc.net/safmc-managed-areas/oculina-bank-2/

Managed Area Coordinates

Below is a link to the metadata for all available SAFMC maps including EFH, HAPCs and SMZs.

https://ocean.floridamarine.org/safmc_dashboard/gis-data.html

Web Mapping Applications

Below is a link the other external mapping services that may be helpful.
https://ocean.floridamarine.org/safmc_dashboard/map-services.html

South Atlantic Habitat and Ecosystem Atlas

Below is the link to the SAFMC managed areas map viewer:

https://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=40c022fb73e84bc99d4c1fb3e3b154b9

South Atlantic Digital Dashboard SAFMC

Below is a link to the dashboard homepage where you can find all of the above tools that are helpful including the three map viewers, metadata for the available maps, and the series of helpful links.

https://ocean.floridamarine.org/safmc_dashboard/index.html

SALCC Conservation Blueprint

Below is a link to the South Atlantic LLC Conservation Blueprint presentation: The SALCC blueprint is a forum in which federal and state agencies, non-profits, businesses and communities work together to develop a shared vision of landscape sustainability, cooperate in its implementation, and collaborate in its refinement.
https://safmc.net/documents/salcc-blueprint-pdf/

Section 7 Research and Monitoring

SAFMC Research and Monitoring Priorities

Below is a link to the most recent SAFMC research and monitoring priorities for 2020-2025.

SAFMC Research and Monitoring Priorities (2020-2025)

SAFMC System Management Plan - Marine Protected Area

Below is a link to SAFMC System Management Plan - Marine Protected Area Amendment 14.

https://safmc.net/documents/amendment_14_smp_may_2016/

SAFMC System Management Plan - Spawning Special Management Zones

Below is a link to System Management Plan for Spawning Special Management Zones Amendment 36.

https://safmc.net/wp-content/uploads/2022/06/SMP_SMZMay2016v2.pdf

SAFMC - Oculina Bank CHAPC

Below is a link to a Fact sheet detailing the Oculina bank experimental closure.

https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/project/1325/OculinaFactSheet.pdf

Deepwater Coral HAPCs

Below is a link to a webpage describing Deepwater Coral CHAPC.

https://safmc.net/managed-areas/deep-water-coral-hapcs/

SEAMAP Five Year Plan (2021- 2025)

To review the SEAMAP five year plan for 2021 – 2025 please visit:
http://www.asmfc.org/files/pub/2021-2025_SEAMAP_Management_Plan.pdf

To view the spatial representations of fishery independent data collected by the SEAMAP South Atlantic (SA) component and by the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program. The application also contains bathymetry, benthic habitats, focal species strata, EcoGIS layers and regulatory boundaries please visit.
https://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=1006075c59144b1c82d3c8ff3919b6a3

South Atlantic Mapping Strategy Overview – June 2017

The South Atlantic Regional Mapping Strategy is a developing comprehensive strategy and integral part of the research section of Fishery Ecosystem Plan II. This effort builds on the Council's Habitat and Ecosystem Atlas (http://safmc.net/habitat-and-ecosystems/safmc-habitat-and-ecosystem- atlas/) and provides an evolving prioritization to facilitate regional collaborative acquisition of data on the physical and biological characteristics of the South Atlantic region. The Strategy is being developed as a living online functional tool highlighted in the Digital Dashboard (http://ocean.floridamarine.org/safmc_dashboard/) and accessible through the Services presented in the Atlas.

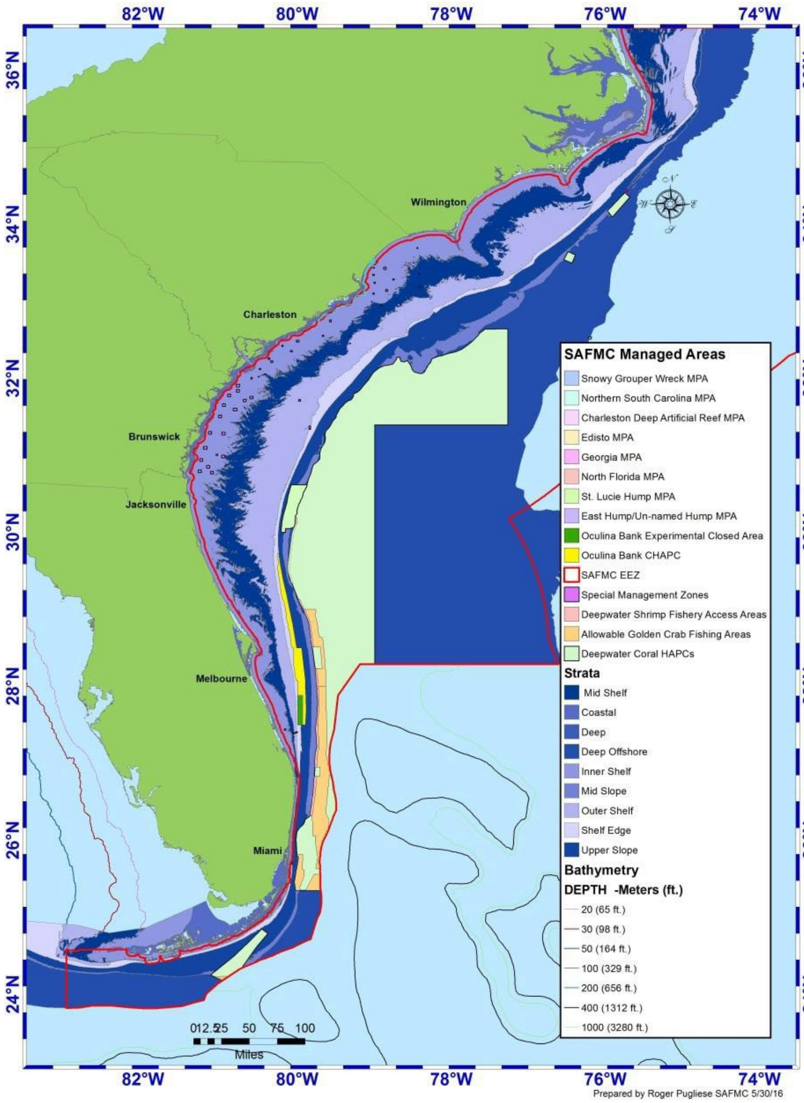


Figure 1. Snapshot of Depth Zones and Managed Areas presented in the SAFMC Habitat and Ecosystem Atlas (http://ocean.floridamarine.org/safmc_atlas/).

To Facilitate development FEP II Managed Species Writing Team provided input on the spatial partitioning of offshore habitat to allow general evaluations of existing mapping efforts and further develop the Strategy the SEAMAP Species Habitat Characterization and Assessment Workgroup and Habitat Protection and Ecosystem Based Management Advisory Panel are being engaged along with other regional partners to refine the strategy.

Table 1. Habitat depth zones established for map strategy.

Meters:	Categories
0-5	Nearshore
5-20	Inner Shelf
20-30	Mid Shelf
30-50	Outer Shelf
50-100	Shelf Edge
100-300	Upper Slope
300-400	Mid Slope
400-5,000	Deep Offshore
>5,000	Deep

In order to build on regional partner activities and planning supporting comprehensive regional mapping and characterization the following regional efforts will be included but not limited to: the development of the 2016-2020 SEAMAP 5 Year Management Plan (http://www.seamap.org/documents/seamapDocs/2016-2020%20SEAMAP%20Management%20Plan.pdf) ; refinement of the Southeast Coastal Ocean Observing Regional Association (SECOORA) 10 Year Build-out Plan (http://secoora.org/wp-content/uploads/sites/default/files/webfm/SECOORA_BuildOut_Submittal_2Dec1011_VERSION5.pdf) and Regional Coastal Ocean Observing System development planning; Integration of SALCC Habitat Mapping Project products; BOEM and GIS from Wind Planning Areas (https://www.boem.gov/Renewable-Energy-GIS-Data/); coordination with and access to products developed pursuant to the 2016 Deep Water Coral Mapping Initiative; and continued development and linkages to distribution of managed species, prey of managed species and other regional species.

The South Atlantic Strategy focuses on needs refining mapping of benthic habitats conserved by or serving as essential fish habitat for species managed by the South Atlantic Council.

1. Identify mapping needs and requirements based on Council managed species, essential fish habitat and managed areas.

2. Develop spatial inventory of existing regional observing/mapping assets and organizations with processing capabilities.

3. Continue to expand and integrate recent mapping products in the regional repository supporting Council management the Habitat and Ecosystem Atlas providing a continual alignment of priorities presented and mapping accomplished to date.

4. Support collaboration in collection of the necessary region-wide physical characteristic data.

Additional Helpful links

NMFS South Atlantic Regional Climate Action Plan - https://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/raps/tech_memos/Draft_South_Atlantic_Regional_Action_Plan_for_public_review%202.14.17.pdf

NMFS Climate Science Strategy: https://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/Climate_Science_Strategy_highlights_web-display.pdf

South Atlantic Habitat and Ecosystem Atlas https://ocean.floridamarine.org/safmc_dashboard/index.html

South Atlantic Citizen Science Initiative and Blueprint – https://safmc.net/citizen-science/

Integrated Ocean Observing- https://ioos.noaa.gov/