CHAPTER 3: BLACK DRUM

EFH, HAPC, and Threats are populated with Habitat Section from the Interstate Fishery Management Plan for Black Drum (ASMFC 2013)

Section I. General Description of Habitat

Black drum in the Atlantic form one population, and two separate populations exist in the Gulf of Mexico (Gold and Richardson 1998). Like many coastal species, oceanic spawning is followed by ingress of eggs and larvae to mid and upper estuarine habitats, although substantial variation likely exists with respect to settlement. Juvenile black drum are largely estuarine-dependent, but throughout the first year of life begin moving to the lower estuary and possibly into the coastal ocean by the fall of year one (Able and Fahay 2010). Geographic adult age structure has been suggested, with older individuals more common in the Mid-Atlantic Bight than in the South Atlantic Bight, although a general movement pattern has been described as north and inshore in the spring, and south and offshore in the fall, which may confound true patterns of habitat use.

Part A. Spawning Habitat[1]

Geographic and Temporal Patterns of Migration

In the Atlantic basin, black drum spawn from April to June in the northern range (Joseph et al. 1964; Richards 1973; Silverman 1979). Black drum have been reported to spawn in nearshore waters, particularly bays and estuaries (Hoese 1965; Etzold and Christmas 1979). In the Mid-Atlantic region, spawning in the mouth of the Chesapeake Bay and larger estuaries has been well documented (Able and Fahay 2010) and the presence of a large spring/early summer fishery on spawning fish in the Delaware Bay also supports evidence of spawning occurring inshore and in the spring. Studies in Florida suggest spawning occurs in deep waters inshore, from November through April, with peaks in February and March (Murphy and Taylor 1989). It is noteworthy that the drumming sound made by black drum is associated with spawning behaviors, and several studies have measured noise in an effort to describe reproduction (Gulf of Mexico, Saucier and Baltz 1993, Locascio and Mann 2011; South America, Tellechea et al. 2010).

Fitzhugh et al. (1993) noted a difference in sex ratios in Louisiana during the spawning season between fish caught offshore by trawls (dominated by males), and fish caught inshore by gillnet and haul-seines (dominated by females). These skewed sex ratios were not found before or after the spawning period. The authors concluded the catches reflected a true segregation of the sexes during the spawning period, suggesting the use of different habitats.

[1] Much of the information in this section comes from two spawning studies in the Gulf of Mexico. These studies focused on the acoustics of spawning, and included a great deal of environmental data. Therefore, the ability to generalize about spawning habitat is somewhat limited, and more research is recommended.

Salinity

Salinity during drumming aggregations has been reported to range from 18.8–20.8 ppt in Louisiana (Saucier and Baltz 1993). Based on coastal ocean and lower estuary reported spawning habitats, euryhaline or full seawater salinities would be expected as optimal.

Substrate

None of the spawning studies describe substrate in association with a particular spawning aggregation; however, Saucier and Baltz (1993) generally describe the study sites to be heterogeneous, and include silt, clay, mud, sand, and detritus, and Locascio and Mann (2011) describe their sites as soft muddy composite.

Temperature

From studies limited to the Gulf of Mexico, spawning aggregations have been associated with temperatures ranging from 18–22°C (Locascio and Mann 2011) and with means of 18.8°C (for large drumming aggregations) and 20.8°C (for moderate drumming aggregations; Saucier and Baltz 1993).

Dissolved Oxygen

Saucier and Baltz (1993) present the only DO data associated with black drum spawning. They report means of 12.3 and 11.6 mg L^{-1} for large and moderate spawning aggregations, respectively. Inference on DO preference or tolerance ranges (or in other spatial spawning aggregations) should be approached cautiously.

Feeding Behavior

No published work has reported on the feeding behaviors of spawning individuals. It might be inferred—based on nearshore and estuarine habitats—that spawning black drum feed on the same food sources as adults, which includes primarily crustaceans and mollusks.

Competition and Predation

Competition among black drum and with other species is undocumented for spawning adults. Because spawning habitat is not yet described at a fine scale (microhabitat), it is unclear whether spawning habitats are limiting, and if competition exists for these habitats or inclusion in spawning aggregations. Predation of spawning adults is likely similar to adult *P. cromis*, although possibly depressed from both lower predatory metabolic demands from cooler winter and spring water temperatures, and the absence of many estuarine shark species until late spring (Ulrich et al. 2007).

Part B. Egg Habitat

Geographic and Temporal Patterns of Migration

Along the Atlantic coast, black drum eggs are spawned during the spring, from April to June in the northern range (Joseph et al. 1964; Richards 1973; Silverman 1979), and in February and March in the southern range (data from Florida; Murphy and Taylor 1989). Most spawning has been reported or estimated to take place nearshore in the coastal ocean, though some eggs have been sampled in the lower reaches of larger estuaries, such as the Chesapeake Bay (Daniel and Graves 1994). Spawning takes place when temperatures are between 17.5 and 19°C (Joseph et al. 1964; Richards 1973). Black drum eggs are pelagic, and at 20°C hatch in less than 24 h (Joseph et al. 1964). Some migration from tidal stream transport may take place; however, due to the short duration of the egg stage, it is unlikely that much distance is covered.

Salinity
Even though spawning occurs nearshore, black drum eggs in the coastal ocean are assumed to be exposed to full marine salinity (35 ppt) or at least polyhaline conditions for the brief duration before hatching (~24 hours).

Substrate
Since black drum eggs are pelagic and positively buoyant, substrate is not considered a critical habitat parameter.

Temperature
Spawning has been reported to take place when temperatures are between 17.5 and 19°C (Joseph et al. 1964; Richards 1973), and thus optimal (or tolerated) egg temperatures are likely very similar.

Dissolved Oxygen
Because the egg stage of black drum occurs entirely offshore, eggs are likely only ever exposed to normoxic waters (>5 mg L^{-1}). It is not currently thought that DO is a limiting factor to survival of black drum eggs.

Feeding Behavior
Black drum eggs subsist entirely off of the yolk sac prior to hatch.

Competition and Predation
Black drum eggs likely do not enter into any meaningful ecological competition, as their habitat demands are basic (and largely met by the oceanic or estuarine conditions). Predation of eggs undoubtedly occurs by a variety of oceanic and estuarine consumers. Specifically, Cowan et al. (1992) reported predation of black drum eggs by ctenophores and hydromedusae in the Chesapeake Bay with potentially very high levels of predation during years where both gelatinous predators have high abundances.

Part C. Larval Habitat

Geographic and Temporal Patterns of Migration
Black drum larvae hatch around 2.5 mm SL (Able and Fahay 2010) and ingress from nearshore and lower estuarine egg habitats using tidal stream transport to variable locations within estuaries. Overall the general pattern documented for larvae is to move from higher salinity areas to lower salinity estuarine habitats (from otolith microchemical analyses; Rooker et al. 2004), and Gold and Richardson (1998) used molecular methods to characterize black drum as estuarine-dependent in the early years. However, black drum may be less dependent on upper, oligohaline and mesohaline estuarine habitats as larvae have been collected in higher salinities of 21 ppt (Peters and McMichael 1990). As with other sciaenids, it is likely that larval black drum settle in a range of estuarine habitats with confounding of estuarine-specific habitat availabilities.

Salinity
Peters and McMichael (1990) collected larvae off the Gulf Coast of Florida in salinities ranging from 21–31 ppt. The larval stage of black drum likely uses the lowest salinity habitats of any life stage, although there are few records of larvae collected in low salinity, upper estuarine habitats.

Substrate
Peters and McMichael (1990) collected larvae off the Gulf Coast of Florida over a variety of substrates, including sand, mud, and shells. Larval collections in the Atlantic, particularly with respect to substrate, are poorly known.

Temperature
Peters and McMichael (1990) collected larvae off the Gulf Coast of Florida in water temperatures ranging from 21.9–24.6°C.

Dissolved Oxygen
DO demands are likely met offshore, as well as inshore after ingress. Both of these habitats typically do not experience hypoxic conditions in the winter and spring, although no published studies have reported on any limitations.

Feeding Behavior
Like most larval fish, black drum feed on their yolk sac initially (up to 4 days, or to an estimated 2.8 mm SL; Joseph et al. 1964). Post-yolk sac larvae then begin to feed generally on zooplankton (Benson 1982), and more specifically copepods (Peters and McMichael 1990).

Competition and Predation
Black drum larvae may experience density dependence, although this phenomenon has not been documented and the variety of settlement habitats may release them from specific habitat or spatial constraints. Additionally, the species' relatively long spawning season may mitigate against a temporal bottleneck for habitat. Larval black drum are likely subject to predation by a range of estuarine predators; particular attention to hydromedusa and ctenophore predators has been hypothesized to impact recruitment in years of low black drum production and high densities of hydrozoans (Cowan et al. 1992).

Part D. Juvenile Habitat

Geographic and Temporal Patterns of Migration
Broadly, juvenile black drum likely use a range of estuarine habitats. Small juveniles have been documented in upper and middle parts of estuaries, where salinities are low (<6 ppt; Able and Fahay 2010). However, by the summer months, juveniles begin moving down in the estuary into tidal and marsh habitats and are not found in rivers. By the fall, some juveniles are even found in ocean habitats. Beach seine sampling in Florida nearshore lagoons found high levels of juveniles, indicating juvenile black drum remain inshore (Peters and McMichael 1990).

Salinity
Salinity exposure is likely variable both across a cohort as well as the individual level. Some juveniles have been sampled in lower estuary, high salinity (>30 ppt) locations (Peters and McMichael 1990), while others have reported juvenile black drum in freshwater (Frisbie 1961; Thomas and Smith 1973). Some reports have discussed a size effect to down-estuary movement, in which migrations to lower estuarine or oceanic habitats is influenced by size. In general, smaller individuals inhabit low salinity tributaries whereas larger individuals inhabit higher salinity regions found at the mouths of bays and rivers (Frisbie 1961).

Substrate

Peters and McMichael (1990) reported juvenile black drum over unvegetated mud bottoms, and Pearson (1929) reported muddy, estuarine bottoms as the most common juvenile substrate. However, as with salinity, juveniles likely use a range of habitats and substrates.

Temperature

Juveniles likely experience a range of temperatures throughout their first year in an estuary. Juveniles in the Gulf of Mexico primarily sampled over summer and fall months were captured at 20.8–26.3°C (Peters and McMichael 1990). Winter temperature drops are common causes of estuarine fish kills, and black drum are vulnerable to this condition (Simmons and Breuer 1962). McEachron et al. (1994) noted black drum in several winter kills in Texas coastal waters, though the length data suggests many of these fish were adults and not juveniles.

Dissolved Oxygen

Currently, there is no known information on juvenile black drum sensitivity to DO levels.

Feeding Behavior

Small juveniles primarily feed on amphipods, mollusks, polychaetes, and small fishes (Peters and McMichael 1990). As juveniles grow, Peters and McMichael (1990) found their consumption of shrimp, crabs, fish, and mollusks became more dominant, with the shift correlating to the development of pharyngeal jaw toothplates and molariform teeth.

Competition and Predation

Based on the within-estuary movement during the first year of life and wide use of estuarine resources, little is reported on competition among black drum or with other estuarine species, although they likely compete with other sciaenids (Sutter et al. 1986). Pharyngeal teeth permit black drum to eat a wide variety of mollusks and other prey items, which may limit competition on a single food source (Sutter et al. 1986). Predation of juvenile black drum likely takes place by estuarine predators, such as spotted seatrout, jacks, sharks (Murphy and Muller 1995).

Part E. Adult Habitat

Geographic and Temporal Patterns of Migration

While adult black drum likely move between estuarine and nearshore habitats, multiple investigators have noted two trends. The first trend is the expected movement toward deeper waters with age (i.e., out of tidal creeks and into lower estuaries). The second geographic pattern involves general adult movements north and inshore during spring, and south and offshore during fall (Richards 1973; Murphy and Taylor 1989). Jones and Wells (2001) note the possibility of age separation, with greater proportions of older fish north of Cape Hatteras, North Carolina. However, it is unclear what proportion of the Atlantic population undergoes migration or whether they are influenced by factors other than spawning. Even the literature has been inconsistent in regard to how to characterize adult habitat use. For example, Sutter (1986; citing Hoese and Moore 1977) stated that adult black drum are predominantly estuarine but other studies have cited an ocean residency period. Given the long lifespan of black drum (>50 years) and factors driving adult habitat use (e.g., spawning migration, general seasonality), it is likely that they use a variety of inshore and nearshore habitats.

Salinity
Lower estuarine and coastal oceanic environments used by black drum are likely polyhaline or full seawater. Black drum are commonly found in waters with a salinity range of 9–26 ppt (McIlwain 1978) but individauls can tolerate salinities as low as 0 ppt and as high as 80 ppt (Gunter 1956; Simmons and Breuer 1962; Leard et al 1993).

Substrate
Adults likely use a wide variety of habitats and substrates, and Sutter (1986) suggests that adults are most common over sand and soft bottoms where oysters and clams can be found. Black drum in Louisiana were observed to avoid large, open areas of soft sediment (George 2003).

Temperature
McIlwain (1978; in Sutter 1986) reported black drum adults in a range of temperatures consisting of 12–33°C. The range reported here may be interpreted as a suitable range, and more extreme temperatures may be tolerated.

Dissolved Oxygen
No studies have reported on DO requirements for black drum, though there is little reason to suspect that adults experience sustained periods of limited DO. Both their mobility and range of habitats suggest that they are not constrained to or by specific, low oxygen environments.

Feeding Behavior
Adult black drum continue their predation on benthic crustaceans and mollusks, although Ackerman (1951) reported surface feeding on menhaden. Blasina et al. (2010) reported on black drum in Argentina and also found crustaceans and mollusks to dominate the diet. With efforts underway to rehabilitate Atlantic oysters, some have looked into the ability of black drum to depress recovering oyster populations (Benson 1982; Brown et al. 2008).

Competition and Predation
Competition among black drum is likely minimal as there are no suspected habitat or forage limitations regularly imposed on adults. Adult black drum, based on their large size, are unlikely to be consumed, but have been documented to be preyed upon by sharks (Murphy and Muller 1995).

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

Essential Fish Habitat
Prior to transfer of management authority for red drum from the South Atlantic Fishery Management Council (SAFMC) to ASMFC, the SAFMC reviewed the Essential Fish Habitat (EFH) and HAPC designations for red drum. The SAFMC concluded the EFH and HAPCs would still be protected, as similar areas had been designated for other federally managed species. As a result, these areas, which also serve an important role in the black drum life cycle, have retained protection and are referenced here and in the Amendment 2 to the Red Drum FMP (ASMFC 2002).

The designated EFH includes 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), ocean 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 black drum, HAPCs includes the following habitats: tidal freshwater, estuarine emergent vegetated wetlands (flooded salt marshes, brackish marsh, and tidal creeks), estuarine scrub/shrub (mangrove fringe), submerged rooted vascular plants (seagrasses), oyster reefs and shell banks, unconsolidated bottom (soft sediments), ocean high salinity surf zones, and artificial reefs. These areas overlap with the designated HAPCs for red drum, designated in Amendment 2 to the Red Drum FMP (ASMFC 2002). These HAPCs include 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, areas supporting SAV, as well as barrier islands off the South Atlantic states as they maintain the estuarine environment in which young black drum develop.

A species' primary nursery areas are indisputably essential to its continuing existence. Primary nursery areas for black drum can be found in estuaries, such as coastal marshes, shallow tidal creeks, bays, tidal flats of varying substrate, tidal impoundments, and seagrass beds. Since young black drum move among these environments, it is difficult to designate specific areas as deserving more protection than others. Moreover, these areas are not only primary nursery areas for black drum, but they fulfill the same role for numerous other resident and estuarine-dependent species of fish (i.e., other sciaenids) and invertebrates.

Similarly, juvenile black drum habitat extends over a broad geographic range and adheres to the criteria that define HAPCs. Juvenile black drum are found throughout tidal creeks and channels of southeastern estuaries, in backwater areas behind barrier islands and along beach fronts during certain times of the year. It is during this period that juveniles begin moving between low and higher salinity areas (Rooker et al. 2004). 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.

<u>Section III. Threats and Uncertainties</u>

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

Threats to black drum habitats include the following: loss of estuarine and marine wetlands, loss of oyster reefs, coastal development, nutrient enrichment of estuarine waters, poor water quality, hydrologic modifications, and alteration of freshwater flows into estuarine waters.

Present Condition of Habitat Areas of Particular Concern

Coastal Spawning Habitat: Condition and Threats Coastal Spawning

It is reasonable to assume that areas where coastal development is taking place rapidly, habitat quality may be compromised. Coastal development is a continuous process in all states and all coastal areas in the nation are experiencing significant growth. The following section describes particular threats to the nearshore habitats in the South Atlantic that meet the characteristics of suitable spawning habitat for black drum.

One threat to the spawning habitat for black drum is navigation and related activities such as dredging and hazards associated with ports and marinas (ASMFC 2013). According to the SAFMC (1998), impacts from navigation related activities on habitat include: direct removal/burial of organisms from dredging and disposal of dredged material, effects due to turbidity and siltation; release of contaminants and uptake of nutrients, metals and organics; release of oxygen-consuming substances, noise disturbance, and alteration of the hydrodynamic regime and physical characteristics of the habitat. All of these impacts have the potential to substantially decrease the quality and extent of black drum spawning habitat as well as prey resources.

Besides creating the need for dredging operations that directly and indirectly affect spawning habitat for black drum, ports also present the potential for spills of hazardous materials. The cargo that arrives and departs from ports includes highly toxic chemicals and petroleum products. Although spills are rare, constant concern exists since huge expanses of productive estuarine and nearshore habitat are at stake. Additional concerns related to navigation and port utilization are discharge of marine debris, garbage, and organic waste into coastal waters.

Maintenance and stabilization of coastal inlets is of concern in certain areas of the southeast. Studies have implicated jetty construction to alterations in hydrodynamic regimes thus affecting the transport of larvae of estuarine-dependent organisms through inlets (Miller et al. 1984; Miller 1988).

Estuarine Nursery, Juvenile and Sub-Adult Habitat: Condition and Threats

Coastal wetlands and their adjacent estuarine waters constitute primary nursery, juvenile, and sub-adult habitat for black drum along the coast. Between 1986 and 1997, estuarine and marine wetlands nationwide experienced an estimated net loss of 10,400 acres. However, the rate of loss was reduced over 82% since the previous decade (Dahl 2000). Most of the wetland loss resulted from urban and rural activities and the conversion of wetlands for other uses. Along the southeast Atlantic coast, the state of Florida experienced the greatest loss of coastal wetlands due to urban or rural development (Dahl 2000). However, the loss of estuarine wetlands in the southeast has been relatively low over the past decade although there is some evidence that invasion by exotic species, such as Brazilian pepper (*Schinus terebinthifolius*), in some areas could pose potential threats to fish and wildlife populations in the future (T. Dahl, personal communication).

Throughout the coast, the condition of estuarine habitat varies according to location and the level of urbanization. In general, it can be expected that estuarine habitat adjacent to highly developed areas will exhibit poorer environmental quality than more distant areas. Mollusks, which are a dominant component of the black drum diet, bioaccumulate toxins in their tissues (Shumway et al. 1990) although the impact of this bioaccumulation on black drum is not known. Hence, environmental quality concerns are best summarized on a watershed level.

Threats to estuarine habitats of the southeast were described in Amendment 2 to the Red Drum FMP (ASMFC 2002). Due to the black drum's dependence on estuarine habitats throughout its early years, these same threats are likely to impact black as well as red drum.

Nutrient enrichment of estuarine waters throughout the southeast is a major threat to the quality of estuarine habitat. Forestry practices contribute significantly to nutrient enrichment in the southeast. Areas involved are extensive and many are in proximity to estuaries. Urban and suburban developments are perhaps the most immediate threat to black drum habitat in the southeast. The almost continuous expansion of ports and marinas in the South Atlantic poses a threat to aquatic and upland habitats. Certain navigation-related activities are not as conspicuous as port terminal construction but have the potential to significantly impact the estuarine habitat that black drum require. Activities related to watercraft operation and support pose numerous threats including discharge of pollutants from boats and runoff from impervious surfaces, contaminants generated in the course of boat maintenance, intensification of existing poor water quality conditions, and the alteration or destruction of wetlands, shellfish and other bottom communities for the construction of marinas and other related infrastructure.

Estuarine habitats of the southeast can be negatively impacted by hydrologic modifications. The latter include activities related to aquaculture, mosquito control, wildlife management, flood control, agriculture, and silviculture. Also, ditching, diking, draining and impounding activities associated with industrial, urban, and suburban development qualify as hydrologic modifications that may impact the estuarine habitat. Alteration of freshwater flows into estuarine areas may change temperature, salinity and nutrient regimes as well as alter wetland coverage. Studies have demonstrated that changes in salinity and temperature can have profound effects in estuarine fishes (Serafy et al. 1997) and that salinity partly dictates the distribution and abundance of estuarine organisms (Holland et al. 1996). Hence, black drum are probably as susceptible as any other estuarine organism to such changes in the physical regime of their environment.

Oyster reefs in Louisiana are a preferred habitat (George 2003) and oysters are a common prey (Blasina et al. 2010). However, in the Chesapeake Bay, oysters have been reduced to 1% of historical levels (Kemp et al. 2005), which represents a significant decline in both a preferred habitat and prey of black drum.

Adult Habitat: Condition and Threats

Threats to the black drum's adult habitat are not as numerous as those faced by postlarvae, juveniles, and subadults in the estuarine and coastal waters. Current threats to the nearshore and offshore habitats that adult black drum utilize in the South Atlantic include navigation and related activities, dumping of dredged material, mining for sand and minerals, oil and gas exploration, offshore wind facilities, and commercial and industrial activities (SAFMC 1998).

An immediate threat is the sand mining for beach nourishment projects. Associated threats include burial of bottoms near the mine site or near disposal sites, release of contaminants directly or indirectly associated with mining (i.e. mining equipment and materials), increases in turbidity to harmful levels, and hydrologic alterations that could result in diminished desirable habitat.

Offshore mining for minerals may pose a threat to black drum habitat in the future. Currently, there are no mineral mining activities taking place in the South Atlantic. However, various proposals to open up additional areas off the Atlantic coast to seabed mining have been introduced by the Federal Executive and Legislative branches.

Offshore wind farms may also pose a threat to black drum habitat at different life stages in the future (ASMFC 2011). Currently, there are no offshore wind farms established in the United States. However, the Atlantic coast is a potential candidate for future wind farm sites.

Unknowns and Uncertainties

Habitat preferences, physiological tolerances to temperature, salinity, and DO, and life history information is lacking for black drum. Without these data, it is extremely difficult to predict how black drum populations will respond to climate variability, ocean acidification, environmental toxins, and hypoxic conditions. For example, during an hypoxic event black drum are mobile and are able to avoid hypoxic waters whereas their prey (sessile mollusks) are unable to avoid these conditions, potentially increasing mortality of black drum prey. Therefore, there are many ecological linkages in estuarine and coastal ecosystems that need to be examined to understand direct and indirect impacts of habitat degradation on the various life stages of black drum.

Section IV. Recommendations for Habitat Management and Research

Habitat Management Recommendations

Particular attention should be directed toward black drum habitat utilization and habitat condition (environmental parameters). A list of existing state and Federal programs generating environmental data such as sediment characterization, contaminant analysis, and habitat coverage (marsh grass, oyster beds, SAV) should also be produced and updated as new information arises. Habitats utilized by black drum range from the tidal freshwater out to and likely beyond, the shelf break. Thus, virtually any study generating environmental data from estuarine or coastal ocean systems could be of value.

1. Where sufficient knowledge is available, states should designate black drum HAPCs for special protection. These locations should be accompanied by requirements that limit degradation of habitat, including minimization of non-point source and specifically storm water runoff, prevention of significant increases in contaminant loadings, and prevention of the introduction of any new categories of contaminants into the area.

2. Where habitat areas have already been identified and protected, states should ensure continued protection of these areas by notifying and working with other Federal, state, and local agencies. States should advise these agencies of the types of threats to black drum and recommend measures that should be employed to avoid, minimize, or eliminate any threat to current habitat quality or quantity.

3. States should minimize loss of wetlands to shoreline stabilization by using the best available information, incorporating erosion rates, and promoting incentives for use of alternatives to vertical shoreline stabilization measures (e.g., sea walls), commonly referred to as living shorelines projects.

4. All state and Federal agencies responsible for reviewing impact statements and permit applications for projects or facilities proposed for black drum spawning and nursery areas should ensure that those projects will have no or only minimal impact on local stocks. Any project that would eliminate essential habitat should be avoided, if possible, or at a minimum, adequately mitigated.

5. Each state should establish windows of compatibility for activities known or suspected to adversely affect black drum life stages and their habitats, with particular emphasis to avoid spawning season. Activities may include, but are not limited to, navigational dredging, bridge construction, and dredged material disposal, and notify the appropriate construction or regulatory agencies in writing.

6. Each state should develop water use and flow regime guidelines, where applicable, to ensure that appropriate water levels and salinity levels are maintained for the long-term

protection and sustainability of the stocks. Projects involving water withdrawal or interrupt water flow should be evaluated to ensure that any impacts are minimized, and that any modifications to water flow or salinity regimes maintain levels within black drum's tolerance limits.

7. The use of any fishing gear that is determined by management agencies to have a negative impact on black drum habitat should be prohibited within HAPCs. Further, states should protect vulnerable habitat from other types of non-fishing disturbance as well.

8. States should work with the USFWS's Divisions of Fish and Wildlife Management Assistance and Ecological Services and NMFS's Offices of Fisheries Conservation and Management and Habitat Conservation to identify hydropower and water control structures that pose significant threats to maintenance of appropriate freshwater flows (volume and timing) to black drum nursery and spawning areas and target these dams for appropriate recommendations during FERC re-licensing.

9. States should conduct research to evaluate the role of SAV and other submersed structures in the spawning success, survival, growth, and abundance of black drum. This research could include regular mapping of the bottom habitat in identified areas of concern, as well as systematic mapping of this habitat where it occurs in estuarine and marine waters of the states.

10. States should continue support for habitat restoration projects, including oyster shell recycling and oyster hatchery programs as well as seagrass restoration, to provide areas of enhanced or restored bottom habitat, which serve as nurseries or foraging grounds.

11. Water quality criteria for black drum spawning and nursery areas should be established, or existing criteria should be upgraded, to ensure successful reproduction of these species. Any action taken should be consistent with Federal Clean Water Act guidelines and specifications.

12. State fishery regulatory agencies, in collaboration with state water quality agencies, should monitor water quality in known habitat for black drum, including turbidity, nutrient levels, and DO.

13. States should work to reduce point-source pollution from wastewater through improved inspections of wastewater treatment facilities and improved maintenance of collection infrastructure.

14. States should develop protocols and schedules for providing input on water quality regulations, and on Federal permits and licenses required by the Clean Water Act, Federal Power Act, and other appropriate vehicles, to ensure that black drum habitats are protected and water quality needs are met.

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

Habitat Research Recommendations

The Interstate Fishery Management Plan for Black Drum (2013) states three research needs for black drum habitat.

- Expand existing fishery independent surveys in time and space to better cover black drum habitats, if possible (especially adults).
- Conduct otolith microchemistry studies to identify regional recruitment contributions.
- Conduct new and expand existing acoustic tagging programs to help identify spawning and juvenile habitat use and regional recruitment sources.

Additional research objectives also need to focus on resolving the preferred and physiological tolerances of black drum, at all life stages, for temperature, salinity, and DO. Studies also need to examine the impact of black drum consuming mollusks in polluted, industrialized regions since mollusks bioaccumulate toxins.

Literature Cited

Able, K. W. and M. P. Fahay. 2010. Ecology of Estuarine Fishes: Temperate waters of the western North Atlantic. Johns Hopkins University Press. Baltimore, MD.

Ackerman, B. 1951. Handbook of fishes of the Atlantic seaboard. The American Publishing Co. Washington, D.C. pp. 144.

ASMFC (Atlantic States Marine Fisheries Commission). 2002. Amendment 2 to the Red Drum Interstate Fishery Management Plan. Washington (DC): ASMFC. pp. 162.

ASMFC (Atlantic States Marine Fisheries Commission). 2011. An Evaluation of Black Drum Data Sources and Recommendations for Coastwide Stock Assessment. Report to ISFMP Policy Board. Washington (DC): ASMFC. pp. 147.

ASMFC (Atlantic States Marine Fisheries Commission). 2013. Harbor Deepening: Potential Habitat and Natural Resources Issues. Habitat Management Series #12. Arlington (VA): ASMFC. pp. 10.

ASMFC (Atlantic States Marine Fisheries Commission). 2013. Interstate Fishery Management Plan for Black Drum.

Benson, N. G. 1982. Life history requirements of selected finfish and shellfish in Mississippi Sound and adjacent areas. U.S. Fish and Wildlife Service. Biological Service Program. FWS/035-81/15.

Blasina, G. E., S. A. Barbini and J. M. Díaz de Astarloa. 2010. Trophic ecology of the black drum, *Pogonias cromis* (Sciaenidae), in Mar Chiquita coastal lagoon (Argentina). Journal of Applied Ichthyology 26: 528–534.

Brown, K. M., G. J. George, G. W. Peterson, B. A. Thompson and J. H. Cowan, Jr. 2008. Oyster predations by black drum varies spatially and seasonally. Estuaries and Coasts 31: 597–604.

Cowan, Jr., J. H., R. S. Birdsong, E. D. Houde, J. S. Priest, W. C. Sharp and G. B. Mateja. 1992. Enclosure experiments on survival and growth of black drum eggs and larvae in lower Chesapeake Bay. Estuaries 15: 392–402.

Dahl, T. E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Dept. of Interior, USFWS, Washington, DC. pp. 81.

Daniel, III, L. B. and J. E. Graves. 1994. Morphometric and genetic identification of eggs of spring-spawning sciaenids in lower Chesapeake Bay. Fishery Bulletin 92: 254–261.

Etzold, D. J. and J. Y. Christmas (eds). 1979. A Mississippi marine finfish management plan. Mississippi-Alabama Sea Grant Consortium. MASGP-78-146. pp. 36.

Fitzhugh, G. R., B. A. Thompson and T. G. Snider III. 1993. Ovarian development, fecundity, and spawning frequency of black drum *Pogonias cromis* in Louisiana. Fishery Bulletin 91: 244–253.

Frisbie, C. M. Young black drum, *Pogonias cromis*, in tidal fresh and brackish waters, especially in the Chesapeake and Delaware Bay areas. Chesapeake Science 2 (1/2): 94–100.

George, G. J. 2003. Acoustic tagging of black drum on Louisiana oyster reefs: Movements, site fidelity, and habitat use. M.S. Thesis. Louisiana State University. Baton Rogue. pp. 71.

Gold, J. and L. Richardson. 1998. Mitochondrial DNA diversification and population structure in fishes from the Gulf of Mexico and Western Atlantic. Journal of Heredity 89: 404–414.

Gunter, G. 1956. A revised list of euryhalin fishes of North and Middle America. American Midland Naturalist Journal 56(2): 345–354.

Hoese, H. D. 1965. Spawning of marine fishes in the Port Aransas, Texas area as determined by the distribution of young larvae. Ph.D. Dissertation. University of Texas. Austin. pp. 144.

Hoese, H. D. and R. H. Moore. 1977. Fishes of the Gulf of Mexico. Texas A&M University Press, College Station. pp. 327.

Holland, A. F., G. H. M. Riekerk, S. B. Lerberg, L. E. Zimmerman, D. M. Sanger, G. I. Scott and M. H. Fulton. 1996. Assessment of the impact of watershed development on the nursery functions of tidal creek habitats. ***In:*** G. S. Kleppel and M. R DeVoe (eds). The South Atlantic Bight land Use Coastal Ecosystems Study (LU-CES), pp. 28–31. Univ. of Georgia Sea Grant and S.C. Sea Grant Program. Report of a planning workshop.

Jones, C. M. and B. Wells. 2001. Yield-per-recruit analysis for black drum, *Pogonias cromis*, along the East Coast of the United States and management strategies for Chesapeake Bay. Fishery Bulletin 99: 328–337.

Joseph, E. B., W. H. Massmann and J. J. Norcross. 1964. The pelagic eggs and early larval states of the black drum from Chesapeake Bay. Copeia 1964(2): 425–434.

Kemp, W. M., W. R. Boynton, J. E. Adolf, D. F. Boesch, W. C. Boicourt, G. Brush, J. C. Cornwell, T. R. Fisher, P. M. Blibert, J. D. Hagy, L. W. Harding, E. D. Houde, D. G. Kimmel, W. D. Miller, R. I. E. Newell, M. R. Roman, E. M. Smith and J. C. Stevenson. 2005. Eutrophication of Chesapeake Bay: historical trends and ecological interactions. Marine Ecology Progress Series 303: 1–29.

Leard, R. et al. 1993. The black drum fishery of the Gulf of Mexico, United States: a regional management plan. Gulf States Marine Fisheries Commission, Number 28, Ocean Springs, MS.

Locascio, J. V. and D. A. Mann. 2011. Diel and seasonal timing of sound production by black drum (*Pogonias cromis*). Fishery Bulletin 109: 327–338.

McEachron, L. W., G. C. Matlock, C. E. Bryan, P. Unger, T. J. Cody and J. H. Martin. 1994. Winter mass mortality of animals in Texas bays. Northeast Gulf Science 13: 121–138.

McIlwain, T. D. 1978. An analysis of recreational angling in Biloxi Bay – 1972–1974. Ph.D. Dissertation. University of Southern Mississippi. Hattiesburg. pp. 156.

Miller, J. M. 1988. Physical processes and the mechanisms of coastal migrations of immature marine fishes. In: M.P. Weinstein (ed). Larval Fish and Shellfish Transport Through Inlets. American Fisheries Society, Bethesda, MD. pp. 68–76.

Miller, J. M., J. P. Read and L. J. Pietrafesa. 1984. Pattern, mechanisms and approaches to the study of migrations of estuarine-dependent fish larvae and juveniles. In: McCleave, J. D., G. P. Arnold, J. J. Dodson and W. H. Neill (eds). Mechanisms of Migrations in Fishes. Plenum Press, NY.

Murphy, M. D. and R. G. Muller. 1995. Stock assessment of black drum *Pogonias cromis* in Florida. Florida Marine Research Institute, In-house Report Series IHR 1995-005.

Murphy, M. D. and R. G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Science 10: 127–137.

Pearson, J. C. 1929. Natural history and conservation of the redfish and other commercial sciaenids on the Texas Coast. Bulletin of the U.S. Fish Commission 4: 129–214.

Peters, K. M. and R. H. McMichael Jr. 1990. Early life history of the black drum *Pogonias cromis* (Pisces: Sciaenidae) in Tampa Bay, Florida. Northeast Gulf Science 11(1): 39–58.

Richards, C. E. 1973. Age, growth and distribution of black drum *(Pogonias cromis)* in Virginia. Transactions of the American Fisheries Society 3: 584–590.

Rooker, J., R. Kraus and D. Secor. 2004. Dispersive behaviors of black drum and red drum: it otolith Sr:Ca a reliable indicator of salinity history? Estuaries 27: 334–341.

SAFMC (South Atlantic Fishery Management Council). 1998. Habitat plan for the South Atlantic region: essential fish habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. SAFMC, Charleston, SC. pp. 457 + appendices.

Saucier, M. H. and D. M. Baltz. 1993. Spawning site selection by spotted seatrout, *Cynoscion nebulosus*, and black drum, *Pogonias cromis*, in Louisiana. Environmental Biology of Fishes 36: 257–272.

Serafy, J. E., K. C. Lindeman, T. E. Hopkins and J. S. Ault. 1997. Effects of freshwater canal discharges on subtropical marine fish assemblages: field and laboratory observations. Marine Ecology Progress Series 160: 161–172.

Shumay, S. E., J. Barter and S. Sherman-Caswell. 1990. Auditing the impact of toxic algal blooms on oysters. Environmental Auditor 2(1): 41–56.

Silverman, M. J. 1979. Biological and fisheries data on black drum, *Pogonias cromis* (Linnaeus). Sandy Hook Laboratory, NMFS Technical Series Report 22. pp. 22.

Simmons, E. G. and J. P. Breuer. 1962. A study of redfish, *Sciaenops ocellata* Linnaeus, and black drum, *Pogonias cromis* Linnaeus. Publications of the Institute of Marine Science 8: 184–211.

Sutter, F. C., R. S. Waller and T. D. McIlwain. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico): Black Drum. U.S. Fish and Wildlife Biological Report 82 (11.51). U. S. Army Corps of Engineers, TR EL-82-4. pp. 10.

Tellechea, J. S., W. Norbis, D. Olsson and M. L. Fine. 2010. Calls of the black drum (*Pogonias cromis*: Sciaenidae): geographical differences in sound production between Northern Hemisphere and Southern Hemisphere populations. Journal of Experimental Zoology 313A: 1–8.

Thomas, D. L. and B. A. Smith. 1973. Studies of young of the black drum, *Pogonia cromis*, in low salinity waters of the Delaware Estuary. Chesapeake Science 14: 124–130.

Ulrich, G. F., C. M. Jones, W. B. Driggers III, J. M. Drymon, D. Oakley and C. Riley. 2007. Habitat utilization, relative abundance, and seasonality of sharks in the estuarine and nearshore waters of South Carolina. American Fisheries Society Symposium 50: 125–139.