Chapter 3

HICKORY SHAD

(*Alosa mediocris*)

Section I. Hickory Shad Description of Habitat

Hickory Shad General Habitat Description and Introduction

Hickory shad (*Alosa mediocris*) are anadromous fish that spend most of their adult lives at sea, entering brackish and freshwater only to spawn (Colette and Klein-MacPhee 2002). Little is known about the life history and specific habitat requirements of this species. However, coastal migrations and habitat requirements are thought to be similar to that of other alosine species, particularly American shad (Klauda et al. 1991). Very few spawning studies have been conducted in part due to a general lack of interest in this species relative to other alosines (Klauda et al. 1991).

Historically, hickory shad abundance has been lower than other alosine species in many areas (Atran et al. 1983; Speir 1987). The historical range of hickory shad is thought to have extended as far north as the Gulf of Maine and possibly to Campobello Island, New Brunswick (Hildebrand 1963). The current northern boundary of hickory shad is Cape Cod, Massachusetts (Batsavage and Rulifson 1998), with the highest abundances occurring from New York southward. According to Klauda et al. (1991), spawning does not frequently occur north of Maryland. Hickory shad are reported to occur as far south as central Florida (Hildebrand 1963; Williams et al. 1975; McBride 2000). Waters south of Cape Canaveral, Florida, are unsuitable for hickory shad due to semi-tropical water temperatures (Williams et al. 1975).

Hickory shad have only supported minor commercial fisheries because the bony meat is considered to be inferior to American shad (Whitehead 1985). However, some consider hickory shad roe to be more delectable than the roe of any of the other river herrings (Nichols 1959). Furthermore, adult hickory shad are highly sought after by sport fishermen when they ascend rivers and tributaries during their spawning run (Mansueti 1962; Pate 1972). Although hickory shad populations have not been adequately monitored, there is information indicating that some stocks are healthy (Street 1970; Batsavage and Rulifson 1998; ASMFC 1999). Since 1989, the Albemarle Sound, North Carolina, population of hickory shad has experienced a surge in numbers, which supports a growing sport fishery on the Roanoke River and increased commercial fishing in Albemarle Sound. A short life span and low fecundity, however, makes this North Carolina population vulnerable to overharvest (Batsavage and Rulifson 1998). In contrast, hickory shad have been found to be highly fecund in other areas. For example, egg production was estimated to be as high as 509,749 eggs per female in the Altamaha River, Georgia (Street 1970).

Since the mid-1990s, hickory shad numbers have increased in the upper Chesapeake Bay and its tributaries (ASMFC 1999), including the lower Susquehanna, Potomac near Washington, D.C., upper Rappahannock, and James rivers (R. St. Pierre, U.S. Fish and Wildlife Service, personal communication). Some landings data also support the idea that hickory shad populations are thriving. The National Marine Fisheries Service (NMFS) estimated that 5.6 metric tons of hickory shad were landed in 1990, and by 1999, estimated landings dramatically increased to 61.9 metric tons (Waldman and Limburg 2003).

Part A. Hickory Shad Spawning Habitat

Geographical and temporal patterns of migration

Little is known about hickory shad behavior or utilization of riverine or marine habitats (Colette and Klein-MacPhee 2002). It is assumed that female hickory shad broadcast their eggs into the water between dusk and midnight where one or more males fertilize them; this behavior is similar to the spawning behavior of American shad (Mansueti 1962; Jones et al. 1978). Hickory shad are known to be repeat spawners, with individuals spawning an average of three to five times before dying (Schaeffer 1976). Unlike American shad, there is no progressive increase in spawning frequency from south to north. Most river systems have 70 to 80% repeat spawners, although there are exceptions (Street and Adams 1969; Loesch et al. 1979; Rulifson et al. 1982; Richkus and DiNardo 1984). Data collected from Maryland rivers indicated that 72% of females and 62% of males had previously spawned (B. M. Richardson, Maryland Department of Natural Resources, personal communication). In sharp contrast, Sholar (1977) found that in the Cape Fear River, North Carolina, only 19% of males and 9% of females were repeat spawners.

The age distribution of adult hickory shad in coastal rivers from Florida to North Carolina ranges from two to eight years (Rulifson et al. 1982). Eighty percent of males in the Octoraro Creek, Maryland, were sexually mature at age 2 (Schaeffer 1976). Data collected from a group of Maryland rivers found that 50% of males and 36% of females were sexually mature at age 2; by age 3, 89% of males and 90% of females had spawned (B. M. Richardson, Maryland Department of Natural Resources, personal communication). Further south, in the Altamaha River, Georgia, 75% of females and 49% of males were sexually mature by age 2 (Street and Adams 1969). In general, the majority of females are likely to become sexually mature at least one year later than males (Klauda et al. 1991; Batsavage and Rulifson 1998).

Hickory shad ascend coastal rivers during spring migration. Although it is assumed that these fish return to their natal rivers to spawn, there is no documented evidence of this behavior (Batsavage and Rulifson 1998). Hickory shad distribution in the riverine environment is similar to that of American shad (Rulifson et al. 1982). In North Carolina, the freshwater reaches of coastal rivers are the major spawning sites for hickory shad. In the Roanoke River, eggs have been collected during April and early May from the main channel near Weldon, North Carolina (Sparks 1998; Harris and Hightower 2007), and larvae have been collected farther downstream (Walsh et al. 2005). In the Neuse River, North Carolina, Pate (1972) detected spawning in flooded swamps and sloughs off channels of tributary creeks, but not in the mainstem river. However, Burdick and Hightower (2006) detected spawning in both mainstem Neuse River and tributary sites. In Georgia, hickory shad apparently spawn in flooded areas off the Altamaha River, and not in the mainstem of the upper reaches (Adams 1970). Major spawning sites in Virginia have been discovered in mainstem rivers at the fall line, further downstream, and in tributaries (Davis et al. 1970). Mansueti (1962) found that hickory shad spawned approximately 6 to 10 km (3.7 to 6.2 miles) upriver of major spawning sites of American shad in the mainstem of the Patuxent River, Maryland. In contrast, hickory shad in the St. Johns River, Florida, did not migrate as far upstream as American shad (Moody 1961). Compared to American shad and striped bass, hickory shad in the Neuse River basin tended to spawn further downstream and made greater use of tributaries (Burdick and Hightower 2006).

Adult hickory shad can be found in the St. Johns River, Florida, as early as December or possibly even November (McBride 2000), but may be absent by late January to mid-February (Williams et al. 1975) or early March (McBride 2005). Spawning in the Santee and Cooper rivers, South Carolina, may occur between early March through mid-May (Bulak and Curtis 1979). In the Chesapeake Bay, spawning may begin in early April (Mansueti and Hardy 1967), and typically peaks in early May (Mansueti 1962). However, spawning may occur as late as June in freshwaters of Virginia (Davis et al. 1970). Furthermore, a weaker second run of spawners may also migrate later through the Chesapeake Bay (Hildebrand and Schroeder 1928). It is unknown if the hickory shad that spawn during the fall run also participate in the spring run (Schaeffer 1976).

Large variations in the size of young hickory shad have been reported at spawning sites. This has lead researchers to hypothesize that this species has a protracted spawning period, where small amounts of eggs are released over a long period of time (Mansueti 1962; DesFosse et al. 1994). Mansueti (1962) found very few ripe-running hickory shad on the spawning grounds in the Chesapeake Bay area, and suggested that gonads mature rapidly and spawning occurs at night.

In Albemarle Sound, North Carolina, hickory shad appear to have a prolonged spawning period when compared to other alosines, but that period occurs earlier in the season (Batsavage and Rulifson 1998). It is unknown how long adult hickory shad remain in freshwater after they have spawned.

Spawning substrate associations

B. M. Richardson (Maryland Department of Natural Resources, personal communication) has reported catching adult hickory shad in waters of Maryland rivers, where complex structures, such as ledges and fallen trees are present. Bottom composition in these waters tended to be mud, sand, and/or gravel. Harris and Hightower (2007) reported that hickory shad spawning in the Roanoke River were concentrated in areas of moderate to high water velocity and sediments dominated by cobble, gravel, and sand, but not silt.

Spawning depth associations

Little information is available on spawning depth preferences for hickory shad. Hawkins (1980) noted that hickory shad prefer to spawn in the deep, dark tributaries of the Neuse River, North Carolina. Similarly, Moody (1961) found that hickory shad were more abundant (by frequency of occurrence and by weight) in deeper water than American shad in the St. Johns River, Florida.

Spawning water temperature

Temperature (^{o}C)	Location	Citation
13 - 21	Albemarle, NC	Street et al. 1975
14 - 19	Tar River, NC	Marshall 1976
15 - 22	Altamaha River, GA	Street 1970
7.8 - 20.5	Maryland rivers	B. M. Richardson, MD DNR, personal communication

Table 3-1. Hickory shad spawning temperatures for locations along the Atlantic coast of North America

Some studies have examined spawning temperature preferences for hickory shad (Table 3-1). Spawning activity occurs in water temperatures that range from 8 to 22°C (Rulifson et al. 1982; Batsavage and Rulifson 1998), but typically peaks in waters temperatures between 15 and 19°C (Mansueti 1962; Street 1970; Pate 1972; Schaeffer 1976; Rulifson et al. 1982). In the Neuse River, North Carolina, spawning occurred at water temperatures of 10 to 23°C , with peak numbers of eggs collected at 12 to 16°C (Burdick and Hightower 2006). Eggs were collected in the Roanoke River at temperatures ranging from 10.2 to 17.0°C (Harris and Hightower 2007).

Spawning dissolved oxygen associations

Adults have been found spawning in Maryland waters where the dissolved oxygen level was between 5.7 and 11.8 mg/L (B. M. Richardson, Maryland Department of Natural Resources, personal communication). Eggs were collected in the Roanoke River at dissolved oxygen levels ranging from 6.76 to 11.27 mg/L (Harris and Hightower 2007).

Spawning water velocity/flow

Hawkins (1980) reported that hickory shad might prefer slow-flowing areas of the Neuse River, North Carolina, for spawning. Conversely, hickory shad in Maryland have been reported to favor habitat with faster moving water than that of American shad (B. M. Richardson, Maryland Department of Natural Resources, personal communication). Roanoke River sites where hickory shad spawning occurred had significantly higher water velocities than nearby sites with no spawning (Harris and Hightower 2007). Main channel sites where spawning occurred had median current velocities of 0.20 to 0.39 m/s (Harris and Hightower 2007).

Spawning feeding behavior

Pate (1972) did not find any stomach contents in over 400 adult migrating hickory shad that he examined from the Neuse River, North Carolina. However, adult hickory shad in the St.

Johns River, Florida, were found actively feeding, with 62.4% of the food items consisting of fish, and to a lesser extent, crustaceans (Williams et al. 1975).

Spawning competition and predation

Although no information on predation was found in the literature, striped bass have been reported preying heavily on hickory shad beginning in early April at Deer Creek, Maryland (B. M. Richardson, Maryland Department of Natural Resources, personal communication).

Part B. Hickory Shad Egg and Larval Habitat

Geographical and temporal movement patterns

In general, little is known about the movement of hickory shad eggs and larvae. Eggs are generally adhesive and typically sink to the bottom in undisturbed or moderately agitated water, but are semi-demersal in slow moving currents and buoyant under turbulent conditions (Mansueti 1962).

Egg and larval depth associations

As with adult hickory shad, little habitat information is known about larval individuals. Mansueti (1962) found hickory shad (9 to 20 mm) at depths of 20 feet at approximately 35 to 40 miles upstream from the mouth of the Patuxent River, Maryland.

Egg and larval water temperature

In the wild, hickory shad eggs have been collected in water temperatures between 9.5 and 22°C in rivers of North Carolina (Street 1970; Pate 1972; Marshall 1976; Hawkins 1980). In the laboratory, early efforts to propagate hickory shad failed. Eventually, Mansueti (1962) successfully hatched eggs in the laboratory at 18.3°C and 21.1°C, with hatching occurring 5 to 10 hours sooner under the warmer conditions. Prolarvae hatching occurred 2 to 3 days after fertilization, with an average hatch time of 55 to 60 hours. Prolarvae fully absorb the yolk sac after 4 to 5 days, and postlarvae begin feeding exogenously at this point. The size range of postlarvae is from 5.5 to 7.0 mm (Mansueti 1962). The state of Maryland reported successful incubation of eggs at 17.8°C (64°F), with hatching occurring in 5 to 6 days (B. M. Richardson, Maryland Department of Natural Resources, personal communication). Newer aquaculture spawning methods have been highly successful, and larvae and fingerlings have been transplanted in large quantities to Chesapeake Bay tributaries (Hendricks 2003).

Egg and larval dissolved oxygen associations

Viable hickory shad eggs have been collected in the Neuse River, North Carolina, where dissolved oxygen concentrations were between 5 and 10 mg/L (Hawkins 1980).

Egg and larval pH associations

Hickory shad eggs were found in water with a pH range of 6.4 to 6.6 in the Neuse River, North Carolina (Hawkins 1980).

Part C. Hickory Shad Juvenile (Riverine/Estuarine) Habitat

Geographical and temporal movement patterns

Postlarval hickory shad begin transforming into juveniles when they are 10 to 35 mm long (Ulrich et al. 1979; Krauthamer and Richkus 1987); the minimum size at which they are considered fully developed juveniles is 35 mm (Mansueti and Hardy 1962). Capture of juvenile hickory shad in Maryland rivers often occurs at sharp drop-offs, in schools of several dozen, which suggests a strong schooling behavior (B. M. Richardson, Maryland Department of Natural Resources, personal communication).

Several studies suggest that most young hickory shad leave freshwater and brackish habitats in early summer and migrate to estuarine nursery areas at an earlier age than other anadromous alosines (Mansueti 1962; Adams 1970; Pate 1972; Sholar 1977). Juveniles have also been caught in the surf zone off Long Island, New York, from April to November, which supports this hypothesis (Schaefer 1967). In the Altamaha River, Georgia, juveniles drift downstream and reach the estuary by late spring (Street 1970). Juveniles also drift down the Pee Dee and Waccamaw rivers, in South Carolina, earlier than young American shad, and enter Winyah Bay by July, remaining there throughout the first summer. By early fall, juveniles have moved into oceanic waters (Crochet et al. 1976). Trippell et al. (2007) found a few juvenile hickory shad in the St. Johns River, Florida, near Palatka (rkm 127), from May to October, with the highest catch rates occurring in October.

Some juvenile hickory shad may forego estuarine waters altogether and move directly into saltwater, unlike other alosine species that use freshwater nurseries before moving into marine waters (Pate 1972; Sholar 1977; Batsavage and Rulifson 1998). This ability to move directly into saltwater is believed to occur in hickory shad at an earlier age than for other anadromous alosines (Mansueti 1962; Schaefer 1967; Adams 1970; Pate 1972; Sholar 1977; Batsavage and Rulifson 1998). Additionally, some researchers suggest that juvenile hickory shad initially move to shallow offshore areas in Georgia near the mouth of the Altamaha River, and then disperse farther by August and September (Godwin and Adams 1969; Street 1970). Juvenile hickory shad are thought to be larger in size than other alosines at similar ages due to an earlier spawning period and a faster growth rate (Godwin and Adams 1969). Juvenile hickory shad that are larger than average compared to other alosines have been captured in Maryland (Mansueti 1962; Virginia (Atran et al. 1983) and Georgia rivers (Adams 1970).

Juveniles and the saltwater interface

In Maryland, juvenile hickory shad were captured in waters with salinities that ranged from 0 to 7.2 ppt (B. M. Richardson, Maryland Department of Natural Resources, personal communication). In addition, juveniles were found during the summer in estuarine waters of the Altamaha River, Georgia, when salinities reached 10 ppt, and during the winter, when salinities ranged from 10 to 20 ppt (Street 1970). As noted above, juveniles may forego the oligohaline portion of the estuary in favor of a more saline nursery environment (Pate 1972).

Juvenile depth associations

In South Carolina, juvenile hickory shad are more predominant in shallow expanses of sounds and bays, compared to deeper, channel habitats occupied by juvenile American shad and blueback herring. The variation in distribution is likely the result of differences in food preferences. Small fishes preferred by hickory shad are likely more numerous in shallower habitats adjacent to marshlands (McCord 2003).

Juvenile water temperature

B. M. Richardson (Maryland Department of Natural Resources, personal communication) has caught juveniles in Maryland rivers with water temperatures between 16 and 31°C, usually corresponding to early July through early October. Davis (1973) reported that hickory shad remain in freshwater until temperatures drop in October and November, then move downstream as temperatures continue to decrease.

Juvenile dissolved oxygen associations

Juveniles in Maryland waters were captured where dissolved oxygen ranged from 4.1 to 10.9 mg/L (B. M. Richardson, Maryland Department of Natural Resources, personal communication).

Part D. Hickory Shad Late Stage Juvenile and Adult Marine Habitat

Geographical and temporal patterns at sea

As with many aspects of hickory shad life history, very little is known about the distribution and movements of hickory shad in the ocean (Street 1970; Richkus and DiNardo 1984). Adults have been caught along the southern New England coast in the summer and fall (Bigelow and Schroeder 1953) and off Long Island, New York (Schaefer 1967). Anglers report catching them in nearshore waters at Cape May, New Jersey, from May to November, and then capturing them in inlets from November through December (W. Gordon, recreational angler, personal communication). Unlike American shad, hickory shad rarely migrate to the Gulf of Maine or upper Bay of Fundy during the summer (M. J. Dadswell, Canada Department of Fisheries and Oceans, personal communication). Furthermore, some researchers believe that adults do not move far from land while at sea (Mansueti and Hardy 1967).

Temperature associations at sea

Little information is available on hickory shad habitat associations offshore. Anglers fishing for hickory shad have reported that they will move further offshore from the nearshore waters of New Jersey, when water temperatures reach above 21°C (W. Gordon, recreational angler, personal communication).

Feeding behavior at sea

Adult hickory shad are piscivorous; they generally feed on sand lance, anchovies, cunner, herring, scup, and silversides. This species may also feed on squid, fish eggs, small crabs, and pelagic crustaceans (Hildebrand and Schroeder 1928; Williams et al. 1975; Bigelow and Schroeder 2002).

Section II. Significant Environmental, Temporal, and Spatial Factors Affecting Distribution of Hickory Shad

Table 3-2. Significant environmental, temporal, and spatial factors affecting distribution of hickory shad. Given that there is very little information on hickory shad, this table should be used only as a general reference. The term "reported" is used to denote ranges that were found in the literature, but should not be regarded as the full range tolerated by this species. NIF = No Information Found.

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Spawning Adult	Early December (FL) through late June (VA) in natal rivers and tributaries from Connecticut River southward to Halifax River, Florida (mostly found from Maryland rivers southward)	**Tolerable:** NIF **Optimal:** NIF **Reported:** May prefer deeper waters than American shad	**Tolerable:** 8-23 **Optimal:** 12-19 **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Usually freshwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Cobble, gravel, sand	**Tolerable:** NIF **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Found 5.7-11.8
Egg & Larvae	Early December (FL) through late June (VA) (eggs may be released in batches) at spawning areas or slightly downstream	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** 9.5-22 (egg) **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 5
Early Juvenile – Riverine/ Estuarine Environment	When they reach 35 mm TL (begin moving downstream at an earlier age than other alosines); reach estuaries by late spring/ early summer and ocean by early fall; or may forego estuarine waters and move directly to saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** Generally shallow waters	**Tolerable:** 16-31 **Optimal:** NIF **Reported:** Variable	**Tolerable:** NIF **Optimal:** NIF **Reported:** Freshwater, brackish, and saltwater	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Minimum 4

Life Stage	Time of Year and Location	Depth (m)	Temperature (°C)	Salinity (ppt)	Substrate	Current Velocity (m/sec)	Dissolved Oxygen (mg/L)
Subadult & Non-spawning Adult– Estuarine / Oceanic Environment	Up to 8 years in Cape Cod, Massachusetts to Cape Canaveral, Florida (concentrated from NY southward)	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** Move offshore when temperatures reach 21^{o}C	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF	**Tolerable:** NIF **Optimal:** NIF **Reported:** NIF

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