LIST OF REFERENCES

RESEARCH

Smith, L.D. *Notes on the Distribution, Relative Abundance and growth of Juvenile Anadromous Fish in the Altamaha River System Georgia with Specific Reference to Striped Bass.* Georgia Game and Fish Commission. Sport Fisheries Division. Brunswick, Georgia. 1968.

Smith (1968) studied the juvenile anadromous fish found in the Altamaha River, Georgia. Stiped Bass, American shad, Hickory shad, and Blueback herring were studied in particular. Collections for the study were made from June 12 to November 3. All species were collected throughout the duration of the study. Juvenile American shad were found throughout the study area, from the Altamaha Sound to RM 134.2. Juvenile Hickory shad were found only in the estuarine stations, Altamaha Sound to RM 14.0. Juvenile Blueback herring was the most abundant species caught during the study, 93.10-percent of the total catch. The juveniles Blueback herring were found in all areas in the study area.

Smith (1968) describes the relation of where the fish were collected to possible nursery areas. "The fact that Striped bass and Hickory shad were collected solely in the estuary suggests the possibility that in this zone is the primary nursery area for juveniles of both species." "It is of interest to note that juvenile American shad were present in all river zones throughout the entire sampling period. The likelyhood thus prevails that American shad utilize all river zones as nursery areas." "Juvenile Blueback herring were collected from all zones. It is probable however, that the primary nursery area is in the estuarine zones as concentrations were observed in this zone (pg. 17)."

Goodwin, W.F. and Adams, J.G.. *Young Clupeids of the Altamaha River, Georgia*. Georgia Game and Fish Division. Marine Fisheries Division. Brunswick, Georgia. 1969.

Smith (1968) used electrofishing devices and methods to capture juveniles. Goodwin and Adams (1969) tested a variety of capturing methods during their study. Methods included surface trawls, bottom trawls, mid-water trawls, and bag seines. Trawls were also performed offshore, beyond the Altamaha Sound, to correlate the absence of juveniles in the river system to their appearance offshore in the trawl studies. The Goodwin and Adams study is designed to study the temporal migrations of juvenile American shad, Blueback herring and Hickory shad.

A variety of locations in the river were sampled in order to collect juveniles by Goodwin and Adams including small streams and backwater sloughs. Only main river channel areas adjacent to sandbars "consistently produced young cluepeids (pg. 7)." Capture in main channel areas adjacent to sandbars is common in studies where juveniles are found.

The Goodwin and Adams (1969) study was conducted from July 1 to June 1. Juvenile American shad "were not found in the river between January and July (pg. 17)." Juveniles were first collected in the month of April. Therefore the juvenile American shad were first collected in April and migration out of the river was complete by January. Juvenile Blueback herring "left the rivers system in October and dispersed into the Atlantic Ocean (pg. 29)." Offshore trawling data shows juveniles offshore in the month of November, supporting the theory they move out of the river by October. A total of 14 juvenile Hickory shad were captured in the study. However 869 young adult Hickory shad, post-juveniles, were captured in offshore trawling. Therefore Goodwin and Adams state, "The results of juvenile fish sampling for this species suggests that the Altamaha River is not used as a nursery area….but that these fish move out of the river system to the offshore waters soon after hatching. Offshore trawl catches which were highest in August decreased markedly by September indicating further dispersal to the offshore waters by that time (pg 24)." Therefore, Hickory shad are more likely to leave the river system after hatching and before the juvenile blue back herring and juvenile American shad.

Goodwin and Adams also discussed where in the river system the juvenile American shad and Blueback herring captures were concentrated. Juvenile American shad were found throughout the study area but were concentrated between RM 20 to RM 40 and RM 100 to RM 130.

Goodwin and Adams state their observations of juvenile American shad migrations out of the river system do not correlate with decreasing water temperatures. The data from the study supports the theory that the juvenile American shad leave the "river system" once they approach the size of 90 to 100 mm. Goodwin and Adams further state that a progressive departure of juveniles, as the juveniles approach the size of 90 to 100 cm, is probable. Goodwin and Adams point out that the size of

the sample is small but are "representative" of the American shad found in the Altamaha River.

Goodwin and Adams describe the duration of the downriver movement of juvenile American shad in one sentence. "There was a downstream movement of these juvenile fish during the summer which resulted in the fish leaving the river system in November to disperse into the offshore waters of the Atlantic Ocean (pg. 29)." No other references are given to the duration of a juvenile's migration before leaving the river system. Duration needed for juveniles to become acclimated to the salt water environment is also not discussed. Another topic not discussed is locations where premigratory juveniles, young adult, and American shad could be found before they join the adult ocean-migrating populations.

Cooke, D.W. and Chappelear, S.J *Santee-Cooper Blueback Herring Sudies, Rediversion Project, Annual Report, January 16, 1994 to Septermber 30, 1994*. South Carolina Department of Natural Resources. Division of Wildlife and Freshwater Fisheries. 1994.

A two year cast net study was initiated on May 19, 1992 and ended May 19, 1999. The purpose of the study was to evaluate outmigration of juvenile American shad and blueback herring. Data collect during the study is to be used in redesigning the St. Stephen fish lift to ensure safe passage out to the estuary and ultimately the ocean. A cast netting technique was finally decided on because of the best results per unit of effort. Sampling was done twice a week at dusk each evening. The evening and night is shown to the period of peak movement of American shad and Blueback herring.

American shad were most abundant per cast for juvenile American shad when water temperatures were approximately 27 degrees Celsius. Other peaks abundant casts occurring at 26 and 12 degrees C. Blueback herring were most abundant per cast when the water temperatures were approximately 27 degrees Celsius. Other abundant casts occurred at 26, 21, 18 and 14 degrees Celsius.

It should be noted that 3 times more juvenile Blueback herring and 5 times more American shad were caught when all three generators were operating. This data leads to the to conclusion that catches are not representative of actual populations. Higher flow rates passing through the hydroelectric plant may have attracted more fish from the reservoir to migrate out toward the ocean.

The cast netting data showed juvenile Blueback herring and American shad were abundant in the forbay from December to June.

Data also shows that once the water temperature reached 27 degrees Celsius, "very few juveniles were caught (pg. 72)." When water temperatures went below 9 degrees Celsius, "few fish were caught (pg. 72)." Fish were most commonly caught during periods of increasing and decreasing temperatures.

Concerning the migrating pattern observed in the data, Cooke and Chappelear state the following. "The data suggested that juvenile alosid emigrations may be substantially different in southern waters than emigrations in northern waters, where migration has been tried to declining water temperatures and increasing river flows". Northern outrmigration data cited by Cooke and Chappelear is Oleary and Kynard (1986), a study included in this review. Oleary and Kynard (1986) report American shad and blueback herring were reported to begin outmigration at 21 degrees Celsius and end by 10.8 degrees Celsius.

Further evidence that southern outmigrations are substantially different is evidence of year old fish outmigrating at the end of the summer months. Cooke and Chappelear discuss evidence in length data. "Length data suggested that juveniles hatched in the spring begin to emigrate during their first autum. The emigration continued through the winter, past the following spring and into the summer. This resulted in some of the juveniles being over one year old before they tried to emigrate (pg. 72)." These observations support the concept that juveniles remain in the nursery area or near before outmigrating to join the migrating adult population. These individuals are premigratory juveniles.

Ross, R.M., Backman, W.H. and Bennett, R.M. *Evaluation of Habitat Suitability Index Models for Riverine Life Stages of American Shad, with Purposed Models for Premigratory Juveniles*. United States Fish and Wildlife Service. Washington, District of Colombia. Biological Report 14. 1993.

The study area was the Delaware River. The duration of the study was two years, from April 15 to June 20 in 1991 and April 13 to July 9, 1992. Ross et al. found premigratory juvenile American shad were not habitat specific in the Delaware River and were considered "generalist". Juveniles could not be correlated with a particular habitat type or environmental factor. Earlier life stages and spawning adults however are environmental factor sensitive.

O'Leary, J.A. ***Characteristics of the Downstream Migration of Juvenile American Shad (Alosa Sapidissima) and Blueback Herring (Alosa Aestivalis) in the Connecticut River.*** **University of Massachusetts Master's Thesis. 1984. 58p.**

The study area was the Connecticut River. Fish were collected only during September and October. Peak migration occurred in mid-October in the two full years of the study. Peak migration of Blueback herring are concluded by mid October and migration is concluded by the end of October.

Effects of Lunar Periodicity. Peaks in migrations were observed during the new moon phase. Migration, quantified by catch rates, lowed until zero at the full moon.

Daily Patterns of Migration for American Shad: Between 80 to 95 percent of the fish migrated from afternoon, 14:00, to late evening, 22:00. During the peak migrations of the two full years of the study, little migration occurred during the day before 1600 hours. Migration peaked at 2000 hours and ceased by 400 hours.

Daily Patterns of Migrations for Blueback Herring: Between 78 to 98 percent of blueback herring migration occurred during daylight, 0600 to 1800 hours. Peak hours of migration varied from 1600 to 0800 hours.

Several researchers have investigated the correlation between water temperature and the timing of migrations, both spawning runs and downriver to the ocean. Oleary sites Chiuttenden to summarize these studies. "Temperature was one of the important factors involved in the timing of the diadromous movement of American shad. The lower thermal tolerance sets a general limit on when adults can enter and when the young must leave fresh water".

Oleary states "I believe the daily pattern of outmigration in blueback herring may also be a change in behavioral response due to decrease in water temperature for a threshold of 20 C but nothing is known about the daily activity patterns."

Probst, W. ***Evaluation of Successive Year Class Strength of Juvenile American Shad in the Ogeechee River.*** **Georgia Department of Natural Resources. Game and Fish Division. Altanta Georgia. 1988.**

"In southern waters American shad spawn at 4-6 years of age and die soon afterward (by then they are into their life expectancy. In Georgia the spawning run begins in January and continues into April. Young shad remain in their natal rivers the first summer and migrate to the sea in late summer. Juvenile shad feed on insects and crustaceans in the water column or on the surface (Reference to get). After leaving natal rivers they become plankton strainers and maintain this mode of feeding throughout the remainder of their lives." "Godwin and Adams sample a variety of habitats and found that main river channel areas adjacent to sandbars consistently produced numbers of young shad while backwaters, sloughs and other areas of reduced water flow produced few juveniles (pg 5)."

"River Temperature was considered to be a possible mechanism triggering movement of juvenile shad out of the sample area….. (pg. 7)."

"During this study juvenile shad appeared to be more active in the daylight hours showing no tendency to stay within a particular habitat. (pg. 21)."

Steier and Crance (1985) noted that juvenile shad are opportunistic feeders and appear to select food from the water column rather than from the stream bed or water surface (pg. 21)."

Boltin, W.R. ***New Savannah Bluff Lock and Dam American Shad Mark/Recapture Report, April 1999 to July 1999*****. South Carolina Department of Natural Resources. Wildlife and Freshwater Fisheries Section.Abbeville, South Carolina. 1999.**

Shad migrations in early January and first capture at the lock February 23, 1999 (pg. 28).

Eager, R. ***Central Savannah River American Shad Study: 1986-1987. Draft Report.*** **U.S. Fish and Wildlife Service. 1987**

Boltin sites Eager (1987) contains over two years of data collection. Observed were juvenile American Shad shifting habitats as they approached 95 mm. Juveniles shifted from shallows (up to 5 feet) to deeper waters. pg 10.

Outmigration: American shad passed over the New Savannah Bluff Lock and Dam from September 26, 1986 to December

5, 1986. Seventy-four percent of the movement occurred between 2300 and 0600 hours.

Witherell, D.B. Kynard, B. *Vertical Distribution of Adult American Shad in the Connecticut River*. Transactions of the American Fisheries Society. Vol 119. pg 151-155.

Gill nets deployed to cover the vertical profile of the river. The majority of the adult American shad were captured in the lower half of the river depths, 83 and 73 percent at each station over the two of the study. Witherell and Kynard further define the location in the water depth by stating "most fish were caught more than 2 meters off the bottom".

Witherell and Kynard point out swimming depths of other adult anadromous fishes during riverine migration are limited. However, a pattern among species that do not feed during freshwater migrations is suggested. Other species that do not feed during freshwater migrations and are mentioned in the report include adult Atlantic salmon and Sockeye salmon.

Witherell and Kynard simultaneously collected data on the location of adult Blueback herring in the water column during their study of adult American shad. Conclusions reached after "preliminary investigations" indicate adult Blueback herring are found at "mid-water" depths and not at "deeper water".

Unlike adult American shad, Adult Blueback herring feed during their freshwater migration (pg. 10).

Witherell and Kynard however did not differentiate between adult and premigratory juvenile American shad. Adults are the only age group reported captured in the gill nets. The distance upriver and proximity to the spawning habitat indicate the species were upriver of the nursery area. Migration out of the river and the location in the water of juveniles was not discussed. Locations of premigratory juvenile that remain in the river system was also not discussed.

LIST OF REFERENCES (CONTINUED)

PERSONAL COMMUNICATION

Doug Cooke - Freshwater Fisheries Anadramous Coordinator - SCDNR (Bono, South Carolina)

By observations in the view windows at the St. Stephen Dam and Fish lift, fish are migrating the most in the summertime. August being the peak observed migration.

New England research on American shad, Hickory shad and Blueback herring show migration out of estuary areas into the Atlantic Ocean correlates with avoidance of lowering water temperatures (Oleary, 1984). However observations at St. Stephen Dam and Fishlift show migrations in mid summer. It can be assumed that peak migrations are being observed due to avoidance of higher water temperatures.

Migration studies on anadromous species found in South Carolina are presently being considered for research. South Carolina Department of Natural Resources are presently considering several study proposals. Studies to be done in South Carolina will address when American shad, Hickory shad and Blueback herring are outmigrating. Presently the question is unanswered.

Considerations when designing fish passage structures include where a species can be found in the water column. Accepted assumptions when considering the American shad and Blueback herring are to build the fish passage structure near the surface.

Billy McCord - Marine Division Shad Biologist - SCDNR (Charleston, South Carolina)

Northern migration research on American shad and Blueback herring is largely done in areas where capture is more likely. New England Rivers tend to have more confined shallow areas when the river flows down toward the coastal plain. These shallow areas are easily accessible to beach seine methods and are relatively free of underwater obstacles. When Seine nets are not practical push nets and other methods can be used. Virginia, South Carolina, and Georgia all report using variations of push net samplers. Sampling at night with the push nets to capture negative phototrophic juvenile American shad further increases the effectiveness of the data collection.

One reason for little or no data on the Southeast migration habits of clupeid and alosid species is the labor intensive nature of the data collection. Juvenile index studies were recently attempted by SCDNR although abandoned because of lack of captures. The juveniles are so spread out throughout the estuary that it would be difficult to get data to support a conclusion.

There has been no literature concerning outmigration of American Shad, Hickory shad, and blueback herring in the last 10 years.

General patterns in feeding behavior during downriver migrations in juveniles of American shad, Hickory shad, and Blueback herring can be applied to Southeast migration habits. American shad and blueback herring are selective feeders. Selective feeders prey on small animals and insects. Hickory shad are fish eaters and prey on larva of other fish species. Juvenile shad and Blueback herring feed on insects in larva found on the surface and upper water column during the night hours. Hickory shad are also thought to feed during the night hours.

Generalizing Northern, specifically New England, research and applying the concepts to the Southeast does not always explain observations in data collection. According to New England research, juvenile American shad remain in the estuary to become acclimated to the salinity.

Trawl studies are done monthly in the Charleston Harbor Rivers to study shrimp populations. Trawl nets are pulled from a boat near the bottom. While capture data for American shad, Hickory shad and Blueback herring are not published, Mr. McCord shared his observations of species captured in the trawl studies. From Mr. McCord's observations, the juvenile American shad are present in Charleston Harbor from November to March. The majority of the juveniles do not move out of the Charleston Harbor until late winter or early spring. Juveniles remain in estuaries longer in the Southeast because of the availability of food.

The presence of juvenile American shad in the trawl nets indicate they are bottom orientated. Mr. McCord has inspected the stomachs of juvenile American shad caught in the trawl nets. The stomachs consisted mostly of mysid shrimp. Mysid shrimp are bottom orientated organisms.

American shad are more commonly caught in the Charleston Harbor trawl nets relative to the Hickory shad and Blueback herring. Mr. McCord estimates their runs are much smaller than the American Shad. The American shad are also captured for a longer period of time. Hickory shad and Blueback herring migrate out of the river before the juvenile American shad.

American shad, Hickory shad and Blueback herring migrating in the Savannah River were described by Mr. McCord as follows:

-American Shad-strong run in South Carolina.

-Hickory Shad- not real strong run in Savannah River.

-Blueback herring- small run, thought to be Santee stock. Blueback herring captured with other cupelids. Blueback herring were not removed from other cupelid stock and put in for aging lake trout prey. Stock is now landlocked but spawning in creeks and other lake tributaries. It is believed individuals from the South Carolina stock are able to travel to the Savannah River, traveling up tributaries to the Savannah River from land locked water bodies. Once in the Savannah River the blueback herring migrate out to the ocean. Adult Blueback herring returning from the ocean to spawn account for the blueback herring spawning runs. Native stock of the Savannah River are also thought to exist but are a small percentage to the total population.

Gerrit Jobsis - Freshwater Fisheries - SCDNR

Adults try to stay on the bottom (American Shad). Outgoing juveniles can be observed at the surface. Observations are just downriver from the spawning area and in nursery areas.

Timing of arrival and abundance data is not available but for the best idea call Billy McCord. Mr. McCord reportedly works with commercial fishermen and would be a good source for temporal migration information of the Savannah River.

Mr. Jobsis sent a report on work done from April 1999 to July 1999 on the New Savannah Bluff Lock and Dam and it's affect on migration of American shad. The report discusses the arrival of adult American shad.

Bert Deener - Wildlife Resources Division, Fisheries Mangement Section - Georgia Department of Natrual Resources (Waycross, Georgia)

Mr. Deener collected research material on anadromous species with respect to migration. The collected research material includes the following (see RESEARCH section of this REFERENCES SECTION for complete bibliography and relevant material) :

-*Notes on the Distribution, Relative Abundance and Growth of Juvenile Anadromous Fish in theAltamaha River System, Georgia*

-*Young Clupeids of the Altamaha River, Georgia*

-*Evaluation of Habitat Suitability Index Models for Riverine Life Stages of American Shad, with Purposed Models for Premigratory Fish*

Ron Michaels - Marine Fisheries Division - Georgia Department of Natural Resources

Personally trawled for juveniles off sandy banks in the Altamaha River (data already known).

American Shad are planktonavores and are sensitive to light.

No signs of repeat spawning were observed in Georgia in a statewide effort. Researchers looked for spawning marks on the scales of fish captured while migrating upriver to spawn.

A ten-year study on juvenile shad in the Altamaha river was attempted in 1982. The Altamaha River study was a trawling study to correlate the number of juveniles to the number of returning adults in the Altamaha River. Even with a high number of shad returning in 1986, no correlation could be made and the study was abandoned. Unknown environmental factors were given as reasons for abandoning the study. Locations and temporal migration habits of juveniles were not studied in the abandoned Altamaha study.

Kathy Hattala - Cornell Universtiy, Section of Ecology and Systematics Ithaca, New York.

Kathy Hattala was a faculty advisor for Karen Limburg, a PhD student who did thesis on theory concerning the timing of juvenile American shad migration. The theory called, "Grow and Go" related to juvenile American shad migrating out of the nursery habitat when they reached a particular size.

Karen Limburg is on sabatical in Sweden and was unavailable to discuss her findings by phone. Contact is being attempted via email but was not established for the purposes of this report.

Little is known about the first two years of life of American shad. It is believed that juveniles remain in the estuary areas for two to three years before joining the coastal migrating adults. Research well documents the movements of adult American shad of the coastal migrating adults. Spawning migrations in New England rivers are well documented.