Atlantic States Marine Fisheries Commission

ADDENDUM I TO AMENDMENT 2 TO THE RED DRUM FISHERY MANAGEMENT PLAN: *HABITAT NEEDS & CONCERNS*

ASMFC Vision Statement:
Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015

Approved August 2013

RED DRUM HABITAT ADDENDUM

1.4 HABITAT CONSIDERATIONS

1.4.1 Description of Habitat Important to the Stocks

1.4.1.1 Spawning Habitat

Red drum (*Sciaenops ocellatus*) spawn from late summer to early fall in a range of habitats, including estuaries, near inlets, passes, and near bay mouths as opposed to further offshore or inland habitats (Peters and McMichael 1987). Earlier studies have illustrated that the spawning often occurred in nearshore areas relative to inlets and passes (Pearson 1929; Miles 1950; Simmons and Breuer 1962; Yokel 1966; Jannke 1971; Setzler 1977; Music and Pafford 1984; Holt *et al.* 1985). More recent evidence, however, suggests that in addition to nearshore vicinity habitats, red drum also utilize high-salinity estuarine areas along the coast (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994; Luczkovich *et al.* 1999; Beckwith *et al.* 2006). Coastal estuarine areas that have high salinity levels provide optimal conditions for eggs and larval development, as well as circulation patterns beneficial to transporting larvae to suitable nursery areas (Ross and Stevens 1992). Spawning in laboratory studies have also appeared to be temperature dependent, occurring in a range from 22° to 30° C but with optimal conditions between temperatures of 22° to 25° C (Holt *et al.*1981). Renkas (2010) was able to duplicate environmental conditions of naturally spawning red drum from Charleston Harbor, SC in a mariculture setting, and corroborated that active egg release occurred as water temperature dropped from a peak of ~30^{o} C during August. Cessation of successful egg release was found at 25^{o} C, with no spawning effort found at lower temperatures (Renkas 2010). Pelagic eggs, embryos, and larvae are transported by currents into nursery habitats for egg and larval stages, expectedly due to higher productivity levels in those environments (Peters and McMichael 1987; Beck *et al.* 2001).

Part 1.4.1.2 Eggs and Larvae Habitat

Red drum eggs have been commonly encountered in several southeastern estuaries in high salinity, above 25 ppt (Nelson *et al.* 1991). Salinities above 25 ppt allow red drum eggs to float while lower salinities cause eggs to sink (Holt *et al.* 1981). In Texas, laboratory experiments conducted by Neill (1987) and Holt *et al.* (1981) concluded that an optimum temperature and salinity for the hatching and survival of red drum eggs and larvae was 25° C and 30 ppt. Spatial distribution and relative abundance of eggs in estuaries, as expected, mirrors that of spawning adults (Nelson *et al.* 1991); eggs and early larvae utilize high salinity waters inside inlets, passes, and in the estuary proper. Currents transport eggs and pelagic larvae into bays, estuaries and seagrass meadows (when present), where they settle (Levin *et al.* 2001) and remain throughout early and late juvenile stages (Pattillo *et al.* 1997; Holt *et al.* 1983; Rooker and Holt 1997, Rooker *et al.* 1998b; Levin *et al.* 2001). Larval size generally increases as distance from the mouth of the bay increases (Peters and McMichael 1987), possibly due to increased nutrient availability. Research conducted in Mosquito Lagoon, Florida, by Johnson and Funicelli (1991) found viable red drum eggs being collected in average daily water temperatures from 20° C to 25° C and average salinities from 30 to 32 ppt. During the experiment, the highest numbers of eggs were gathered in depths ranging from 1.5 to 2.1 m and the highest concentration of eggs was collected at the edge of the channel.

Upon hatching, red drum larvae are pelagic (Johnson 1978) and laboratory evidence indicates that development is temperature-dependent (Holt *et al.* 1981). Newly hatched red drum spend around twenty days in the water column before becoming demersal (Rooker *et al.* 1999; FWCC 2008). However, Daniel (1988) found much younger larvae already settled in the Charleston Harbor estuary. Transitions are made between pelagic and demersal habitats once settling in the nursery grounds (Pearson 1929; Peters and McMichael 1987; Comyns *et al.* 1991; Rooker and Holt 1997). Tidal currents (Setzler 1977; Holt *et al.* 1989) or density-driven currents (Mansueti 1960) may be utilized in order to reach a lower salinity nursery in upper areas of estuaries (Mansueti 1960; Bass and Avault 1975; Setzler 1977; Weinstein 1979; Holt *et al.* 1983; Holt *et al.* 1989; Peters and McMichael 1987; McGovern 1986; Daniel 1988). Once inhabiting lower salinity nurseries in upper areas of estuaries, red drum larvae grow rapidly, dependent on present environmental conditions (Baltz *et al.* 1998).

Red drum larvae along the Atlantic coast are reportedly common in southeastern estuaries, with the exception of Albemarle Sound, and are abundant in the St. Johns and Indian River estuaries in Florida (Nelson *et al.* 1991). Daniel (1988) and Wenner *et al.* (1990) found newly recruited larvae and juveniles through the Charleston harbor estuary over a wide salintity range. Mercer (1984) has also summarized spatial distribution of red drum larvae in the Gulf of Mexico. More recent studies conducted by Lyczkowski-Shutlz and Steen (1991) reported evidence of diel vertical stratification among red drum larvae found at lower depths less than 25 m at both offshore and nearshore locations. Larvae (ranging between 1.7 to 5.0 mm mean length) were found at lower depths during night and higher in the water column during the day. At the time of the study, water was well mixed and temperature ranged between 26° C to 28° C. There was no consistent relationship between distribution of larvae and tidal stage. Survival during larval (and juvenile) stages in marine fish, such as the red drum, has been identified as a critical bottleneck determining their survival and contribution to adult populations (Cushing 1975; Houde 1987; Rooker *et al.* 1999).

1.4.1.3 Juvenile Habitat

Juvenile red drum utilize a variety of inshore habitats within the estuary, including seagrass meadows, tidal freshwater, low-salinity reaches of estuaries, estuarine emergent wetlands, estuarine scrub/shrub, submerged aquatic vegetation, oyster reefs, shell banks, and unconsolidated bottom (SAFMC 1998; ASMFC 2002). Smaller red drum seek out and inhabit rivers, bays, canals, boat basins, and passes within estuaries (Peters and McMichael 1987; FWCC 2008). Wenner's studies (1992) indicate that red drum juvenile habitats vary slightly seasonally: most often between August and early October, red drum inhabit small creeks that cut into emergent marsh systems and have some water in them at lower tides, while in winter, red drum reside in main channels of rivers ranging in depths from 10 to 50 feet with salinities from one-half to two-thirds that of seawater. In the winter of their first year, 3 to 5 month old juveniles migrate to deeper, more temperature-stable parts of the estuary during colder weather (Pearson 1929). In the spring, they move back into the estuary and shallow water environments. In the following spring, juveniles become more common in the shallow water habitats. Studies show that red drum inhabiting non-vegetated sand bottoms exhibit the greatest vulnerability to natural predators (Minello and Stunz 2001). Juvenile red drum in their first year generally avoid wave action by living in more protected waters (Simmons and Breuer 1962; Buckley 1984).

In the Chesapeake Bay, juveniles (20-90 mm Total Length, TL) were collected in shallow waters from September to November, but there is no indication as to the characteristics of the habitat (Mansueti 1960). Some southeastern estuaries where juvenile (and subadult) red drum are abundant are Bogue Sound, NC; Winyah Bay, SC; Ossabaw Sound, and St. Catherine/Sapelo Sound, GA; and the St. Johns River, FL (Nelson *et al.* 1991) and throughout SC (Wenner *et al.* 1990; Wenner 1992). They were highly abundant in the Altamaha River and St. Andrews/St. Simon Sound, GA, and the Indian River, FL (Nelson *et al*. 1991).

Peters and McMichael (1987) found in Tampa Bay that juvenile red drum were most abundant in protected backwater areas, such as rivers, tidal creeks, canals, and spillways with freshwater discharge, as well as in areas with sand or mud bottom and vegetated or non-vegetated cover. Juveniles found at stations with seagrass cover were generally smaller in size and fewer in number (Peters and McMichael 1987). Near the mouth of the Neuse River, as well as smaller bays and rivers between Pamilico Sound and the Neuse river, surveys from the North Carolina Division of Marine Fisheries (NCDMF) indicate that juvenile red drum were consistently abundant in shallow waters of less than 5 feet. Generally, habitats identified as supporting juvenile red drum in North Carolina can be characterized as detritus laden or mud-bottom tidal creeks (in Pamlico Sound) and mud or sand bottom habitat in other areas (Ross and Stevens, 1992). In a Texas estuary, young red drum (6-27 mm Standard Length, SL) were never present over non-vegetated muddy-sandy bottom; areas most abundant in red drum occurred in the ecotone between seagrass and non-vegetated sand bottom (Rooker and Holt 1997). In SC, Wenner (1992) indicated that very small red drum occupy small tidal creeks with mud/shell hash and live oyster as common substrates (since sub-aquatic vegetation is absent in SC estuaries).

1.4.1.4 Subadult Habitat

The subadult phase of the red drum's life cycle begins when late-stage juveniles leave shallow nursery habitats at a size of approximately 200 mm TL and 10 months of age. These subadults later attain sexual maturity, at about 3-5 years of age. Subadult red drum are most vulnerable to fishery exploitation (Pafford *et al.* 1990; Wenner 1992). They utilize many habitats within the estuary, including tidal creeks, rivers, inlets, and waters around barrier islands, jetties and sandbars (Pafford *et al.* 1990; Wenner 1992). While subadults are found in habitats similar to that of juvenile red drum, they are also found in large aggregations on seagrass beds, over oyster bars, mud flats, and sand bottoms (FWCC 2008). In a study conducted by Bacheler *et al.* (2009a), age-0 to age-3 red drum are commonly found in upper estuarine environments, but each fall a portion of age-1 and age-2 cohorts move to high-salinity coastal waters, while some red drum remain in upper estuarine habitat until age-3; at this age the last remaining red drum move to coastal environments. Tagging studies conducted throughout the species' range indicate that most subadult red drum generally remain in the vicinity of a given area (Beaumarriage 1969; Osburn *et al.* 1982; Music and Pafford 1984; Wenner *et al.* 1990; Pafford *et al.* 1990; Ross and Stevens 1992; Woodward 1994; Marks and DiDomenico 1996). Movement within estuaries is assumed to be related to temperature changes and food availability (Pafford *et al.* 1990; Woodward 1994). The following is taken from the Atlantic States Marine Fisheries Commission (ASMFC) Red Drum Fishery Management Plan (2002):

"During 1994 and 1995, the Inshore Fisheries Section of the South Carolina DNR conducted several aerial surveys to attempt to evaluate abundance and habitat utilization of subadult red drum along the South Carolina coast. Aerial surveys were generally deemed inefficient at estimating the number of fish inhabiting particular areas, especially inlets and beachfront areas because of the visibility of schools from the air depends on the interplay of temporal, climactic, topographic and behavioral factors. On the occasions when red drum schools were reliably located, they were found in flats at the confluence of rivers, inside inlets, creeks, sounds and bays. Aerial surveys proved useful to characterize the general topography of subadult red drum habitat in the intertidal and shallow-subtidal portions of the coast. It appears that typical habitats where subadult red drum are found in South Carolina are of two general types. In the northern portion of the coast, typical subadult habitat consists of broad (up to 200 m or more in width), gently sloping flats often leading to the main channel of a river or sound. Along the southern portion of the coast, subadult red drum habitat consists of more narrow (50 m or less), fairly level flats traversed by numerous small channels, typically 5-10 m wide by less than 2 m deep at low tide*."*

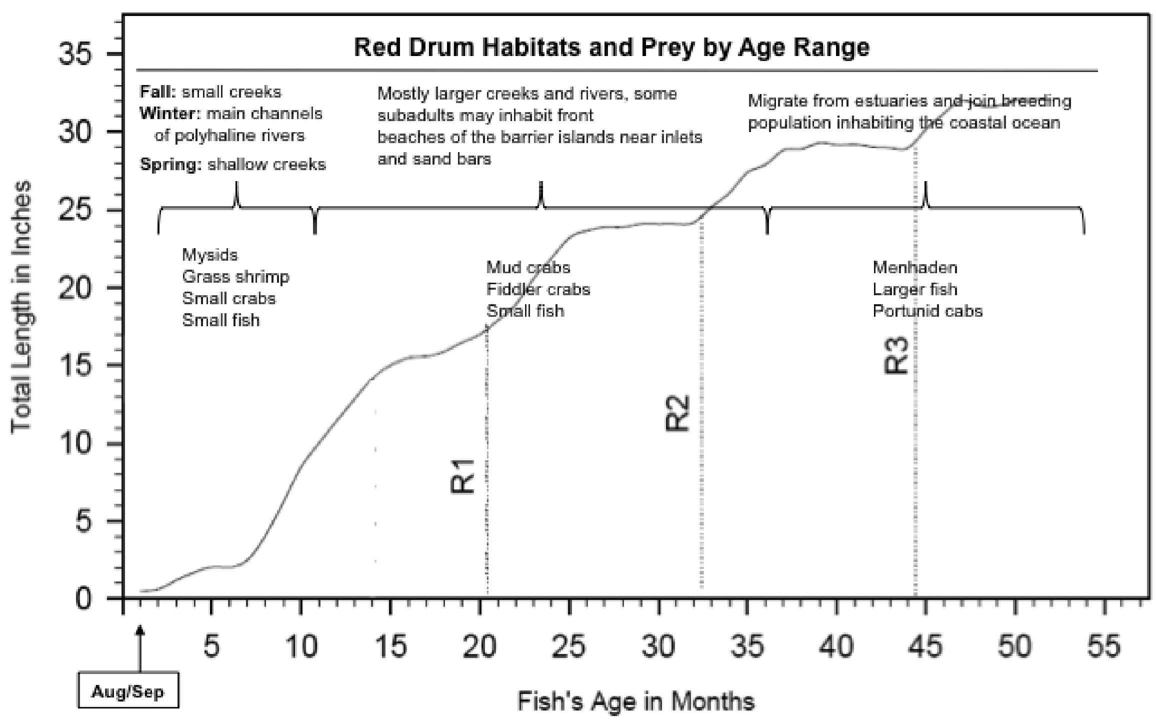

Figure 1. Red drum habitats and primary prey by age and size. Figure adapted from Wenner (2004) and based on research in South Carolina. R1, R2, and R3 are the ages of red drum when they have deposited 1, 2, or 3 rings on their ear bones or scales.

1.4.1.5 Adult Habitat

The adult phase begins when the fish are mature and can spawn regularly (Wenner 1992). Along the Atlantic coast adult red drum migrate north and inshore in the spring. In the fall, they migrate offshore and south (from Virginia to North Carolina). South of Hatteras, movement of adult red drum is typically described as inshore and offshore as opposed to north and south. Adults generally spend more time in coastal waters after they reach sexual maturity, but they do frequent inshore waters on a seasonal basis. Bacheler *et al.* (2009b) collected data that concluded that red drum of age 4+ generally moved furthest north and south, but traveled distances shorter than other life stages when moving east or west, from coastal waters to inshore waters. According to the 2008 Stock Assessment, red drum are found most abundantly in nearshore (coastal) shelf waters, and males reach maturity at an earlier age (1 to 3 years) than females (3 to 6 years) (FWCC 2008). The biology of the adult red drum is less well known than the younger stages, and therefore there is a lack of information regarding habitat utilization by adults. The South Atlantic Fishery Management Council's (SAFMC) Habitat Plan (SAFMC 1998; ASMFC 2002) cited high-salinity surf zones and artificial reefs as Essential Fish Habitat (EFH) for red drum in oceanic waters, which comprise the area from the beachfront seaward. Both nearshore and offshore hard/live bottom areas have been known to attract concentrations (schools) of adult red drum. Tagging studies have shown repeatedly that adult red drum in the Gulf of Mexico move tens and even hundreds of kilometers from original capture locations (Ingle *et al.* 1962; Osburn *et al.* 1982; Overstreet 1983; Julien *et al.* 2004). The following description of these habitats is taken from the SAFMC's Habitat Plan (1998) and ASMFC's Fishery Management Plan (2002):

> "Hard, or live bottom (Struthsaker 1969), consists of aggregations of coral generated habitats that have a thinner layer of live corals (soft and hard), among other biota types, existing among different sediments, older reefs or rock bottom. Often these bottom assemblages of coral provide reef structure for aggregations of red drum. Coral assemblages vary with geographical area. On the South Atlantic coast, coral communities are dominated by ahermatypic species, which are not reef building species. In the South Atlantic Bight (SAB), hard or live bottom habitats are generally small outcropping areas scattered in a patchy distribution over the continental shelf north of Cape Canaveral, FL. These habitats are most numerous off the coast of northeastern Florida and typically occur at depths greater than 27 m. Benthic temperatures in deeper areas range from 11° C to 27° C, while nearshore temperatures are typically cooler (from SEAMAPs South Atlantic Bottom Mapping Work Group effort, beginning in 1992). Data suggest that red drum prefer higher salinities as they age (Neill *et al.* 2004), which could partially provide an explanation as to why red drum move more into coastal areas during their subadult and adult life stages (Bacheler *et al.* 2009b)."

In addition to natural hard/live bottom habitats, adult red drum also use artificial reefs and other natural benthic structures. As of 2002, 120,000 acres of ocean and estuarine bottom along the south Atlantic has been permitted for the development of artificial reefs (ASMFC 2002). In Florida alone, 34 out of 35 coastal counties have been involved in artificial reef development (FWCC 2012). Most Atlantic coast states are in the process of establishing or have already established artificial reef management programs in their coastal waters.

Red drum were found from late November until the following May at both natural and artificial reefs along tide rips or associated with the plume of major rivers in Georgia (Nicholson and Jordan 1994). Data from this study suggests that adult red drum exhibit high seasonal site fidelity to these features. Fish tagged in fall along shoals and beaches were relocated 9 to 22 km offshore during winter and then found back at the original capture site in the spring. In summer, fish moved up the Altamaha River nearly 20 km to what the authors refer to as "pre-spawn staging areas" and then returned to the same shoal or beach again in the fall.

1.4.2 Identification and Distribution of Habitat and Habitats of Concern (HOC)

Red drum populations along the Atlantic coast are managed through the Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Act). Unlike the Magnuson-Stevens Fishery Conservation and Management Act which addresses fishery management by federal agencies, the Atlantic Coastal Act does not require the Atlantic States Marine Fisheries Commission to identify habitats that warrant special protection because of their value to fishery species. Nonetheless, the Commission believes this is a good practice so that appropriate regulatory, planning, and management agencies can consider this information during their deliberations.

As reviewed in section 1.4.1.1, habitats used by the various life stages of red drum include: tidal freshwater wetlands, estuarine wetlands, tidal creeks, mangrove wetlands, submerged aquatic vegetation (SAV), oyster reefs and shell banks, ocean high-salinity surf zone, hard bottom, and natural and artificial reefs. Spawning occurs within passes and inlets of high salinity estuaries on the southeastern U.S. coast and outer bars within surf zones (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994). In more recent studies, increased spawning habitat of red drum upriver to Oriental, NC, was due to elevated levels in salinity (Beckwith *et al.* 2006). Specific "hot spots" for red drum spawning include: North Carolina – waters of Pamlico Sound near Hatteras, Ocracoke and Drum Inlets and between the Neuse and Pamlico rivers in the western portion of the sound; South Carolina – main channel leading to Charleston Harbor and estuarine waters of St. Helena Sound; Georgia – the Altamaha River estuary; Florida – Ponce de Leon inlet and the Mosquito Lagoon system (ASMFC 2002). For red drum, nursery areas exist throughout estuarine environments, usually in shallow waters with varying salinities. Areas included are coastal marshes, shallow tidal creeks, bays, tidal flats of varying substrate type, tidal impoundments, and SAV beds. Red drum larvae and juveniles occur within a broad range of estuarine habitats. Similarly, subadult red drum are found throughout tidal creeks and channels of southeastern estuaries, in backwater areas behind barrier islands, and in the front along ocean beaches during certain seasons. Estuarine systems as whole, ranging from lower salinity rivers to the mouths of inlets, are needed to support populations of red drum.

A subset of red drum habitats, which the Commission refers to as Habitats of Concern (HOC), is especially important as spawning and nursery areas for red drum. HOC for red drum include all coastal inlets, SAV beds, the surf zone (including outer bars), and state-designated nursery habitats (e.g., Primary Nursery Areas in North Carolina; Outstanding Resource Waters in South Carolina's coastal counties; Aquatic Preserves along the Atlantic coast of Florida).

Table 1. Summary of red drum life stage dependent physical and temporal habitat characteristics.

Life stage	Optimal Temperature Range	Salinity range	Habitats	Timing
Adults-spawning	22-25^{o}C (up to 30^{o}C)	>25ppt (high salinities)	Estuary, passes/inlets, along open coasts	Late Summer-Early Fall
Eggs	20-30 ^{o}C	>25ppt (high salinities)	Estuary, passes/inlets, seagrass meadows	Fall
Larvae	Based on regional temperature regime (10-25 ^{o}C)	Low Salinities (10-20 ppt)	Pelagic-20days; then demersal Upper estuary	Late Fall-Spring
Juveniles	Based on regional seasonal temperature regime (10-30 ^{o}C)	Low-High Salinities (15-25 ppt)	*Estuary:* seagrass, tidal freshwater, low-salinity reaches, emergent wetlands, estuarine scrub/shrub, submerged aquatic vegetation, oyster reefs, shell banks, unconsolidated bottom Passes/Inlets	*Winter:* Deeper bay and river channels *Spring/Summer:* Shallow creeks and shorelines
Sub-Adults	Based on regional seasonal temperature regime	Low-High Salinities (high estuarine to marine)	*Estuary to Marine:* tidal creeks, rivers, inlets, shallows near barrier islands, jetties and sandbars; large aggregations in seagrass beds, over oyster bars, mud flats, and sand bottoms	Seasonal movement within habitats based on temperature changes and food availability
Adults	Based on regional seasonal temperature regime	High salinities (25-35 ppt)	*Marine*: Frequent inshore shelf waters on a seasonal basis; nearshore and offshore hard/live bottom, high salinity surf zones, artificial reefs *Lower Riverine*: pre-spawning	*Virginia and N.C.:* Seasonal migrations north and inshore in the spring; offshore and south in the fall *South of Cape Hatteras*: Seasonal migration onshore in the spring; offshore in the fall Summer

1.4.3 Present Condition of Habitats and Habitat of Concern

1.4.3.1 Coastal Spawning Habitat: Condition and Threats

The productivity and diversity of coastal spawning habitat can be compromised by the effects of industrial, residential, and recreational coastal development (Vernberg *et al.* 1999). Coastal development continues in all states and coastlines of the nation despite the increased protection afforded by federal and state environmental regulations. Threats to nearshore habitats in the south Atlantic that are documented spawning habitats for red drum or are suitable spawning habitats are described below.

Navigation and boating access development and maintenance activities, such as dredging and hazards from ports and marinas, are a threat to spawning habitats of red drum. According to the SAFMC (1998) and ASMFC (2002), navigation related activities can result in removal or burial of organisms from dredging or disposal of dredged material, effects due to turbidity and siltation, release of contaminants and uptake in nutrients, metals and organics, release of oxygen-consuming substances, noise disturbance, and alteration of hydrodynamic regime and habitat characteristics. All listed effects have potential effects to decrease the quality and quantity of red drum spawning habitat.

Ports also pose the threat of potential spills of hazardous materials. Cargo that arrives and departs from ports can contain highly toxic chemicals and petroleum products. While spills are rare, constant concern exists for extensive spans of estuarine and nearshore habitat being at risk of contamination. Even a small spill could result in a huge exposure of productive habitats. Oil releases such as the MC 282 or Deepwater Horizon oil release (2010) into the Gulf of Mexico has severely affected aquatic life, water quality and habitat posing many threats such as mortality, disease, genetic damage, and immunity issues (Collier *et al.* 2010). Chemicals in crude oil can cause heart failure in developing fish embryos (Incardona *et al.* 2004, 2005, 2009). Chronic exposures for years after the Exxon Valdez oil spill were evident in fish and other marine life, resulting in a higher pattern of mortality (Ballachey *et al.* 2003). Oiling of nearshore high-energy habitat along beaches of the Gulf of Mexico from Louisiana to Florida occurred for prolonged periods of time during the spring of 2010, and weathered oil products were found in offshore benthos where spawning red drum can occur. The discharge of oil may have also altered migration patterns and food availability. Port discharge of marine debris, garbage, and organic waste into coastal waters is also a concern.

Beach nourishment projects and development of wind and tidal energy could also alter red drum spawning and offshore adult habitat dynamics. Beach nourishment can result in removal of offshore sediments resulting in depressions and altering sediment characteristics along the shoreline (Wanless 2009). Sediments eroded from beaches after nourishment projects can also be transported offshore and bury hard bottoms, which can diminish spawning aggregation habitat for red drum. Beach nourishment projects can also alter forage species abundance, distribution and species composition in the high-energy surf zone for a time, but this varies by species and timing of nourishment activities (Irlandi and Arnold 2008). Wind and tidal energy projects can create artificial structure in migration corridors and submarine cables may produce electrical fields that can affect red fish movement patterns and habitat use in affected areas (DONG 2006; OEER 2008; ASMFC-Habitat Committee 2012).

Use of certain types of fishing gear, such as trawls and bivalve dredges can also adversely affect spawning habitat (Northeast Region Essential Fish Habitat Steering Committee 2002). Trawls and dredges remove structure-forming epifauna, alter sediment contours, redistribute reef aggregate materials (e.g. fractured rock outcroppings and boulders) and change infaunal and demersal organism assemblages in areas where fishing gear is operated. These effects can reduce forage species abundance for red drum thereby affecting spawning success. The most significant effect of this type of fishing gear is long-term changes in bottom structure and long-term changes in benthic trophic or ecosystem functions. These effects can be on the order of months to years in low energy environments, so alterations can have a long-term effect on red drum spawning habitat.

Spawning is optimal within a specific range of temperatures. Climate change and resulting temperature regime changes in spawning habitats could alter the timing of spawning and egg development, which may be detrimental in a specific habitat area of concern. Such alterations in phenology are recognized as such a threat to the survival of many species (USFWS 2011). Significant climate change could alter current patterns and significantly change water temperatures, affecting migration and spawning patterns, and larval survival (Hare and Able 2007; USFWS 2011).

1.4.3.2 Estuarine Spawning, Nursery, Juvenile and Subadult Habitat: Condition and threats

Between 1986 and 1997, estuarine and marine wetlands nationwide experienced an estimated net loss of 10,400 acres (Dahl 2000). The majority of this loss was from urban and rural activities and the conversion of wetlands for other uses. Along the south Atlantic coast, Florida experienced the greatest loss due to urban or rural development (Dahl 2000). In Tampa Bay, 3,250 acres of seagrass have been recovered between 2008 and 2010 (EPA 2011b).

Conditions of red drum estuarine habitats vary depending on the level of urbanization. Generally, an estuarine environment closer to a highly developed urban area will exhibit degradation when compared to the quality of estuarine habitat with less development of its surrounding landscape. Runoff, waste, and sewage pollution of sensitive coastal environments and can result in the proliferation of pathogens. Pathogens can result in lesions, developmental issues, disease of major organs, and mortality in red drum and other fishes (Conway *et al.* 1991) Red drum may exhibit a higher tolerance to bacteria with age, and antibody response also increases as water temperature does (Evans *et al.* 1997). Atrazine, a widely used pesticide in the United States, was exposed to red drum in low levels to test its' affect on growth, behavior, and survival of red drum. In laboratory experiments, using realistic doses of atrazine with respect to runoff amounts, red drum larvae exhibited a 7.9% - 9.8% decrease in growth rate (Alvarez & Fuiman 2005).

Nutrient enrichment of estuarine waters is a major threat to water quality and habitat available to the red drum. In the southeast, forestry practices significantly contribute to nutrient enrichment, as does pesticide use, fertilizers, and pollution runoff (ASMFC 2002; NSCEP 1993). Urban and suburban development are the most immediate threat to red drum habitat in the southeast. Port and marina expansion also impact the estuarine habitat important to red drum by pollution contributed from stormwater originating from altered uplands and through alterations to hydrodynamic flows and tidal currents. Watercraft operation can result in pollutant discharge, contributing to poor water quality conditions. Facilities supporting watercraft operations also result in the alteration and destruction of wetlands, shellfish and other bottom communities through construction activities. Motorized vehicles in Class A (< 16 ft) and Class 1 (16 to 25 feet) have seen major recreational growth in estuarine waterways (NMMA 2004). Operation of watercraft equipped with outboard and inboard engines and propellers over shallow seagrass communities can cause increased seagrass scarring (Sargent *et al.* 1995). Mining activities in nearby areas can also pose a threat with nutrient and contaminant runoff, dredging material deposition, and through alternations of the hydrology of the estuary.

Hydrologic modifications can negatively affect estuarine habitats. Aquaculture, mosquito control, wildlife management, flood control, agriculture, and silviculture activities can result in altered hydrology. Ditching, diking, draining, and impounding activities also qualify as hydrologic modifications that can impact estuarine environments (ASMFC 2011). Alteration of freshwater flows into estuarine areas may change temperature, salinity, and nutrient regimes as well as wetland coverage. Studies have shown that alteration in salinity and temperature can have profound effects in estuarine fishes (Serafy *et al.* 1997) and that salinity can dictate the abundance and distribution of organisms residing in estuaries (Holland *et al.* 1996). Certain areas in the southeast concern the maintenance and stabilization of coastal inlets. Construction of groins and jetties has altered hydrodynamic regimes and in turn, transport of larvae of estuarine dependent organisms through inlets (Miller *et al.* 1984; Miller 1988).

Shoreline erosion patterns can also affect the hydrodynamics and transport of larvae to estuarine environments. Erosion has the potential to alter the freshwater flow into habitats essential for egg, larval, and juvenile survival. Whether erosion is human-induced or naturally occurring, nearshore habitats are consequently affected and eroded sediment is transported and deposited elsewhere (ASFMC 2010). Beach nourishment activities can result in sedimentation in estuaries, covering seagrass beds and other nearshore habitats, and causing water quality to deteriorate (Green 2002; DEP 2011). Along the Atlantic coast, living shorelines are becoming a more popular management strategy to control and minimize erosion (ASFMC 2010).

As with other red drum habitat, trawl fisheries represent a threat to estuarine habitat for this species. In combination with the physical and biological effects identified in the Northeast Region Essential Fish Habitat Steering Committee workshop proceedings (2002), trawling activities and bivalve harvesting activities(oyster tonging, clam raking, clam kicking, etc.) can severely damage seagrass systems (Stephan *et al*. 2000). Such activities can reduce the productivity of estuarine red drum habitat and alter the ecology of this habitat. Forage species abundance can diminish and movement patterns for red drum schools within the estuaries they inhabit can be altered. Effects of these fishing gears can be ameliorated through effective management strategies, such as exclusion of trawl fisheries from seagrass communities, but without such management, the adverse effects of the fishery activities can be long-term.

Climate change has the potential to cause sea level rise, which could result in faster erosion of certain nearshore areas and loss of shallow nursery habitats to inundation. Projections of global sea level rise are from 18-59 cm by the year 2100, with an additional contribution from ice sheets of up to 20 cm (IPCC 2007). In addition to sea level rise, climate change could alter the amount of freshwater delivery and salinity levels in estuarine areas (USFWS 2011). Estuarine environments are highly vulnerable to changes in climate, so any change in temperature regime is also a concern. As temperature increases, the surface water in estuaries and marshes increases, which makes oxygen solubility more difficult (EPA 2011a) and can stress the environment. This can also minimize saltwater and freshwater mixture, and affect nutrient supply by changing hydrodynamics. Increases in carbon dioxide levels in ocean water, as a result of climate change, causes rises in acidity and pH levels. Estuarine waters are vulnerable to acidification, but seagrasses are particularly susceptible to changes in water column acidity (EPA 2011a).

Increases in temperature can also affect metabolism of seagrass (Evans *et al.* 1986, Marsh *et al.* 1986; Bulthuis 1987; Zimmerman *et al.* 1989b; Neckles and Short 1999), which alter the carbon balance and nutrient cycle. Changes could result in alterations in species distribution and abundance varying both geographically and spatially (McMillan 1984; Walker 1991).

1.4.3.3 Adult Habitat: Condition and Threats

While threats to adult red drum habitat exist, they are not as numerous as those faced by post-larvae, juveniles, and subadults in estuarine and coastal waters. According to the SAFMC (1998) and ASMFC (2002), threats to both nearshore and offshore habitats that adult red drum utilize in the south Atlantic include navigation management and related activities; dredging and dumping of dredged material; mining for sand or minerals; oil and gas drilling and transport; and commercial and industrial activities, and are similar to those for red drum coastal spawning habitat as mentioned in section 1.4.3.1 above.

Currently, mineral mining activities in the South Atlantic are highly limited. Offshore mining has the potential to pose a threat to adult red drum habitat in the future. Mining activities could alter the hydrology, sediment landscape, and water quality of surrounding areas, affecting both fish and their habitat, by causing sediment plumes or releasing metallic substances into the water column (Halfar 2002).

A more immediate threat to red drum adult habitat is the mining of sand for beach nourishment projects. Associated risks include burial of hard bottoms near mining or disposal sites, contamination, and an increase in turbidity and hydrological alterations that could result in a diminished habitat (Green 2002; Peterson and Bishop 2005).

Although adult red drum are euryhaline and eurythermal, drastic or sudden changes in salinity or temperature can result in mortality (Gunter 1941; Buckley 1984). While climate change is not an immediate threat, drastic fluctuations in seasonal temperature regimes and predicted extreme weather events could potentially pose threats the future.

1.4.4 Habitat Bottlenecks

Red drum utilize all available estuarine and nearshore habitats throughout their life history. Although regional habitat types, such as mesohaline SAV communities, might be limited locally, red drum can use multiple habitat types at each stage of their development. There is no supporting evidence that habitat is currently limiting to populations of red drum throughout their range.

For example, oyster reefs are an important habitat to red drum at the juvenile and subadult life stages. In South Carolina, the abundance of red drum is not limited by the availability or health of oyster reef habitat, despite significant reductions of oyster reef habitat throughout the range of the red drum population. Data from Georgia’s Marine Sportfish Health Survey (MSPHS) suggests over 80% of all juvenile red drum (≤ 375mm CL) captured since 2003 are associated with shell/oyster habitat. In comparison, less than half of the stations sampled were associated with shell. Since red drum use multiple habitat types at each stage of their development, limitation of one habitat type does not necessarily reduce survival of that life stage's cohort.

Creeks, tributaries, and estuaries are important habitats for red drum. Larval, juvenile, and subadult red drum are particularly sensitive to pollution contributed by watershed scale human activities. There is currently no evidence that chemical pollution is a limiting factor for juvenile and subadult red drum. However, changes in hydrology due to watershed activities that alter stormwater flow and sedimentation might restrict red drum larval recruitment both locally and regionally. The potential for impact on larval red drum recruitment is dependent upon the scale of stormwater change within the watershed and creek systems. Additionally, sediment accumulation may alter SAV abundance and circulation patterns resulting in lower recruitment into small creeks.

While these sensitive habitats have been identified as important to various life stages of red drum, none of them are believed to currently limit the successful recruitment of red drum individuals to regional stocks.

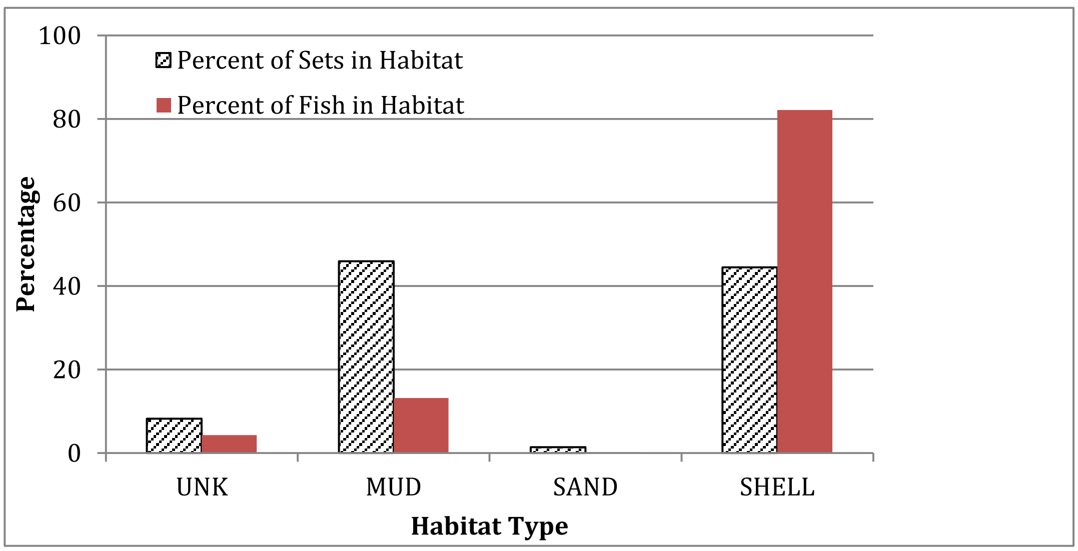

Figure 2. Red drum habitat preference from Georgia DNR MSPHS. Total sets across habitat types from 2003-2012.

1.4.5 Ecosystem Considerations

Ecosystem management considerations for red drum include protection and enhancement of habitat features, which can contribute to fish production, as well as consideration of how harvesting one species may impact the focus species and the biotic communities both supporting it, and which it supports.

The complexity of available habitat structure determines the ability of juvenile fish to avoid predation (Crowder and Cooper 1982; Salvino and Stein 1982; Nelson and Bonsdorff 1990; Heck *et al.* 1997; Minello and Stunz 2001). When available, seagrass environments serve as primary habitats for eggs and pelagic larvae and are also important to the juvenile stage of red drum. Seagrass habitats provide multiple ecosystem services in addition to their function as nursery systems (Constanza *et al.*1997; Heck *et al.* 2003), are highly productive environments that are nutrient rich from detrital sources, and they produce suitable habitat for prey and predators. Productivity outputs from seagrass habitats include carbon that enters coastal food webs and into other physiochemical structural pathways (Heck *et al.* 2003). Maintenance and restoration of seagrass habitats is beneficial to red drum by increasing nutrient and habitat availability, and in turn, increasing growth and development rates for larvae and juvenile red drum stages which have been previously described as a bottle-neck in determining regional populations and the future survival of the species (Cushing 1975; Houde 1987; Rooker *et al.* 1999).

Marsh environments are also valuable habitats to the larval and juvenile life stages of red drum. Red drum use tidal creeks from post-larval through sub-adult life stages. Seasonally, tidal currents move and guide early life stages of red drum into new environments as they transition from pelagic to juvenile stages. Under certain tidal conditions, water levels in marsh habitats may be lower or remain higher than water levels of open water systems in estuaries, which reduces water exchange and in turn affects physiochemical conditions, such as oxygen levels, salinity, and temperature (Levin *et al.* 2001). In a closed environment, depleted oxygen levels can lead to fish kills, which can either directly affect red drum, or indirectly affect local populations by killing off much of their forage resource. Hypoxia can also lead to avoidance behavior, relative to affected system, in addition to reduced growth and survival rates of local populations of juvenile to sub-adult red drum (Pihl *et al.* 1991; Eby and Crowder 2002; Thornson and Quigg 2008; Bacheler *et al.* 2009a). Red drum are susceptible to harmful algal blooms in estuarine environments, which can be due to elevated nutrient levels and can cause anoxic water column conditions. (Steidinger *et al.* 1998; Adams *et al.* 2011). Because red drum have shown some selectivity in salinity and temperature levels in the waters they inhabit (Neill 1987; Holt *et al.* 1981), reduced water exchange in marsh habitats may affect pelagic life stages.

In estuarine habitats, red drum growth and survival may suffer from sub-lethal effects due to anthropogenic degradation of water quality (Adams *et al.* 2011). Beckwith *et al.* (2006) concluded that, in low-salinity years, poorer water quality has a greater impact and can result in higher egg mortality. Bacheler *et al.* (2009a) collected 5,961 red drum in Pamilco Sound, North Carolina, where age-1 red drum were in greatest abundance at low (0 to 8 psu) or high (20 to 30 psu) salinities while the lowest catches occurred in moderate salinities (10 to 15 psu). Age-1 red drum were also most abundant in bottom habitats where there was algae, detritus, and shell, but lowest in areas with seagrass. Along the Outer Banks, North Carolina, however, higher catches of red drum were made in seagrass areas, suggesting that shallow, nearshore areas may provide subadults with a greater amount of foraging opportunities (Ross and Epperly 1986; Ruiz *et al.*1993; Miltner *et al.* 1995; Craig and Crowder 2000; Bacheler *et al.* 2009a). Inhabiting nearshore areas may also minimize predation, because predators of the red drum, such as bottlenose dolphins (*Turisops trucatus*), primarily occur in deeper waters (Gannon 2003; Bacheler *et al.* 2009a).

Regarding biotic factors, growth and survival rates of red drum larvae are similar to other marine fishes in that they are associated with prey availability (G.J. Holt, unpublished data; Rooker *et al* 1999). In Minello's *et al.*'s experiment (2001), wild-caught red drum had higher average predation rates in non-vegetated mesocosms than in areas sampled with oyster reefs. Predation rates in seagrass and marsh systems were intermediate when compared to these other habitats and experimental conditions. Hatchery-reared red drum showed little difference in mortality rates among these different habitats when released and subsequently sampled from them. Because of the complex physical structure provided, oyster reefs have the potential to provide better sheltering habitat for red drum, and thereby minimize predation. If oyster reefs provided a substantial enough advantage in protection from predation for red drum living in this habitat, more juveniles would survive the life stage associated with use of this habitat. This could result in an increase in individuals reaching reproductive maturity, which would positively affect the reproductive standing stock of regional populations recruiting individuals from this habitat. Research has concluded that oyster reefs provide more protection from predators to juveniles than seagrasses, marshes, or non-vegetated sand (Levin *et al.* 2001). Recruiting population vulnerability to depredation generally decreases as habitat complexity increases (Heck and Orth 1980; Levin *et al.* 2001).

Oyster reefs can also provide benthic-pelagic coupling (Hare and Maranick, 2007; ASMFC 2007b). Feeding activities by the oysters can cause a reduction in water column turbidity, which generally has a positive impact on submerged aquatic vegetation by allowing a higher degree of ambient light penetration in the water column. In addition to increasing water quality, oyster reefs reduce erosion (ASMFC 2007b), which can threaten estuarine habitats with sediment smothering, and baffle tidal currents that carry pelagic larvae into upper reaches of estuarine rivers.

Invasive species indirectly pose a potential threat to red drum by displacing or minimizing the populations of native species of animals and plants, which can alter the trophic structure of red drum communities, prey availability, and predator behavior dynamics. While red drum are considered a predatory fish, juveniles, eggs, and larvae may be adversely affected if they are directly displaced or if food sources upon which they depend are displaced by an invasive species or suite of species.

In south Texas estuarine habitats, spatial and temporal variation in meiofaunal prey density is common, so seasonal trends in prey abundance may affect early life survival of red drum (Rooker *et al* 1999). Predator suites also vary spatially and temporally, and abundance may be a factor in survival. Post-settlement red drum are often exposed to a large variety of predators with a shifting abundance and distribution in seagrass meadows (Rooker *et al.* unpublished data; Rooker *et al.* 1999). Predators inhabiting seagrass meadows are capable of consuming large numbers of red drum, which can result in prey and predator density fluctuations critical to the survival of red drum in the egg and larval stages (Rooker *et al.* 1998a).

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