Atlantic States Marine Fisheries Commission

HABITAT ADDENDUM IV
TO AMENDMENT 1 TO THE
INTERSTATE FISHERY MANAGEMENT PLAN
FOR ATLANTIC STURGEON

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

September 2012

ATLANTIC STURGEON HABITAT ADDENDUM

Section I. Description of Atlantic Sturgeon Habitat

Part A. Atlantic Sturgeon Spawning Habitat

Atlantic sturgeon are believed to spawn in flowing water between the salt front of estuaries and the fall line of large rivers, where optimal flows are 46 to76 cm/s, depths are 11 to 27 m, and when water temperature is 13°C to 26°C (Borodin 1925; Dees 1961; Leland 1968; Scott and Crossman 1973; Dovel 1978, 1979; Smith 1985; Crance 1987; Van Eenennaam et al. 1996; Shirey et al. 1999; Bain et al. 2000; Collins et al. 2000; Caron et al. 2002; Hatin et al. 2002). Sturgeon eggs are highly adhesive and deposited on the bottom substrate, usually on hard surfaces (Vladykov and Greeley 1963; Huff 1975; Smith 1985; Gilbert 1989; Smith and Clugston, 1997; Secor et al. 2002; Bushnoe et al. 2005). Within rivers, the areas of cobble-gravel, coarse sand, and bedrock outcrops, which occur in the rapids complex, may be considered prime habitat (Table 1). This habitat provides Atlantic sturgeon with well-oxygenated water, clean substrates for egg adhesion, crevices that serve as shelter for post-hatch larvae, and macroinvertebrates for food. In northern rivers, these areas are nearer to the salt wedge than in southern rivers.

Substrate	Activity	Location	Citation
Rock and bedrock	spawning	St. Lawrence River, Québec	Hatin et al. 2002
Rock, clay, & sand	spawning	St. Lawrence River, Québec	Caron et al. 2002
Irregular bedrock, silt, & clay	spawning	Hudson River, NY	Bain et al. 2000
Clay/silt with rocky shoreline	post-spawning	Hudson River, NY	Bain et al. 2000
Hard clay	spawning	Delaware River	Borodin 1925
Small rubble & gravel	spawning	Delaware River	Dees 1961
Clay	spawning	Delaware River	Scott & Crossman 1973
Limestone	spawning	Edisto River, SC	Collins et al. 2000
Fine mud, sand, pebbles, & shell	post-spawning	Edisto River, SC	Collins et al. 2000
Cobble/gravel	spawning	HSI Model	Brownell et al. 2001

Table 1. Spawning (and post-spawn) substrate type for Atlantic sturgeon along the Atlantic coast

Some researchers and managers have attempted to identify likely spawning areas for Atlantic sturgeon using modeling techniques. Brownell et al. (unpublished) developed a Habitat Suitability Index (HSI) model for spawning Atlantic sturgeon and early egg development, and concluded that cobble/gravel (64 mm to 250 mm) was the optimal spawning substrate for Atlantic sturgeon. Boulder (250 mm to 4000 mm) was viewed as second highest in the model, and silt/sand (<2.0mm) and mud/soft clay/fines were viewed as the lowest. The HSI curve and the data values used in this study were based on a model for shortnose sturgeon, and factors such as oxygenation, substrate embeddedness, available egg attachment sites, protection of eggs from predators, light intensity, and solar warming were also hypothesized to be available in cobble/gravel and boulder substrates.

Part B. Atlantic Sturgeon Egg, Larval, and Early Juvenile Habitat

Atlantic sturgeon eggs hatch approximately 94 and 140 hours after egg deposition at temperatures of 20°C and 18°C, respectively (Kelly and Arnold 1999; Smith et al. 1980; Mohler 2003). After hatching, Atlantic sturgeon larvae are assumed to inhabit the same areas where they were spawned (Bain et al. 2000; Kynard and Horgan 2002). Hard substrate is important to larval Atlantic sturgeon as it provides refuge from predators (Kieffer and Kynard 1996; Fox et al. 2000). A study by Kynard and Horgan (2002) showed that embryos immediately sought cover after hatching. However, larvae are also active swimmers and leave the bottom when 8 to 10 days old to swim in the water column (Kynard and Horgan 2002).

The yolksac larval stage is completed in about 8 to12 days, during which time the larvae move downstream to the rearing grounds (Kynard and Horgan 2002). During the first half of this migration, larvae move only at night and use benthic structure (e.g., gravel matrix) as refuge during the day (Kynard and Horgan 2002). During the latter half of migration to the rearing grounds, when larvae are more fully developed, movement occurs during both day and night. Subsequent to the yolksac larval period, late-stage larvae settle in the demersal habitat (Smith et al. 1980, 1981; Bain 1997; Kynard and Horgan 2002). Bath et al. (1981) caught free embryos by actively netting the bottom near the spawning area, demonstrating that early life stages are benthic. Based on the intolerance of Atlantic sturgeon embryos and larvae to even low salinities, Van Eenennaam et al. (1996) speculated that Atlantic sturgeon spawning sites may require a certain amount of freshwater habitat downstream of the spawning area to allow suitable habitat for the downstream migration of larvae.

Larvae transition into the juvenile phase as they move further downstream into brackish waters, developing a tolerance to salinity as they go, and eventually become residents in estuarine waters for months to years before emigrating to open ocean (Holland and Yelverton 1973; Bath et al. 1981; Dovel and Berggen 1983; Dadswell 2006; ASSRT 2007). Nevertheless, there is a large amount of variation in the salinity tolerance of juvenile Atlantic sturgeon (Table 2).

Some Atlantic sturgeon may occupy freshwater habitats for two or more years, while others move downstream to brackish waters when the water temperature drops (Scott and Crossman 1973; Dovel 1978; Hoff 1980; Lazzari et al. 1986). Bioenergetic studies on young-of-year (YOY) juveniles indicate poor survival at salinities greater than 8 ppt, but euryhaline behaviors are exhibited by juveniles age 1 and 2 (Niklitschek 2001).

Salinity Range (ppt)	Location	Citation
>3	Hudson River, New York	Appy and Dadswell 1978
3 - 16	Hudson River, New York	Brundage and Meadows 1982
0 - 6	Hudson River, New York	Dovel and Berggren 1983
3 - 16	Hudson River, New York	Smith 1985b
3 - 16	Hudson River, New York	Haley et al. 1996
>3	Hudson River, New York	Bain et al. 2000
0 - 12	Delaware River	Shirey et al. 1999
<10	Brunswick River, North Carolina	Moser and Ross 1995

Table 2. Salinity tolerance ranges for young juvenile Atlantic sturgeon along the Atlantic coast

Temperature as well as dissolved oxygen concentration are key habitat parameters for the structuring of juvenile Atlantic sturgeon habitat (Table 3) (Niklitschek and Secor 2005; 2009a; 2010). Temperatures in excess of 28ºC are judged to have sublethal effects on Atlantic sturgeon. Secor and Niklitschek (2001) report that in habitats with less than 60% oxygen saturation (4.3 mg/L to 4.7 mg/L at 22°C to 27°C), YOY fish aged 30 to 200 days will experience a loss in growth. Mortality of juvenile Atlantic sturgeon has been observed for summer temperatures at levels of less than or equal to 3.3 mg/L (Secor and Niklitschek 2001). Maximum growth and food consumption rates of captive YOY and 1-year-old Atlantic sturgeon were observed above 70% dissolved oxygen saturation, at 20°C and between salinities of 8 and 15 (Niklitschek and Secor 2009a,b). Mohler (2003) similarly found that in cultured juvenile Atlantic sturgeons, a noticeable decrease in feeding occurred when temperatures dropped to 10°C. Minimum weight gains were noticed at temperatures as low as 5.4°C, and weight loss occurring at lower water temperatures (Mohler 2003). Their low tolerance to elevated temperature and low oxygen is of particular concern during the first two summers of life when juveniles are restricted to lower saline waters, and are unable to seek out thermal refuge in deeper waters (Secor and Gunderson 1998; Niklitschek 2001; Niklitschek and Secor 2005).

Temperature may also be an important habitat parameter with regard to migration patterns, since juvenile Atlantic sturgeon appear to migrate in response to certain temperature thresholds. Dovel and Berggren (1983) stated that downstream migrations in the Hudson River began when temperatures reached 20°C, and peaked between 12°C and 18°C. By the time the temperature was 9°C, juvenile Atlantic sturgeon had congregated for the winter in deep holes (Dovel and Berggren 1983) where water temperatures can approach 0°C (Bain et al. 2000). Similar migration patterns were noted by Dovel (1979) in the Hudson River and by Brundage and Meadows (1982) in the Delaware River. In southern rivers, temperature plays a role in the movement of juvenile sturgeon during warm weather months. Moser and Ross (1995) report that juvenile Atlantic sturgeon in North Carolina use deep and cool areas as thermal refuges, particularly in the summertime.

Part C. Atlantic Sturgeon Late Stage Juvenile and Adult Marine Habitat

Atlantic sturgeon that have transitioned to the marine environment undertake a migratory existence using marine waters, including coastal bays and estuaries. Stein et al. (2004) reported that Atlantic sturgeon were found mostly over sand and gravel substrate, and that they were associated with specific coastal features, such as the mouths of the Chesapeake Bay and Narragansett Bay, and inlets in the North Carolina Outer Banks. Laney et al. (2007) found similar results off the coasts of Virginia and North Carolina. The researchers used a GIS to analyze data from the Cooperative Winter Tagging Cruise and found that Atlantic sturgeon were located primarily in sandy substrates. However, the authors state that their GIS data did not depict small-scale sediment distribution, thus only a broad overview of sediment types was used. In addition, sediment sampling done along the North Carolina coast shows that gravel substrates are found a little farther offshore from where the sturgeon were found (Laney et al. 2007).

Depth associations at sea

The greatest depth in the ocean at which Atlantic sturgeon have been reported caught was 75 m (Collette and Klein-MacPhee 2002). Collins and Smith (1997) report that Atlantic sturgeon were captured at depths of 40 m in marine waters off South Carolina. Stein et al. (2004) found that Atlantic sturgeon were caught in shallow (<60 m) inshore areas of the Continental Shelf. Sturgeon were captured in depths less than 25 m along the Mid-Atlantic Bight, and in deeper waters in the Gulf of Maine (Stein et al. 2004). Dunton et al. (2010) reported that Atlantic sturgeon in the northwest Atlantic Ocean were largely confined to water depths less than 20 m and aggregations tended to occur at the mouths of large bays (Chesapeake and Delaware) or estuaries (Hudson and Kennebec rivers).

Upon entering the marine habitat, Atlantic sturgeon have been documented near the shore in shallow waters where the depths measure less than 20 m (Gilbert 1989; Johnson et al. 1997: Johnson et al. 2005; Laney et al. 2007). The Northeast Fisheries Science Center bottom trawl survey caught 139 Atlantic sturgeon from 1972 to 1996 in waters from Canada to South Carolina. They found the fish in depths of 7 to 75 m, with a mean depth of 17.3 m. Of the fish caught, 40% were collected at 15 m, 13% at 13 m, and less than 5% at all the depth strata (NEFC, unpublished data, reviewed in Savoy and Pacileo 2003).

Section II. Habitats of Special Significance and Trends for Atlantic Sturgeon

Spawning sites/hatching grounds occur in freshwater portions of estuaries and large river tributaries along the Atlantic coast. These areas provide the habitat parameters essential for reproduction, including well oxygenated water, clean substrates for egg adhesion, and crevices that provide cover for post-hatch larvae and abundant macroinvertebrate prey items. This habitat type is very sensitive to anthropogenic impacts, including dams and other river impoundments, nutrient and sediment loading, pollution, navigational dredging, and other coastal developments (especially those with intake structures). Spawning sites are very limited and have been rendered inaccessible and/or degraded since coastal areas have become industrialized and developed.

Nursery areas are limited to freshwater/estuarine tributaries for Atlantic sturgeon age 0 to age 2; nursery areas include bays, estuaries, and nearshore ocean environments for older juveniles (age >2). Freshwater areas are important to larvae and low salinity areas are important to age 0 juveniles, because they cannot tolerate high salinity (Altinok et al. 1998; Secor and Niklitschek 2002). Nursery habitats for juvenile Atlantic sturgeon are essential for growth of this species. This habitat provides foraging grounds for juvenile Atlantic sturgeon, and in some cases, thermal refuge during the summer and winter months (Moser and Ross 1995). Nursery habitats are severely impacted by hypoxic conditions, particularly during summer months when high temperatures can combine with low oxygen levels to degrade and eliminate valuable habitat for juveniles (Secor and Niklitschek 2002; McBride 2004). Other anthropogenic impacts include navigational dredging and port development, sedimentation, nutrient loading (which leads to hypoxic conditions), and recreational and commercial vessel traffic. While nursery areas are less limited in extent than spawning areas, they are still scarce.

Estuarine inlets provide adult and intermediate/late juvenile Atlantic sturgeon with migration corridors to and from freshwater spawning habitat and estuarine nursery grounds. The importance of these areas to Atlantic sturgeon has not been researched; inlets are potentially more rare than spawning habitats. Inlets are impacted by channel alterations (deepening and stabilization) and commercial and recreational coastal development activities.

Wintering grounds for adult and late juvenile Atlantic sturgeon include the nearshore areas off the Atlantic coast from the Gulf of Maine south to at least Cape Lookout, North Carolina (Stein et al. 2004; Laney et al. 2007). These areas provide Atlantic sturgeon with foraging grounds and habitat (Johnson et al. 1997). Erickson et al. (2011) identified aggregation areas off southwest Long island, along the New Jersey coast, off Delaware Bay, and off Chesapeake Bay. Depth distribution was seasonal: fish inhabited deepest waters during winter and shallowest waters during summer and early fall. Anthropogenic impacts include habitat degradation due to fishing activities, commercial navigation, oil and gas exploration, and construction of offshore liquefied natural gas facilities. Ghost fishing may result in sturgeon losses due to entanglement in lost gear. Winter habitat occurs in coastal nearshore waters, which is expected to not be as limited as spawning habitats and inlets.

Trends Habitat Quantity and Quality

Table 3 summarizes the current literature on Atlantic sturgeon habitat associations. Although the amount has not been quantified, Atlantic sturgeon habitat has decreased or been degraded by clear-cutting, agricultural practices, dams, and other channel and watershed modifications since the eighteenth and nineteenth centuries (Hill 1996; Secor et al. 2002; Bushnoe et al. 2005). Historically, Atlantic sturgeon were documented in 38 rivers ranging from the Hamilton Inlet on the coast of Labrador to the St. Johns River in Florida. The ASSRT (2007) most recently reported that 35 of those historical rivers have Atlantic sturgeon present, and 20 are believed to be extant reproducing populations. Once abundant in most rivers and associated estuaries within their range, Atlantic sturgeon have now either been extirpated, or are at historically low levels. Consequently, although Atlantic sturgeon still remain throughout much of their former range, their numbers have been severely reduced (ASSRT 2007). Currently the National Marine Fisheries Service has proposed that five populations of Atlantic sturgeon along the East Coast receive protection under the Endangered Species Act. The Gulf of Maine population is proposed for listing as threatened, and endangered status is proposed for the Chesapeake Bay, New York Bight, Carolina, and South Atlantic populations.

The quality of Atlantic sturgeon habitat has been seriously impacted by human actions. Since European settlement, overfishing, habitat loss, and poor water quality have all contributed to the decline of Atlantic sturgeon stocks. Most of these impacts have been gradual and are poorly understood (Smith 1985b; ASFMC 1998; USFWS-NMFS 1998; Secor and Gunderson 1998; Secor et al. 2000; Secor and Niklitschek 2001; ASSRT 2007).

Section III. Atlantic Sturgeon Recommendations

Water Quality and Quantity

1) Maintain water quality and suitable habitat for all life stages of Atlantic sturgeon in all rivers with extant populations.
2) Reduce non-point and point-source pollution in Atlantic sturgeon habitat areas.
3) Implement agricultural, suburban, and urban best management practices to reduce sediment, toxicant, nutrient, and organic inputs into streams:
    a. Utilize buffers along rivers and streams.
    b. Restore hydrologic connectivity to wetlands.
    c. Implement nonstructural stormwater management designs.
4) Upgrade wastewater treatment plants, remove biological and organic nutrients from wastewater, and prevent introduction of new categories of contaminants. Upgrade current, and eliminate future permitting for, septic tanks in Atlantic sturgeon watersheds.
5) Reduce thermal effluents into rivers. On larger rivers, include a thermal zone of passage or thermal discharge windows.
6) Time water withdrawals, releases, and discharges to reduce impacts to migrating fish; screens should be used to reduce impacts when necessary (also see item 6 under Habitat Protection and Restoration). Time water releases and duration to increase reproductive/recruitment success for spawning fishes.
7) Use best management practices, such as Time of Year restrictions (also referred to as environmental windows, seasonal restrictions, or moratoria), whenever navigation dredging or dredged material disposal operations would occur in a given waterway occupied by Atlantic sturgeon.

Habitat Protection and Restoration

1) State marine fisheries agencies should identify habitat protection and restoration needs, and coordinate habitat restoration plans with other agencies. Agencies should coordinate with public, private, and non-profit organizations to obtain funding for plan implementation and monitoring.
2) Map critical/key habitats for Atlantic sturgeon using the literature, existing tracking data, and expert knowledge and use existing authorities to maximize the scrutiny given to projects likely to impact key habitats. Any project that would unavoidably alter critical/key habitat (e.g., dredging, filling) should be minimized to the extent possible. Time of Year restrictions should be used to minimize impacts from activities conducted in areas where Atlantic sturgeon occur.

3) Map suitable, current, and historic Atlantic sturgeon habitat and prioritize for protection and restoration. Protection of critical/key habitat is the most beneficial conservation method for restoration of Atlantic sturgeon. The possibility of creating new spawning habitat in areas where hard substrate has been degraded should be investigated.
4) Determine the effects of dredging on Atlantic sturgeon behavior, habitat, and migration.
5) States should notify in writing the appropriate federal and state regulatory agencies of the locations of habitats used by Atlantic sturgeon. Regulatory agencies should be advised of the types of threats to sturgeon populations, and recommendations to avoid, minimize, or eliminate threats to current habitat quantity or quality.
6) Each state encompassing and federal agencies regulating dams blocking Atlantic sturgeon spawning rivers and/or producer areas should develop water use and flow regime guidelines protective of sturgeon spawning and nursery areas to ensure the long-term health and sustainability of the stocks (also see item 6 under Water Quality and Quantity).
7) ASMFC should support state and federal designation of important habitats for Atlantic sturgeon spawning and nursery areas.

Section IV. Atlantic Sturgeon Research Needs

Water Quality and Contamination

1) Determine effects of temperature, salinity, and pH changes on each life stage of Atlantic sturgeon, and use this information to forecast impacts of climate change on this species and to scope mitigation measures.
2) Document the concentrations at which contaminants impact the various life stages of Atlantic sturgeon.
3) In reference to Table 3, determine the unknown optima and tolerance ranges for depth, temperature, salinity, dissolved oxygen, pH, substrate, current velocity, and suspended solids.

Habitat Protection and Restoration

1) Use multi-scale approaches (including GIS) to assess indicators of suitable habitat, using watershed and stream-reach metrics if possible (it should be noted, that where site-specific data are lacking, it may not be appropriate to assess at this scale).
2) Use multi-scale approaches for restoring Atlantic sturgeon habitat, including vegetated buffer zones along streams and wetlands, and for implementing measures to enhance acid-neutralizing capacity.
3) Conduct studies on the effects of land use change, especially wetland alteration, on Atlantic sturgeon population size, density, distribution, health, and sustainability.
4) Examine how Atlantic sturgeon are impacted by deviation from the natural flow regimes. This work should focus on key parameters, such as rates of flow change (increase and decrease), seasonal peak flow, and seasonal base flow, so that the results can be more easily integrated into a year-round flow management recommendation by state officials.

Table 3. Significant environmental, temporal, and spatial factors affecting distribution of Atlantic sturgeon. This table summarizes the current literature on Atlantic sturgeon habitat associations. For most categories, optimal and tolerable ranges have not been identified, and the summarized habitat parameters are listed under the category reported. In some cases, unsuitable habitat parameters are defined. NIF = No Information Found. N/A = Not Applicable.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Adult (Spawning)	Freshwater rivers and possibly tidal freshwater regions of large estuaries (in the north) Feb – Southern states April and May – Mid-Atlantic May to July – Northern States and Canada Sept to Dec – Second spawning documented in Southern regions	**Tolerable:** NIF **Optimal:** 2.4 to 8+ m (HSI model for Southern Regions) **Reported:** 3 to 27 m	**Tolerable:** NIF **Optimal:** 16-21 (HSI model for Southern Regions); 20 to 21°C for cultured sturgeon **Reported:** Male migrations 5.6 to 6.1°C; Female migrations 12.2 to 13°C; Spawning 13 to 23.4°C	**Tolerable:** 0 ppt **Optimal:** 0 ppt **Reported:** Above the salt wedge in fresh water.	**Tolerable: NIF** **Optimal:** Cobble/gravel >64mm to 250mm (HSI model for Southern Regions) **Reported:** Hard substrate, including rubble, gravel, clay, rock, bedrock, slag from old steel mills and limestone	**Tolerable:** NIF **Optimal:** 0.2 to 0.76 m/sec **Reported:** 0.46 to 0.76 m/sec okay (based on modeling); unsuitable if ≤0.06 m/sec, or ≥ 1.07 m/sec	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF
Adult (Estuarine)	Sturgeon do not spawn every year, yet may participate in an upstream migration. After spawning, some sturgeon remain in the rivers through the summer, while others migrate to sea. Downstream migrations occur Sept to Nov in Canada. Present in South March to Oct. Overwinter in the ocean.	**Tolerable:** NIF **Optimal:** NIF **Reported:** 1.5 to 60 m	**Tolerable:** NIF **Optimal:** NIF **Reported:** Adult sturgeon documented in waters with temperatures as high as 33.1°C in SC	**Tolerable:** NIF **Optimal:** NIF **Reported:** Documented summer habitat in upper/fresh/ brackish interface, lower interface, and high salinity portions of estuaries in SC. Salinity ranged from 0 to 28.6 ppt.	**Tolerable:** NIF **Optimal:** NIF **Reported:** Found over fine mud, sand, pebbles, and shell substrate	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Egg and Larval	Eggs are laid in flowing water in rivers along the Atlantic coast. Larval sturgeon are found in same habitat where spawned and are benthic.	**Tolerable:** NIF **Optimal:** 2.4 to 8+ m for egg incubation (HSI model for Southern Regions) **Reported:** Embryos remain in deep channels. Larvae collected 9.1 to 19.8 m	**Tolerable:** 15 to 24.5°C **Optimal:** 20 to 21°C in culture **Reported:** Eggs hatch in 94 to 140 hours ranging from 15.0 to 24.5°C	**Tolerable:** <5 ppt **Optimal:** 0 ppt **Reported:** Found upstream of salt front; have a low tolerance to salinity; mortality reported 5 to 10 ppt for some sturgeon species	**Tolerable: NIF** **Optimal:** Cobble/gravel >64mm to 250mm (HSI model for Southern Regions) **Reported:** After 20 minutes, eggs become adhesive and attach to hard substrate. Larvae also use hard substrate as refuge	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF
Juvenile (Estuarine)	Remain in natal habitats within estuary for up to a year before migrating out to sea. Migrations to other estuaries are common. Use brackish water near month of estuary during winter and move up-estuary during warmer months	**Tolerable:** NIF **Optimal:** Deep water and holes serve as thermal refuge **Reported:** 2 to 37 m	**Tolerable:** 3 to 28°C **Optimal:** ~20°C **Unsuitable:** >28°C are sub-lethal **Reported:** Downstream migration begins when water reaches 20°C and peaks between 12 and 18°C. Documented range of 0.5 to 27°C	**Tolerable:** NIF **Optimal:** ~10 ppt **Reported:** Large juveniles found mostly where salinity is >3 ppt; found 0 to 27.5 ppt	**Tolerable:** NIF **Optimal:** NIF **Reported:** Found mostly over sand substrate and mud or transitional habitats. Also found over rocks and cobble	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** >5 mg/L **Reported:** Summer mortality observed at <3.3mg/L and at 26°C
Juvenile and adult (At-sea)	Utilize marine waters during non-spawning seasons. Nearshore areas off the Atlantic coast from the Gulf of Maine to at least Cape Lookout, NC. Little is known about this part of their lives	**Tolerable: NIF** **Optimal: NIF** **Reported:** Most found in shallow waters; greatest depth recorded = 75 m; depth range 7 to 43m	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Marine waters on the continental shelf	**Tolerable:** NIF **Optimal:** NIF **Reported:** Sand, gravel, silt and clay. Suggested that they will use any substrate that supports their food resource	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

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