CHAPTER 4: RED DRUM

Populated with text from the Red Drum Habitat Addendum (2013)

Section I. General Description of Habitat

Part A. Spawning Habitat

Red drum (*Sciaenops ocellatus*) spawn from late summer to late fall in a range of habitats, including estuaries, near inlets, passes, and near bay mouths (Peters and McMichael 1987). Earlier studies have illustrated that 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). Direct evidence of red drum spawning has been documented deep within estuarine waters of the Indian River Lagoon, Florida (IRL) (Murphy and Taylor 1990; Johnson and Funicelli 1991). More recently, an intensive two-year ichthyoplankton survey consistently collected preflexion (2–3 mm) red drum larvae up to 90 km away from the nearest ocean inlet from June to October with average nightly larval densities as high as 15 per 100 m^3 of water in the IRL (Reyier and Shenker 2007). Acoustic telemetry results for large adult red drum in the IRL further support estuarine spawning of this species within the IRL system (Reyier et al. 2011)

Geographic and Temporal Patterns of Migration

Red drum have a range extending from the Long Island south to the western Gulf of Mexico but it rarely occurs north of the Chesapeake Bay. Although spawning can occur in a variety of nearshore habitats, it often occurs near the mouths of large embayments from July to October (Able and Fahay 2010). Peak spawning takes place between August and September. In addition, red drum are thought to return to natal estuaries for spawning (Bacheler et al. 2009a; Patterson et al. 2004).

Salinity

High salinity, coastal estuarine areas provide optimal conditions for egg and larval development, as well as circulation patterns beneficial to transporting larvae to suitable nursery areas (Ross and Stevens 1992).

Substrate

Substrate sediments in spawning habitats are fine to coarse, unconsolidated sands. Current regimes conducive to larval transport ensure that fine sediments are sorted out of the substrate mix. Little is known regarding specific substrate types where spawning occurs within true estuarine habitats, but limited estuarine ichthyoplankton studies on red drum suggests recently hatched larvae are found over a mix of sand, sand-shell hash and sand-mud substrates. However, the release of gametes during spawning occurs in the surface waters, away from the benthos (Barrios 2004).

Temperature

Spawning in laboratory studies have also appeared to be temperature-dependent, occurring in a range from 22–30°C but with optimal conditions between temperatures of 22–25°C (Holt et al. 1981). Renkas

(2010) was able to duplicate environmental conditions of naturally spawning red drum from Charleston Harbor, South Carolina in a mariculture setting, and corroborated that active egg release occurred as water temperature dropped from a peak of approximately 30°C during August. Cessation of successful egg release was found at 25°C, with no spawning effort found at lower temperatures (Renkas 2010). Pelagic eggs, embryos, and larvae are transported by currents into nursery habitats for the duration of egg and larval stages (Peters and McMichael 1987; Beck et al. 2001).

Dissolved Oxygen

Little information exists regarding specific DO concentrations in relation to red drum spawning. Preliminary passive acoustic surveys in North Carolina waters suggest that DO levels of bottom waters may play a significant role for red drum aggregation formation. Spawning fish were significantly lower at sites with DO levels of bottom waters below 2.5 mg L^{-1} (Barrios 2004)

Feeding Behavior

No published work has reported on the feeding behaviors of actively spawning individuals. It might be inferred—based on nearshore and estuarine habitats—that spawning red drum feed on the same food sources as adults, which includes primarily larger fishes, crustaceans, and mollusks. Limited sampling of adult red drum in North Carolina revealed blue crab (*Callinectes sapidus*) made up 51% of the diet by number and occurred in 48% of the stomachs (Peacock 2014). The same study found the diet of adult red drum in South Carolina was more diverse than in North Carolina, where red drum consumed mostly Atlantic menhaden (*Brevoortia tyrannus*) and a diverse group of marine decapods and brachyurans.

Competition and Predation

Predation on spawning adults is likely similar to other adult red drum, depending on habitat. Various shark species (e.g. bull shark, *Carcharhinus leucas*; blacktip shark, *C. limbatus*) are potential predators of spawning adults.

Part B. Egg and Larval Habitat

Nelson et al. (1991) reported that red drum eggs are commonly encountered in several southeastern estuaries, in salinities above 25 ppt. Laboratory experiments in Texas (Neill 1987; Holt et al. 1981) established that optimum temperature and salinity for hatching and survival of red drum larvae are 25°C and 30 ppt, respectively. The spatial distribution and relative abundance of eggs in estuaries mirrors that of spawning adults in the fall (Nelson et. al. 1991). Eggs and early larvae utilize high salinity waters inside inlets and passes and within the estuary. In Florida, Johnson and Funicelli (1991) collected viable red drum eggs in Mosquito Lagoon, Florida, in average daily water temperatures of 20–25°C and average salinities of 30–32 ppt. The largest number of eggs collected during the study was in depths ranging from 1.5–2.1 m and highest concentrations of eggs were found at the edge of the channel.

Geographic and Temporal Patterns of Migration

Upon hatching, red drum larvae are pelagic (Johnson 1978) and growth rates are temperature-dependent (Holt et al. 1981). They make the transition between pelagic and demersal habitats within a few weeks after reaching nursery habitats (Pearson 1929; Peters and McMichael 1987; Comyns et al. 1991; Rooker and Holt 1997; Havel et al. 2015). They ingress into lower salinity nursery habitats in estuaries using tidal (Setzler 1977; Holt et al. 1989) or density-driven currents (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 in the nurseries, red drum larvae grow rapidly (Baltz et al 1998).

Red drum larvae along the Atlantic coast are common in most major southeastern estuaries, with the exception of Albemarle Sound, and they are abundant in the St. Johns and Indian River estuaries, Florida (Nelson et al. 1991). Data on the spatial distribution of red drum larvae in the Gulf of Mexico has been summarized by Mercer (1984). More recently, Lyczkowski-Shultz and Steen (1991) observed diel vertical stratification among red drum larvae found in depths <25 m at both offshore and nearshore locations.

Salinity

Red drum eggs have been commonly encountered in several southeastern estuaries in high salinity waters (above 25 ppt) (Nelson et al. 1991). The highest numbers of eggs were gathered in average salinities from 30–32 ppt at the edge of the channel (Johnson and Funicelli 1991). Salinities above 25 ppt allow red drum eggs to float while lower salinities cause eggs to sink (Holt et al. 1981). However, early stage red drum larvae were commonly found within estuarine waters of the IRL, Florida in salinity as low as 20 ppt (Reyier and Shenker 2007).

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.

Substrate

Upon hatching, red drum larvae are pelagic (Johnson 1978; Holt et al. 1981). Newly hatched red drum spend around twenty days in the water column before associating with benthos (Rooker et al. 1999; FWCC 2008). The size at settlement is determined by the substrate of the settlement site (Havel et al. 2015). Daniel (1988), however, found larvae younger than 20 days old already settled in the Charleston Harbor estuary.

Temperature

Larval red drum (1.7–5.0 mm mean SL length) were found in temperatures between 26–28°C (Lyczkowski-Shultz and Steen 1991). Research conducted in Mosquito Lagoon, Florida, found viable red drum eggs at average daily water temperatures ranging from 20–25°C (Johnson and Funicelli 1991). In Texas, laboratory experiments conducted by Neill (1987) and Holt et al. (1981) concluded that an optimum temperature for the hatching and survival of red drum eggs and larvae was 25°C.

Dissolved Oxygen

Mean DO concentration where larval red drum were captured in the IRL, Florida was 6.3 mg L^{-1} (Reyier 2005).

Feeding Behavior

Larval red drum are opportunistic feeders (Bass and Avault 1975). In Louisiana waters, larvae <15 mm fed heavily on zooplankton (e.g. copepods and copepod nauplii) whereas in Florida larvae (8–15 mm) in Tampa Bay feed primarily on copepods, mysids, and polychaetes (Peters and McMichael 1987).

Competition and Predation

Little information is available on competition or predation on larval red drum. Predators of larval fishes include a variety of organisms (planktonic crustaceans, chaetognaths, larger planktivorous fishes, and gelatinous organisms) (Duffy et al. 1997). Red drum spawn in the Gulf of Mexico from late summer to early fall, which coincides with elevated numbers of several species of jellyfish that represent dominate predators of eggs and larvae (Kraeuter and Setzler 1975). For example, during peak red drum spawning season in the IRL, no red drum eggs were collected when high ctenophore numbers were present (Johnson and Funicelli 1991).

Part C. Juvenile Habitat

Juvenile red drum utilize a variety of inshore habitats including tidal freshwater habitats, low-salinity reaches of estuaries, estuarine emergent vegetated wetlands, estuarine scrub/shrub, SAV, oyster reefs, shell banks, and unconsolidated bottom (SAFMC 1998).

Geographic and Temporal Patterns of Migration

The distribution of juvenile red drum within estuaries varies seasonally as individuals grow and begin to disperse. Along the South Atlantic coast, they utilize a variety of inshore habitats. Late juveniles leave shallow nursery habitats at approximately 200 mm TL (10 months of age). They are considered subadults until they reach sexual maturity at 3–5 years (C. Wenner, personal communication). It is at this life stage that red drum use a variety of habitats within the estuary and when they are most vulnerable to exploitation (Pafford et al. 1990; Wenner 1992). Tagging studies conducted throughout the species' range indicate that most subadult red drum tend to 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; Adams and Tremain 2000). Movement within the estuary is most likely related to changes in temperature and food availability (Pafford et al. 1990; Woodward 1994).

Tagging studies indicate that late age-0 and 1 year-old red drum are common throughout the shallow portions of the estuaries and are particularly abundant along the shorelines of rivers and bays, in creeks, and over grass flats and shoals of the sounds. During the fall, those subadult fish inhabiting the rivers move to higher salinity areas such as the grass flats and shoals of the barrier islands and the front beaches. With the onset of winter temperatures, juveniles leave the shallow creeks for deeper water in the main channels of rivers (9–15 m) and returned again to the shallows in the spring. Fish that reside near inlets and along the barrier islands during the summer are more likely to enter the surfzone in the fall.

By their second and third year of growth, red drum are less common in rivers but are common along barrier islands, inhabiting the shallow water areas around the outer bars and shoals of the surf and in coastal inlets over inshore grass flats, creeks or bays. In the northern portion of the South Carolina coast, subadults use habitats use broad, gently sloping flats (up to 200 m or more in width). Along the southern part of the South Carolina coast, subadult red drum inhabitat 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 (ASMFC 2002).

Salinity

Wenner et al. (1990) collected post-larval and juvenile red drum in South Carolina from June 1986 through July 1988 in shallow tidal creeks with salinities of 0.8–33.7 ppt, although the preferred salinity range in the IRL is between 19–29 ppt (Tremain and Adams 1995).

Substrate

In general, habitats supporting juvenile red drum can be characterized as detritus or mud-bottom tidal creeks as well as sand and shell hash bottoms (Daniel 1988; Ross and Stevens 1992). Within seagrass beds, investigations have shown that juveniles to prefer areas with patchy grass coverage or sites with homogeneous vegetation (Mercer 1984; Ross and Stevens 1992; Rooker and Holt 1997). In a Texas estuary, young red drum (6–27 mm 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 South Carolina, 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 South Carolina estuaries).

Temperature

Juvenile red drum are tolerant to a wide range of temperatures (8.5–33.5°C) (Bacheler et al. 2009b; Able and Fahay 2010). In the winter of their first year, 3–5 month old juveniles migrate to deeper, more temperature-stable parts of the estuary during colder weather (Pearson 1929). In the following spring, juveniles become more common in the shallow water habitats.

Dissolved Oxygen

In estuarine creek habitats in the IRL, FL, subadults and small adult red drum were collected in waters with mean DO levels ranging from 5 to 10 ppm (year round) (Adams and Tremain 2000). Within main lagoon habitats in the IRL, large subadults were found in DO concentrations ranging from 4–12 ppm (Adams and Tremain 2000).

Feeding Behavior

Larger juveniles are opportunistic feeders foraging on mysids, amphipods, palaemonid and penaeid shrimp, crabs, small fishes, and other sciaenids (Bass and Avault 1975). A higher diversity in prey items was found in stomachs of red drum collected over sand bottoms vs mud bottoms (Odum 1971). In Tampa Bay, FL, juvenile red drum up to 75 mm fed primarily on mysids, polychaetes, amphipods, and insects in juveniles up to 75 mm, with crabs and fish dominant in larger juveniles larger than 105 mm (Peters and McMichael 1987).

Competition and Predation

Small juvenile red drum are prey for numerous estuarine fish species and likely compete with other sciaenids. Larvae and juveniles are also consumed by pinfish (Minello and Stunz 2001).

Part D. Adult Habitat

Along the Atlantic Coast adult red drum migrate north and inshore in the spring and migrate offshore and south in the fall. Overall, adults tend to spend more time in coastal waters after reaching sexual maturity. However, they do continue to frequent inshore waters on a seasonal basis. Less is known about the biology of red drum once they reach the adult stage and accordingly, there is a lack of information on habitat utilization by adult fish. The SAFMC's Habitat Plan (SAFMC 1998) cited high salinity surf zones and artificial reefs as EFH for red drum in oceanic waters, which comprise the area from the beachfront seaward. In addition, nearshore and offshore hard/live bottom areas have been known to attract concentrations of red drum. The following description of these habitats was adapted from that provided in the SAFMC's Habitat Plan (1998b).

Geographic and Temporal Patterns of Migration

Adult red drum make seasonal migrations along the Atlantic coast. In the spring, adults move north and inshore but offshore and south in the fall. Overall, adults tend to spend more time in coastal waters after reaching sexual maturity. However, they do continue to frequent inshore waters on a seasonal basis. In the IRL, FL, limited seasonal migrations (Reyier et al. 2011) including some movement to coastal inlets in fall during the spawning season have been detected (Reyier et al. 2011). In Mosquito Lagoon (northern IRL), a portion of the adult population remain within the estuary where documented spawning occurs (Johnson and Funicelli 1991, Reyier et al. 2011).

Salinity

Adult red drum inhabit high salinity surf zones along the coast and adjacent offshore waters, at full marine salinity. Adults in some areas of their range (e.g. IRL, FL) can reside in estuarine waters year-round, where salinities are variable.

Substrate

In addition to natural hard/live bottom habitats, adult red drum also use artificial reefs and other natural benthic structures. 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 9–22 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.

Temperature

Bottom water temperatures in deeper hard/live bottom areas range from approximately 11–27°C whereas inshore areas typically exhibit cooler temperatures (SEAMAP's South Atlantic Bottom Mapping Work Group effort 1992).

Dissolved Oxygen

Large subadults and small adults were collected in waters of the IRL, FL where mean DO levels ranged from 5–10 ppm (year round) (Tremain and Adams 1995).

Feeding Behavior

Red drum are opportunistic foragers and their prey varies with size and season (Scharf and Schlight 2000). Adults feed on a variety of crustaceans, mollusks, and fishes (Chao 2002). Common prey species of adult red drum of the coast of Texas are white shrimp, gulf menhaden, and swimming crabs (blue crabs and related species) (Scharf and Schlight 2000).

Competition and Predation

Predators of large adult red drum within nearshore and offshore habitats likely include an array of shark species. Blacktip sharks and sandbar sharks have been observed within and surrounding large red drum schools off the Atlantic coast of Florida.

Section II. Essential Fish Habitats and Habitat Areas of Particular Concern

Essential Fish Habitat

The SAFMC recognizes several habitats as EFH for red drum. These natural communities include tidal freshwater, estuarine emergent vegetated wetlands (flooded salt marsh, brackish marsh, and tidal creeks), estuarine scrub/shrub (mangrove fringe), submerged rooted vascular plants (seagrass), oyster reefs and shell banks, unconsolidated bottom (soft sediment), high salinity surf zones, and artificial reefs (SAFMC 1998). The area covered ranges from Virginia through the Florida Keys, to a depth of 50 m offshore.

Identification of Habitat Areas of Particular Concern

For red drum, this includes the following habitats: tidal freshwater, estuarine emergent vegetated wetlands (flooded saltmarshes, brackish marsh, and tidal creeks), estuarine scrub/shrub (mangrove fringe), submerged rooted vascular plants (sea grasses), oyster reefs and shell banks, unconsolidated bottom (soft sediments), ocean high salinity surf zones, and artificial reefs. The SAFMC, which has a similar designation for their HAPCs, has recognized HAPCs for red drum along the U.S. coast including all coastal inlets, all state-designated nursery habitats (i.e. Primary Nursery Areas in North Carolina), sites where spawning aggregations of red drum have been documented and spawning sites yet to be identified, and areas supporting SAV. The SAFMC (1998b) also cited barrier islands off the South Atlantic states as being of particular importance since they maintain the estuarine environment in which young red drum develop. Inlets between barrier islands are of concern because the productivity of the estuary depends on the slow mixing of fresh and seawater that occurs in these areas. Finally, inlets, channels, sounds and outer bars are of particular importance to red drum since spawning activity is known to occur in these areas throughout the South Atlantic. Moreover, subadult and adult red drum utilize these areas for feeding and daily movements.

A species' primary nursery areas are indisputably essential to its continuing existence. Primary nursery areas for red drum can be found throughout estuaries, usually in shallow waters of varying salinities that offer certain degree of protection. Such areas include coastal marshes, shallow tidal creeks, bays, tidal flats of varying substrate, tidal impoundments, and seagrass beds. Since red drum larvae and juveniles are ubiquitous in such environments, it is impossible to designate specific areas as deserving more protection than others. Moreover, these areas are not only primary nursery areas for red drum, but they fulfill the same role for numerous other resident and estuarine-dependent species of fish and invertebrates, especially other sciaenids.

Similarly, subadult red drum habitat extends over a broad geographic range and adheres to the criteria that define HAPCs. Subadult red drum are found throughout tidal creeks and channels of southeastern estuaries, in backwater areas behind barrier islands and in the front beaches during certain times of the year. Therefore, the estuarine system as a whole, from the lower salinity reaches of rivers to the mouth of inlets, is vital to the continuing existence of this species.

SAFMC HAPC Designations for Red Drum

Of the designated EFH, HPACs have been recognized for red drum by the SAFMC. Areas which meet the criteria for HAPC include all coastal inlets, all state-designated nursery habitats of particular importance to red drum, documented sites of spawning aggregations from North Carolina to Florida, other spawning areas identified in the future, and areas supporting SAV (SAFMC 1998). These HAPCs include the most important habitats required during the life cycle of the species, including spawning areas and nursery grounds. Other areas of concern are barrier islands.

Present Condition of Habitat Areas of Particular Concern

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 ASMFC 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.

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).

Coastal Spawning Habitat: Condition and Threat

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 the potential 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. 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. While spills are rare, constant concern exists for extensive spans of estuarine and nearshore habitats proximal to ports are 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 fishes and other marine life, resulting in a higher pattern of mortality (Ballachey et al. 2003). Oiling of nearshore high-energy habitats 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 sediments where spawning red drum can occur.

[Excerpted from Atlantic Sciaenid Habitats: A Review of Utilization, Threats, and Recommendations for Conservation, Management, and Research]

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 drum 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 (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 abundance and community assemblages in fished areas. Fishing also reduces forage species abundance, which are common red drum prey, indirectly affecting spawning success through reduced foraging 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 and 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, spawning patterns, and larval survival (Hare and Able 2007; USFWS 2011).

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, which converted wetlands to 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).

Reduced water quality can lead to increased susceptibility to pathogens, which 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, reduced growth rates in red drum larvae by 7.9% - 9.8% (Alvarez and Fuiman 2005). Potentially toxic contaminants have been detected in red drum, including mercury (Adams and Onorato 2005) and persistant organic pollutants (Johnson-Restrepo et al. 2005).

Nutrient enrichment of estuarine waters is a major threat to water quality and habitat available to 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 (16–25 ft) 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 alterations 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). Construction of groins and jetties has altered hydrodynamic regimes and the 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 popular to control and minimize erosion (ASFMC 2010).

Trawl fisheries are a threat to estuarine habitat for red drum. In combination with the physical and biological effects identified in the 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, reduce forage species abundance, and alter movement patterns for red drum schools. Effects of these fishing gears can be mitigated through effective management strategies, such as exclusion of trawl fisheries from seagrass communities.

Climate change 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). As temperature increases, the surface water in estuaries and marshes also increases, which reduces oxygen solubility (EPA 2011a) and can stress the environment. Estuarine waters are vulnerable to acidification, but seagrasses are particularly susceptible to changes in water column acidity (EPA 2011a), which is an important nursery habitat for larval and juvenile red drum.

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.

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 and/or temperature can result in mortality (Gunter 1941; Buckley 1984).

Section III. Threats and Uncertainties

Significant Environmental, Temporal, and Spatial Factors Affecting Distribution of Red Drum

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.

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. Creeks, tributaries, and estuaries are important habitats for red drum. Larval, juvenile, and subadult red drum are particularly sensitive to pollution contributed to watersheds by 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. Additionally, sediment accumulation may alter SAV abundance and circulation patterns resulting in lower recruitment into small creeks.

Unknowns and Uncertainties

Not much is known regarding the preferred ranges and physiological tolerances of red drum and how it changes during development. In the context of climate change, more information is needed to predict how different life stages of red drum will be impacted by increased temperatures, altered freshwater flow regimes, increased acidity, and decreased DO. In addition to direct physiological impacts of climate change on red drum, indirect effects on red drum also need to be examined (e.g., habitat degradation, reduced prey abundance, and increased disease susceptibility).

Larval and juvenile red drum are also known to use many different habitats as nurseries, although the relative contribution of a particular nursery to the adult population has not currently been assessed.

Section IV. Recommendations for Habitat Management and Research

Habitat Management Recommendations

Amendment 2 to ASMFC's Interstate Fishery Management Plan for Red Drum (2002) states 15 habitat management recommendations for red drum.

1. Each state should implement identification and protection of red drum habitat within its jurisdiction, in order to ensure the sustainability of that portion of the spawning stock that either is produced or resides within its boundaries. Such efforts should inventory historical habitats through mark-recapture studies or other means as available, identify those habitats presently used for spawning or nursery areas (Section 3.8), specify those that are targeted for recovery, and impose or encourage measures to retain or increase the quantity and quality of red drum essential habitats.

2. Each state should notify in writing the appropriate Federal and state regulatory agencies of the locations of habitats used by red drum. Regulatory agencies should be advised of the types of threats to red drum populations and recommended measures which should be employed to avoid, minimize or 95 eliminated any threat to current habitat extent or quality.

3. Each state should establish HAPCs or similar designations appropriate for each state which hosts significant amounts of red drum spawning and nursery habitat. Each protected area should include sufficient amounts of necessary habitats for red drum, i.e., oyster reef, intertidal marsh or submerged rooted vascular vegetation, tidal creeks, intertidal flats, and adjacent deepwater estuarine to provide for individuals from age 0 to age 5 to reside therein. States may determine that such areas may warrant Marine Protected Area status and be closed to harvest either seasonally or permanently. It may be advantageous to locate such areas within existing special management areas such as National Wildlife Refuges, National Parks, including National Seashores, or state-designated areas such as Primary Nursery Areas (North Carolina).

4. Each state should establish freshwater inflow targets for estuaries documented as important red drum spawning, nursery or wintering habitat. Such targets should be derived where possible from flow data which predate significant hydrological alterations, and should mimic as closely as possible a natural hydrograph (defined as the pattern which predates significant anthropogenic alterations).

5. Where sufficient knowledge is available, states should seek to designate red drum essential habitats for special protection. These locations should be designated High Quality Waters or Outstanding Resource Waters and should be accompanied by requirements for non-degradation of habitat quality, including minimization of non-point source runoff, prevention of significant increases in contaminant loadings, and prevention of the introduction of any new categories of contaminants into the are (via restrictions on NPDES discharge permits for facilities in those areas).

6. State fishery regulatory agencies should develop protocols and schedules for providing input on water quality regulations to the responsible agency, to ensure to the extent possible that water

quality needs for red drum are restored, met and maintained. Water quality criteria for red drum spawning and nursery areas should be established or existing criteria should be upgraded to levels which are sufficient to ensure successful reproduction. Any action taken should be consistent with federal Clean Water Act guidelines and specifications.

7. State marine fisheries agencies should work with permitting or planning agencies in each state to develop permit conditions and planning considerations to avoid or mitigate adverse impacts on HAPCs or other habitats necessary to sustain red drum. Standard permit conditions and model policies that contain mitigation protocols should be developed. The development of Memoranda of Understanding (MOU) with other state agencies is recommended for joint review of projects and planning activities to ensure that habitat protections are adequately implemented.

8. Federal and state fishery management agencies should take steps to limit the introduction of compounds which are known or suspected to accumulate in red drum tissue and which pose a threat to human health or red drum health.

9. Each state should establish windows of compatibility for activities known or suspected to adversely affect red drum life states and their habitats, such as navigational dredging, bridge construction and dredged material disposal, and notify the appropriate construction or regulatory agencies in writing.

10. Projects involving water withdrawal from spawning or nursery habitats (e.g. power plants, irrigation, 96 water supply projects) should be scrutinized to ensure that adverse impacts resulting from larval/juvenile impingement, entrainment, and/or modification of flow, temperature and salinity regimes due to water removal will not adversely impact red drum spawning stocks, including early life stages.

11. States should endeavor to ensure the proposed water diversions/withdrawals from rivers tributary to spawning and nursery habitats will not reduce or eliminate conditions favorable to red drum use of these habitats.

12. The use of any fishing gear or practice which is documented by management agencies to have an unacceptable impact on red drum (e.g. habitat damage, or bycatch mortality) should be prohibited within the affected essential habitats (e.g. trawling in spawning areas or primary nursery areas should be prohibited).

13. Each state should review existing literature and data sources to determine the historical extent of red drum occurrence and use within its jurisdiction. Further, an assessment should be conducted of areas historically but not presently used by red drum, for which restoration is feasible.

14. Every effort should be made to eliminate existing contaminants from red drum habitats where a documented adverse impact occurs.

Excerpted from Atlantic Sciaenid Habitats: A Review of Utilization, Threats, and Recommendations for Conservation, Management, and Research

15. States should work in concert with the USFWS Division of Fisheries Resources and Ecological Services and the NMFS Office of Habitat Conservation to identify hydropower dams and water supply reservoirs which pose significant threat to maintenance of appropriate freshwater flows to, or migration routes for, red drum spawning areas and target them for appropriate recommendations during FERC relicensing evaluation.

Habitat Research Recommendations

Amendment 2 to ASMFC's Interstate Fishery Management Plan for Red Drum (2002) states seven research needs for red drum habitat, characterized as high (H), medium (M), and low (L) priority.

1. Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. (H)

2. Identify changes in freshwater inflow on red drum nursery habitats. Quantify the relationship between freshwater inflows and red drum nursery/sub-adult habitats. (H)

3. Determine the impacts of dredging and beach renourishment on red drum spawning and early life history stages. (M)

4. Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast. (M)

5. Identify the effects of water quality degradation (changes in salinity, DO, turbidity, etc.) on the survival of red drum eggs, larvae, post-larvae, and juveniles. (M)

6. Quantify relationships between red drum production and habitat. (L)

7. Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production. (L)

SAFMC's Habitat Plan for the South Atlantic Region (1998) and the NMFS Habitat Research Plan (Thayer et al. 1996) outlines the following needs and recommendations for research.

1. Investigate the relationship between habitat and yield of red drum throughout its range, including seasonality and annual variability as well as the influence of chemical and physical fluxes on these relationships.

2. Identify and quantify limiting conditions to red drum production, particularly in HAPCs.

3. Conduct cause-and-effect research to evaluate the response of red drum populations and HAPCs to anthropogenic stresses including responses to alterations in upland areas and the role of buffer zones.

4. Encourage research in the development of bio- or photo-degradable plastic products to minimize impact of refuse on inshore, coastal and offshore habitats that red drum utilize at various stages of development.

5. Quantify the impacts of acid deposition on red drum estuarine habitats.

6. Conduct research on habitat restoration and clean-up techniques including the development of new approaches and rigorous evaluation protocols. Research should focus on such topics as contaminant sequestration, bio-remediation techniques, the role and size of buffer zones, and the role of habitat heterogeneity in the restoration process.

7. Conduct research to assess the impacts of oil, gas and mineral exploration, development or transportation on red drum and red drum HAPCs.

8. Determine impacts of dredging nearshore and offshore sandbars for beach renourishment on all life history stages of red drum, particularly spawning adults.

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