

Jennifer R. Woodroffe. **HISTORICAL ECOLOGY OF STRIPED BASS STOCKING IN THE SOUTHEASTERN UNITED STATES.** (Under the direction of Dr. Roger A. Rulifson). Department of Biology, 2011.

Striped bass (*Morone saxatilis*) is the most recreationally and commercially important non-salmonid fish species in the continental United States. As such, it has been exploited to the point of collapse at various points throughout our Nation's history. The population crash of the 1980s made both fishers and fishery scientists aware of its sensitivity to overfishing and habitat degradation, joining two disparate groups in a common cause with a common goal--recovery. Fishing moratoriums, habitat restoration, and intensive stocking efforts were utilized throughout the 1980s and 1990s in order to restore the severely depleted stocks of America's favorite fish. Research conducted during this study focused on the states of Virginia, North Carolina, South Carolina, Georgia, and Florida at both the state and Federal level. Roanoke River/Albemarle Sound striped bass have been stocked throughout the United States, particularly within the study area. This population has been artificially propagated since 1879 with the number of fry and fingerlings stocked numbering in the billions. The discovery of a self-sustaining land-locked population in the Santee-Cooper Reservoir renewed interest in this game fish, spawning hatchery production in Virginia, South Carolina, Georgia, and Florida as well as other states. Like the Roanoke River/Albemarle Sound population, the Santee-Cooper population has been heavily stocked throughout the study area, creating a potential loss of genetic integrity. Our awareness of the effects of cross-stocking different strains of striped bass has grown over the last 30 years and it is necessary to determine what the historical stocking record has been so that we might better manage future stockings with an eye to restoring native strains where they have been previously depleted or extirpated. Genetic work by other researchers has been hindered due to a lack of knowledge regarding the number and strength of the strains stocked. This study is an attempt to rectify that unfortunate imbalance.

HISTORICAL ECOLOGY OF STRIPED BASS STOCKING IN THE SOUTHEASTERN UNITED
STATES

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DEDICATION

To my mother, Nell Murphy Campbell Woodroffe (July 13, 1952 – present) and my godfather Hubert Elmer Medford (April 16, 1921 – October 16, 1994). Your belief, faith, and unswerving love have shaped the woman I am today. I will never be able to express my gratitude to have had you both in my life. It has been an honour and a privilege. I love you both so very much.

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INTRODUCTION

Historical Ecology

Historical ecology is the study of past ecosystems by tracking changes over time. The field of historical ecology is relatively new, having come into existence in the 1990s. As such, it is a relatively new viewpoint with theorists and practitioners continually striving to define the field. Carole Crumley defined it as a discipline that “traces the ongoing dialectical relations between human acts and acts of nature, made manifest in the *landscape*” (Crumley 1994). While this definition is perfectly appropriate with respect to anthropological studies, it does not adequately explain the ecological aspect of the field. A more complete definition is “Historical ecology is an interface between ecology and historical geography that undertakes studies of lost or degenerated historical ecosystems” (Dirkx 1999). As such, this area of study is ideal for tracing the striped bass progression from the birth of artificial propagation in the 1870s to the stock enhancement programs of the 1980s. In this respect, ecological restoration is a positive counterbalance to the disruptive effects of modern human activities (Egan and Howell 2001).

If we are to reestablish historic processes and determine the components needed to repair damaged ecosystems, we must understand the past conditions and recognize the pivotal role of passing time (Falk 1990):

“Restoration uses the past not as a goal but as a reference point for the future. If we seek to recreate the temperate forests, tallgrass savannas, or desert communities of centuries past, it is not to turn back the evolutionary clock but to set it ticking again.”

The historical ecology approach is expected to answer four questions. (1) What is the existing environment for the study (baseline data); (2) what are the current practices that are likely to be affected by changing the environment (impacts); (3) what are the traditional and innovative adaptive strategies for the study environment and what is the nature and magnitude of the anticipated change (effective responses); and (4) how might the adaptations be put into effect (policy)?

Striped Bass as a Species

Striped bass (*Morone saxatilis*) has been a culturally and commercially important fish species since pre-European settlement of North America. Its original native range stretches from the St. Lawrence River in the Canadian provinces of Québec and Ontario (Leim and Scott 1968) to the St. Johns River in Florida (Merriman 1941, Rogers *et al.* 1982) and along the Gulf of Mexico from the Suwannee River, Florida, to Lake Ponchartrain, Louisiana (Brown 1965, Frugé 2006). Anonymous anecdotal evidence in the literature suggests that the Gulf Coast distribution extended farther west into Texas (Fuller *et al.* 1999). As there are no other mentions of striped bass in Texas prior to stocking introductions, it is likely that this was an incidental, potentially errant, migration.

Striped bass are mentioned by name as early as the 1630s. According to Setzler *et al.* (1980), the Massachusetts Bay Colony passed the first legislation to conserve a natural resource, to whit -- fish, in 1639. Neither the striped bass nor the codfish (*Gadus morhua*) could be used as fertilizer (Rulifson *et al.* 1982). Landings increased so that by 1776 the colonies of New York and Massachusetts enacted laws prohibiting the sale of this species of fish during the winter months (Bayless 1972). In 1670, an act of the Plymouth Colony stated that all income collected annually from the Cape Cod fisheries [striped bass, mackerel (Family Scombridae), and herring (Family Clupeidae)] must be used to fund a free school in the jurisdiction as well as to provide pensions for widows and orphans of men formerly in the service of the Colony (Pearson 1938).

The ultimate success of any species of fish is successful spawning and survival to reproductive age. Anadromous species such as the striped bass have been hindered, both historically and currently, by habitat destruction, degradation and alteration (e.g., dams), pollution, and overfishing. These anthropogenic factors have had definite and damaging effects on the species. As early as 1762, striped bass and sturgeons (*Acipenser sp.*) were extirpated from the Exeter River, New Hampshire, as a result of overfishing and habitat destruction (Stickney 1996). Striped bass is generally considered to be anadromous; that is, adult individuals spawn in freshwater while spending the rest of their lives in saltwater. However, striped bass populations in the northern and southern extremes of the range, as well as those found throughout the Gulf of Mexico, are considered to be potamodromous; that is, they spend their lives in their natal rivers following the thermoclines, rarely entering the sea (Burdick 2005, Frugé

2006, Shepherd 2006). Some populations have resident individuals that remain in the river systems while other portions of the population migrate (i.e., Stewiacke, Hudson, and Roanoke rivers). The Atlantic Coastal stock of striped bass is generally divided into four distinct stocks—the Chesapeake Bay, the Delaware Bay, the Hudson River, and the Roanoke River/Albemarle Sound (ASMFC 1981, Rogers *et al.* 1982, Richards and Rago 1999). Colloquially referred to as “rock” or “rockfish” from the Chesapeake Bay southward and “striper” or “linesider” in New England, the striped bass throughout its native range has undergone significant fluctuation in abundance. Landings reached a historic high in 1973 of 14.7 million pounds before reaching its nadir of 3.1 million pounds in 1979 (ASMFC 1981). More than 90% of all commercial and recreational catches occur between Maine and North Carolina, and the migratory stock is subject to the regulations of 12 states and one federal interstate commission (ASMFC 1981).

The difficulty in managing striped bass is due not only to its complex life history but also to its sensitivity to anthropogenic effects, which are further compounded by the stressors that occur in conjunction with its anadromous nature (ASMFC 1981, Rogers *et al.* 1982). In order to adequately manage and restore striped bass to their former historic levels we need to create a “base datum of normality” (a picture of how a healthy population maintains itself). This is a difficult endeavor as the environment has changed drastically since the United States was first settled by Europeans and the Industrial Revolution took hold in the New World. The best we can hope for are snapshots taken at different times throughout history. According to Curt Meine (Egan and Howell 2001):

“History complicates things. It undermines easy answers. ... To incorporate history into one’s research and conservation plans takes time, money, persistence, imagination, concentration, self-criticism, attention to detail, a lot of reading, respect for the obscure, breadth of interest, and a capacity for respectful collaboration.”

An historical view offers compensations. It makes landscapes richer and more interesting. It has the potential to bring together disparate people who would normally be conflicted. Science is almost as universal as mathematics and is understood across cultures and language barriers. It gives us the tools to determine our bearings and guide our restoration attempts, and “inform our search for a viable conservation ethic.” One of these tools is historical ecology.

History of Striped Bass Culture

The creation of the U.S. Fish and Fisheries Commission in February 1871 by President Ulysses S. Grant and the subsequent appointment of Spencer F. Baird as the commissioner (Figure 1) was the dawning of a new era and the acknowledgement that United States fisheries were not an inexhaustible resource. Mr. Baird, then assistant secretary of the Smithsonian Institution, first approached Henry L. Dawes, the representative from Massachusetts and chair of the House Appropriations Committee, for funding for the Smithsonian Institution to study the fisheries decline. After another consultation with Mr. Baird, Mr. Dawes submitted a joint resolution to Congress to create a commission whose charge was to establish if a diminution in the numbers of America's food fishes in U.S. coastal waters and the Great Lakes had occurred and, if so, to propose how the circumstances could be ameliorated (Stickney 1996). Coincidentally, the American Fish-Culturists' Association, the precursor to the American Fisheries Society (AFS), was formed in 1870. At the 1872 meeting it was suggested that the U.S. should

“take part in the great undertaking of introducing or multiplying shad, salmon, and other valuable food-fishes throughout the country, especially in waters over which its jurisdiction extended, or which were common to several States, none of which might feel willing to incur expenditures for the benefit of the others (Baird 1875).”

Mr. Baird's focus was propagation, production, and distribution of food fishes in an attempt to gain the greatest yields from U.S. waters. By 1874, shad (*Alosa sapidissima*), alewife (*Alosa pseudoharengus* and *A. aestivalis*), striped bass, salmon (Atlantic and Pacific), whitefish (*Coregonus lavaretus*), and carp (*Cyprinus carpio*) were the focus of the newly formed Commission (Stickney 1996). At the time, other species were also being studied including black sea bass (*Centropristis striata*) (Stickney 1996). Thus, the culture of striped bass began in the late 19th century during the early days of American fish culture (Rogers *et al.* 1982). Prior to that time, fishing was either conducted as part of a subsistence diet or as a commercial endeavor.

The first successful hatching of striped bass occurred in 1873 at Weldon, North Carolina (Figure 2), by Mr. M.G. Holton. Subsequent culture of striped bass was unsuccessful until 1879 when Dr. W.R. Capehart, at Scotch Hall, Albemarle Sound, provided three large females who were ready to spawn. They were subsequently stripped and fertilized with milt (Baird 1880). Portions of the resulting fry were shipped to Druid Hill Park, Maryland and to Washington, D.C., for study (Baird 1880). From 1879 until the

project was abandoned (~1910), millions of eggs were hatched and the fry were released in an attempt to augment and enhance the commercial fishery (Stickney 1996). By 1910 the fundamental technology was in place; however, plans to supplement marine stocks were discarded (Stickney 1996).

The creation of the Santee-Cooper Reservoir in 1941 and the subsequent discovery of a large population of small striped bass in the reservoir in 1949 renewed interest in the culture of striped bass (Harrell *et al.* 1990). Scruggs and Fuller (1954) determined that the Santee-Cooper Reservoir population was in point of fact land-locked, with the Wateree and Congaree Rivers upstream providing the necessary spawning grounds (Harrell *et al.* 1990).

The Kerr Reservoir was constructed on the Roanoke River along the North Carolina-Virginia border in 1952. From 1953-1955, the North Carolina Wildlife Resources Commission stocked more than 3 million striped bass fry from the Weldon Hatchery (Surber 1958) into Kerr Reservoir in an attempt to create a landlocked population similar to the one occurring in the Santee-Cooper Reservoir. By the end of the decade, a strong sport fishery for striped bass had been established in Kerr Reservoir (Harrell *et al.* 1990). This land-locked population became self-sustaining using upstream areas of the Roanoke and Dan rivers as spawning grounds (Harrell *et al.* 1990).

With the successful development of these two land-locked striped bass populations, there was renewed interest in inland stocking. In Mr. Baird's time, the concept of invasive species was unheard of, and the consequences of the extirpation of native species were not considered. However, in the 1960s there was some concern regarding the potential impact the introduction of the non-native striped bass might have on the local ecosystems and fish assemblages. Both the South Carolina Department of Wildlife and Marine Resources (Stevens 1958) and the Virginia Department of Game and Inland Fisheries (Neal 1969) conducted studies and determined that the potential negative interactions of striped bass with native fish assemblages would be minimal with the added bonus of being able to control the gizzard shad (*Dorosoma cepedianum*) populations (Harrell *et al.* 1990).

To meet the national demand for striped bass fry, a striped bass hatchery was established at Moncks Corner, South Carolina. Attempts to induce striped bass spawning via hormonal therapy began at the Moncks Corner Hatchery in 1962 (Stevens *et al.* 1965). Bayless (1972) later refined the procedure,

which enabled the production of more than 100 million fry annually and motivated the building of additional striped bass hatcheries throughout the United States (Harrell *et al.* 1990).

In 1965, Oklahoma obtained striped bass fry from North Carolina with the intention of raising them to fingerling size; survival rates in the ponds were 15-60% (Stickney 1996). The experiment was continued at Auburn University in Alabama in 1967 with fingerlings being raised to sub-adult size (Stickney 1996). It was discovered at this time that striped bass could be reared on prepared food (Stickney 1996).

After the codifying of the procedures for striped bass spawning with hormonal therapy, the Moncks Corner Hatchery expanded into the production of hybrid striped and white bass (Stickney 1996). In 1968, it was discovered that the hybrids were fertile and were backcrossing with striped bass in the wild (Stickney 1996).

Virginia contains three active striped bass hatcheries: the Vic Thomas Hatchery (*neé* Brookneal), the King and Queen Hatchery (1935-present), and the Harrison Lake National Fish Hatchery (1936-present). The Vic Thomas Fish Hatchery (1961-present) spawns and grows Roanoke River strain striped bass collected from land-locked regions of the Roanoke River; primarily from the Kerr Reservoir, Lake Gaston, and Smith Mountain Lake. The King and Queen Hatchery (*neé* Stevensville) primarily spawns and hatches the Chesapeake Bay strain striped bass with some Roanoke River strain overlap. At the present time, the King and Queen Hatchery collects the Chesapeake strain brood stock from the Pamunkey and Mattaponi Rivers. The Harrison Lake National Fish Hatchery currently spawns and hatches both Roanoke and Chesapeake strain striped bass for the state of Virginia. (Note: No independent tagging or spawning of striped bass has occurred at the Harrison Lake National Fish Hatchery since 1993 (Michael Odom, U.S. Fish and Wildlife Service, personal communication)). The Front Royal Hatchery was built in 1932. The Buller Fish Hatchery, was built in 1957. Both were utilized for striped bass grow out between 1975-1999.

North Carolina possesses the distinction of being home to the first striped bass hatchery in the United States, the Weldon Fish Hatchery (Figure 2), which operated from 1873-1991 (Baird 1874; Jeff Evans, North Carolina Wildlife Resources Commission, Division of Inland Fisheries, personal communication,). Utilizing shad boxes he designed and patented, Marcellus G. Holton (a trained

assistant of Seth Green) and Chester K. Green successfully stripped several freshly caught female striped bass and subsequently fertilized the eggs with collected milt (Baird 1874). The discovery that striped bass could be propagated like shad, which had declined equally, was the impetus for further research. Research into the artificial propagation of striped bass was continued by Steven G. Worth, Fisheries Commissioner for the State of North Carolina, but was unsuccessful until 1879 when three females were stripped and the eggs were fertilized at Scotch Hall on the Albemarle Sound (Baird 1882). The State of North Carolina experimented with artificially propagating striped bass at Weldon from 1879-1884 at which time the state ceased all fish culture activities leaving future research and production up to the federal government (Elliot Astupenas 1998). The North Carolina Fish Commission operated between 1877-1884. Currently there are two active striped bass hatcheries within North Carolina: the Watha Fish Hatchery (1992-present) and the Edenton National Fish Hatchery (1898-present, Figure 4).

In 1898 the Edenton National Fish Hatchery was established on part of the plantation owned by Stephen Carrabus, which dated back to 1802. In 1906, the Weldon sub-station of the Edenton NFH (Figure 4) produced ~2.1 million striped bass fry. In 1923, operation of the Weldon sub-station ceased when the level of pollution in the nearby Roanoke River was deemed too high for striped bass fry survival. In 1927, the state of North Carolina furnished a new hatchery for striped bass at Weldon. Production of striped bass resumed in 1928. The Edenton National Fish Hatchery resumed striped bass production in 1944 where they were grown out in earthen ponds and reared to several inches before being harvested. The Carrabus Plantation site of the Edenton NFH closed in 1954 due to lack of available land for expansion. A new hatchery was built in 1958 -- 0.6 miles from the old site -- and went into production in 1960. In 1967, human chorionic gonadotropin was injected into striped bass producing 1.1 million eggs—16% hatched. In 1976, the Edenton National Fish Hatchery had five different strains of striped bass brood fish on site (Elliott Atstupenas 1998). By 1980, only the Weldon and Maryland strains were being produced. In 1990, Luteinizing Hormone-Releasing Hormone Agonist (LHRHa) was tested on the striped bass to increase maturation and spawning (Elliott Atstupenas 1998). The Weldon Hatchery substation was transferred back to state control in 1948 (Meacham 1976) and remained the primary producer of striped bass until it closed in 1991. Until the 1960s all striped bass artificially produced came from North Carolina (Harrell *et al.* 1992).

Historically, striped bass were grown out at the Fayetteville (1924-1992), Marion (1926-present), Table Rock (1946-present), and McKinney Lake (1936-present) hatcheries. During the 1960s as part of the ongoing hybridization experiments, Marion, Fayetteville, and Table Rock hatcheries were utilized. Fayetteville Fish Hatchery (now the John E. Pechmann Fishing Education Center) participated in the experiments because of its status as a warmwater facility (Kent Nelson, NCWRC, Division of Inland Fisheries, personal communication). Table Rock Fish Hatchery was chosen for the experiments because of its distinction as the sole “coolwater” facility in the state. (This term is used to designate a hatchery where the water temperature ranges <10°C in winter to <27°C in the summer) (Kyle M. Briggs, NCWRC, Division of Inland Fisheries, personal communication, May 2009). The Table Rock State Fish Hatchery continues to be the primary research site used to evaluate marking techniques for use on hatchery reared fish. Marion State Fish Hatchery is unique in that it maintains a reasonably steady temperature throughout the year, with winter temperatures not getting as cold as the other cold water¹ sites (Armstrong (1957-present) and Bobby M. Setzler (1937-present)) nor the summer temperatures getting warmer than 20°C in the summer (Kyle M. Briggs, NCWRC, Division of Inland Fisheries, personal communication, May 2009).

In 1879, Congress appropriated \$45,000 for the US Commission of Fish and Fisheries to purchase a vessel for use as a floating hatchery; the decision was to use a coastal steamer designed by C. W. Copeland of the Light House Board. Prior to 1880, the US Navy provided steamers for the Commission’s summer work, except in 1872 and 1876. The Fish Hawk was a coal burning twin-screw steamer. It was 157 feet long with 484 tons of displacement. The ship was commissioned in the spring of 1880 and the Department of the Navy provided officers and crew under the command of Lt. Z. L. Tanner. The USS Fish Hawk was outfitted as a hatchery for shad, striped bass, mackerel, and herring, and also for general scientific research with a hoisting winch and over a 1,000 fathoms of steel cable for trawling and dredging. “She was also outfitted with: a pump supplying 10,000 gallons per hour, two distribution tanks of 500 gallons each, 36 hatching cones, each capable of hatching 200,000 shad eggs, and 18 hatching cylinders, which were suspended nine on each side from beams outside the vessel. Fertilized

¹ Historically, there was a third National Fish Hatchery located in the NC mountains and referred to as the Smokemont Hatchery (1935-?).

eggs were placed in each cone and the current was regulated by feed valves to keep them gently in motion so they would not mat or settle to the bottom. The hatching cylinders with wire gauze bottoms were suspended, partially submerged, over the side and cam machinery gave them a gentle ascent and a more rapid descent of about 8 inches causing the eggs to rise from the bottom and circulate freely. Each cylinder held about 250,000 eggs. The trawling, dredging and collecting gear consisted of an otter trawl and three beam trawls, 9, 11 and 17 feet, Blake and Chester rake dredges and a tangle bar. The angle bar was an iron axle and wheels with deck swabs or bundles of rope yarn on chains that were dragged along the rocky bottom to capture marine organisms. Hydrographic equipment consisted of a sounding machine with 600 fathoms of piano wire, deep sea reversing thermometers and density salinometers (NOAA 2010).” The USS Fish Hawk was the first vessel built by any nation expressly for the promotion of the fisheries research.

South Carolina has two active striped bass hatcheries: the Orangeburg National Fish Hatchery (1911-present) and the Jack D. Bayless Fish Hatchery (1986-present). The fish are spawned out at the Jack D. Bayless Fish Hatchery in Bonneau before being transported and grown out at the Cohen Campbell Fish Hatchery (né Richardson Hatchery, Pine Ridge Hatchery and Styx Hatchery) (1935-present), the Spring Stevens Fish Hatchery (1936-present), and the Cheraw Fish Hatchery (1937-present).

Georgia has two active striped bass hatcheries: the Warm Springs National Fish Hatchery (1899-present) and the Richmond Hill Hatchery (1933-present). The Warm Springs National Fish Hatchery solely cultivates Gulf-Strain striped bass. The Richmond Hill Hatchery spawns and hatches all Atlantic Strain striped bass in the state of Georgia. Once hatched, the striped bass fry are then grown out in one of five additional fish hatcheries (the Bowens Mill Fish Hatchery (1933-present), the McDuffie Fish Hatchery (1935 -present), the Walton Fish Hatchery (1941-present), the Cordele Fish Hatchery (1938 - present), and the Dawson (Steve Cocke) Fish Hatchery (1956-present)) before being stocked into the pre-determined waterway.

Florida² has three active striped bass hatcheries: the Richloam Fish Hatchery (1965-present), the Blackwater Fish Hatchery (1966-present), and the Welaka National Fish Hatchery (1926-present). The Welaka National Fish Hatchery currently cultivates Gulf-Strain striped bass exclusively but has historically cultivated Atlantic Strain striped bass as well. The Richloam Fish Hatchery handles primarily the Atlantic strain with some cultivation of the Gulf-Strain. The Blackwater Fish Hatchery produces primarily Gulf-Strain striped bass with intermittent production of Atlantic Strain.

Striped Bass Collapse and Recovery

The Atlantic States Marine Fisheries Commission was formed by the 15 Atlantic coastal states in 1942 and was chartered by Congress eight years later in 1950. The member states recognize that fish do not discriminate arbitrary human boundaries and that any attempt to manage them must be a joint effort. The first species managed was the striped bass.

To many, the striped bass is as synonymous with the United States as the bald eagle and has been the impetus for environmental change and conservation efforts over the last sixty years. According to Russell (2005), concern for striped bass was the earliest documented effort by private citizens to establish the right to take legal action against a government agency in order to protect a natural resource. Russell (2005) also claims that Environmental Impact Statements were developed from a study on striped bass. This situation eventually evolved into the National Environmental Policy Act of 1969, the cornerstone of American environmental law, and, even now, affects every fishery scientist and manager. Despite its initial recovery during the 1990s, the striped bass remains an important species requiring better understanding and further study of its history.

With the collapse of the Atlantic coast striped bass fishery beginning in 1979, which led to commercial and recreational fishing bans by 1984, the previously developed technology for hormone induced spawning was utilized to assist striped bass population recovery. The successive stocking of striped bass throughout the affected area created a mix of genetic strains due to cross-stocking (Rulifson and Laney 1999, Bergey *et al.* 2003). By 1971, the Roanoke strain of striped bass had been stocked in

² There are three additional former fish hatcheries in the state of Florida: Oviedo, Winter Haven, and Wewahatchka. They have been decommissioned and the land transferred to the state parks system. None were responsible for producing striped bass.

Virginia, Georgia, South Carolina, Florida, Alabama, Michigan, Tennessee, New York, and Oklahoma (Rulifson and Laney 1999). The cross-stocking of the various strains may have had a negative effect on the survivability of the resulting spawn. It was later discovered that the egg buoyancy of certain strains (e.g., Roanoke and Chesapeake) were ideally suited for certain flow types. For example, the Chesapeake strain eggs are lighter and can maintain their position in the water column of tidal waters through floating, whereas the Roanoke strain eggs are much heavier and maintain their position in the more turbulent, high energy system of the Roanoke River (Bergey *et al.* 2003).

Striped bass have been affected by changes in their ecosystems as far back as the early colonists. Before there were hydroelectric dams and huge manmade reservoirs, there were wooden dams that powered grist or textile mills and blocked the upriver migrations of native anadromous fishes such as the American shad (*Alosa sapidissima*) and the striped bass. These dams not only blocked the spawning runs of the fish but the mills also polluted the water and destroyed or degraded the nursery habitats (Rulifson and Laney 1999). As the dams were modernized, fishways were sometimes constructed (Rulifson and Laney 1999). These fishways were ultimately unsuccessful due to lack of understanding of fish behavior and hydromechanics (Rulifson and Laney 1999). As our knowledge of fish behavior and hydromechanics has increased, many of the same dams have been retrofitted with fish passage structures or the dams are removed altogether as many no longer serve a purpose (Rulifson and Laney 1999). Other issues caused by dams that affect fish production are altered flow rates. While changes in flow rates may be necessary to produce sufficient electricity to meet peak hour demands, the frequent and substantial changes in flow velocity and volume, with attendant changes in temperature, hinder successful spawning (Rulifson and Laney 1999). Changes have been made in the Army Corps of Engineers reservoir and Dominion Generation hydropower releases to return the Roanoke River to pre-impoundment flow levels in order to assist the native anadromous fish stocks to recover (Rulifson and Laney 1999).

The migratory population of striped bass has recovered throughout its native range, thanks mostly to the fishing moratoriums (Richards and Rago 1999) and potentially to stock enhancement / stock restoration projects implemented by state and Federal governments. Our knowledge of its ecosystem has increased and so has our understanding of the pitfalls of the introduction of non-native species or

strains. In order to better understand the impact of stocking, it is necessary to document the stocking history of striped bass for each waterway so that we may better understand potential problems with natural populations and to provide information for better management of the resource.

METHODS

Originally, the objective of this study was to analyze the stocking history of striped bass throughout the entire United States to gain an understanding of how stocking may have altered or influenced watersheds from repeated stocking practices. A thorough investigation and literature review revealed that striped bass are present in all U.S. states except Idaho, Montana, Wyoming, and South Dakota due either to natural extension of the range, or by inadvertent or intentional introduction. According to Fuller *et al.* 1999, Alaska should be included in this list; however, there is a well-publicized Alaskan sport fishery for a migrating striped bass population that likely originates from California, which was originally stocked from the Navesink and Shrewsbury Rivers in 1879 and 1881. Thus, Alaska is excluded from this statement (<http://www.stripers247.com/Alaskafishing.php>).

Striped bass hatchery data were compiled from public documents such as mimeograph reports and government reports, and from other sources not readily available to the public including anecdotal information gleaned from hand written notes, discarded files, hatchery correspondence, original raw production and trip records, and e-mail correspondence to state/federal agency personnel. There were obvious commonalities to these data such as the mention of fish production numbers or weights, watersheds stocked, and transfer of fish between states and hatcheries, but there the commonalities stop. Each set of records was unique as hatchery personnel had their own way of presenting information, which made data sets inconsistent and incompatible. Therefore a considerable portion of the research was devoted to standardizing the data so it could be entered into this network analysis.

Methods of Network Analysis

The purpose of this study was to examine the relationships between the state and federal fish hatcheries, and the bodies of water where hatchery-produced striped bass were stocked. After careful evaluation of the utility of social network theory and statistical analysis, it was determined that social network analysis (SNA) would provide more accurate insight for this than the more traditional forms of statistical analysis. Social network analysis is based on an assumption of the importance of relationships between interacting units (Wasserman and Faust 2007).

Social network analysis views relationships in terms of network theory which consist of *nodes* and *ties*. *Nodes* are individual actors. In this study they are the fish hatcheries, the presumed genetic strains, and the bodies of water that have been stocked. The *ties* are the connections, the relationships, between the nodes. It is the relations that are defined by the linkages between nodes that are the fundamental basis of network theory. As in life, there are multiple ties between the nodes and to varying degrees. In its most basic form, a social network is visualization of specified ties.

According to Wasserman and Faust (2007) the principles that distinguish network analysis from other research approaches are as follows:

- Actors and their actions are interdependent, not separate units;
- Relational ties (linkages) between the actors are channels for the transfer or “flow” of material; and
- Network models conceptualize structure as lasting patterns of relations among actors.

Ultimately, it is the inclusion of relationships among the units in a study that provide the fundamental difference between a social network explanation and a non-network explanation (Wasserman and Faust 2007).

Analysis takes places as either a *complete network* or as an *egocentric network*. *Complete networks* view and analyze all of the ties comprising all specialized relations for a defined population (in this case, a hatchery). An *egocentric network* considers how the ties lead from a single actor (hatchery) to a group of *alters* (other hatcheries or stocked watersheds) who have ties to the ego and the measurements on the ties of the alters (Wasserman and Faust 2007).

The difference between the two systems is based on how the data were collected. With a complete network, all of the actors were interviewed, whereas with the egocentric network only the main actor was interviewed. In relation to my study, a complete network would be one where all of the hatcheries were contacted regarding their stocking. In an egocentric network only one hatchery would be contacted regarding its stocking practices. In other words, complete networks have complete information regarding who is in the network with all actors as possible egos and/or alters, and egocentric networks know only who the egos are. By using a visual representation of the data that a graph provides, we are able to discern patterns not readily apparent with statistical analysis.

Generally, anecdotal information does not lend itself to any kind of intense or standard statistical analysis. Information was collected and used to create a series of variables that describe the nature of the relationships between hatcheries and water bodies. Most of the collected data are dissimilar from state to state but we have attempted to standardize the data. Just as with psychology, the hypotheses of this study are difficult to test as the data are auto-correlated and non-randomly sampled.

We must also artificially *bound* the network or else the data sets become too large to process. In this study we bound the data to the five states of the southeastern Atlantic coast (Virginia, North Carolina, South Carolina, Georgia, and Florida). Outliers (i.e., U.S.S.R., Republic of South Africa, etc.) are noted but not included as part of the study. It is important to note that several of the river systems of Georgia and Florida drain into the Gulf of Mexico and are stocked with Gulf Strain striped bass. The dates and locations where the cross-stocking of Gulf Strain striped bass into coastal Atlantic watersheds have occurred are noted in the individual figure legends.

When designing this study it was necessary to decide whether to conduct an egocentric or a complete network analysis. A two-mode network that focuses on two sets of actors was determined to be the most logical for data collected. In the case of this study and for the purposes of analysis, the N actors were the hatcheries, and the M actors were the bodies of water stocked. The linkage or flow that was specifically analyzed was the artificial movement of fish from one location to another (i.e., stocking). It was further decided that the data were directional; in other words, fish moved from a hatchery to a body of water, and that it would be valued (the actual number of fish stocked was used rather than converting it to binary, which would only provide information regarding the presence or absence). The valued data provided the opportunity to indicate the strength, intensity, or frequency of the ties between the actors.

UCInet, a network analysis program written by Borgatti, Everett, and Freeman, L.C. (2002) was chosen for the analysis of the data due to the availability of several professors within the East Carolina University Departments of Biology and Coastal Resource Management knowledgeable in its operation and function.

The data were divided up by state and then by decade. The ten year increment was chosen due to the fact that most state fishery management plans cover five year terms. The data were then entered into the spreadsheet function of UCInet with the hatchery names in the rows and the bodies of water

stocked in the columns. The data sets were then named according to state and decade covered before being saved to the data library created by the program. All instances in which data were not present were filled with a zero. Watersheds/hatcheries that were not stocked/utilized were also assigned a “zero” for that year so as to retain the presence of the watershed /hatchery in the analysis. As a result, hatcheries or bodies of water utilized during some decades and not in others are retained in the data set but appear in the graph as an outlier. Results were then visualized using the NetDraw program that was included as part of the UCInet package. It was necessary to import the data into NetDraw from the data library. This provided a simple graph of the hatcheries that stocked a specific body of water. The physical locations of the nodes in the graph were arbitrarily determined by what would provide the clearest visualization of the data.

Results

As discussed in the Methods section, Social Network Analysis (SNA) was utilized in order to analyze the connections between the hatcheries in the different states and the different bodies of water stocked by those hatcheries; in many situations those stockings crossed state boundaries further complicating an already obscured state of affairs. The reader should note that in several analyses, bodies of water/hatcheries that were stocked in previous decades were deleted due to the size function of the analysis package. They were retained when possible.

Virginia

It should be noted that extant records for hatchery production in the Commonwealth of Virginia do not begin until 1975 and then occur only in the form of annual reports. Anecdotally, production began in the late 1890s to early 1900s. Modern production of striped bass did not occur until 1960 at the Brookneal Hatchery. Mr. Eugene Gwathmey was contacted regarding annual reports for Brookneal/Vic Thomas Fish Hatchery for 1973 or earlier. According to Mr. Gwathmey, records from that time period are incomplete so what data were available were entered into Appendix B.

During the mid to late 1970s (Figure 8), Brookneal Hatchery (presently known as the Vic Thomas Hatchery) was the only producer of striped bass fry in the Commonwealth of Virginia. It is located on the Staunton River in Campbell County, VA. As such, it would collect broodstock from the Staunton River via electroshocking, harvest the eggs and the milt, fertilize the eggs, then hatch out the fertilized eggs to fry, Most of these fry would then be transferred to one of the other state hatcheries (i.e., Stevensville, Buller, Front Royal), with a portion maintained on sight, or transferred to Harrison Lake National Fish Hatchery for grow out to fingerling size (See Appendix B). It should be noted that, during the 1970s, there was no distinction made between Atlantic Strain striped bass (in this case, originating from the Staunton/Roanoke River) and Chesapeake Bay Strain (CSB) striped bass. All surviving fingerlings were stocked into rivers and reservoirs that drain into the Chesapeake Bay or Roanoke River/Albemarle Sound. During 1978, striped bass broodstock were obtained from Lake Gaston and Kerr Reservoir due to flooding of the Brookneal Hatchery and the high turbidity of the Staunton River. Broodstock harvest returned to the

Staunton River in ensuing years due to the poor performance and viability of the fry produced during the 1978 season.

During the 1980s (Figure 9), Brookneal/Vic Thomas Hatchery continued to be the primary producer of striped bass fry for the Commonwealth of Virginia (Appendix B). All broodstock originated from the Staunton River (Roanoke River) except in 1988 when the Commonwealth of Virginia first experimented with Chesapeake Bay Strain (CBS) striped bass that were obtained from the Pamunkey River. Approximately 147,000 fry were produced that year at Brookneal. They were subsequently destroyed due to low production numbers. In 1989, broodstock from the Mattaponi River were obtained and spawned out at Brookneal before being transferred to Stevensville (a.k.a. King & Queen) Hatchery. The surviving fingerlings were then stocked back into the Mattaponi River.

During the 1990s (Figure 10), The Commonwealth of Virginia markedly increased its production of Chesapeake Bay Strain striped bass with the broodstock coming from the Mattaponi and Pamunkey Rivers. The resulting fry were grown out to fingerling size at Stevensville/King & Queen Hatchery. Unfortunately, Chesapeake Bay Strain stripers were stocked into the Roanoke River drainage system as well as the Chesapeake Bay drainage. This cross-stocking could explain the occurrence of floating eggs noted by the Edenton National Fish Hatchery, the Watha (North Carolina) State Fish Hatchery, and the Aurora aquaculture facility (NCSU) from broodstock obtained from the Roanoke River; most Roanoke eggs are heavy and sink readily (Bergey et al. 2003).

Striped bass production was reduced during the 2000s (Figure 11) when compared with production in previous decades. This is primarily due to the recovery of the striped bass after the population crash of the late 1970s and 1980s. Staunton River (Roanoke River) stock continued to be the predominant strain produced by Virginia (See Appendix B) while the James River was targeted as an additional source of Chesapeake Bay Strain striped bass. Cross-stocking of Roanoke River Strain striped bass into the Chesapeake Bay drainage system continued as well as Chesapeake Bay Strain striped bass being stocked into the Staunton/Roanoke River drainage system. It should be noted that, in the case of CSB strain striped bass being stocked into the Staunton/Roanoke River drainage system, the stocking occurred primarily into the Staunton River, the Kerr Reservoir, and Lake Gaston. These stockings took place above the dams and it would seem logical to assume that few, if any, fish or fertilized

eggs survived to make it through several locks and dams to contribute their genetics to striped bass occurring in the lower reaches of the Roanoke River. However, as noted above in Bergey *et al.* 2003, as well as in anecdotal information, floating eggs, typical of CBS strain striped bass, were produced from broodstock obtained from the Roanoke River by Edenton National Fish Hatchery staff, by NC Wildlife Resources Commission staff at Watha State Fish Hatchery, and the Aurora Aquaculture facility operated by North Carolina State University.

North Carolina

As noted in the Introduction, North Carolina is the birth place of striped bass culture. Unfortunately, records from the late 1800s until the 1950s are less than ideal with the majority providing only the number of eggs produced and not how many were viable or where they were stocked. The earliest extant records pertaining to the Weldon Hatchery begin in 1937 and continue through 1972; they are presented in Appendix C. The first real production records for fry and the locations of stocking began in the 1950s. (Appendix D). It should be noted by the reader that the State of North Carolina has only stocked striped bass produced by broodstock collected from the Roanoke River from 1950-1992 and that all resultant fry were produced at the historic Weldon Fish Hatchery until it ceased operation in 1991 before moving production to Watha. During those decades, fry were grown out at the Fayetteville State Fish Hatchery (now known as the John E. Pechmann Fishing Education Center), Table Rock Fish Hatchery (North Carolina's only "Coolwater" hatchery), Marion Fish Hatchery, McKinney Lake National Fish Hatchery (which is now in State hands), and the Edenton National Fish Hatchery. The resultant fry/fingerlings that were produced at Fayetteville and Table Rock fish hatcheries were stocked into lakes and reservoirs of the Catawba and Yadkin-Pee Dee Rivers. No extant records for the dissemination of the fry/fingerlings produced at the Marion Fish Hatchery have been located at the time of this writing. The reader should also be aware that during this same time, experiments utilizing hormone injections (gonadotropin and luteinizing hormone) and attempts to hybridize striped bass with white bass (*Morone chrysops*) and white perch (*Morone americanus*) were conducted at the same hatcheries. Records regarding the experiments are missing. All information regarding the specifics of these experiments were

obtained through personal communication with NC Wildlife Resources personnel, the majority of whom did not join the Commission until the 1990s, several decades after these experiments were conducted.

Per available records (Figure 12), the Weldon Fish Hatchery was the primary and most consistent producer of striped bass for both North Carolina and the Southeast. Roanoke River (RR) strain striped bass were used to stock the Tar/Pamlico River, the Neuse River, the Cape Fear River, Yadkin-Pee Dee River, and the Catawba River. It should also be noted that the Little River mentioned repeatedly in the stocking records is the one that is a tributary of the Albemarle Sound and not one of the other half dozen or so found throughout the state. The majority of the stocking focus was, and continues to be, the Roanoke River/Albemarle Sound region. Initially the focus was due to location and difficulty in successfully transporting viable fish. Later, the Roanoke River was singled out due to the superiority of both quality and numbers of striped bass. The Roanoke River/Albemarle Sound populations, along with the Chesapeake Bay and Hudson River populations, are considered by most to be the foundation of the Atlantic Strain of striped bass. It should also be noted that the majority of the striped bass stocked at this time were fry or fertilized eggs.

During the 1960s (Figure 13), stocking practices were expanded. In much of the Southeast, significant time and money were expended in experimenting with human gonadotropin and luteinizing hormones and with hybridizing striped bass with other members of the Genus *Morone*. In North Carolina, the initial experiments were conducted at the Fayetteville, Marion, and Table Rock Fish Hatcheries. Most of the hybrid experiments were unsuccessful and the resulting fry were destroyed due to insufficient numbers. No records for the Marion Hatchery during this time-frame were located during research. There was also much international interest in introducing striped bass to other climes. Notably, several shipments of striped bass fry were shipped to both the Republic of South Africa and the former Union of Soviet Socialist Republics (USSR). The requests were handled through the US Embassy in Denmark in the case of the U.S.S.R. and directly with the US Fish and Wildlife Service (USFWS) in the case of the Republic of South Africa. Stocking of Roanoke River strain striped bass into the Neuse, Tar/Pamlico, Cape Fear, Catawba, and Yadkin-Pee Dee Rivers continued during this time with the resultant fingerlings and Phase II fish from Fayetteville and Table Rock hatcheries being stocked into the lakes and reservoirs of the Catawba and Yadkin-Pee Dee Rivers.

By the 1970s (Figure 14), grow out of striped bass fry to fingerling size was accomplished at state and federal fish hatcheries around North Carolina, with stocking focused on the Roanoke River, Yadkin-Pee Dee River, Catawba River, and Neuse River along with incidental stockings in Lake Mattamuskeet, Cape Fear River, Tar/Pamlico River, New River, and the Albemarle Sound. Broodstock was still being obtained from the Roanoke River/Albemarle Sound. Fayetteville was the most successful of the different hatcheries at growing out striped bass fry to fingerling size followed by McKinney Lake National Fish Hatchery and Edenton National Fish Hatchery. Most of the resultant fingerlings from Fayetteville were stocked into the Yadkin-Pee Dee and Catawba Rivers with a smaller portion being stocked back into the Tar/Pamlico, the Neuse, the Roanoke, the New, and the Cape Fear Rivers in that order. The majority of the fingerlings produced by the Edenton National Fish Hatchery were stocked into the Albemarle Sound followed by the Neuse River, Lake Mattamuskeet, and Roanoke River. McKinney Lake National Fish Hatchery's fingerlings went to the Yadkin-Pee Dee, the Catawba, and the Roanoke Rivers. Table Rock produced less than 100,000 fingerlings and all survivors were stocked into the Yadkin-Pee Dee River.

With the population crash beginning in 1979 and the subsequent moratorium of the 1980s (Figure 15), supplemental stocking of striped bass was increased to help rebuild the depleted stocks throughout the species native range. Despite this increase, fingerling production was terminated at the Table Rock Fish Hatchery but was continued at the Fayetteville, McKinney Lake, and Edenton hatcheries.

As you can see in Figure 16, a new hatchery was added to production. Watha State Fish Hatchery began producing striped bass fry and fingerlings in the spring of 1992. The historic Weldon Hatchery closed its doors and ceased production in 1991. The majority of the broodstock was still obtained from the Roanoke River. It should be noted that during this period, Chesapeake Bay Strain striped bass were being grown-out at Edenton National Fish Hatchery at the same time and in close proximity to the Roanoke River strain. It is possible that some inadvertent and undocumented cross-stocking occurred between the two strains.

By the new millennium (Figure 17), all striped bass production in North Carolina occurred at either the Watha State Fish Hatchery or the Edenton National Fish Hatchery. The moratorium on fishing for striped bass was terminated and creel and size limits were imposed depending upon the location being fished.

South Carolina

The earliest extant records of striped bass production begin in 1985. Despite this, it should be noted that striped bass production has been occurring in South Carolina since the 1950s. When the Santee and Cooper Rivers were dammed in 1941 it was thought that the striped bass had been extirpated from its native run. The subsequent discovery of a self-sustaining landlocked population of striped bass in 1949 renewed interest in the fish, and the population was carefully monitored. By 1952, the Santee-Cooper Reservoir was home to a thriving sport fishery. The reservoir also served as a source of broodstock already adapted to living in a land-locked environment and became the genetic source for many of the introductions of the species throughout the land-locked United States.

The stocking records for South Carolina from 1985-1989 (Figure 18) show that broodstock originated at the Dennis Wildlife Center/Jack D. Bayless Fish Hatchery near Moncks Corner. The resulting fry then were shipped to Spring Stevens, Cohen Campbell, or Cheraw for grow-out to fingerling size before being stocked into targeted bodies of water. During this same period, fry/fingerlings were obtained from Welaka National Fish Hatchery in Florida and the Orangeburg National Fish Hatchery in Orangeburg, South Carolina. The reader may also note that there is an icon for "DWC/Orangeburg", which was how the data were recorded in the records. The broodstock records failed to provide any clarification on this issue and so the data were recorded and analyzed as is.

It should also be noted that South Carolina shares river systems with both North Carolina and Georgia so there is resulting overlap of stocking efforts. This can be seen with the Catawba River (NC), the Pee Dee River (NC), and Lake Hartwell (GA).

It should be noted that all fish stocked in 1996 (Figure 19) were of the Roanoke River stock as the native South Carolina fry were all lost due to flooding.

Cross-stocking of Welaka striped bass continued in the 1990s and through the 2000s (Figure 20) as did the duplicate stocking efforts in Lake Hartwell, the Catawba and Pee Dee Rivers. It should also be noted that Lakes Hartwell, Thurmond, and Secession are formed by damming the Savannah River at various points. Lake Hartwell in particular crosses state boundaries and is stocked jointly by both South Carolina and Georgia.

The Santee and Cooper Rivers were dammed to create the Santee-Cooper Reservoir, while the Congaree and Wateree Rivers provide the upstream habitat that the land-locked striped bass utilize for spawning. It should also be noted that striped bass populations south of the Roanoke River and throughout the Gulf of Mexico drainage are considered to be potadromous or riverine.

Georgia

Georgia is the first state of this study to possess two different and competing drainage systems that are both historically home to striped bass. The focus of this study is the stocking of Atlantic coastal drainage systems. However, as there is often overlap between the Atlantic and Gulf of Mexico Drainages, both have been analyzed and differentiated. Like South Carolina, the majority of striped bass in the river systems of Georgia are potamodromous; that is, they rarely venture out to sea and spend the majority of their time migrating within the river to spawn and thereby complete the life cycle.

The stocking records for the State of Georgia begin in 1986 (Figure 21). While stocking took place prior to this time, the records were lost/destroyed and so only the extant records were analyzed. Lake Hartwell, which is stocked by both South Carolina and Georgia, also possess the distinction of being stocked with South Carolina (Santee-Cooper fish), Savannah River fish, Gulf Strain striped bass, and Florida striped bass from both the Atlantic and Gulf of Mexico drainages.

As shown in Figures 22 and 23, cross-stocking occurs throughout the state. Gulf strain striped bass from Welaka and Bo-Ginn National Fish Hatcheries are stocked into the Savannah River and Lake Hartwell. Atlantic Strain striped bass are stocked into the Altamaha and Ogeechee Rivers.

Florida

Florida³ is home to three fish hatcheries: two are operated by the state and one (Welaka) by the federal government. Stocking records begin in 1974 (Figure 24) at Richloam Fish Hatchery. Unless otherwise noted, fish originating at Richloam are Atlantic Strain striped bass from the St. Johns River. Fish originating from the Blackwater Fish Hatchery are from Lake Talquin and therefore of the Gulf Strain unless otherwise noted.

³ Striped bass were introduced into the Blackwater River in 1987 and the Yellow River in 1990.

Despite the focus of this study on the Atlantic Drainage, due to the pervasive cross-stocking (Table 8) in Florida, it was necessary to include Gulf Drainage systems and Gulf strain stocking in Atlantic Drainage systems.

It should also be noted that both Gulf strain and Atlantic strain were produced/grown-out at all three of the hatcheries located in Florida. It is likely, although not documented, that cross-stocking occurred onsite at the fish hatcheries during grow-out.

During the 1980s⁴ (Figure 25), Chesapeake Bay strain striped bass were stocked into both the Gulf and Atlantic Drainages. Also during this time a cross of Atlantic Strain and Gulf strain striped bass was produced at Richloam and stocked throughout the state. In addition, Santee-Cooper fish from the Dennis Wildlife Center were also stocked into both the Atlantic Drainage system as well as the Gulf of Mexico Drainage system.

Beginning in the 1990s, the state of Florida began genotyping their broodstock according to mitochondrial type. It was during this time that fish originating from the Roanoke River, Chesapeake Bay, and Santee-Cooper were stocked alongside Lake Talquin and the St Johns River fish. The mitochondrial DNA line is noted along with location of stocking in Figures 26 and 27). A number of fish were also sent to the University of Maryland and to a wide variety of National Fish Hatcheries throughout the Continental United States.

It should be noted that actual stocking of striped bass terminated in 2002 according to extant records (i.e., annual reports). Stocking of hybrid striped bass⁵ took priority throughout the state at that time and has continued to be the predominate *Morone* species produced.

⁴ It should also be noted that the University of Maryland was able to create a triploid striped bass from Gulf strain striped bass stock obtained from the state of Florida during the 1970s and 1980s.

⁵ The original hybrid is commonly referred to as the "Palmetto Bass" (striped bass ♀ x white bass ♂) as it was originally created in South Carolina which is known as the "Palmetto State". The reciprocal hybrid striped bass (white bass ♀ x striped bass ♂) is referred to as the "Sunshine Bass" as it was first successfully created in the "Sunshine State" of Florida.

DISCUSSION

At the beginning of this project, it was assumed that cross-stocking (Table 8) occurred primarily during the 1970s and 1980s in the more heavily stocked regions (i.e., Virginia and North Carolina) and ceased when awareness of the importance of genetic integrity and genotyping became more widely understood and utilized. Upon analysis, cross-stocking was a wide-ranging and long-term practice throughout the southeastern United States.

As previously discussed, the Commonwealth of Virginia possesses the majority of the coastline of the Chesapeake Bay and historically has been its greatest polluter. It also possesses the distinction of being the only state in this study to contain two separate, distinct stocks that form part of the migratory Atlantic coastal population. According to Setzler *et al.* 1980, Virginia had three distinct populations of striped bass—York, James and Rappahannock Rivers in addition to the members of the upper Chesapeake drainage basin existing in the system based on meristic studies (Raney 1957). The James River was stocked with fish from the Roanoke River during the 1970s and Chesapeake Bay strain fish from the Mattaponi and Pamunkey Rivers during the 1990s, thus potentially creating a loss of genetic integrity. Now, it could be argued that the original population was almost extinct as of 1973 (Merriner and Hoagman) and so there was no loss of genetic integrity. Coincidentally, according to extant records, North Carolina's rivers and sounds have only been stocked with fish obtained from local rivers, predominantly, the Roanoke River. Based on meristics, the Roanoke River population, specifically the Albemarle Sound, is distinct from the James River population but closely related to the Rappahannock and York Rivers based on the lateral line scales and morphometrics (Murawski 1958). The Roanoke River population is also distinct from South Carolina and eastern Florida populations based on fin ray counts as well as lateral-line scales (Raney and Woolcott 1955). The Cape Fear River, as of 1958, was distinct from the Roanoke River, Santee-Cooper Reservoir fish, and St. Johns River populations based on lateral-line counts. This was despite regular stocking of Roanoke River fish throughout the 1950s and possibly earlier. It is the loss of these records that poses such conundrums in this study. Without knowing specifically whether or not the Cape Fear River was stocked during the 1930s and 1940s, it

lends credence to the popular belief as espoused by Richards and Rago (1999) that stocking has no effect, positive or negative, on population recovery.

We do know that stocking can work to establish populations where striped bass did not originally exist (i.e., California). It must be noted that the fish used to stock California in 1879 and 1881 were adults and not the more fragile fry and fingerlings commonly used in stock enhancement projects of the late 20th century. The Santee-Cooper Reservoir, the Savannah River, the Edisto River, the Catawba River, and the Great Pee Dee River were all stocked with fish from the Santee-Cooper Reservoir, Welaka National Fish Hatchery, Orangeburg National Fish Hatchery, and on one occasion, the Roanoke River. The fish from Welaka were of the St. Johns River population until the 1980s when Welaka began to produce Gulf strain striped bass. Unfortunately, we do not know the origin of the broodfish from Orangeburg as they failed to provide the requested records despite numerous phone calls and emails. Based on what we do know, the Santee-Cooper Reservoir has been stocked with at least three additional strains. Georgia, which possesses rivers that drain into both the Atlantic Ocean and the Gulf of Mexico, also suffers from a lack of available records. Existing stocking records for Atlantic strain striped bass (collected near the Richmond Hill Hatchery) do not begin until 1986. Gulf strain stocking records are available as far back as 1967. Those data were not included in any of the analyses as rivers that drain into the Gulf of Mexico were not part of this study. However, the records were examined for any overlap or tie into this study and none were found. No population distinct to any river in Georgia was noted in Setzler *et al.* 1980. However, it is likely that the current population would be found to have similarities to all of the rivers discussed thus far due the multiple stockings from a multitude of sources as well as from stockings from other states that share the rivers, specifically, the Savannah River. Florida, like Virginia, possessed two distinct populations of striped bass according to Barkuloo (1970) -- the Appalachicola and the St. Johns River. The Appalachicola population is distinct from the Alabama River population and the St. Johns River population due to the number of soft dorsal and anal rays and the number of lateral line scales. Both the Gulf drainage rivers and the Atlantic drainage rivers have been cross-stocked with Chesapeake Bay Strain, Roanoke River strain, Santee-Cooper strain, in addition to deliberate Atlantic x Gulf strain crosses. As you can see in Figure 26, the number of distinct mitochondrial genotypes stocked into Florida's rivers is significant. In Figure 27, you can also see the more common mitochondrial lines that

were stocked until stocking of striped bass was halted and replaced by hybrids. Clearly, stocking has some effect on the native river populations.

Richards and Rago (1999) argue that the extensive stocking efforts that occurred during the 1980s and 1990s had little to no effect and therefore an insignificant genetic input into the recovering striped bass populations, implying that the recovery of Chesapeake Bay striped bass was due wholly to the fishery closures and habitat improvements. I caution against unilateral acceptance of this theory. The recovery of any fishery is a multidimensional endeavor. In the case of the striped bass recovery, there is no doubt that the moratoriums and habitat improvements did allow the native strains of striped bass to flourish and gradually increase population numbers, but to dismiss the impact of hatchery reared fish is unwise. Wirgin *et al.* (1997, 2005), using naturally spawned striped bass from the Appalachicola, were successful in identifying introgression of Atlantic strain mtDNA and nDNA into the wild-caught Appalachicola (i.e., Gulf strain) striped bass when compared with museum samples from the 1950s and 1960s prior to the wide spread stocking of Santee-Cooper fish. It is important to note that the genetic characteristics of the female have twice the impact of the male on the resultant progeny. As you can see in Table 2, there are physical dissimilarities between the Appalachicola stock and the St Johns stock. Wirgin *et al.* (1997, 2005) postulated that the native run of striped bass in the St. Johns River had likely been extirpated during the 1970s, yet the annual reports from both the Blackwater Hatchery and Richloam Hatchery make no mention of this and state that the majority of their broodstock were obtained from that river. Wirgin *et al.* (1997, 2005) also speculated that the St. Marys River was the southern-most self-sustaining striped bass population extant along the Atlantic coast. While there were several years where broodstock were obtained from the St. Marys River, it was the St. Johns and the Blackwater rivers that provided the bulk of the spawning stock used for production.

According to Bulak *et al.* 2004, there are approximately five distinct populations in the coastal rivers of South Carolina despite the widespread stocking of Santee-Cooper fish, Chesapeake Bay fish, and Roanoke River fish in the different drainages. Based on the stocking records, the reader should expect to see at least four populations so the occurrence of five distinct populations is reasonable. It would be beneficial to genetically analyze samples from the major river systems and look for identifying

genetic markers unique to the different strains stocked in order to determine the actual impact of the stocked fish in those rivers.

In North Carolina, there were six distinct genotypes (Stellwag *et al.* 1994), especially Type III, which was determined to be synonymous with the Chesapeake Bay. As you can see in Table 2, the Albemarle Sound population is distinct from the Cape Fear River, Upper Chesapeake Bay, and York River populations but has similarities to the James and Rappahannock Rivers. Prior to the 1960s and the building of the Brookneal (Vic Thomas) Hatchery, the majority of the fish stocked in the Roanoke River/ Albemarle Sound were of that stock: taken and spawned out at Weldon before being transferred to a variety of hatcheries around the state and country with the majority of the resultant fry/fingerlings being returned to the Roanoke River. Prior to the construction of a permanent hatchery at Weldon, broodstock were obtained from fishermen fishing in the river and the Albemarle Sound. We know that the Roanoke stock formed 2.7% of the migratory stock (circa 1975), so it is possible that fish from the Chesapeake Bay and the Hudson River were caught and spawned out at Weldon as early as 1879. We also know that the mortality rate of fertilized eggs and fry is >90%, so the overall percentage of genetic input into the Roanoke strain during the late 1800s is likely small. We do know that Chesapeake Bay fish were stocked into the Staunton (Roanoke) River as of 1989. If we were to embrace Richards and Rago's belief that stocking has no noticeable impact, it would still not explain the occurrence of "floating eggs", which are distinct to tidally influenced striped bass populations, most notably the Chesapeake Bay in fish caught and spawned out from the Roanoke River.

It is easy to presume that stocking's effects are negligible when faced with the high cost of stocking verses the much more fiscally moderate approach of habitat improvement and creel guidelines. Habitat improvement occurs over time and monetary expenditures are of much smaller amounts than the immediate costs of harvesting and growing out fish to a reasonable size. Unfortunately, habitat improvement does not have the panacea effect compared to stocking. Even if stocking has no scientifically perceptible effect on the endemic river population, it demonstrates to the public that the government is taking the matter seriously and is "fixing" the problem. As the public are the ones utilizing the resource and their taxes are used to support the agencies managing the resource, it is of utmost importance that the public perceive that something is being done to maintain or increase the fish

population. What the public perceives as an issue becomes an issue, whether or not there is any scientifically supported data to confirm that there is a problem.

When faced with such conflicting data, it becomes difficult to establish which theory is right and which is wrong. It is this dichotomy that has generated such interest and ardently expressed opinions on the subject of stocking. Based on the research conducted in this study, it is this author's belief that stocking may have had an effect, and further genetics work utilizing museum and wild-caught specimens should be conducted. As technology improves and we are able to definitively and accurately establish stable, inheritable traits within the striped bass genus, the results of this study will become essential in precisely determining the introgression of non-native DNA into native stocks. When this occurs we will at last be able to make a fully informed decision as to whether or not to continue stocking striped bass as a management tool. In the meantime it is important to maintain as much genetic diversity as possible in the broodstock and subsequent production of fry/fingerling/juvenile striped bass utilized in stock management endeavors.

LITERATURE CITED

Atlantic State Marine Fisheries Commission. 1981. Interstate Fishery Management Plan for the Striped Bass. ASMFC. Fisheries Management Report 1. Washington, D.C.

Bailey, W.M. 1975. An evaluation of striped bass introductions in the southeastern United States. Proceedings of the Annual Conference of Southeastern Game and Fish Commissioners. 28: 54-68.

Baird, S. F. 1875. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1874. Government Printing Office, Washington D.C.

Baird, S. F. 1880. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1879. Government Printing Office, Washington D.C.

Barkuloo, J.M. 1970. Taxonomic and reproductive status of striped bass (*Morone saxatilis*) in Florida. US Bureau of Sport Fisheries and Wildlife Technical Papers 44.

Bayless, J.D. 1968. Striped bass hatching and hybridization experiments. Proceedings of the 21st Annual Conference of the Southeastern Association of Game and Fish Commissioners. 1967: 233-244.

Bayless, J.D. 1972. Artificial propagation and hybridization of striped bass, *Morone saxatilis* (Walbaum). South Carolina Wildlife and Marine Resources Department, Columbia.

Bergey, L.L., R.A. Rulifson, M.L. Gallagher, and A.S. Overton. 2003. Variability of Atlantic coast striped bass egg characteristics. North American Journal of Fisheries Management 23:558-572.

Berggren, T.J. and J.T. Lieberman. 1978. Relative contribution of Hudson, Chesapeake, and Roanoke striped bass, *Morone saxatilis*, stocks to the Atlantic coast fishery. U.S. Fishery Bulletin. 76: 335-345.

Borgatti, S.P., M.G. Everett, and L.C. Freeman. 2002. Ucinet for Windows: software for social network analysis. Analytic Technologies, Harvard, MA.

Borgatti, S.P. 2002. What is social network analysis? <http://www.analytictech.com/networks/whatis.htm>.

Bulak, J.S., C.S. Thompson, K. Han, and B. Ely. 2004. Genetic variation and management of striped bass populations in the coastal rivers of South Carolina. North American Journal of Fisheries Management. 24: 1322-1329.

Coutant, C.C. 1985. Striped bass: environmental risks in fresh and salt water. Transactions of the American Fisheries Society 114: 1-2.

Crumley, C. L., editor. 1994. Historical ecology: cultural knowledge and changing landscapes. School of American Research. Sante Fe, New Mexico.

Dickson, A.W. 1958. The status of striped bass (*Roccus saxatilis*) (Walbaum) in North Carolina waters. Proceedings of the 11th Annual Conference of the Southeastern Association of Game and Fish Commissioners. 1957: 264-268.

Dirkx, G.H.P. 1999. Workinggroup on Historical Ecology Web site:
www.archweb.leidenuniv.nl/wlo/werkgr_ecol.html.

Dovel, W.L. and J.R. Edmunds IV. 1971. Recent changes in striped bass (*Morone saxatilis*) spawning sites and commercial fishing areas in upper Chesapeake Bay; possible influencing factors. Chesapeake Science. 12: 33-39.

Dudley, R.G., A.W. Mullis, and J.W. Terrell. 1977. Movements of adult striped bass (*Morone saxatilis*) in the Savannah River, Georgia. Transactions of the American Fisheries Society. 106: 314-322.

Dunham, R.A., R.O. Smitherman, R.W. Chapman, T. Hess, and C. Mesing. 1989. Mitochondrial DNA polymorphism of striped bass in the Southeast. Proceedings of the Annual Southeastern Association of Fish and Wildlife Agencies. 42 (1988): 21-26.

Egan, D. and E.A. Howell, editors. 2001. The historical ecology handbook: a restorationist's guide to reference ecosystems. Island Press, Washington, D.C.

Falk, D. 1990. Discovering the future, creating the past: Some reflections on restoration. Restoration & Management Notes 8(2): 71-72.

Fearing, D.B. 1903. Some early notes on striped bass. Transactions of the American Fisheries Society. 32: 90-98.

Frugé, D. J., editor. 2006. The striped bass fishery of the Gulf of Mexico, United States: A Regional Management Plan. NOAA (National Oceanic and Atmospheric Administration). Publication 137.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publications 27, Bethesda, Maryland.

Goode, G.B. 1884. The food fishes of the United States. In G.B. Goode and a Staff of Associates, The fisheries and fishery industries of the United States. Section I. Natural history of useful aquatic animals, p. 163-682. U.S. Government Printing Office, Washington, D.C.

Goodyear, C.P. 1985. Toxic materials, fishing, and environmental variation: simulated effects on striped bass population trends. Transactions of the American Fisheries Society 114: 107-113.

Hanneman, B. and M. Riddle. 2005. Introduction to social network methods. University of California, Riverside.

Harrell, R. M., J. H. Kerby, and R. V. Minton, editors. 1990. Culture and propagation of striped bass and its hybrids. American Fisheries Society. Bethesda, MD.

Hartman, K.J. and F.J. Margraf. 2003. US Atlantic coast striped bass: issues with a recovered population. Fisheries Management and Ecology. 10: 309-312.

Hassler, W.W. 1958. The striped bass in relation to the multiple use of the Roanoke River, North Carolina. Transactions of the 23rd North American Wildlife Conference. 378-391.

Hassler, W.W., N.L. Hill, and J.T. Brown. 1981. The status and abundance of striped bass, *Morone saxatilis*, in the Roanoke River and Albemarle Sound, North Carolina 1958-1980. N.C. Department of Natural Resources and Community Development, Division of Marine Fisheries, Special Report 38, Morehead City.

Holland, B.F., Jr., and G.F. Yelverton. 1973. Distribution and biological studies of anadromous fishes off-shore North Carolina. Division of Commercial Sport Fisheries, NC Department of Natural and Economic Resources Special Science Report. 24, 132p.

Humphries, E.T. 1966. Spawning grounds of the striped bass, *Roccus saxatilis* (Walbaum) in the Tar River, North Carolina. M.S. Thesis, East Carolina University, Greenville. 50p.

Jordan, D.S. 1886. Notes on the scientific name of the yellow perch, striped bass, and other North American fishes. Proceedings of the US Natural Museum. 8(1885): 72-73.

Koo, T.S.Y. 1970. The striped bass fishery in the Atlantic states. Chesapeake Science. 11: 73-93.

Kornegay, J. W. and E. T. Humphries. 1975. Spawning of the striped bass in the Tar River, North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners. . 29: 317-325.

LeCompte, E. L. 1926. The striped bass (rockfish) of the Atlantic coast. Transactions of the American Fisheries Society 56: 203-206.

Lewis, R.M. 1957. Comparative study of populations of the striped bass. US Fish and Wildlife Service. Special Science Report Fisheries. 204, 54p.

Manooch, C.S. III. 1973. Food habits of yearling and adult striped bass, *Morone saxatilis* (Walbaum) from Albemarle Sound, North Carolina. Chesapeake Science. 14: 73-86.

Mansueti, R. J. 1958. Eggs, larvae, and young of the striped bass, *Roccus saxatilis*. Maryland Research and Education Contribution 112:1-35.

Mansueti, R.J. 1962. Effects of civilization on striped bass and other estuarine biota in the Chesapeake Bay and tributaries. Proceedings of the Gulf Caribbean Fishery Institute. 14th Annual Session p. 110-136.

May, O.D., Jr., and J.C. Fuller, Jr. 1965. A study on striped bass egg production in the Congaree and Wateree Rivers. Proceedings of the 16th Annual Conference of the Southeastern Association of Game and Fish Commissioners. 1962: 285-301.

McIlwain, T.D. 1968. Distribution of the striped bass, *Roccus saxatilis* (Walbaum) in Mississippi waters. Proceedings of the 21st Annual Conference of the Southeastern Association of Game and Fish Commissioners. 1967: 254-257.

McIlwain, T. D. 1980. Striped bass in coastal waters, south Atlantic and Gulf. Marine Recreational Fisheries, (5): 37-43.

Merriman, D. 1937. Notes on the life history of the striped bass, *Roccus lineatus*. Copeia. 1937: 15-36.

Merriman, D. 1941. Studies of the striped bass *Morone saxatilis* of the Atlantic Coast. U.S. Fish and Wildlife Service Fishery Bulletin 50 (35): 1-77.

Merriner, J.V., and W.J. Hoagman. 1973. Feasibility of increasing striped bass populations by stocking of underutilized nursery grounds. Completion Report Project FA-VA-AFS 6. Virginia Institute of Marine Sciences, Gloucester Point, VA. 197p.

Murawski, W.S. 1958. Comparative study of the striped bass, *Roccus saxatilis* (Walbaum), based on lateral-line scale counts. MS Thesis. Cornell University, Ithaca, New York. 80p.

Neal, W.E. 1969. Landlocked striped bass of John H. Kerr Reservoir. Project Completion Report, Federal Aid in Fish Restoration Project F-5-R. Virginia Department of Game and Inland Fisheries, Richmond.

Overton, A.S., F.J. Margraf, C.A. Weedon, L.H. Pieper, and E.B. May. 2003. The prevalence of mycobacterial infections in striped bass in Chesapeake Bay. Fisheries Management and Ecology. 10: 301-308.

Pearson, J C. 1938. The life history of the striped bass or rockfish, *Roccus saxatilis* (Walbaum). Bulletin of the U.S. Bureau of Fisheries. 49(20): 825-851.

Price, K.S., D.A. Flemer, J.L. Taft, G.B. Mackiernan, W. Nehlsen, R.B. Biggs, N.H. Burger, and D.A.

Blaylock. 1985. Nutrient enrichment of Chesapeake Bay and its impact on the habitat of striped bass: a speculative hypothesis. Transactions of the American Fisheries Society 114: 97-106.

Raney, E.C., E.F. Tresselt, E. H. Hollis, V.D. Vladykov, and D.H. Wallace, editors. 1952. The striped bass (*Roccus saxatilis*). Bulletin of the Bingham Oceanographic Collection, Yale University 14.

Raney, E.C. 1957. Subpopulations of the striped bass *Roccus saxatilis* (Walbaum), in tributaries of Chesapeake Bay. In J.C. Marr (coordinator), Contributions to the study of subpopulations of fishes, p. 85-107. U.S. Fish and Wildlife Service, Fish Leaflet. 451, 6p.

Raney, E.C. and D.P. de Sylva. 1953. Racial investigations of the striped bass, *Roccus saxatilis* (Walbaum). Journal of Wildlife Management. 17: 495-509.

Raney, E.C. and W.S. Woolcott. 1955. Races of the striped bass, *Roccus saxatilis* (Walbaum), in the southeastern United States. Journal of Wildlife Management. 19: 444-450.

Raney, E.C., W.S. Woolcott, and A.G. Mehring. 1954. Migratory pattern and racial structure of Atlantic coast striped bass. Transactions of the 19th North American Wildlife and Natural Resources Conference, p. 376-396.

Richards, R.A. and P.J. Rago. 1999. A case history of effective fishery management: Chesapeake Bay striped bass. North American Journal of Fisheries Management 19: 356-375.

Rinaldo, R.G. 1971. Analysis of *Morone saxatilis* and *Morone americana* spawning and nursery area in the York and Pamunkey Rivers, Virginia. M.S. Thesis, College of William and Mary, Williamsburg, 56p.

Rulifson, R. A., M. T. Huish, and R. W. Thoesen. 1982. Anadromous fish in the southeastern United States and recommendations for development of a management plan. U.S. Fish and Wildlife Service, Fishery Resources, Region 4, Atlanta, GA, 525p.

Rulifson, R.A. and R.W. Laney. 1999. Striped bass stocking programs in the United States: ecological and resource management issues. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Resource Document 99-07, Ottawa.

Russell, D. 2006. Striper wars: an American fish story. Island Press, Washington, D.C. 368p.

Sandoz, O. and K.H. Johnston. 1966. Culture of striped bass *Roccus saxatilis* (Walbaum). Proceedings of the 19th Annual Conference of the Southeastern Association of Game and Fish Commissioners. 1965: 390-394.

Scruggs, G.D., Jr. 1957. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Transactions of the American Fisheries Society. 85: 144-159.

Scruggs, G.D., Jr., and J.C. Fuller, Jr. 1955. Indications of a freshwater population of striped bass, *Roccus saxatilis* (Walbaum), in the Santee-Cooper Reservoirs. Proceedings of the Southeastern Association of Game and Fish Commissioners 1954: 64-70.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihursky. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). NOAA (National Oceanic and Atmospheric Administration) Technical Report NMFS (National Marine Fisheries Service) Circular 433. (Also: FAO (Food and Agriculture Organization of the United Nations) Fisheries Synopsis 121).

Smith, H.M. 1907. The fishes of North Carolina. North Carolina Geological and Economic Survey. Raleigh, North Carolina.

Stellwag, E.J., E.S. Payne, and R.A. Rulifson. 1994. Mitochondrial DNA diversity of Roanoke River striped bass. Transactions of the American Fisheries Society. 123: 321-334.

Stevens, R.E. 1958. The striped bass of the Santee-Cooper Reservoir. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 11: 253-264.

Stevens, R.E., O.D. May, Jr., and H.J. Logan. 1965. An interim report on the use of hormones to ovulate striped bass (*Roccus saxatilis*). Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 17: 226-237.

Stickney, R. R. 1996. Aquaculture in the United States: A Historical Survey. John Wiley & Sons. New York.

Surber, E.W. 1958. Results of striped bass (*Roccus saxatilis*) introductions into freshwater impoundments. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 11: 273-276.

U.S. Commission of Fish and Fisheries. 1889. The rockfish or striped bass, *Roccus lineatus*. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1886. Government Printing Office, Washington D.C. 14: XXX-XXXI.

U.S. Commission of Fish and Fisheries. 1896. A manual of fish culture. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1895. Government Printing Office, Washington D.C.

U.S. Commission of Fish and Fisheries. 1897. A manual of fish culture. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1896. Government Printing Office, Washington D.C.

U.S. Commission of Fish and Fisheries. 1898. A manual of fish culture. Report of Commissioner of Fish and Fisheries for the Year Ending June 30, 1897. Government Printing Office, Washington D.C.

Walbaum, J.J. 1792. *Petri Artedi suici genera Piscium in quibus systema totum ichthyologiae proponitur cum classibus ordinibus generum characteribus, specierum differentiis, observationibus plurimis.* Ichthyologiae Pars III. Grypeswaldiae, (ed. II), 723 p.

Waldman, J.R., J. Grossfield, and I.I. Wirgin. 1988. Review of stock discrimination techniques for striped bass. North American Journal of Fisheries Management. 8: 410-425.

Ware, F.J. 1971. Early life history of Florida's inland striped bass, *Morone saxatilis*. Proceedings of the 24th Annual Conference of the Southeastern Game and Fish Commissioners. 1970: 439-447.

Wirgin, I.I., D. Currie, N. Roy, L. Maceda, and J.R. Waldman. 2005. Introgression of nuclear DNA (nDNA) alleles of stocked Atlantic coast striped bass with the last remaining Gulf of Mexico population. North American Journal of Fisheries Management. 25: 464-474.

Wirgin, I., L. Maceda, J. Stabile, and C. Mesing. 1997. An evaluation of introgression of Atlantic coast striped bass mitochondrial DNA in a Gulf of Mexico population using formalin preserved museum collections. Molecular Ecology. 6: 907-916.

Worth, S.G., 1884. Report upon the propagation of striped bass at Weldon, NC, in the spring of 1884. Bulletin of the United States Fish Commission 4(15): 225-230.

Worth S.G. 1903. Striped bass hatching in North Carolina. Transactions of the American Fisheries Society. 32: 98-102.

Table 1. List of state and federal fish hatcheries in southeastern US coastal states.

Name of hatchery	Location	Water temperature designation	Latitude / Longitude
Buller Fish Hatchery	VA	Warmwater	N36.7592, W-81.5386
Coursey Springs Fish Culture Station	VA	Coldwater	N38.0509 W-79.6727
Front Royal Fish Hatchery	VA	Warmwater	N38.9519, W-78.2968
Harrison Lake National Fish Hatchery	VA	Warmwater	N37.3389, W-77.1944
King and Queen Fish Hatchery	VA	Warmwater	N37.7376, W-76.9341
Marion Fish Culture Station	VA	Coldwater	N36.7592 W-81.5386
Montebello Fish Culture Station	VA	Coldwater	N37.8446 W-79.1302
Paint Bank Fish Culture Station	VA	Coldwater	N37.5406 W-80.2823
Vic Thomas Hatchery	VA	Warmwater	N37.0875, W-79.5728
Wytheville Fish Culture Station	VA	Coldwater	N36.9314 W-80.8913
Armstrong Fish Hatchery	NC	Coldwater	N35.7977, W-82.1121
Bobby M. Setzler Fish Hatchery	NC	Coldwater	N35.2781, W-82.6699
Edenton National Fish Hatchery	NC	Warmwater	N36.0569, W-76.6377
Fayetteville Fish Hatchery	NC	Warmwater	N35.0275, W-79.0412
Marion State Fish Hatchery	NC	Coldwater	N35.7308, W-82.0265
McKinney Lake Hatchery	NC	Warmwater	N35.0324, W-79.5475
Table Rock Fish Hatchery	NC	Coolwater	N35.8408, W-81.8317
Watha Fish Hatchery	NC	Warmwater	N34.6227, W-77.9950
Weldon Fish Hatchery	NC	Warmwater	N36.2538 W-77.3544
Bears Bluff National Fish Hatchery	SC	Warmwater	N32.6440 W-80.2510
Cheraw Fish Hatchery	SC	Warmwater	N34.6977, W-79.8834
Cohen Campbell Fish Hatchery	SC	Warmwater	N33.9157, W-81.1001
Jack D. Bayless Fish Hatchery	SC	Warmwater	N33.3035, W-79.9672
Orangeburg National Fish Hatchery	SC	Warmwater	N33.5158, W-80.8628
Spring Stevens Fish Hatchery	SC	Warmwater	N34.5807, W-80.6791
Walhalla Fish Hatchery	SC	Coldwater	N34.9814 W-83.0757
Bowens Mill Fish Hatchery	GA	Warmwater	N31.8374, W-83.2080
Buford Hatchery	GA	Coldwater	N34.1379 W-84.0922
Burton Fish Hatchery	GA	Coldwater	N34.7151 W-83.5710
Chattahoochee Forest National Fish Hatchery	GA	Coldwater	N34.7097 W-84.1506
Cordele Fish Hatchery	GA	Warmwater	N31.9679, W-83.8235
Dawson Fish Hatchery	GA	Warmwater	N31.7697, W-84.4810
McDuffie Fish Hatchery	GA	Warmwater	N33.3787, W-82.4232
Richmond Hill Fish Hatchery	GA	Warmwater	N31.9534, W-81.3176
Summerville Hatchery	GA	Coldwater	N34.4571 W-85.4148
Walton Fish Hatchery	GA	Warmwater	N33.6262, W-83.6745
Warm Springs National Fish Hatchery	GA	Warmwater	N32.8854, W-84.6747
Blackwater Fish Hatchery	FL	Warmwater	N30.7315, W-86.8016
Richloam Fish Hatchery	FL	Warmwater	N28.4747, W-82.0511
Welaka National Fish Hatchery	FL	Warmwater	N29.4791, W-81.6715

Table 2. Meristic characteristics (mean count $\pm$ 2 standard errors) of striped bass from southeastern US populations.⁴

Bodies of water	Gill rakers total no. ¹	Lateral line scales ²	Dorsal fins		Anal rays
			1st dorsal spines	2nd dorsal soft rays	
Upper Chesapeake Bay, MD	24.48 $\pm$ 0.06	62.55 $\pm$ 0.16	⁵ 0.09 $\pm$ 0.08	11.74 $\pm$ 0.04	⁵ 10.90 $\pm$ 0.01
York River, VA	24.02 $\pm$ 0.20	60.72 $\pm$ 0.28	9.02 $\pm$ 0.02	11.93 $\pm$ 0.02	10.96 $\pm$ 0.02
Rappahannock River, VA	24.02 $\pm$ 0.20	60.72 $\pm$ 0.28	9.02 $\pm$ 0.02	11.93 $\pm$ 0.02	10.96 $\pm$ 0.02
James River, VA	25.22 $\pm$ 0.20	61.66 $\pm$ 0.26	9.31 $\pm$ 0.04	11.53 $\pm$ 0.04	10.74 $\pm$ 0.04
Albemarle Sound, NC	24.51 $\pm$ 0.30	60.48 $\pm$ 0.70		³ 11.8 $\pm$ 0.10	10.9 $\pm$ 0.06
Cape Fear River, NC		56.94 $\pm$ 0.76			
Santee-Cooper, SC	23.33 $\pm$ 0.24	58.59 $\pm$ 0.54		11.6 $\pm$ 0.16	10.9 $\pm$ 0.08
St. John's River, FL		54.33 $\pm$ 0.44		11.9 $\pm$ 0.12	11.0 $\pm$ 0.14
Appalachicola River, FL		66.7		11.55 $\pm$ 0.12	9.8 $\pm$ 0.50

¹ Lewis 1957

³ Raney and Woolcott 1955

⁵ Raney 1957

² Murawski 1958

⁴ Setzler *et al.* 1980

Table 3. Total number of striped bass stocked into Virginia's rivers and lakes.

	1975- 1979	1980- 1989	1990- 1999	2000-2008	Total
Appomattox River	106384	98798	0	0	205182
Bealer's Pond	2010000	0	0	0	2010000
Beaver Dam	0	35102	22337	0	57439
Buggs Island Lake	300000	0	0	0	300000
Burton Lake	6400	0	0	0	6400
Carsbrook Pond	6000	0	0	0	6000
Carvins Cove Lake	16337	630	0	0	16967
Chesdin Lake	46000	28295	508598	537490	1120383
Chickahominy River	180969	174036	0	0	355005
Claytor Lake	329853	634512	300744	569956	1835065
Emporia Reservoir	5000	0	0	0	5000
Gaston Ponds	2535000	0	0	0	2535000
Gaston Reservoir	601736	0	6540470	458490	7600696
Harwood Mill Pond	6100	0	0	0	6100
Holiday Lake	0	5650	0	0	5650
James River	261346	1031285	0	0	1292631
Kerr Reservoir	258504	20050000	5800000	12344654	38453158
Lake Anna	1132887	1365348	1532133	1245518	5275886
Lake Mead	118231	0	103458	143138	364827
Lake Prince	137733	0	132446	159491	429670
Lee Hall Reservoir	0	0	609137	135141	744278
Leesville Lake	78500	226881	139031	482897	927309
Mattaponi River	8000	3000	2000000	9705	2020705
Maury Lake	18326	13960	13138	0	45424
Occoquan Reservoir	142873	94250	0	0	237123
Pamunkey River	0	0	950000	0	950000
Roanoke River	5371816	9000000	2426000	0	16797816
Smith Lake	32123	0	0	0	32123
Smith Mountain Lake	2291832	4752430	1965387	3618509	12628158
Staunton River	10438000	32441433	0	10000000	52879433
Trashmore Lake	5000	15783	7174	0	27957
Waller Mill Reservoir	0	0	55234	85578	140812
Western Branch Reservoir	178312	576757	294920	322553	1372542
Whitehurst Lake	94718	0	16352	0	111070

Table 4. Total number of striped bass stocked into North Carolina's rivers and lakes.

	1950- 1959	1960- 1969	1970- 1979	1980- 1989	1990- 1999	2000-2007	Total
Albemarle Sound	0	0	102371	1408296	9466	0	1520133
Alligator River	550000	2181000	0	0	0	0	2731000
Bay River	200000	0	0	0	0	0	200000
		1510000				159479	1822945
Cape Fear River	694000	0	3000	436654	401004	6	4
Catawba River	0	0	554531	1868214	294603	0	2717348
Chowan River	505000	2181900	0	0	0	0	2686900
Contentnea Creek	324000	2142600	0	0	0	0	2466600
Little River	450000	2180900	0	0	0	0	2630900
Neuse River	2927000	4601600	222912	643017	692307	878272	9965108
New River	534000	1014500	25400	146011	0	0	1719911
Pasquotank River	450000	2180900	0	0	0	0	2630900
Perquimans River	450000	2231000	0	0	0	0	2681000
		1042900					1849137
Roanoke River	6641000	0	339267	767092	315013	0	2
Scuppernong River	550000	2180900	0	0	0	0	2730900
Shallote Creek	0	85000	0	0	0	0	85000
Six Runs Creek	0	350000	0	0	0	0	350000
Swift Creek	353000	2837600	0	0	0	0	3190600
							2034509
Tar River	6204000	9967000	167485	212897	2849668	944044	4
Trent River	529000	1401600	0	0	0	0	1930600
Upper Broad Creek	0	951500	0	0	0	0	951500
White Oak River	530000	1268600	0	71932	0	0	1870532
Yadkin-Pee Dee River	0	0	1191258	1617513	160670	0	2969441

Table 5. Total number of striped bass stocked in South Carolina's rivers and lakes.

	1985-1989	1990-1999	2000-2007	Total
Catawba River	40000	138060	66983	245043
Combahee River	180538	10000	0	190538
Congaree River	0	0	0	0
Cooper River	381049	2340598	1163533	3885180
Edisto River	118300	40404	0	158704
Great Pee Dee River	0	94611	0	94611
Lake Ashwood	0	2048	0	2048
Lake Greenwood	1053772	751926		1805698
Lake Hartwell	66470	3160737	3900352	7127559
Lake Marion	800556	4914792	2708222	8423570
Lake Moultrie	6138138	17,483,143	17610668	41231949
Lake Murray	4311047	9924870	3399944	17635861
Lake Secession	62500	97497	0	159997
Lake Thurmond	0	3939469	4023839	7963308
Lake Wateree	0	1773245	1807029	3580274
Lake Wylie	0	0	48578	48578
Lynches River	0	46000	0	46000
Santee River	488848	2128721	160366	2777935
Wateree River	605155	222,900	43578	871633

Table 6. Total number of striped bass stocked in Georgia's rivers and lakes.

	1986-1989	1990-1999	2000-2008	Total
Allatoona River	188771	494788	204376	887935
Altamaha River	0	230337	57798	288135
Clarks Hill	733884	2235551	2251824	5221259
Lake Hartwell	250471	1673403	1715419	3639293
Lake Sinclair	91000	0	253046	344046
Oconee River	144025	0	336315	480340
Ogeechee River	93826	4815	1300000	1398641
Savannah River	458659	2178876	129547	2767082
Stevens Creek	25025	0	0	25025

Table 7. Total number of striped bass stocked in Florida's rivers and lakes.

	1974- 1979	1980- 1989	1990- 1999	2000- 2006	Total
Appalachicola River	0	134000	1006226	0	1140226
Blackwater River	0	185800	688296	90300	964396
Chipola River	0	8	11900	0	11908
Choctawhatchee	0	0	574954	526180	1101134
Lake Talquin	482932	1560700	1826013	0	3869645
Nassau River	32050	54500	41625	76920	205095
Seminole River	39000	816068	1767455	0	2622523
St. John's River	3849251	7860045	5728478	412025	17849799
St Mary's River	0	54500	0	28200	82700
Yellow River	0	0	608772	83100	691872

Table 8. Striped bass strains stocked by each hatchery 1873-2008.

	Appalachicola	Blackwater River	Chesapeake Bay	Gulf	Hudson River	Maryland	Roanoke River	St. Johns	Santee-Cooper	Savannah River
Blackwater (FL)	X	X	X	X	X	X	X	X	X	X
Bowens Mill (GA)				X					X	X
Buller (SC)							X		X	
Cheraw (SC)							X		X	
Cohen Campbell (VA)			X				X			
Cordele (GA)				X					X	X
Dawson (GA)				X			X		X	X
Edenton NFH (NC)			X		X	X	X			
Fayetteville (NC)							X			
Front Royal (VA)			X				X			
Harrison Lake NFH (VA)			X				X			
Dennis Wildlife Center (SC)				X			X		X	X
King & Queen (VA)			X				X			
Marion (NC)							X			
McKinney Lake NFH (NC)			X				X			
McDuffie (GA)				X						X
Orangeburg NFH (SC)			X				X		X	X
Richloam (FL)	X	X	X			X	X	X	X	X
Richmond Hill (GA)				X						X
Spring Stevens (SC)							X		X	
Table Rock (NC)							X			
Vic Thomas (VA)			X				X			
Walton (GA)			X							X
Warm Springs NFH (GA)				X						
Watha (NC)							X			
Welaka NFH (FL)	X	X	X	X		X	X	X	X	X
Weldon (NC)							X			



Figure 1. Mr. Spencer F. Baird, assistant secretary of the Smithsonian Institution named Commissioner of the U.S. Fish and Fisheries Commission in February 1871 by President Ulysses S. Grant. Source: <http://www.loc.gov/pictures/resource/cwpbh.03689/>

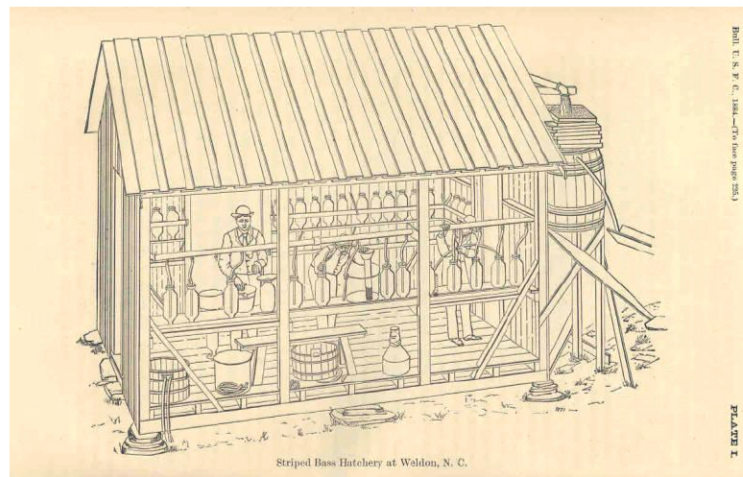


Figure 2. The first striped bass hatchery, constructed in 1873 on the banks of the Roanoke River in Weldon, North Carolina. Source: http://content.lib.washington.edu/cdm4/item_viewer.php?CISOROOT=/fishimages&CISOPTR=36334

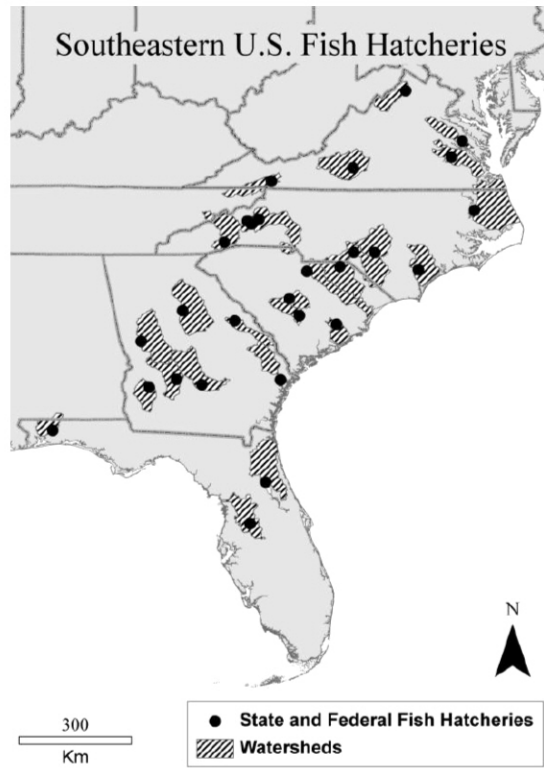


Figure 3. Map of Southeastern US Fish Hatcheries and adjacent watersheds. Courtesy of Jennifer Cudney-Burch.



Figure 4. The Edenton Shad Hatchery established by the US Bureau of Commercial Fisheries, located on Pembroke Creek at Edenton, North Carolina. Source: http://content.lib.washington.edu/cdm4/item_viewer.php?CISOROOT=/fishimages&CISOPTR=51533

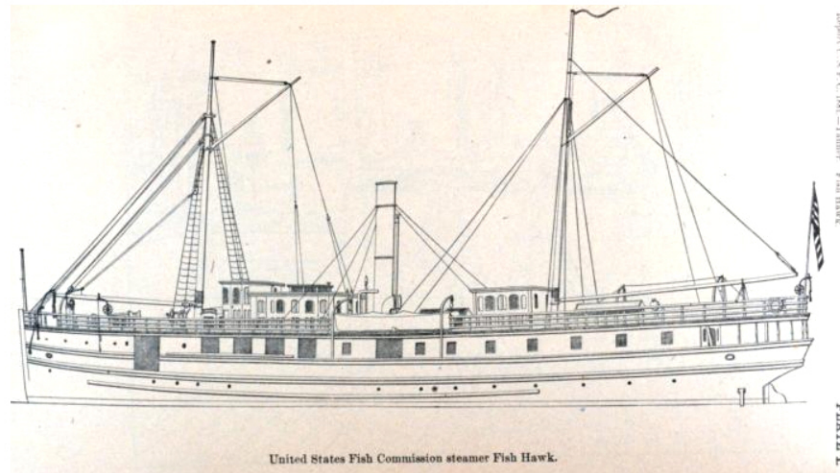


Figure 5. The USS Fish Hawk (1885-1900), a coastal steamer used as the first floating fish hatchery in the United States. Source: <http://www.nefsc.noaa.gov/history/ships/fishhawk/lineart.jpg>.

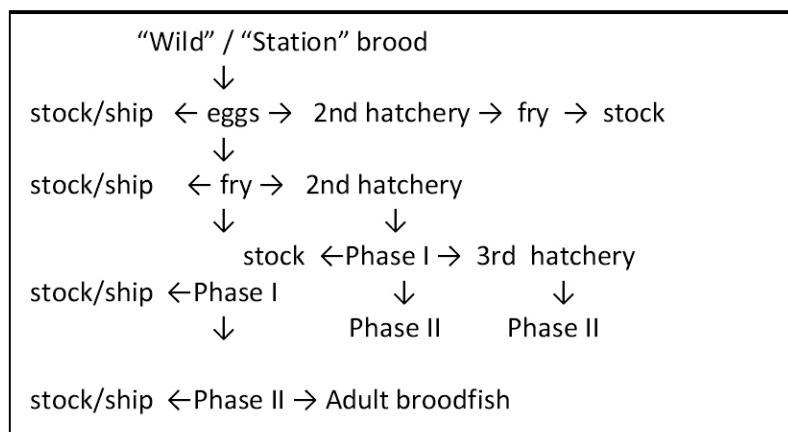


Figure 6. Diagram of the striped bass rearing process involving just one, or multiple, hatcheries. Wild brood fish usually were collected from adjacent striped bass spawning rivers. Some hatcheries held brood fish for multiple years, often of several different strains, as “insurance” for meeting their production quota for the year.

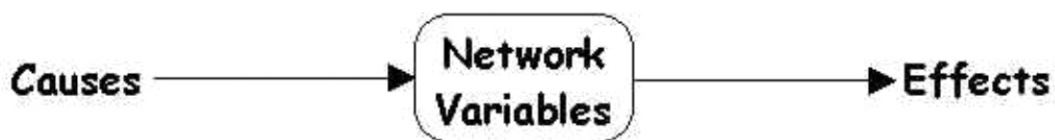


Figure 7. Network Analysis Description (Borgatti 1998).

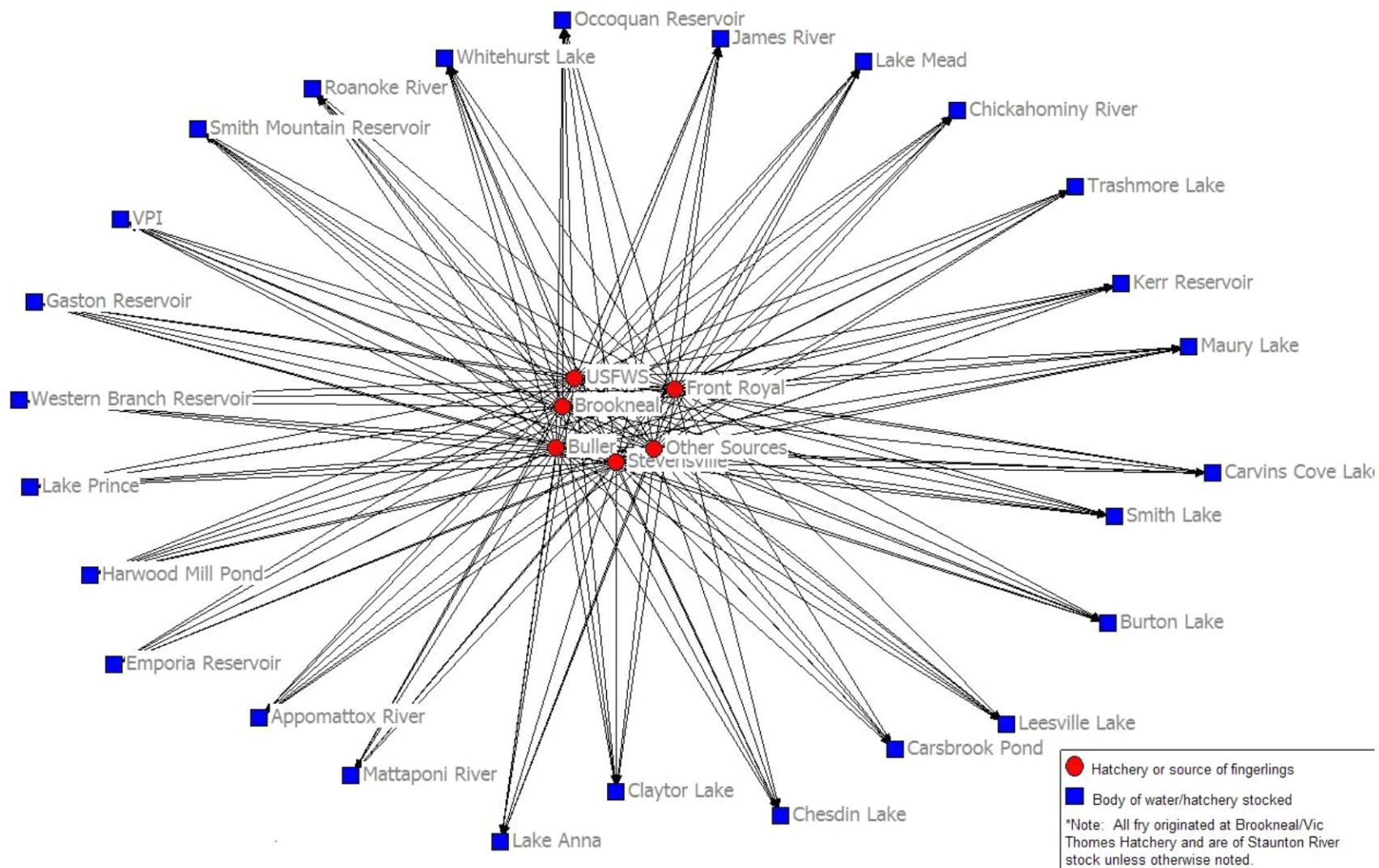


Figure 8. Virginia striped bass stockings 1975-1979.

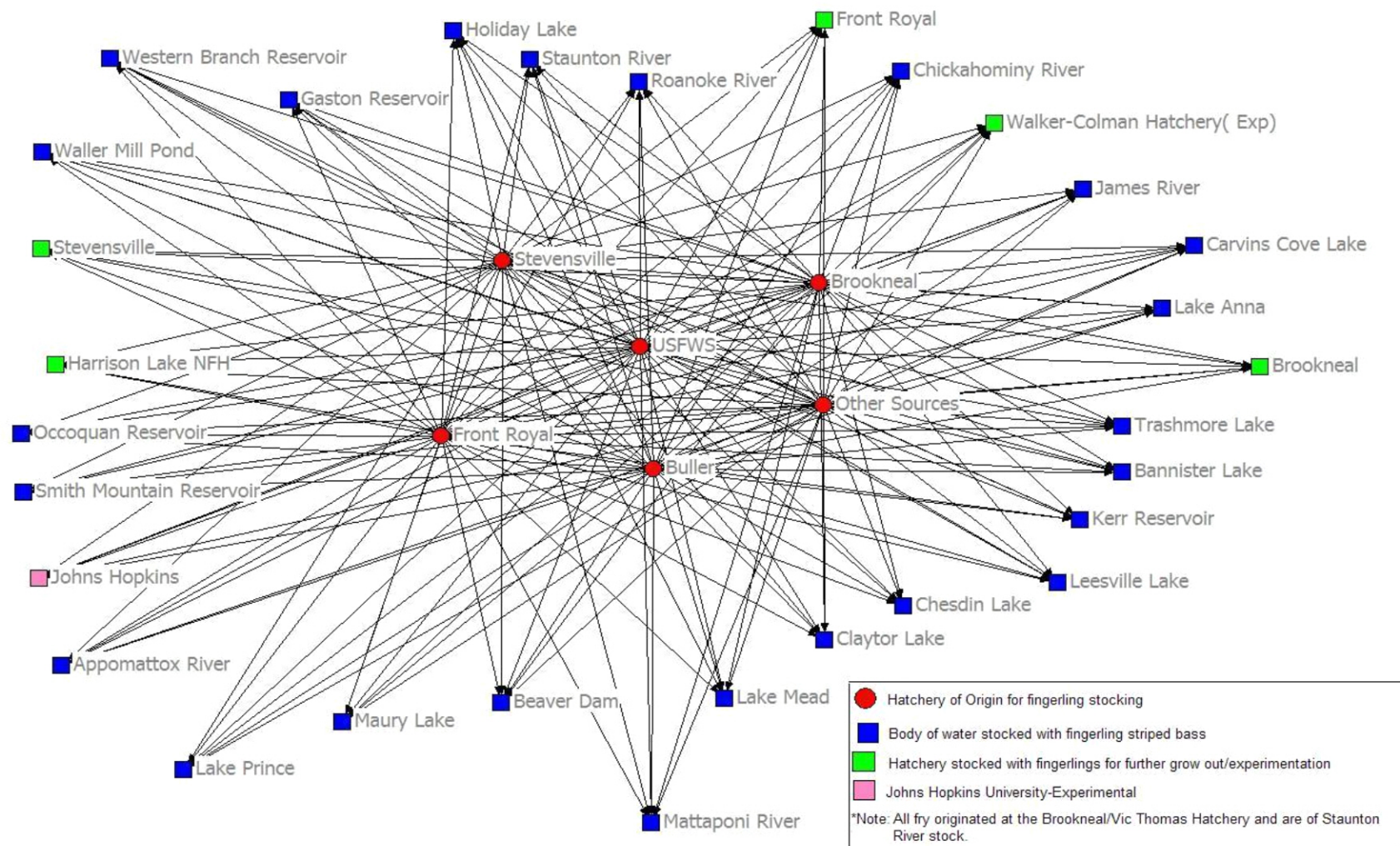


Figure 9. Virginia striped bass stocking 1980-1989.

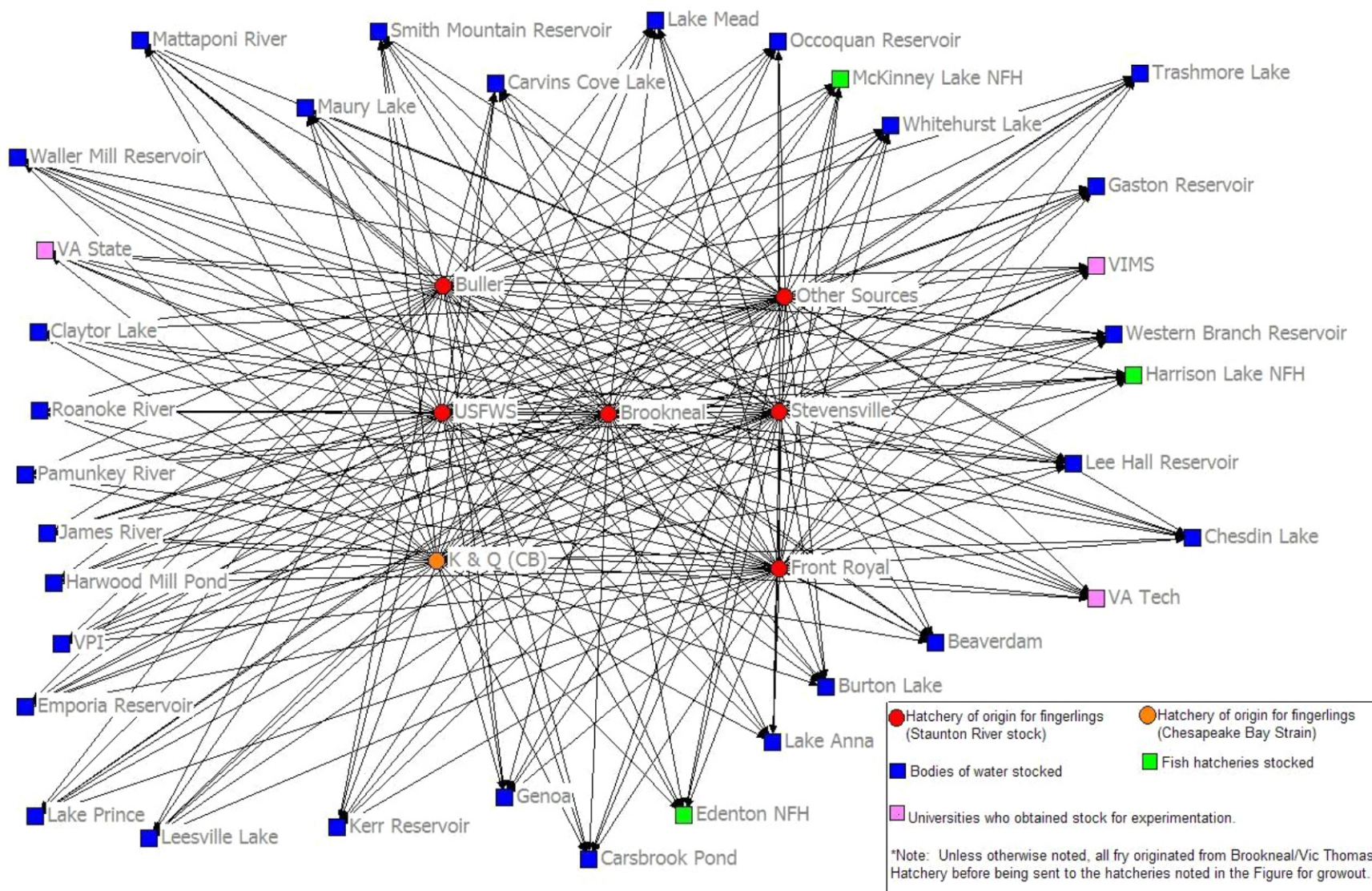


Figure 10. Virginia striped bass stockings 1990-1999.

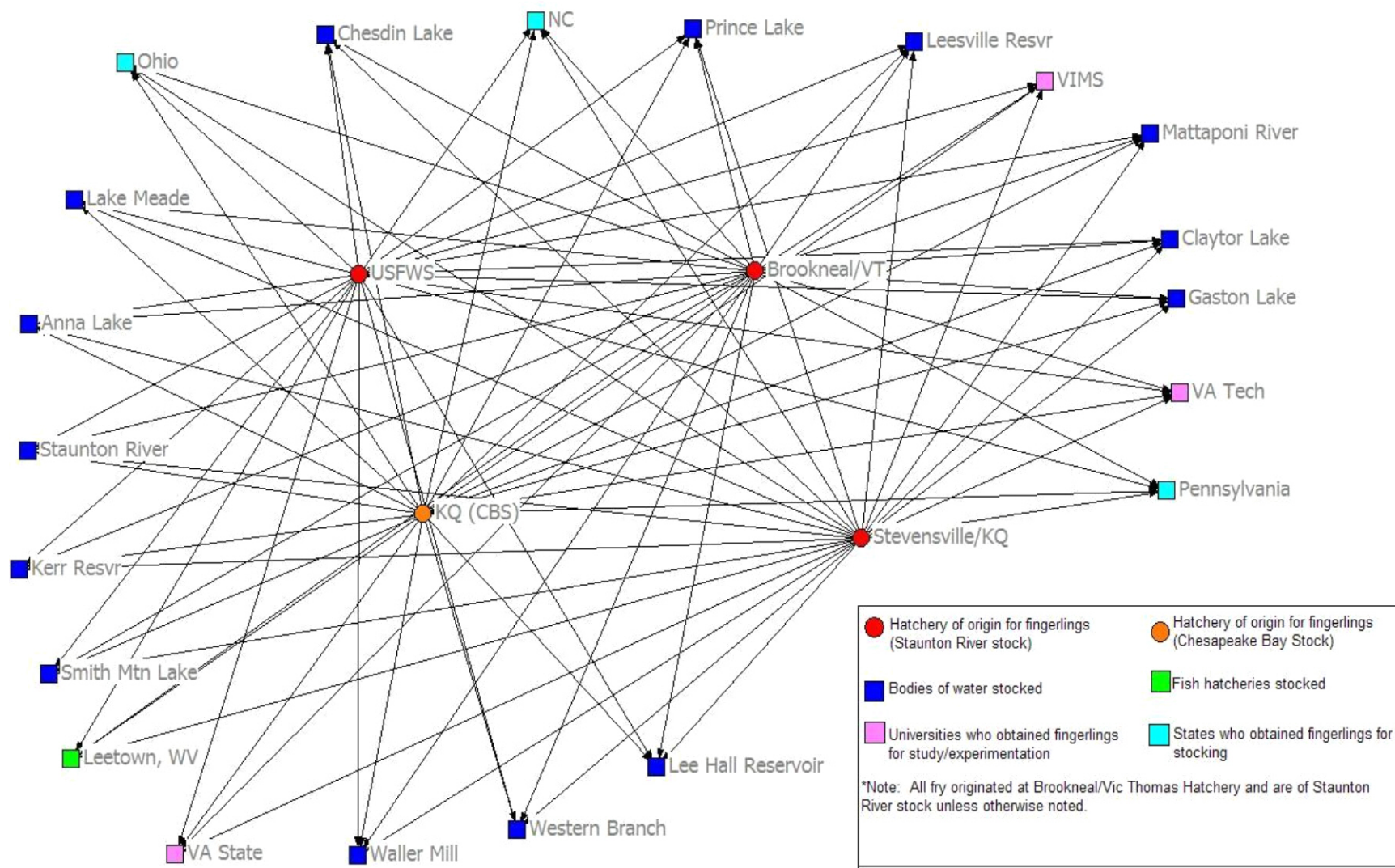


Figure 11. Virginia striped bass stockings 2000-2008.

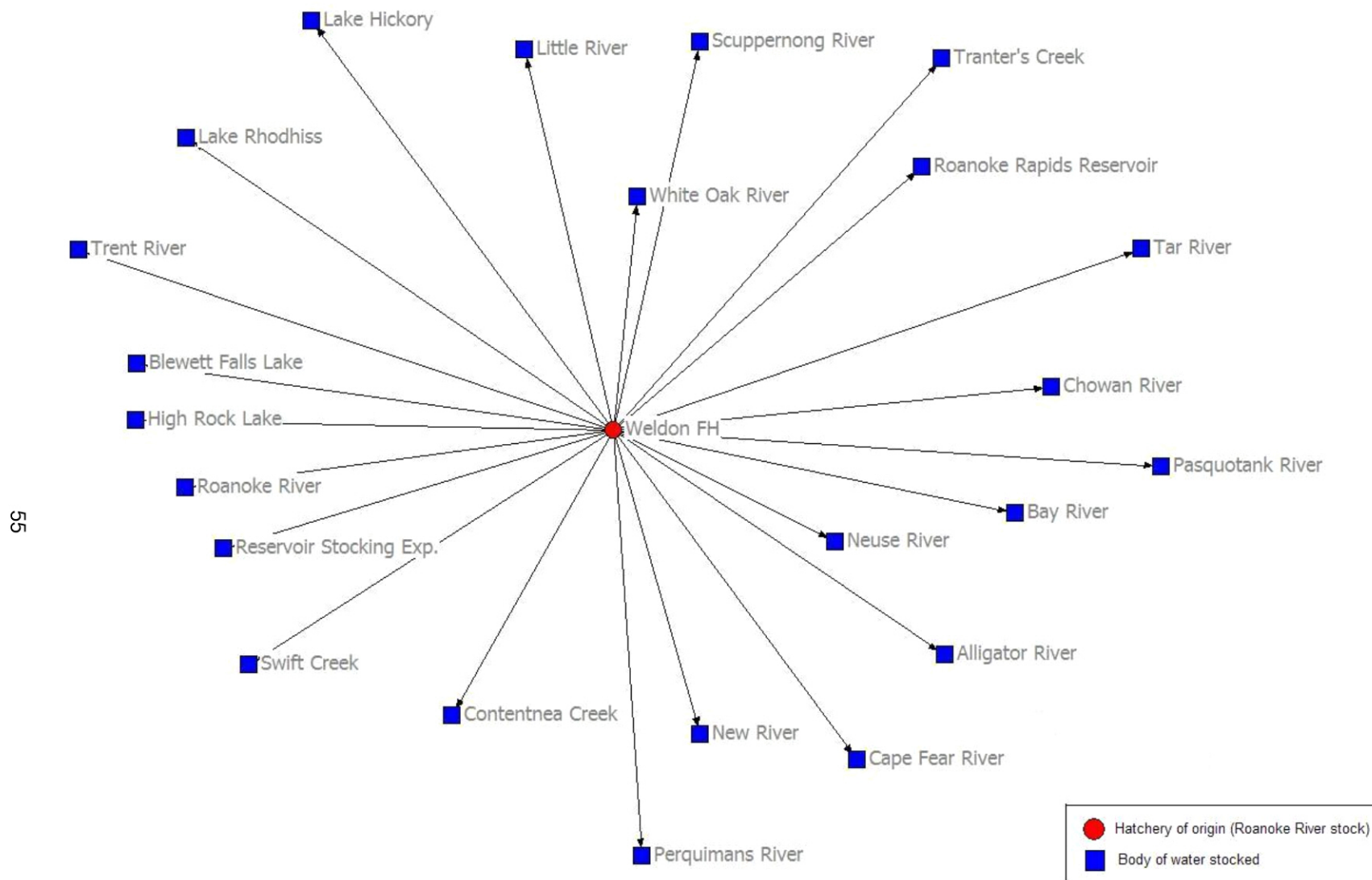


Figure 12. North Carolina striped bass stocking 1950-1959.

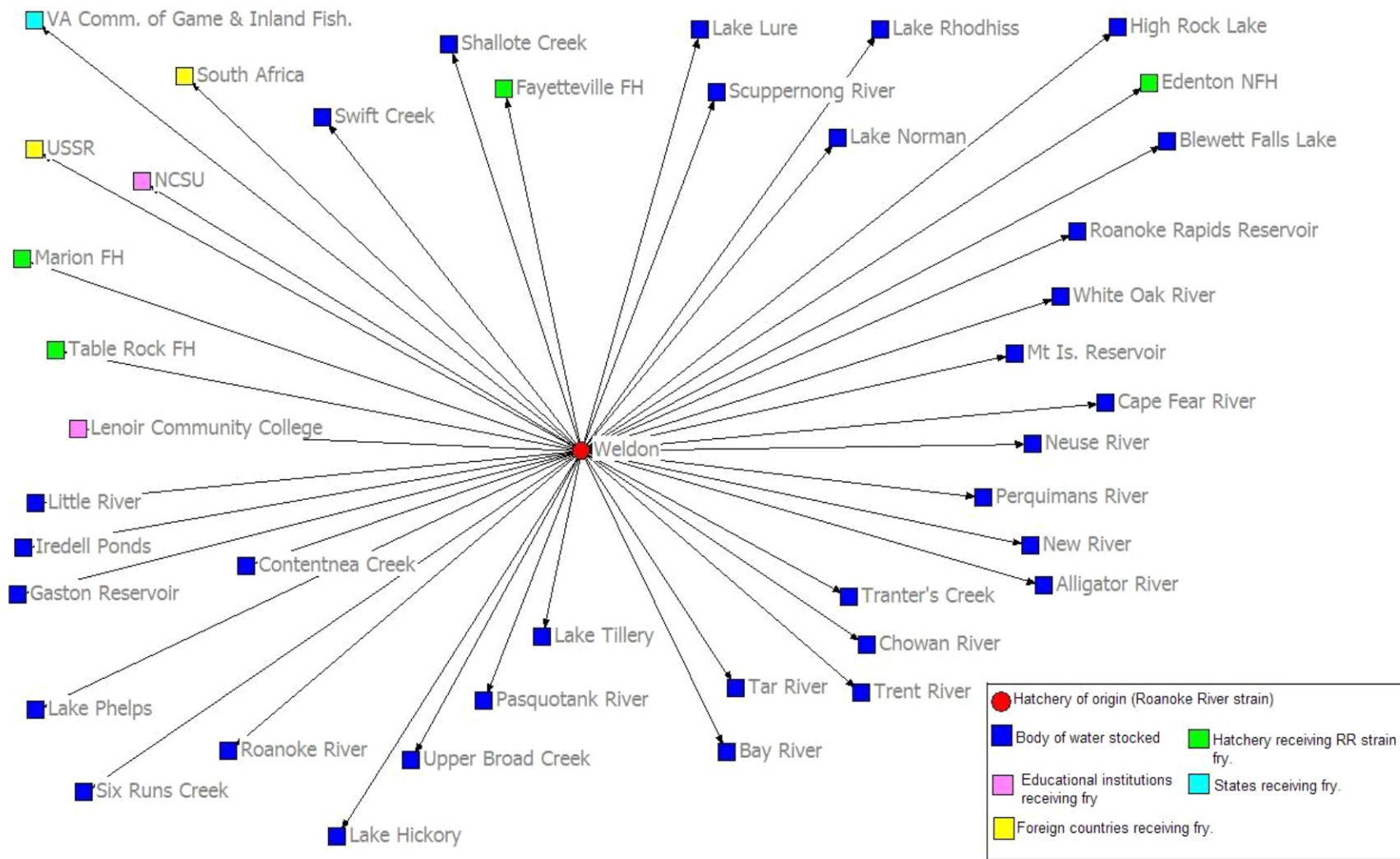


Figure 13. North Carolina striped bass stocking 1960-1969.

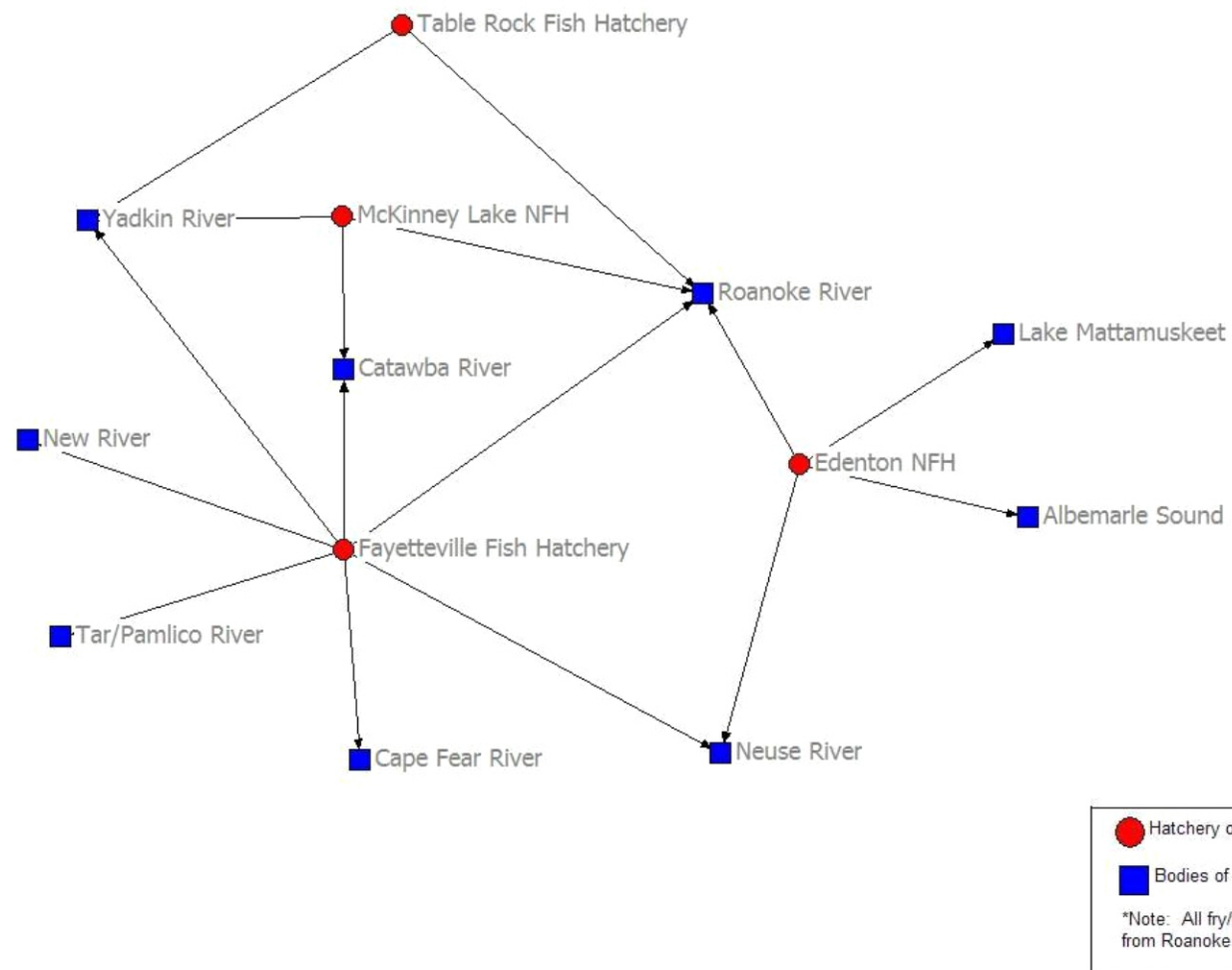


Figure 14. North Carolina striped bass stocking 1970-1979.

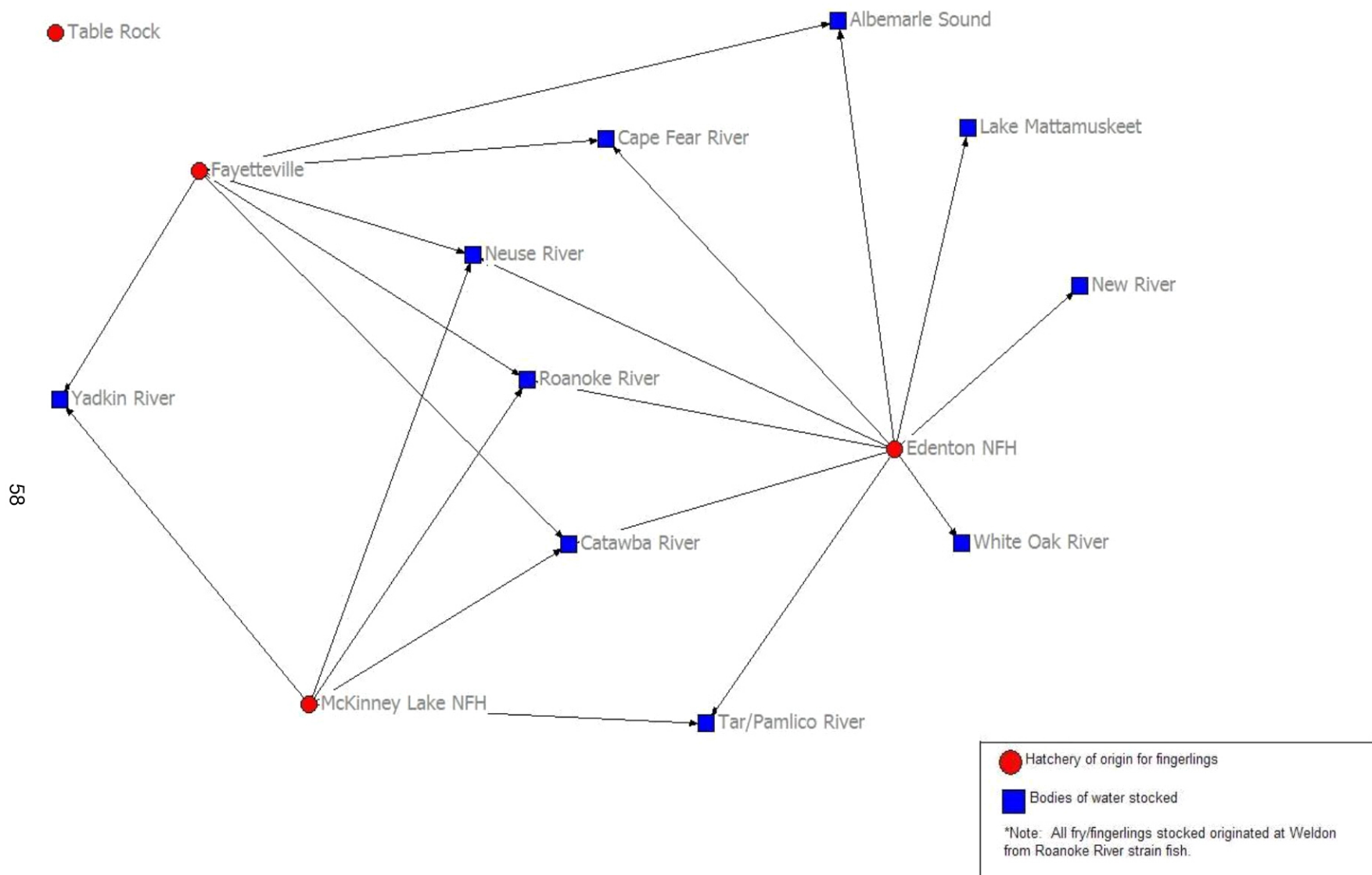


Figure 15. North Carolina striped bass stocking 1980-1989.

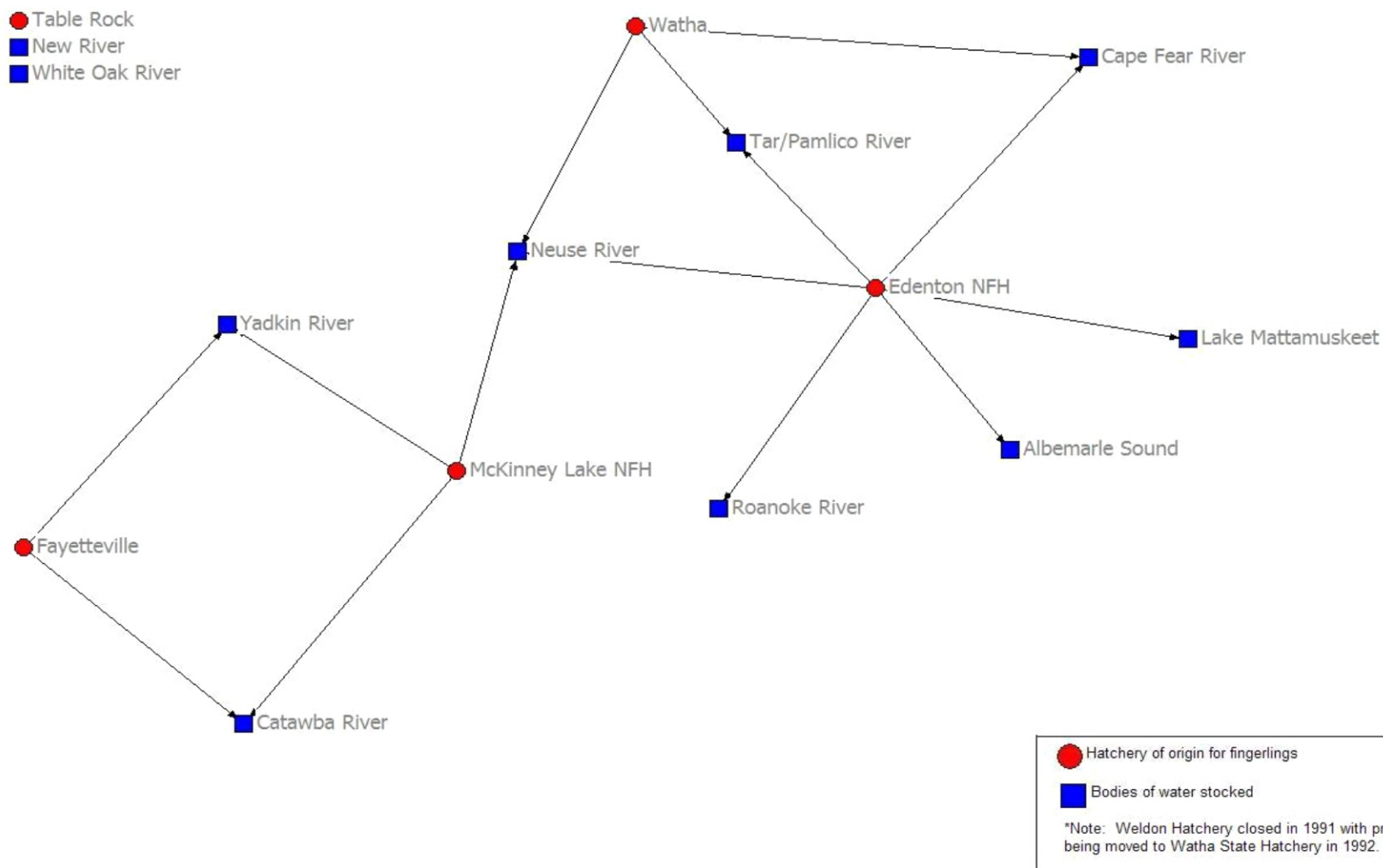


Figure 16. North Carolina striped bass stocking 1990-1999.

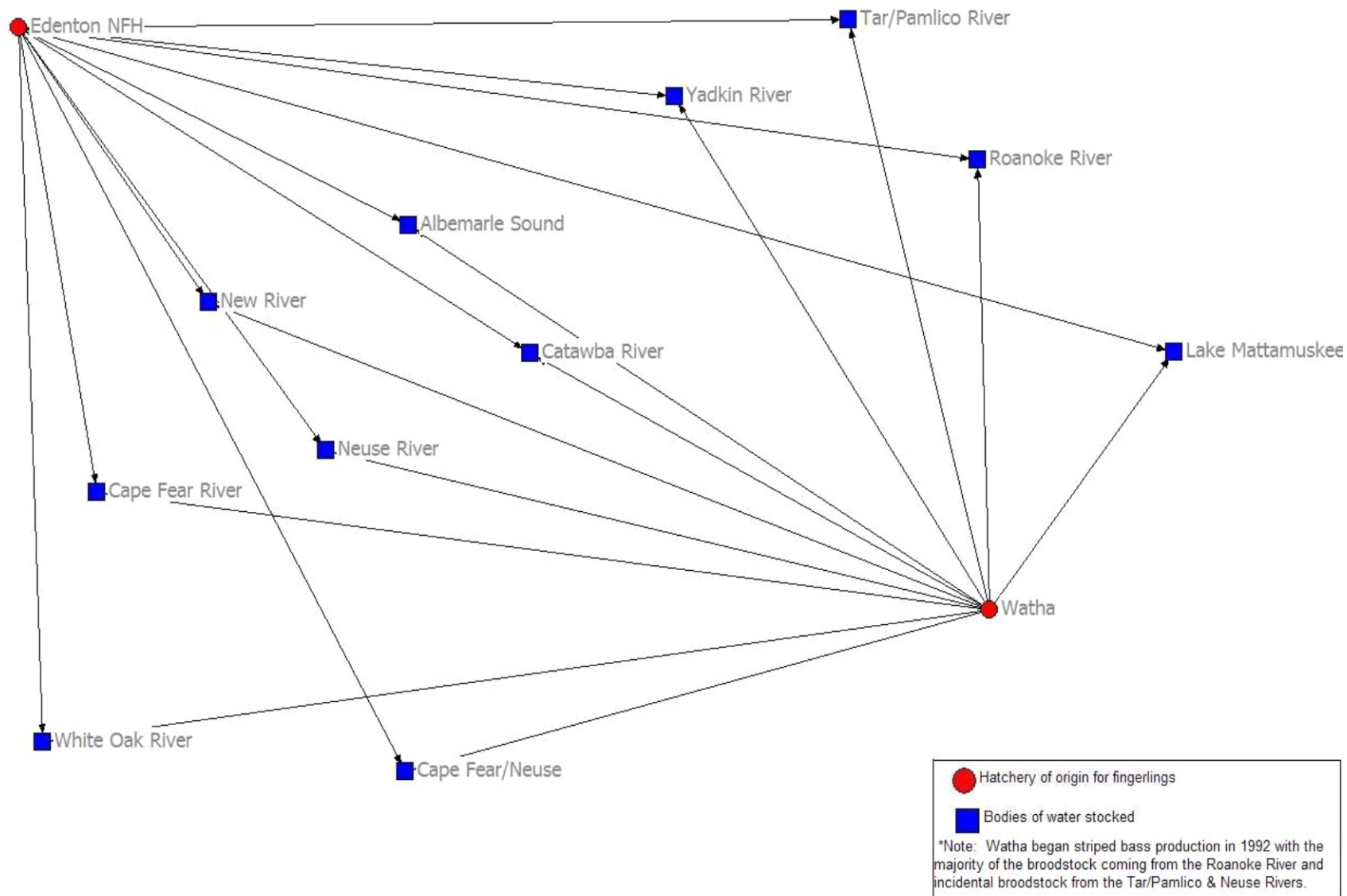


Figure 17. North Carolina striped bass stocking 2000-2007.

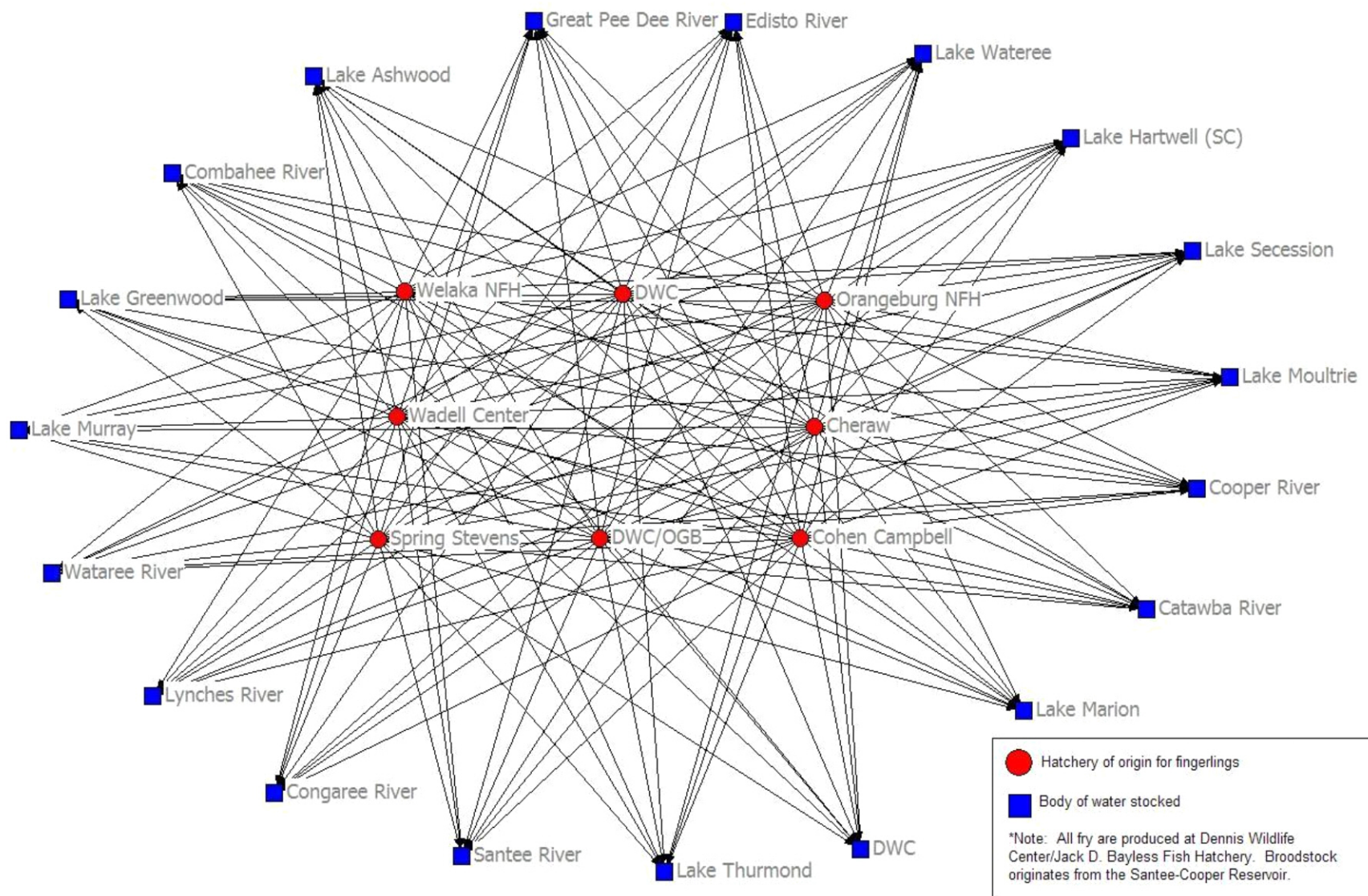


Figure 18. South Carolina striped bass stockings 1985-1989.

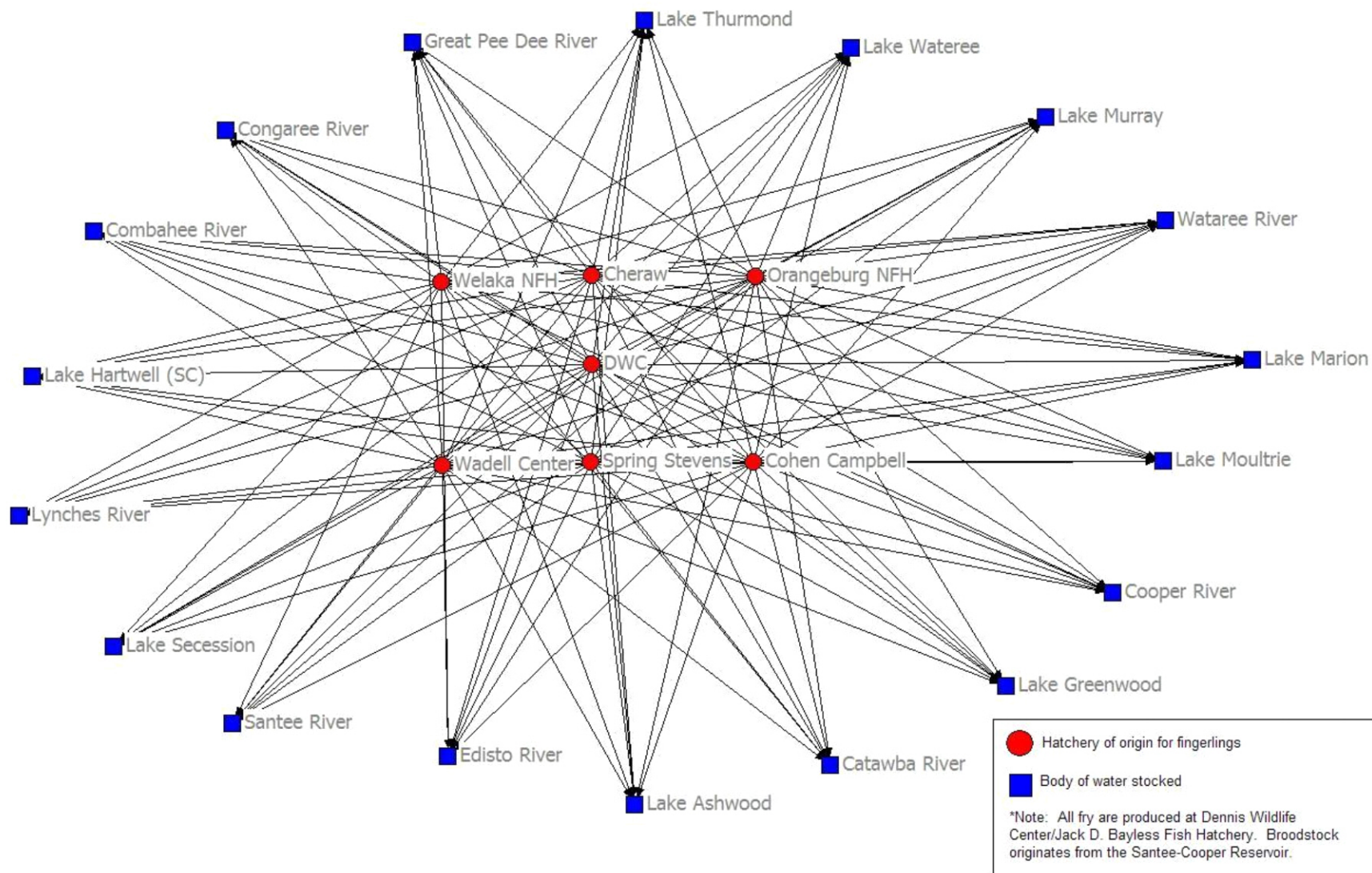


Figure 19. South Carolina striped bass stocking 1990-1999.

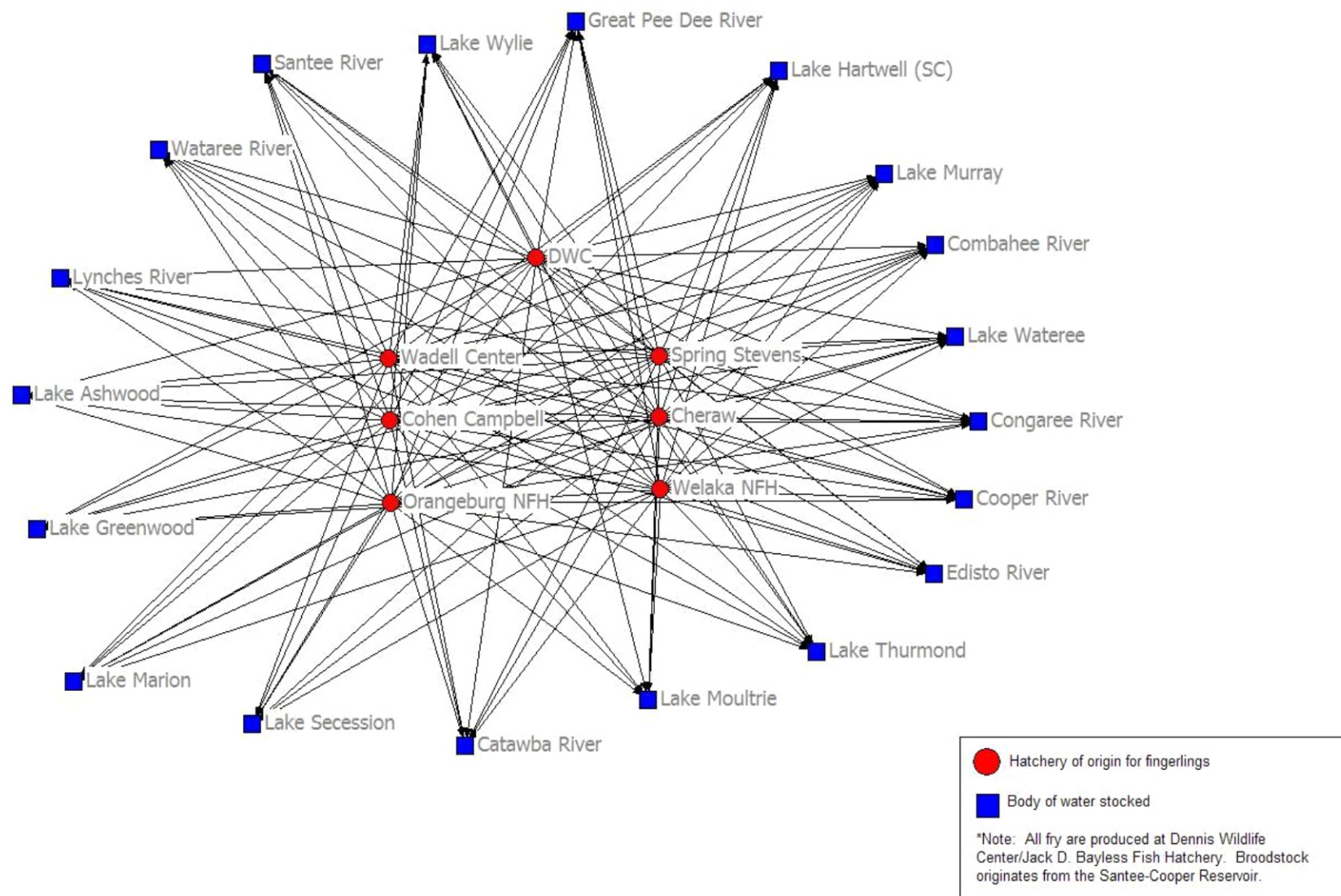


Figure 20. South Carolina striped bass stocking 2000-2008.

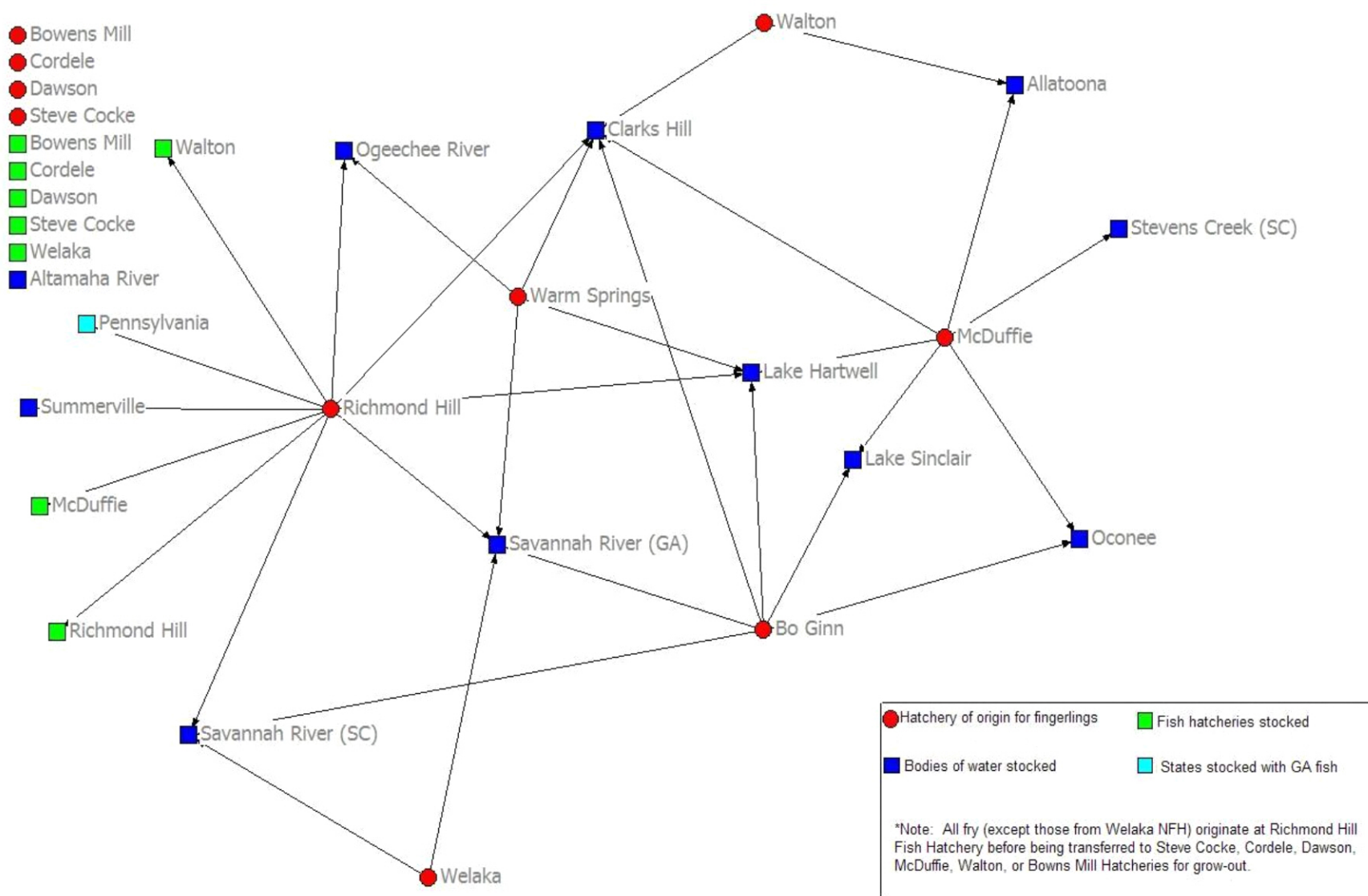


Figure 21. Georgia striped bass stocking 1986-1989.

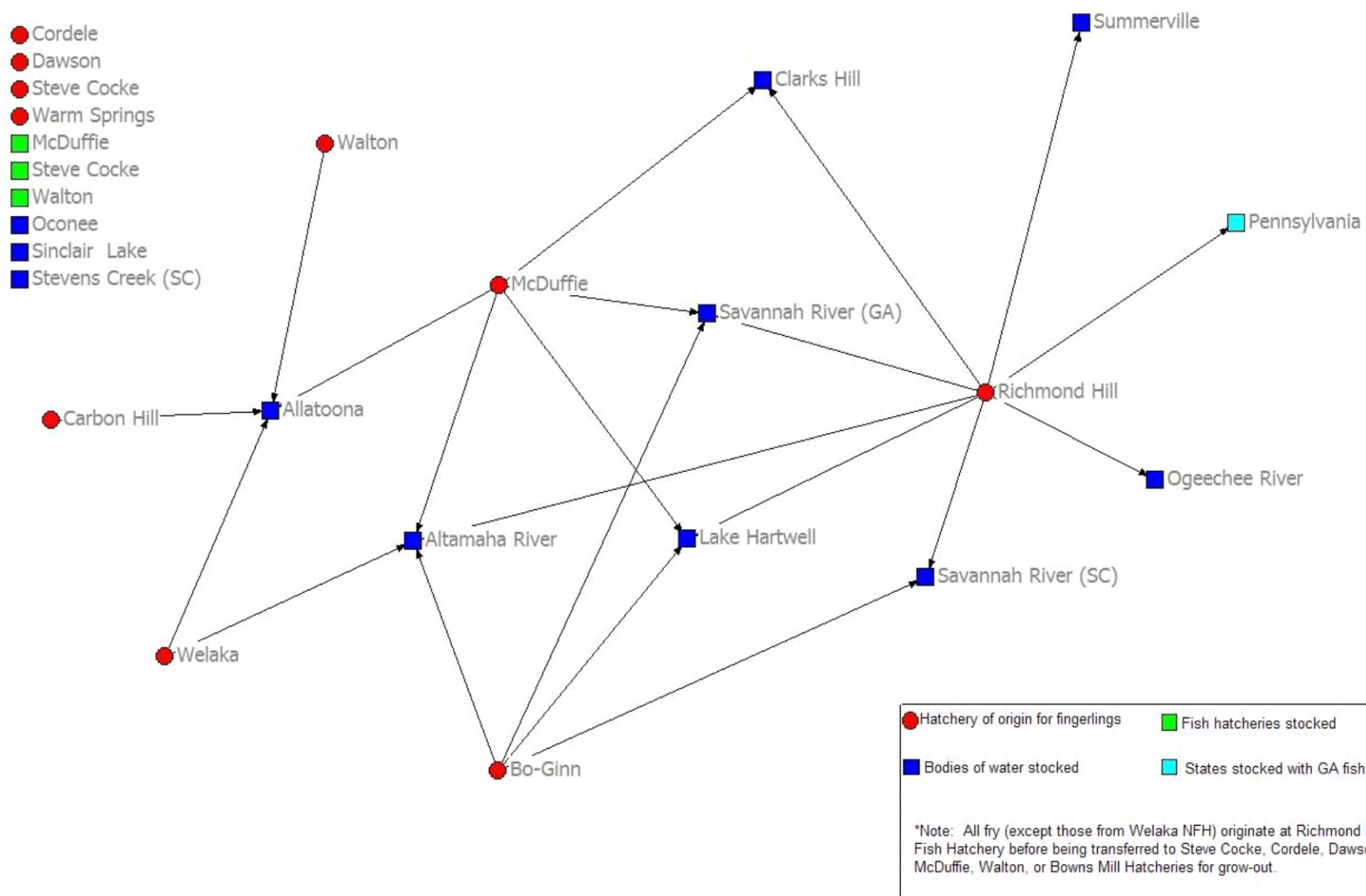


Figure 22. Georgia striped bass stocking 1990-1999.

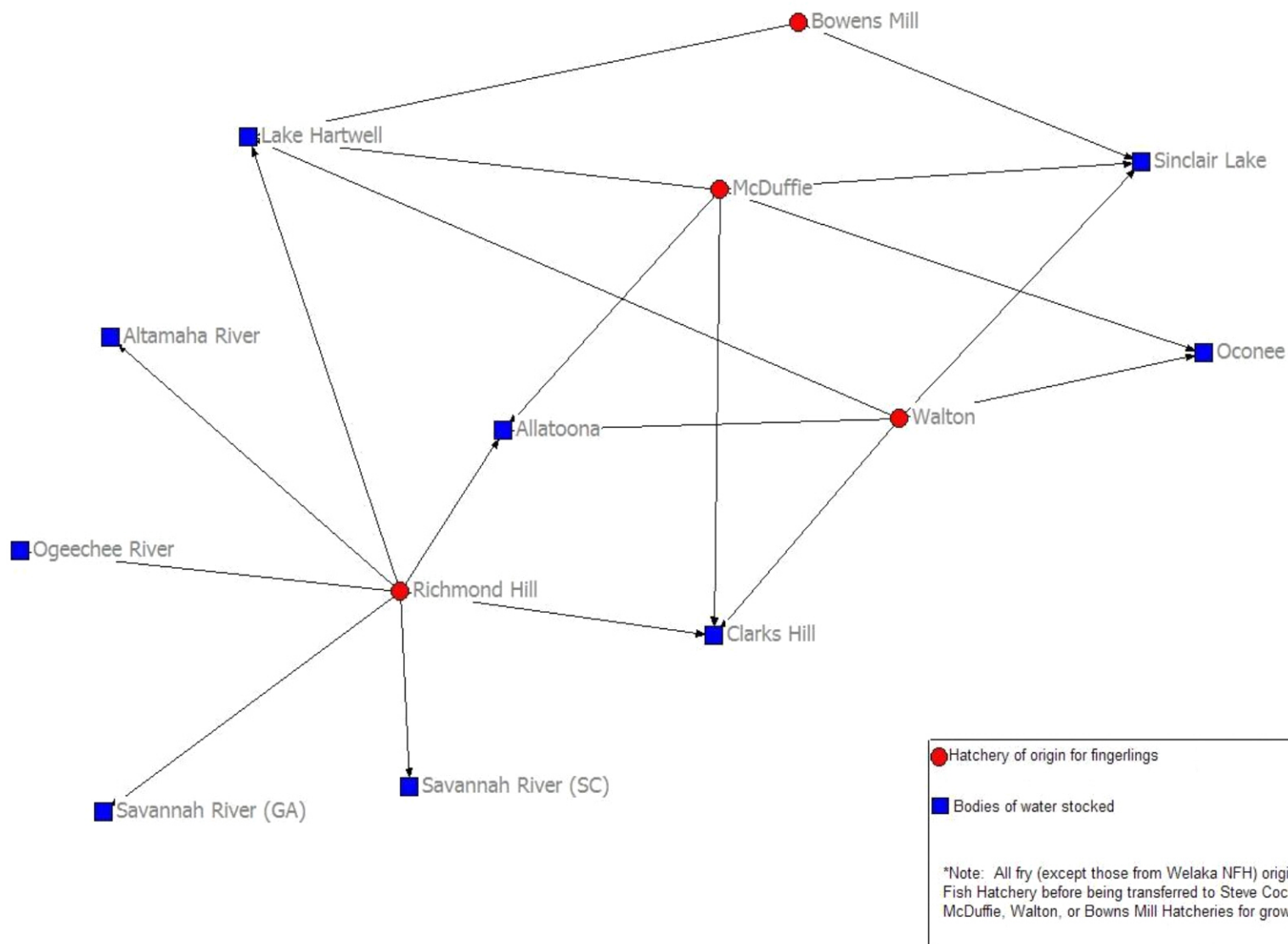


Figure 23. Georgia striped bass stocking 2000-2007.

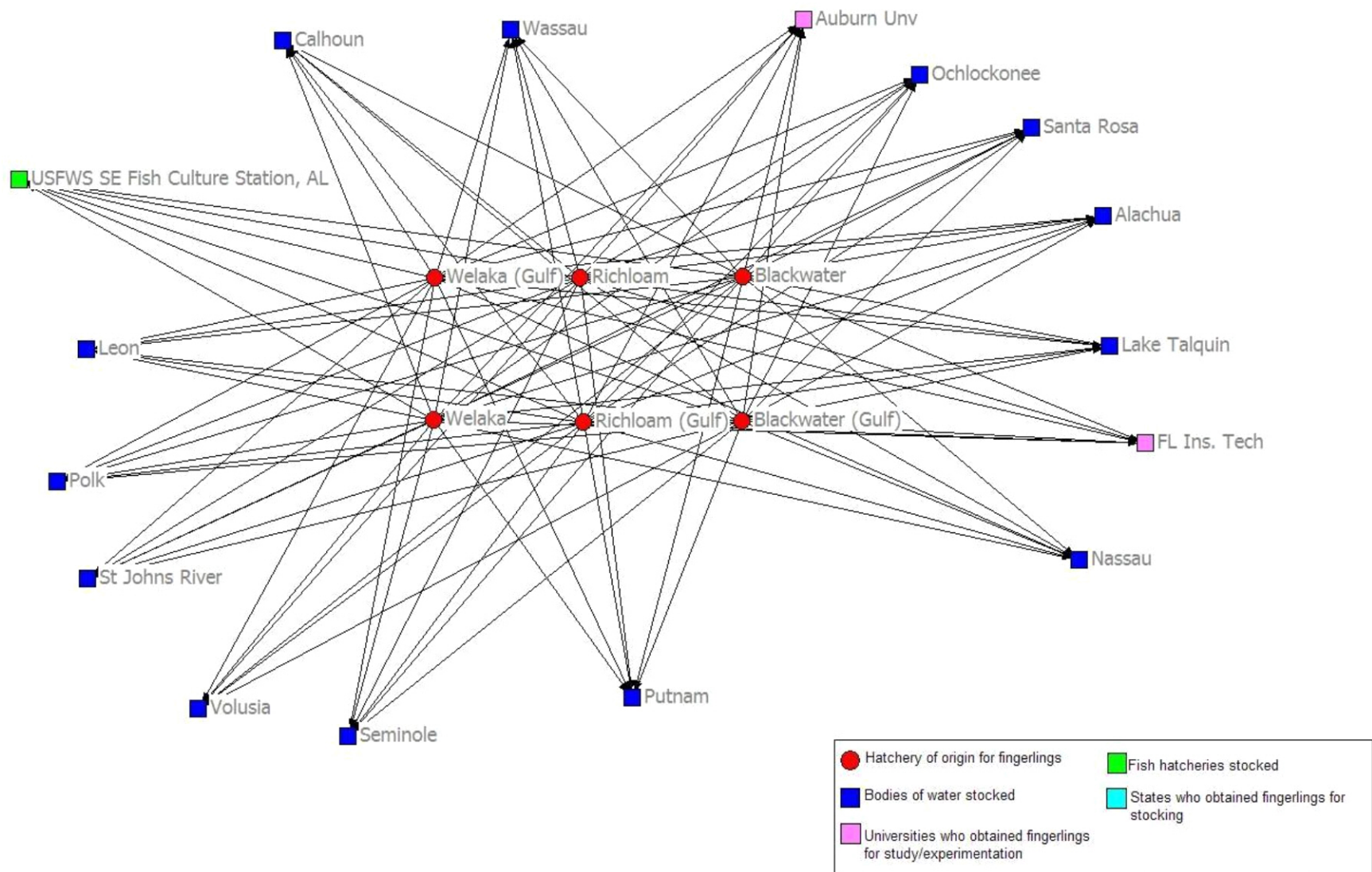


Figure 24. Florida striped bass stocking 1974-1979.

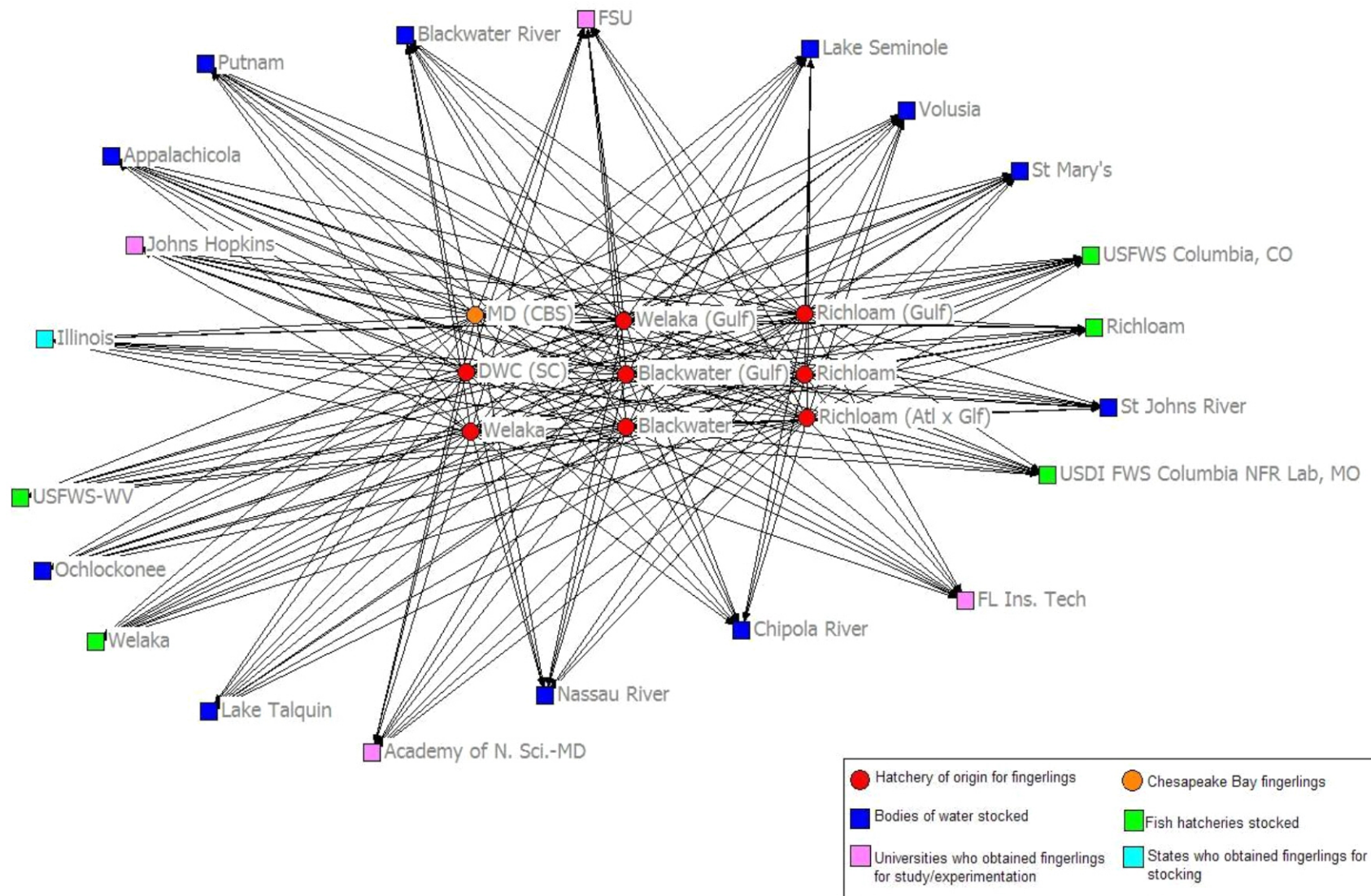


Figure 25. Florida striped bass stocking 1980-1989.

Figure 26. Florida striped bass stocking 1990-1999.

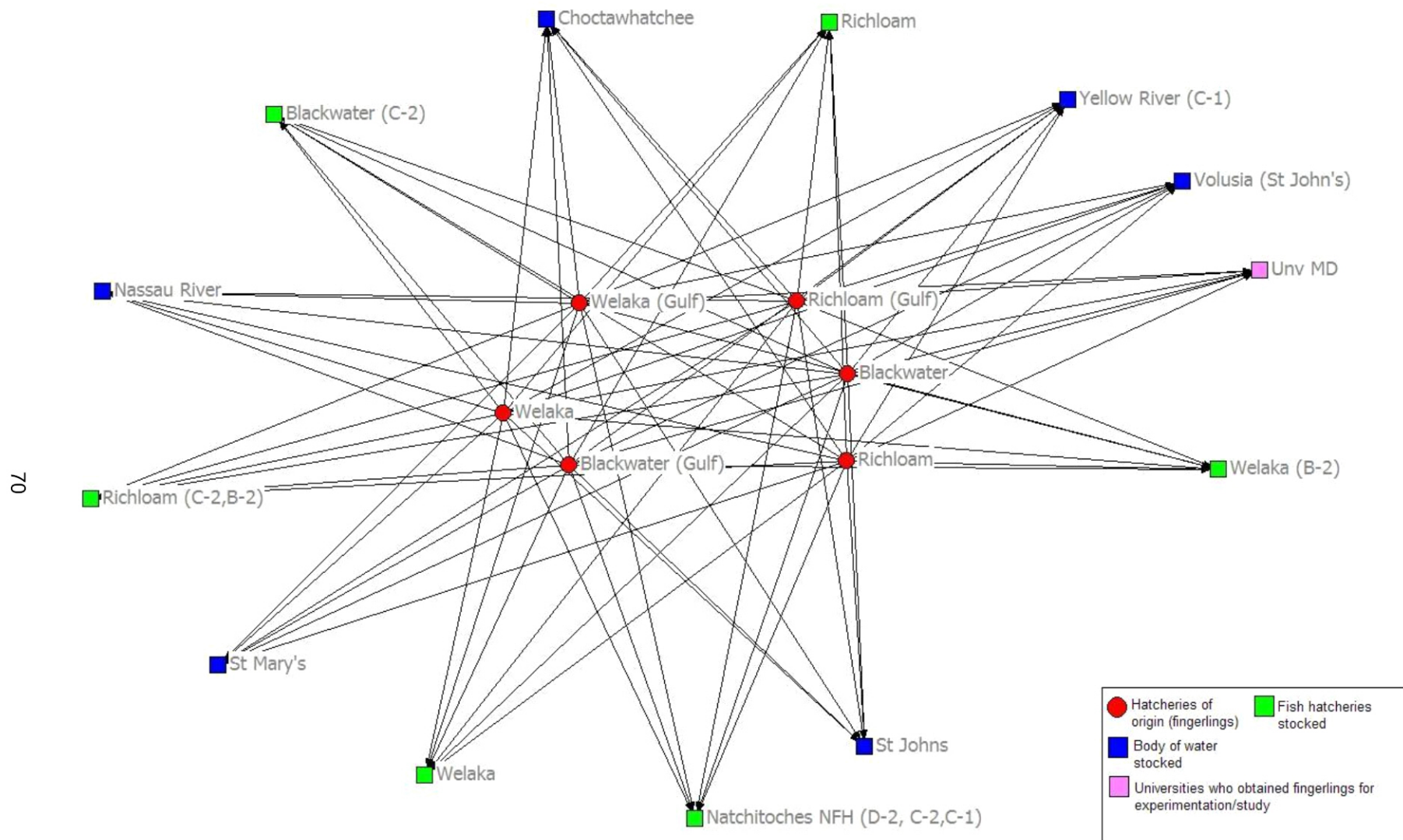


Figure 27. Florida striped bass stocking 2000-2006.

APPENDIX A. Permission Letters.

October 31, 2011

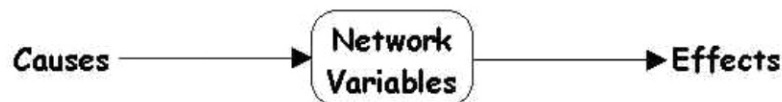
Stephen P. Borgatti, Ph.D.
Chellgren Endowed Chair and Professor
Department of Management
Gatton College of Business and Economics
University of Kentucky
Lexington, KY 40506

Dear Dr. Borgatti:

I am completing a master's thesis at East Carolina University entitled "Potential Genetic Implications of Striped Bass Stocking in the Southeastern United States." I would like your permission to reprint in my thesis excerpts from the following:

Borgatti, S.P. 1998. What is social network analysis? Source:
<http://www.analytictech.com/networks/whatis.htm>

The excerpts to be reproduced are:



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If these arrangements meet with your approval, please sign this letter where indicated below and return it to me. Thank you very much.

Sincerely,

Jennifer R. Woodroffe

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

Stephen P. Borgatti, Ph.D.

Date: 11/09/2011

----- Forwarded by Wilson Laney/R4/FWS/DOI on 11/29/2011 09:31 PM -----

Elliott Atstupenas

<e_atstupenas@yahoo.com>

To "Wilson_Laney@fws.gov"

<Wilson_Laney@fws.gov>

11/29/2011 11:36 AM

cc

Please respond to
Elliott Atstupenas

<e_atstupenas@yahoo.com>

Subject: Re: Permission to Reprint Edenton
NFH History

Wilson glad to hear your thanksgiving was fine so was ours, we all got together down in greenville at my daughters. I believe it was Jennifer who called me a couple of weeks ago and asked for permission which of course I gave and give again.

Elliott

From: "Wilson_Laney@fws.gov" <Wilson_Laney@fws.gov>

To: Elliott Atstupenas <e_atstupenas@yahoo.com>

Cc: Jennifer R Woodroffe <missentropy@suddenlink.net>; RulifsonR@ecu.edu

Sent: Monday, November 28, 2011 2:46 PM

Subject: Permission to Reprint Edenton NFH History

Hello Elliott:

I hope that you, Rita and all the family are doing well and had a great Thanksgiving. Gail's family were all at our house for dinner, along with Mom (who will celebrate birthday 90 December 14), and Matt.

I am writing on behalf of Jennifer Woodroffe, MS candidate at East Carolina University. She would like your permission to reprint the Edenton National Fish Hatchery history of which you had provided her a mimeographed copy. I believe that she intends to reproduce it as an appendix to her thesis.

Please advise us if that is okay with you. If you have any questions, give me a call.

/s/ Wilson

R. Wilson Laney, Ph.D., Coordinator
South Atlantic Fish and Wildlife Conservation Office
U.S. Fish and Wildlife Service
P.O. Box 33683
Raleigh, North Carolina 27636-3683
Voice: 919-515-5019
Cell: 252-339-5717
Fax: 919-515-4454
e-mail: Wilson_Laney@fws.gov

Appendix B. Virginia Stocking Records (Brookneal 1975-1979)

	Kerr Resvr	Roanoke River	Smith Mt. Lake	Front Royal	Buggs Island Lake	Bealer's Pond	Stevensville	Buller	Brookneal	Gaston Ponds	AR Fish & Game	AL
1975	403117	5371816	1652430	875000		900000	484500		3334000	2000000	1000000	
1976												
1977			300000	800000			630000		4215000	535000		1000000
1978				500000		500000	600000	750000	3683768			
1979	300000		2800000	1410000	300000	610000	800000	1285000	3335000			

Virginia Stocking Records (Brookneal 1975-1979) continued.

	Auburn Unv.	Harrison Lake NFH	IA Cons. Dept.	IL	KA Dept. of Cons.	KY Dept. of Cons	NE Game & Parks	OK Dept. of Cons	Staunton River	Gulf Coast Research Lab.	Carbon Hill NFH	Senacavill e NFH
	30000											
1975	0	500000	500000		1000000	2800000	2250000	2700000				
1976												
				20000								
1977	50000	700000	500000	0	2000000	2100000	1950000	1000000				
1978		500000			1000000		1000000					
	20000											
1979	0	500000	1000000		1000000	2000000	2000000		10438000	600000	300000	500000

Virginia Stocking Records (Brookneal 1975-1979) continued.

	Hebron NFH	Frankfort NFH	Edenton NFH	McKinney Lake NFH	Unv. of MD	VIMS	SC	Benedictine Estuarine Research Lab	Southeastern Fish Lab	Unv. of Nova Scotia	Johns Hopkins	MN
1975					19250							
1976												
1977							1000000		100000		63000	
1978								50000	100000	100000		800000
1979	500000	500000	1500000	300000		100000		60000				1200000

Virginia Stocking Records (Brookneal 1975-1979) continued.

	Chesapeake Biological Inst.	WV Dept. of Cons
1975		500000
1976		
1977	23000	500000
1978		
1979	45000	

Virginia Stocking Data (1975-1979).

	Lake Anna	Burton Lake	Carsbrook Pond	Chesdin Lake	Claytor Lake	Smith Mountain Reservoir	Kerr Reservoir	Smith Lake	Leesville Lake	Maury Lake	Trashmore Lake
Buller		6400			71069	160495					
Brookneal	198998				119246	1324415	65073				
Front Royal	479472		6000		139538	108662					
Stevensville	112667					64200	120000	32123	53500	18326	5000
USFWS	341750			46000		634060	73431		25000		
Other Sources											

Virginia Stocking Data (1975-1979) continued.

	Appomatto x River	Chickahomi ny River	Mattapo ni River	James River	Lake Prince	Carvins Cove Lake	Lake Mead	Emporia Resvr	Occoqua n Resvr	Harwoo d Mill Pond	Western Branch Resvr
Buller						6740					
Brookneal				51390							
Front Royal	74384			23814		9597	5000		142873		
Stevensville		180969	8000	108142	109021		54483	5000		6100	106000
USFWS	32000			78000	28712		58748				72312
Other Sources											

Virginia Stocking Data (1975-1979) continued.

	Gaston Reservoir	VPI	Whitehur st Lake	Roano ke River
Buller				
Brookneal	414763	4940		3200
Front Royal			23000	
Stevensville	124973		71718	
USFWS	62000			
Other Sources				

Virginia Stocking Data (Brookneal 1980-1989).

	Kerr Reservoir	Roanoke River	Front Royal	Stevensville /K & Q	Buller	Brookneal	Marion FH, AL	Harriso n Lake NFH	KA Dept. of Cons.	KY Dept. of Cons	NUS Corp., Pittsburgh , PA
1980			875000	11750000	800000	2600000	1000000	500000	2000000	3600000	78000
1981											
1982			40000	300000		1800000		500000	1250000	3700000	
1983	9400000		240000	150000		1200000		200000 115000	1000000	3000000	
1984		1650000	250000	300000		1250000		0	300000	1000000	
1985	4200000	1600000				2075000			500000	2000000	
1986		4100000	150000			2250000			1000000	1950000	
1987		250000	400000	500000		2250000			1300000	2700000	
								112500			
1988	3250000	400000	400000			2275000		0	2500000	1000000	
1989	3200000	1000000		600000		2400000		85000*	1400000	2400000	

Virginia Stocking Data (Brookneal 1980-1989) continued.

	Staunton River	Gulf Coast Research Lab.	Carbon Hill NFH	Senacaville NFH	Metchintochs NFH	Frankfort NFH	Edenton NFH	McKinney Lake NFH	Unv. of MD	VIMS	SC
1980	12626433	500000	1250000	1000000	1000000		1600000	500000		14000	
1981											
1982	16865000	500000	3000000				1800000	1500000			
1983	2950000		1500000	500000				1500000			
1984			1300000			500000	2000000	1600000	4000		500000
1985			2000000			500000	600000	1200000	55000		
1986			1600000	500000				950000		10000	
1987			700000						50000	5000	
1988							600000			8000	
1989											

Virginia Stocking Data (Brookneal 1980-1989) continued.

	Benedictine Estuarine Research Lab	NYU Med Ctr	Johns Hopkins	MN	Columbia NF Research Lab	Millen NFH	NCSU	Natchitochs NFH	Biological Monitoring, Inc.	Towsen Unv.	Orangeburg NFH
1980	390000	20000	20000	1000000							
1981											
1982			10000	2000000	100000	1500000	20000	2000000			
1983			200000		200000						
1984			100000		100000	1700000	30000		123000	75000	2000000
1985					100000	1000000					
1986					30000						
1987					50000						
1988						800000					
1989						1500000					

	Warm Springs NFH	Unv. of RI	James River	IN	MD	National Fisheries Center, WV	National Marine Fisheries , NC	Meridian NFH	Welaka NFH	CO	NC
1980											
1981											
1982											
1983											
1984	1000000	3000	3000000								
1985	500000	3000		500000	50000	900000	15000				
1986				500000				1000000			
1987				550000					700000		
1988	400000			1000000				1000000	1500000	100000	100000
1989				850000		140000		1000000	4500000	200000	

Virginia Stocking Data (1980-1989).

[illegible]

Virginia Stocking Data (1980-1989) continued.

	Appomattox River	Chickahominy River	Mattaponi River	James River	Lake Prince	Carvins Cove Lake	Lake Mead	Occoquan Reservoir	Western Branch Resvr	Gaston Resvr	Holiday Lake
Buller						630					
Brookneal	75038	47786		222209	126836		81954		232968	418585	
Front Royal				445368	33600			94250	56832		
Stevensville			3000	498	7566		4800		32650		5650
USFWS	23760	126250		363210	19425		29930		254307	241379	
Other Sources											

Virginia Stocking Data (1980-1989) continued.

	Roanoke River	Johns Hopkins	Harrison Lake NFH	Staunton River	Stevensville/ K & Q	Front Royal	Brookneal	Walker-Colman Hatchery (Exp.)
Buller								
Brookneal	705168		235000	1690000	800000	390000	2075000	1302
Front Royal		5000						
Stevensville			502700		1488			
USFWS								
Other Sources			1125000					

Virginia Stocking Data (Brookneal 1990-1999).

	Kerr Resvr	Roanoke River	Front Royal	Stevensville /K & Q	Buller	Brookneal	Lake Gaston	MO	USFWS- Philadelphi a, PA	USFW S Leetow n, WV	OH	McKinne y Lake NFH
1990	5800000	826000	200000			2300000		750000	50000	500000		
1991		1600000				2500000						
1992											99611	
1993					155000	2300000	6275000				200000	1000000
1994												
1995												
1996												
1997		650000	490000	450000	160000	2375000					300000	
1998												
1999												

Virginia Stocking Data (Brookneal 1990-1999) continued.

	Edenton NFH	Neosho NFH, MO	PA	Kansas Dept of Cons.	Kentucky Dept of Cons	VPI & SU	NC	VA State	Carbon Hill NFH	VIMS	Indiana	National Fisheries Center, WV
1990				2000000	1750000	60000			1800000		500000	500000
1991				2000000		60000				50000		
1992				79835								
1993	750000	200000	200000	1600000	1100000					15000		
1994			9976									
1995			96105									
1996	400000						200000	25000				
1997	100135		241868				160984					
1998												
1999												

Virginia Stocking Data (Brookneal 1990-1999) continued.

	Welaka NFH	CO
1990	3000000	
1991		100000
1992		
1993		
1994		
1995		
1996		
1997		
1998		
1999		

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Virginia Stocking Data (1990-1999).

	Lake Anna	Beaverdam	Burton Lake	Carsbrook Pond	Chesdin Lake	Claytor Lake	Smith Mountain Reservoir	Kerr Reservoir	Lee Hall Reservoir	Leesville Lake	Maury Lake
Buller							200				
Brookneal	936009	4900			340183	300744	1684007	6289797		139031	9013
Front Royal		17437					58610				
Stevensville							23895				
K & Q (CB)	596124				157194				609137		4125
USFWS											
Other											
Sources					11221		198675				

Virginia Stocking Data (1990-1999) continued.

	Waller Mill Reservoir	Trashmore Lake	VA Tech	VA State	Pamunkey River	Mattaponi River	James River	Lake Prince	Carvins Cove Lake	Lake Mead	Emporia Reservoir
Buller											
Brookneal	19103	3106	210511	13886				74307	19996	33311	
Front Royal											
Stevensville		1283									
K & Q (CB)	36131	2785			950000	2000000		52994		70147	
USFWS											
Other											
Sources								5145			

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Virginia Stocking Data (1990-1999) continued.

	Occoquan Resvr	Genoa	McKinney Lake NFH	Edento n NFH	Harwood Mill Pond	Harrison Lake NFH	Western Branch Resvr	Gaston Reservo ir	VPI	Whitehur st Lake	Roan oke River	VIMS
Buller												
Brookneal							205790	654047 0	14000 0	16352	2426 000	
Front Royal												
Stevensville												
K & Q (CB)		2000000	5750000	100000 0		592000 0	84230					1800 0
USFWS												
Other Sources							4900					

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Virginia Stocking Data (2000-2008) continued.[illegible]

Appendix C. Egg production at the Weldon Hatchery 1937-1972.

Year	Eggs Taken	Eggs Hatched	
1937	1160000	641000	
1938	646000	515000	
1939	3413000	1798000	
1940	807500	5917000	
1941	635000	469000	
1942	0	0	
1943	2515000	1563000	
1944	11168000	7618000	
1945	465000	279000	
1946	6392000	3517000	
1947	11225000	7756000	
1948	2990000	1681000	
1949	6625000	28686500	
1950	2532000	1668000	
1951	5650000	3689000	
1952	10255000	7016000	
1953	16935000	10763000	
1954	33187000	22113000	
1955	22303000	16334000	
1956	4005000	2300000	
1957	16644000	8356000	
1958	1730000	1118000	
1959	13630000	5891000	
1960	15756000	4475000	
1961	10984000	4282000	
1962	10275000	6445000	
1963	10100000	4881000	
1964	9084000	6136000	
1965	22403000	14227000	
1966	20292000	11605000	
1967	35526000	13136000	
1968	49544000	24396000	5510000 eggs stocked
1969	102385000	2512000	55000000 eggs stocked
1970	23090000	13109500	
1971	25195000	3330998	
1972	14145000	6057000	

Appendix D. North Carolina Stocking Data (Weldon 1950-1959).

	Alligator River	Bay River	Cape Fear River	Chowan River	Contentne a Creek	Little River	Neuse River	New River	Pasquotank River	Perquimans River	Roanoke River	Scuppernon River
1950	0	0	0	0	0	0	0	0	0	0	1500000	0
1951	0	0	0	0	0	0	84000	0	0	0	0	0
1952	0	0	0	0	0	0	100000	0	0	0	0	0
1953	450000	200000	394000	400000	249000	350000	888000	431000	350000	350000	3679000	450000
1954	0	0	0	0	0	0	690000	0	0	0	0	0
1955	0	0	0	0	0	0	330000	0	0	0	0	0
1956	0	0	0	0	0	0	305000	0	0	0	0	0
1957	0	0	0	0	0	0	270000	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	400000	0
1959	100000	0	300000	105000	75000	100000	260000	103000	100000	100000	1062000	100000

North Carolina Stocking Data (Weldon 1950-1959) continued.

	Swift Creek	Tar River	Tranter's Creek	Trent River	White Oak River	Reservoir Stocking Exp.	Roanoke Rapids Reservoir	Blewett Falls Lake	High Rock Lake	Lake Hickory	Lake Rhodhiss	Lookout Shoals
1950	0	160000	0	0	0	0	0	0	0	0	0	0
1951	0	241000	0	0	0	0	0	0	0	0	0	0
1952	0	725000	0	0	0	0	0	0	0	0	0	0
1953	248000	507000	507000	431000	432000	670000	0	0	0	25000	0	0
1954	0	760000	0	0	0	0	0	0	0	150000	0	0
1955	0	1624000	0	0	0	0	0	0	0	0	0	0
1956	0	630000	0	0	0	0	0	0	0	0	0	0
1957	0	410000	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	105000	475000	165000	98000	98000	0	1000000	1000000	250000	350000	60000	0

North Carolina Stocking Data (Weldon) 1960-1969.

	Alligator River	Cape Fear River	Chowa n River	Contentne a Creek	Little River	Neuse River	New River	Pasquotank River	Perquima ns River	Roanok e River	Scuppern ong River	Shallotte Creek
1960		100000				50000	34000			464000		
1961	175000	350000	175000	90000	175000	90000	114000	175000	175000	350000	175000	
1962	225000	480000	225000	120000	225000	720000	160000	225000	275000	1835000	225000	
1963												
1964												
1965	150000	600000	150000	75000	150000	300000	100000	150000	150000	300000	150000	
1966	200000	800000	200000	100000	200000	400000	133000	200000	200000	400000	200000	
		149400										
1967	296000	0	297000	200000	296000	709000	77000	296000	296000	2713000	296000	
		647500				130800						
1968	825100	0	825100	533000	825100	0	255000	825100	825100	1649000	825100	
		480100				102460						
1969	309900	0	309800	1024600	309800	0	141500	309800	309900	2718000	309800	85000

North Carolina Stocking Data (Weldon) 1960-1969 continued.

	Six Runs Creek	Swift Creek	Tar River	Tranter's Creek	Trent River	Upper Broad Creek	White Oak River	Roanoke Rapids Reservoir	Blewett Falls Lake	High Rock Lake	Lake Rhodhiss	Lake Tillery
1960		25000	50000	50000	33000		33000		950000	1250000		
1961		85000	635000	175000	118000	85000	118000					
1962		120000	840000	240000	160000	120000	160000					
1963												
1964												
1965		750000	1350000	150000	100000		100000					943000
1966		100000	400000	200000	133000	152000	150000					1000000
1967		200000	810000	300000	200000	152000	200000					
1968		533000	1750000	700000	533000	360000	383000			136800	152300	
1969	350000	1024600	2130000	187000	124600	82500	124600	110000		158000	158000	

North Carolina Stocking Data (Weldon) 1960-1969 continued.

	Lake Norman	Gaston Reservoir	Mt Island Reservoir	Lake Lure	Lake Phelps	Iredell Ponds	Edenton NFH	Fayetteville FH	Marion FH	Table Rock FH	Lenoir Community College	NCSU
1960							30000	600000		500000		
1961				10000			60000	20000				
1962							60000					
1963												
1964												
1965		1000000	1950000				60000	5000000				
1966			1000000			20000	60000	5000000				
1967				3593000		76000		210000		394000		
1968	1000000				2000000	50000		600000		750000		
1969	2000000				1000000	50000		1100000	200000	250000	260000	145000

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North Carolina Stocking Data (Weldon) 1960-1969 continued.

	VA Comm. of Game & Inland Fish.	USSR	South Africa
1960			
1961			
1962	30000		
1963			
1964			
1965		50000	100000
1966		50000	100000
1967		10000	10000
1968		10000	10000
1969		50000	

North Carolina Stocking Data 1970-1979.

	Albemarle Sound	Catawba River	Cape Fear River	Lake Mattamuskeet	Neuse River	New River	Roanoke River	Tar/Pamlico River	Yadkin River
Edenton NFH	102371	0	0	72508	93480	0	55336	0	0
Fayetteville	0	276131	3000	0	129432	25400	106931	167485	572879
McKinney Lake NFH	0	278400	0	0	0	0	177000	0	525400
Table Rock	0	0	0	0	0	0		0	92979

North Carolina Stocking Data 1980-1989.

	Albemarle Sound	Cape Fear River	Catawba River	Lake Mattamuskeet	Neuse River	New River	Roanoke River	Tar/Pamlico River	White Oak River	Yadkin River
Edenton NFH	1384833	424244	252553	179887	512417	146011	149053	184897	71932	0
Fayetteville	23463	12410	25992	0	7600	0	264039	0	0	76903
McKinney Lake NFH	0	0	1589669	0	123000	0	354000	28000	0	1540610
Table Rock	0	0	0	0	0	0	0	0	0	0

North Carolina Stocking Data 1990-1999.

	Albemarle Sound	Cape Fear River	Catawba River	Lake Mattamuskeet	Neuse River	New River	Roanoke River	Tar/Pamlico River	White Oak River	Yadkin River
Edenton NFH	9466	169792	0	22964	54411	0	315013	127635	0	0
Fayetteville	0	0	152853	0	0	0	0	0	0	30670
McKinney Lake NFH	0	0	141750	0	127933	0	0	0	0	130000
Table Rock	0	0	0	0	0	0	0	0	0	0
Watha	0	231212	0	0	509963	0	0	2722233	0	0

North Carolina Stocking Data 2000-2007.

	Albemarle Sound	Cape Fear River	Cape Fear/Neuse	Catawba River	Lake Mattamuskeet	Neuse River	New River	Roanoke River	Tar/Pamlico River	White Oak River	Yadkin River
Edenton NFH						103000			206786		
Watha		1594796	1699434			775272			737258		

Appendix E. South Carolina Stocking Records (1985-1989).

	Catawba River	Combahee River	Congaree River	Cooper River	DWC	Edisto River	Great Pee Dee River	Lake Ashwood	Lake Greenwood	Lake Hartwell (SC)	Lake Marion
Cheraw											
Cohen Campbell											
DWC	40000	20538		381049	185827	118300			1053772	66470	800556
Orangeburg NFH											
Spring Stevens											
Wadell Center											
Welaka NFH		160000									

South Carolina Stocking Records (1985-1989) continued.

	Lake Moultrie	Lake Murray	Lake Secession	Lake Thurmond	Lake Wateree	Lynches River	Santee River	Wateree River
Cheraw								
Cohen Campbell								
DWC	5856465	4311047	62500				488848	605155
Orangeburg NFH	281673							
Spring Stevens								
Wadell Center								
Welaka NFH								

South Carolina Stocking Data (1990-1999).

	Catawba River	Combahee River	Congaree River	Cooper River	Edisto River	Great Pee Dee River	Lake Ashwood	Lake Greenwood	Lake Hartwell (SC)	Lake Marion
Cheraw Cohen Campbell DWC Orangeburg NFH Spring Stevens Wadell Center Welaka NFH	138060	10000		2340598	40404	94611	2048	751926	3160737	4914792

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South Carolina Stocking Data (1990-1999) continued.

	Lake Moultrie	Lake Murray	Lake Secession	Lake Thurmond	Lake Wateree	Lynches River	Santee River	Wateree River
Cheraw Cohen Campbell DWC Orangeburg NFH Spring Stevens Wadell Center Welaka NFH	17483143	9924870	97497	3939469	1773245	46000	2128721	222900

South Carolina Stocking Data (2000-2007).

	Catawba River	Combah ee River	Congare e River	Cooper River	Edisto River	Great Pee Dee River	Lake Ashwood	Lake Greenwood	Lake Hartwell (SC)	Lake Marion	Lake Moultrie
Cheraw										125000	259100
Cohen											
Campbell										85000	160000
DWC	56983			669533					3900352	2152836	171485
Orangeburg NFH				494000						238300	68
Spring											
Stevens	10000										
Wadell Center											
Welaka NFH										107086	43000

South Carolina Stocking Data (2000-2007) continued.

	Lake Murray	Lake Secession	Lake Thurmond	Lake Wateree	Lake Wylie	Lynches River	Santee River	Wataree River
Cheraw	31200			53020				
Cohen Campbell	228101							
DWC	1624712		4023839	1754009	48578		104816	43578
Orangeburg NFH	1366824							
Spring Stevens	120067							
Wadell Center	29040							
Welaka NFH							55550	

Appendix F. Georgia Stocking Data (1986-1989).

	Bowens Mill	Cordele	Dawson	McDuffie	Richmond Hill	Summerville	Steve Cocke	Walton	Welaka	Allatoona	Altamaha River
Richmond Hill	0	0	0	3685371	3109780	26096	0	306127	0	0	0
Bo Ginn NFH	0	0	0	0	0	0	0	0	0	0	0
Bowens Mill	0	0	0	0	0	0	0	0	0	0	0
Cordele	0	0	0	0	0	0	0	0	0	0	0
McDuffie	0	0	0	0	0	0	0	0	0	172771	0
Steve Cocke	0	0	0	0	0	0	0	0	0	0	0
Walton	0	0	0	0	0	0	0	0	0	16000	0
Warm Springs NFH	0	0	0	0	0	0	0	0	0	0	0
Welaka NFH	0	0	0	0	0	0	0	0	0	0	0

Georgia Stocking Data (1986-1989) continued.

	Clarks Hill	Lake Hartwell	Lake Sinclair	Oconee River	Ogeechee River	Pennsylvania	Savannah River (GA)	Savannah River (SC)	Stevens Creek (SC)
Richmond Hill	117783	58149	0	0	33846	238578	51032	163549	0
Bo Ginn NFH	127960	24222	48000	48000	0	0	20508	15383	0
Bowens Mill	0	0	0	0	0	0	0	0	0
Cordele	0	0	0	0	0	0	0	0	0
McDuffie	389354	112100	43000	96025	0	0	0	0	25025
Steve Cocke	0	0	0	0	0	0	0	0	0
Walton	78719	0	0	0	0	0	0	0	0
Warm Springs NFH	20068	56000	0	0	59980	0	110987	0	0
Welaka NFH	0	0	0	0	0	0	25200	72000	0

Georgia Stocking Data (1990-1999).

	McDuffie	Steve Cocke	Walton	Allatoona	Altamaha River	Clarks Hill	Lake Hartwell	Oconee	Ogeechee River	PA	Savannah River (GA)
Richmond Hill	0	0	0	0	5819	551930	237858	0	4815	372224	583191
Bo-Ginn NFH	0	0	0	0	33558	0	204240	0	0	0	56942
Carbon Hill NFH	0	0	0	85500	0	0	0	0	0	0	0
Cordele	0	0	0	0	0	0	0	0	0	0	0
McDuffie	0	0	0	314746	136000	1683621	1231305	0	0	0	645880
Steve Cocke	0	0	0	0	0	0	0	0	0	0	0
Walton	0	0	0	60192	0	0	0	0	0	0	0
Warm Springs NFH	0	0	0	0	0	0	0	0	0	0	0
Welaka NFH	0	0	0	34350	54960	0	0	0	0	0	0

Georgia Stocking Data (1990-1999) continued.

	Savannah River (SC)	Sinclair Lake	Summerville	Stevens Creek (SC)
Richmond Hill	845240	0		0
Bo-Ginn NFH	47623	0	0	0
Carbon Hill NFH	0	0	0	0
Cordele	0	0	0	0
McDuffie	0	0	0	0
Steve Cocke	0	0	0	0
Walton	0	0	0	0
Warm Springs NFH	0	0	0	0
Welaka NFH	0	0	0	0

Georgia Stocking Data (2000-2008).

	Savannah River (SC)	Savannah River (GA)	Lake Hartwell	Clarks Hill	Ogeechee River	Altamaha River	Allatoona	Oconee	Sinclair Lake
Richmond Hill	109123	20424	894654	866272	1300000	57798	15882	0	0
McDuffie	0	0	313546	1244014	0	0	100494	304685	30986
Walton	0	0	331333	141538	0	0	88000	31630	64959
Bowens Mill	0	0	175886	0	0	0	0	0	157101

Appendix G. Florida Stocking Data (1974-1979).

	Alachua	Auburn Unv.	Calhoun	FL Ins. Tech	Lake Talquin	Leon	Nassau	Ochlockonee	Polk	Putnam	Santa Rosa
Blackwater											
Blackwater (Gulf)			33600		164466	10000	4050				
Richloam	83000	250000		5000	198000			61700			
Richloam (Gulf)					120466		28000	21700	29670		700000
Welaka NFH										818000	
Welaka NFH (Gulf)											

Florida Stocking Data (1974-1979) continued.

	Seminole	St Johns River	USFWS SE Fish Culture Station, AL	Volusia	Wassau
Blackwater					
Blackwater (Gulf)				43200	
Richloam	39000		125000		36400
Richloam (Gulf)					
Welaka NFH		2128981			
Welaka NFH (Gulf)					

Florida Stocking Data (1980-1989).

	Academy of Natural Sci.- MD	Appalachicola	Blackwater River	Chipola River	FL Ins. Tech	FSU	Illinois	Johns Hopkins	Lake Seminole	Lake Talquin
Blackwater										5482
Blackwater (Gulf)			100800							117600
Richloam	50000				100	600	250000	8	510168	1271000
Richloam (Gulf)		134000	85000	8				827000	305900	166050
Richloam (Atl x Glf)										568
Welaka										
Welaka (Gulf)										
DWC (SC)										
MD (CBS)										

Florida Stocking Data (1980-1989) continued.

	Nassa u River	Ochlock onee	Putnam	Richloam	St Johns River	St Mary's	USDI FWS Columbia NFR Lab, MO	USFWS Columbia, CO	USFWS- WV	Volusia	Welaka
Blackwater											
Blackwater (Gulf)				1026							
Richloam	35000	130000	340000	438000	2942560	35000	535000	65000	1650000	1518385	12023700
Richloam (Gulf)											
Richloam (Atl x Glf)		875									
Welaka			2000000		1059100						
Welaka (Gulf)											
DWC (SC)											223500
MD (CBS)	19500					19500					

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Florida Stocking Data (1990-1999) continued.[illegible]

Florida Stocking Data (1990-1999) continued.

	Choctawhat chee(D-1)	Choctawha tchee (C-2)	Choctawhatc hee (A(A)-2)	FSU	Inks Dam NFH, TX (A(A)-2)	Lake Blackshear (D-1)	Lake George	Lake Seminole	L Seminole (D-1)	L Seminole (C-2)
Blackwater										
Blackwater (Gulf)	440276	96580	36000		230000	50000			270445	103155
Richloam							404000			
Richloam (Gulf)				625				1196855		
Richloam (Atl x Glf)										
Welaka NFH										
Welaka NFH (Gulf)										
DWC (SC)										
MD (CBS)										
NC (RR)										
Richmond Hill (GA)										

Florida Stocking Data (1990-1999) continued.

	L Seminole (C-1)	L Seminole (B-2)	L Seminole (B(A)(C)-2)	Talquin	Talquin (C-2)	Talquin (C-1)	Talquin (B-2)	Talquin (D-1)	Talquin (B(D)(C)-2)	Talquin (A(A)-2)	Mammoth Springs NFH
Blackwater											
Blackwater (Gulf)	110000	60000	27000	52400	81582	104000	90000	71400	30400	42300	4000
Richloam				55000							
Richloam (Gulf)				428831							
Richloam (Atl x Glf)											
Welaka NFH											
Welaka NFH (Gulf)											
DWC (SC)				42000							
MD (CBS)				85500							
NC (RR)				100000							
Richmond Hill (GA)											

[illegible][illegible]

Florida Stocking Data (1990-1999) continued.

	Warm Springs NFH	Warm Springs NFH (C-1)	Welaka (C-1)	Welaka (C-2)	Welaka (D-1)	Welaka (B(A)(C)- 2)	Yellow River	Yellow River (D-1)	Yellow River (C-2)	Yellow River (C-1)	Yellow River (B-2)
Blackwater											
Blackwater (Gulf)	3000	250000	535000	625000	200000	472000	25850	233250	73215	75000	2267
Richloam											
Richloam (Gulf)							76190				
Richloam (Atl x Glf)											
Welaka NFH											
Welaka NFH (Gulf)											
DWC (SC)											
MD (CBS)											
NC (RR)											
Richmond Hill (GA)											

Florida Stocking Data (1990-1999) continued.

	Yellow River (DC-1)	Yellow River (B(A)(C)- 2)
Blackwater		
Blackwater (Gulf)	1000	122000
Richloam		
Richloam (Gulf)		
Richloam (Atl x Glf)		
Welaka NFH		
Welaka NFH (Gulf)		
DWC (SC)		
MD (CBS)		
NC (RR)		
Richmond Hill (GA)		

Florida Stocking Data (2000-2006).

	Blackwater (C-2)	Choctawhatchee	Natchitoches NFH (D-2, C- 2,C-1)	Nassau River	Richloam	Richloam (C-2,B-2)	St Johns	St Mary's	Volusia (St John's)	Unv MD
Blackwater										
Blackwater (Gulf)	90300		814000		50000	720000				
Richloam				76920	1795		344445	28200	67580	2045
Richloam (Gulf)		526180								
Welaka NFH										
Welaka NFH (Gulf)										

Florida Stocking Data (2000-2006) continued.

	Welaka	Welaka (B- 2)	Yellow River (C-1)
Blackwater			
Blackwater (Gulf)		695000	83100
Richloam			
Richloam (Gulf)			
Welaka NFH			
Welaka NFH (Gulf)			

A HISTORY OF FISH CULTURE
1898-1998
AT THE
EDENTON NATIONAL FISH HATCHERY
EDENTON, NORTH CAROLINA

BY
ELLIOTT A. ATSTUPENAS
Hatchery Manager

Early Fish Culture in the State of North Carolina

Under the direction of U.S. Fish Commissioner Baird the earliest recorded work on Shad and Striped Bass occurred in 1873 when 45,000 shad eggs were hatched at New Bern and 100,000 Striped bass eggs were hatched at Weldon, N.C.

In 1877 the state began a fish culture operation on it's own account with a shad hatching operation on the Neuse River. One of the local volunteer assistants was S. G. Worth who a few years later became the first superintendent of fisheries for the state and at the turn of the century the first superintendent at the federal shad hatchery at Edenton, N.C.

U.S. Shad operations began on Albemarle Sound in 1878 at the mouth of Salmon Creek.

During 1879 shad hatching operations were continued at the mouth of the Chowan River using the steamer "Lookout".

The state constructed a hatchery at Avoca in 1880, on Salmon Creek, and operated it until 1884. In 1882 North Carolina became the first state to adopt the use of the McDonald hatching jar.

In 1881 the U.S. steamer "Fish Hawk" was detailed to Avoca for shad hatching.

From 1879 to 1884 state superintendent of fisheries Worth experimented with striped bass hatching on the Roanoke River near Weldon, N.C.

In 1885 the state discontinued all fish cultural work, leaving the federal government responsible for artificial propagation. The U.S. steamer "Fish-Hawk" was sent to North Carolina for shad egg hatching operations every spring until 1900 when the newly constructed Edenton Shad hatchery took over those responsibilities.

History of the Edenton National Fish Hatchery (Old Station)

Edenton, North Carolina

The Edenton National Fish Hatchery was established by An act of Congress approved on July 7, 1898. The station property was a part of the plantation owned by Stephen Cabarrus, dating back to 1802. Purchase of the first parcel of land, consisting of 14.85 acres was conveyed to the United States by C.W. Rea and wife by deed dated March 20, 1899. A second parcel of land containing 9.3 acres was purchased from P.H. Bell by the United States Bureau of Fisheries, Dept. Of Commerce, on October 1, 1917.

The first Superintendent of the hatchery was Steven G. Worth. He was responsible for the construction of the first building on the hatchery, a one and one half story frame hatchery building. The first floor consisted of a hatchery room containing tables, boot closet and an office. The second story was made into living quarters for unmarried personnel.

In 1900 the superintendents's residence, a two and a half story frame building was constructed on the highest point of land, on the property facing Pembroke Creek. At the same time a frame pump house on a concrete foundation was built containing generator, electric meters, switches and pumps. Note: commercial electricity was not available to the station at the time, access to the town was by boat across Pembroke Creek.

The first hatching operations were begun in 1900, during the egg collecting season which lasted from April 25 thru May 10, 10,404,000 shad eggs were collected. Adult shad were obtained from commercial gill netters working in Albemarle Sound. Hatchery personnel, aboard power boats, collected the spawn and returned it to the hatchery where the eggs were incubated, A hatch of 6,590,000 fry resulted , all of which were stocked in local waters. The water supply for the hatchery was from Pembroke Creek, pumped by steam pump to a 6,000 gallon reservoir tower for a gravity flow water supply.

In 1906, approximately 2,101,00 striped bass fry were hatched at the Weldon sub-station, located on the Roanoke River at Weldon, N.C. The majority of the fry were returned to the river. The sub-station was operated seasonally (March-May) by the Edenton station, in cooperation with the Division of Inland Fisheries, Department of Conservation and Development, which owned the facilities. The earliest record of hatching striped bass eggs was in 1873, at Weldon, when federal government personal, under direction of the United States Fish Commissioner, Spencer F. Baird, hatched 100,000 fry.

At about this time , propagation of such species as largemouth bass, and bluegill was experimentally undertaken, using ponds which were constructed at the hatchery. Seven ponds with a total of 2.77 acres were constructed using a mule drawn drag pan.

In 1913, white perch eggs were hatched in addition to shad and stripers. Eggs were taken by spawn takers from commercially caught fish. The hatched fry numbering 3,270,000 were returned to open waters of the sound.

Large numbers of shad were collected at Capehart Beach (Sutton Beach) at the mouth of the Chowan River near Avoca (Avoka), North Carolina, using a three-mile seine connected to two stream winches set one mile apart on the beach. The highest number of shad eggs taken numbered 138,912,000 and this happened in 1913. The hatchery had a small fleet consisting of five gas powered boats, several rowboats and a barge used in the egg taking operations.

A fish culturist cottage was constructed in 1915, it was a one story frame building.

In or around 1916 the steam water pump was replaced by an electric pump, which improved operations at a reduced cost

Mr. Edward M. Hayes was made hatchery superintendent around 1916.

In the spring of 1921 a hatching program for river run herring was undertaken with 55,130,000 eggs obtained, yielding a hatch of 43,815,000 fry. During the year a large number of top water minnows (*Gambusia*) were successfully reared and a shipment of 2000 was sent to Europe. Attempts were also made to rear crappie and warmouth.

Mr. William C. Bunch began work at the Edenton station as a fish culturist on November 17, 1921.

In 1922 Mr. Haynes was replaced by William S. Vincent as hatchery superintendent. The herring egg take increased to 313,000,000 in 1923 and reached a peak of 336,000,000 in 1925.

In 1923 it was concluded that pollution of the Roanoke River near Weldon, N.C. was too high for survival of striped bass fry when they were released from the substation. Operations at the sub-station were discontinued. During the year catfish fingerlings were collected in sloughs adjacent to the hatchery for delivery to local ponds.

In 1924 a boat house of corrugated galvanized iron was constructed and a frame work shop was built adjacent to the rear of the hatchery building. During the year the first gasoline driven vehicle was purchased for the station, it was a second hand Model T Ford pickup.

The first collection of yellow perch eggs by the station was made in 1924. Adults were purchased from commercial fishermen and placed in ponds where the fish spawned. The eggs were collected and taken into the hatchery for incubation. Out of 5,460,000 eggs collected 2,450,000 fry were hatched. *Gambusia* were again cultivated and were distributed by the D.C. office. A company came into the area and bought fish scales for use in making artificial pearls.

The State of North Carolina, Department of Conservation and Development in 1927 constructed and furnished a new hatchery for striped bass at Weldon. Spawning operations again resumed in the spring of 1928 under a cooperative agreement. The spawning operation was again halted in 1932. A state hi-way was built with a bridge across Pembroke Creek in 1927 giving access to the town for the station's personnel and access to the station for the public other than by boat.

A frame garage covered with galvanized siding was built in 1928. Many of the power boats were sold because of deterioration and non-use. Trucks were used to pick up eggs at collection points.

The old wooden water supply tank was replaced by a 6000 gallon steel tank in 1929. The telephone line was moved to poles following the hi-way. Average weight for female shad for the year was five pounds.

Prior to 1930 the majority of fish were stocked using especially equipped railroad cars for transportation. With the advent and availability of the gasoline driven vehicle it was found that the fish could be transported more efficiently and economically by truck. This caused the hatchery to discontinue shipment by rail. There was a major run of river herring on April 10 which was so abnormally early as to catch fishermen unprepared.

In 1931 the problem of adhesiveness in herring eggs was solved by extruding eggs directly into a starch water solution before the application of milt. This raised the percentage of hatch from 30 to 50 percent.

A new inlet was cut through the outer banks in 1932. Also the natural spawning time of spawning was mentioned, for shad and herring, being between 4 and 10 PM.

In 1936, Mr. William C. Bunch became Superintendent of the Edenton station.

Shad fry were transferred into a pond on the hatchery and grew to one inch by June 12, 1937. During the same year striped bass fry were transported by a Jno. C. Pearson of the Division of Scientific Inquiry for stocking in hatchery ponds.

In 1938 under the WPA. Four new ponds were constructed; three by excavating and one by building a levee along the creek shore. This added 4.93 acres into cultivation for a hatchery total of 7.7 acres. The water supply for the ponds was furnished by electric pump through an 8 inch spiral weld pipe from Pembroke creek. Under the same WPA project a junior fish culturist residence was constructed. It was a one and one-half story frame "cottage style" building. A second framed garage with one and one-half stories was constructed in the same year. It contained public rest rooms and stalls for three vehicles with the second story used for storage.

During this time egg collecting fields for shad and herring included such areas as Skinner's Point and Sandy Point in Chowan County; Scotch Hall and Sutton Beach in Bertie County. White perch eggs were collected at Newby's Ditch in Washington County. The majority of fish hatched were normally stocked back into the waters where the fish were collected. Shad fry stocked the previous year had grown to four inches by fall, an additional 581,000 fry were placed in a pond in 1938 and by the end of June were two inches. Gambusia were sent to the New York's Worlds Fair.

The old pump house was remodeled with the WPA allotment in 1939.

In 1939 approximately 500 adult shad were tagged. The following year several shad were recaptured, all within three and a half miles of where they were released.

The Reorganization Act of 1939 transferred the Bureau of Fisheries, Department of Commerce, to the Bureau of Sports Fisheries and Wildlife, Department of Interior and the station was given the formal name of the Edenton National Fish Hatchery.

Collection and hatching of herring eggs was terminated in 1940.

Work with striped bass was again undertaken at the Edenton station in 1944 when striped bass fry were stocked in ponds, where they grew several inches before harvest in the fall.

In 1944, 600 yearling shad were transported and stocked in the Pamlico River. Division biologists tagged and released 1,085 five inch fingerlings.

By 1945 shad egg collecting had practically come to an end because of restrictions placed on certain fishing areas and fewer migrating fish. This resulted in a discontinuance of seine fishing in many nearby localities.

By 1945 the propagation of Bluegill was becoming most important. Efforts to rear crappie and yellow perch were discontinued.

In 1947 the collection of shad eggs was terminated after the spring run. White perch propagation was also terminated. The last of the power boats were sold during the year because of no further need.

By 1948 bluegill and largemouth bass became the prominent species sought by farm pond owners. Rearing operations were limited to these fish on station, but the Weldon sub-station continued to hatch striped bass.

In 1951 attempts were made to rear a largemouth bass brood stock for hatchery use. Till this time adult bass were obtained from Currituck Sound.

The Edenton station continued in operation until 1954 when the unavailability of land for expansion caused the service to terminate operations.

History of the Edenton National Fish Hatchery (Modern Era)

In 1958 due to local citizen and congressional interest a new hatchery site was purchased approximately 0.6 mile west of the original location, with a water supply from Pembroke Creek. Mr. William C. Bunch returned to Edenton, from the Mammoth Springs Arkansas NFH, to oversee construction and manage the new hatchery. The new hatchery covered 63.6 acres having 36 ponds with a total cultural acreage of 24.5 acres with its primary water source being Pembroke Creek, the same source of water as the old hatchery.

Production of fish began in 1960 with the farm pond program fish, Large mouth bass, Channel Catfish, Bluegill and Redear Sunfish the major cultured species. Striped bass fry were brought on to the station and stocked into two ponds. One of the two ponds returned some success.

In 1961, 1962 and 1963 striped bass fry were stocked into aquarium and ponds with again minimal success. One pond stocked with 250, 3 ½ week old fry, returned 240 weighting 0.5 lb. When harvested 34 days later.

In 1964 the first appreciable numbers (20,000) of striped bass fingerlings were successfully harvested weighting out at 333 per pound. These were given to the Cooperative unit at North Carolina State university.

Mr. Bunch retired as manager in November of 1964. Mr. Nathan A. Powell became the new manager in January of 1965.

In 1965 two ponds were placed into production and 10,000 fingerlings were harvested.

IN 1966 three ponds stocked with stripers producing 47,000 fingerlings and one pond of hybrid striped bass white bass produced 39,000.

With the initial groundwork of rearing striped bass done at the Edenton station the Service put four more full time employees on the payroll with the charge of investigating all aspects of striped bass fish culture. This charge resulted in the publication of four yearly reports from 1967 to 1970, titled "Striped Bass-Development of Essential Requirements for Production" Aspects of culture studied during that time were: 1. Egg procurement , spawning techniques, care and handling of fry. 2. Stocking rates, feeds, fertilizers, supplemental feeds and feeding techniques. 3. Availability and utilization of zooplankters during fingerling production. 4. Techniques for harvest and distribution of Phase I and Phase II fish. 5. Disease and parasite problems and control. 6. Water quality. 7. Intensive culture. 8. Toxicity of nine therapeutic and herbicidal compounds. 9 Distribution and transportation techniques. In addition to these published studies a captive brood stock population was being grown.

In 1967 Striped bass adults from the lower Roanoke River were injected with human chorionic gonadotropin (hCG) producing 1,185,000 eggs of which 16 % hatched. Advanced fingerlings were produced for the first time in holding house tanks. Fingerling production amounted to 324,000. In November and December advanced fingerlings (Phase II) numbering 174,500 weighed a total of 11642 lbs. were harvested. Average weight was 14.98 per pound which gave a fish almost 6" in length. First fish held back for growing out to adult spawning size.

In 1968 a second attempt was made to spawn lower Roanoke River stripers. Striped bass were again stocked out on station with the specific purpose of growing to spawning adult. This became a yearly practice.

In 1969 Phase II stripers numbering 169,806 with a total weight of 18,239 pounds were distributed. (9.31/lb., 6.5+ inches).

1970 found two French researchers joining the crew for a year in order to learn cultural techniques. Four year old broodfish averaged 4.7 lbs. Lawrence J. Wirtanen becomes manager.

By 1971 striped bass fingerlings had been or were distributed to the states of N.C., VA., S.C., GA., FL., TN., AL., OK., MI., and NY. This year found 76,884 advanced fingerlings, weighting 8,408 lbs. flying to Chaoctowhatchee Bay, Florida via C-124 Air Force Globemaster. The fish were carried in standard four compartment distribution trucks coming from a number of hatcheries. Two shipments of fingerling stripers were sent to Russia.

During 1972, 1973 fingerlings were shipped to Russia. Fry were placed into 20 gallon wash tubs and fed brine shrimp, Phase I production continued with normal production numbers produced both years. Phase II fish were not produced in any numbers in 1973 except for a small number held back for future brood fish.

The year 1974 was the last for production of farm pond fish on the station. Five year old broodfish (140) were checked for ripeness and eligibility. Fingerlings shipped to Russia. Hudson River fry were brought on station. The Service and the State of New York signed an agreement for the station to produce Hudson River Phase I and Phase II for mitigation.

In 1975, 3,000,000 fry were produced from 6 year old hatchery reared brood fish, this was the last year for hand stripping of ripe brood fish. The Hudson River received 30,000, 2 to 3 inch and 60,000, 4 to 6 inch stripers in early 1975. In October another 200,000, 3 to 4 inch Hudson river stripers were delivered by hatchery personal to N.Y. Ron Majors was named interim manager from September 1975 to March 1976.

Elliott A. Atstupenas was named manager in early April of 1976. The spawning of brood fish was done in six foot diameter tanks and hCG injected. This was the third successive year of first generation hatchery reared brood fish spawned on the station. The station was holding 7 year classes of 5 different strains, H., MD., MC., W., and MCED.

In 1977, 9,000,000 eggs were produced from the tank spawned domestics, 1,900,000 fry were stocked into hatchery ponds.

In 1978 the MCED 1972 and 1973 strains produced 4,000,000 eggs. Four strains on station, MDED, MCED, WED, H. A program to stock the Lake Mattamuskeet NWR was started with an annual goal of 25,000 Phase II striper each year.

The second generation of hatchery reared broodfish produced 7,078,000 eggs in 1979. Various year classes of broodfish totaled 1900 fish and were held in 12 acres of ponds.

The Washington office of the F&WS directed this project in 1980 to reduce the numbers of hatchery reared brood stock strains to two: Weldon and Maryland. A cooperative agreement with the State of North Carolina Marine Fisheries was signed with the Service whereby this project will produce 80,000 Phase II striper for stocking into three N.C. coastal river systems. Stockings done in Albemarle Sound prior to 1980 proved successful in increasing fishing success.

In 1981 Phase II production was boosted to 90,000, 6 to 8 inch stripers weighting a total of 6883 lbs., of this number 10,000 fish were tagged with an external dorsal tag. Fingerling production was 886,000. Maximum production numbers can be expected from ponds if fish are harvested when the fingerlings weight between 1000 and 1600 per pound. This station can expect to get to this size range in 35 days post stocking of the 5 day old fry.

In 1982, 1,169,000 Phase I fingerlings were produced by double cropping. Phase II numbered 78,195, weight 6676 pounds. The Mattamuskeet NFH and the Neuse River received the Phase II fish. A high volume low pressure air blower system was installed in 4 ponds to increase mixing of the water column and reduce oxygen problems.

Two more ponds received the blower system in 1983, but the results of two years of tests on the hatchery were inconclusive and the system abandoned. The third generation MDED-III, of hatchery reared brood fish were spawned with 8,000,000 eggs produced. Phase I production was 1,280,000 and Phase II fish numbered 174,099 weighting 13,682 pounds.

Production in 1984: Phase I STB 1,074,858, wgt. 978 lbs., Phase II, 102,209, wgt. 5401 lbs. Fingerlings grown in holding house tanks (400 gal.) Grew from 1,200-1,000 fish per pound to 400-200 fish per pound in less than 30 days. Maryland stripers prove to be formalin sensitive while similar treatments given to North or South Carolina fish caused no noticeable stress.

In 1985 the developmental brood stock program was dropped by Washington directive. The freed up space was to be devoted to the need for greater numbers of Phase II stripers for Chesapeake restoration. We received our first fry from Maryland found that these fry had a problem with uninflated swim bladders. Production: Phase I STB 1,120,000, Phase II, 115,471, wgt., 8931 lbs.

The saline well (600', 3 ppt) was used in 1986 for the full Phase II production season. While research had proved that Stripers grew better in water that had any salinity level, this station hoped to reduce the Pithopora spp. algae problem which caused feeding and harvest problems. Phase I production was 1,148,316, wgt. 1,268 lbs. and Phase II production grew almost 50% compared to the year before to 168,723 fish weighting 16,138 lbs.

In 1987 Phase I stripers were sent to the Navesink River in New Jersey to initiate a restoration program. Production for Phase I stripers was 903,084 weighting 832 pounds. Phase II production came close to our estimated maximum production of 250,000. Actual delivered fish numbered 243,451 weighting 19,745 lbs. Delivery sites were, Albemarle Sound, Chesapeake Bay and the Mattamuskeet NWR. The saline well pump self destructed with only 900 hrs. On it one month beyond the guarantee.

Murphy's Law ruled in 1988. The creek pump our major water supply broke down and was not brought on line until 5 hours before the first Maryland fry of the year were brought on station. Uninflated swim bladder still continued as a serious problem. We received for grow out fry of the endangered Short nosed sturgeon growing them in troughs in the holding house until a shaft snapped in the fresh water well and they were lost to low oxygen levels. A shut down of electricity by the city at 5:00 AM on a Sunday morning without notification to this project caused a loss of 90,000 Roanoke River Phase I stripers. Production for the station of Phase I fingerlings was a record for a single crop: 1,315,000. Phase II distribution was at a five year low (79,000) due to a problem plagued 1987 grow out season, The Navesink River received additional stocking to continue restoration efforts.

In 1989 we were able to complete a grow out, from fry to 8 to 9 inches, of the Short nosed sturgeon and returned them to the Savannah River. An emergency generator was purchased and put into service. It is able to cover power needs for the holding house well and building. The Navesink and Neuse Rivers as well as the Chesapeake received normal distributions for the year. Phase I, 901,676. More Maryland fingerlings were produced than the hatchery had space for grow out so surplus was shipped to VA and WVA. Phase II amounted to 192,035 the second best record for grow out. Maryland fry bladder problems continue.

1990 found one half of our ponds out of production for a much needed renovation. Thirty years of wind, water and muskrat damage was put to right with the help of Pocosin Lakes NWR personnel and equipment. A new, modern holding house was designed with our help and put out on bids. A simple change in the handling of the Maryland fry solved the swim bladder problem. Until this year we were given feeding fry ranging from 6 to 10 days of age which in most cases was beyond the normal time of swim bladder inflation, we requested the fry at five days old so they were in our ponds during the time of normal inflation. It worked. We had a record single crop of 1,316,930 Phase I fish. Phase II amounted to 126,863 fish. We began a cooperative program with Craig Sullivan of NC State to test LHRHa on our spawning stripers to see if we could enhance maturation and spawning.

Again in 1991 station activities dominated by pond renovations and the construction of the new holding house facility. Phase I numbers were cut in half to 636,508 because of lack of production ponds. Phase II numbers were nearly normal (119,000) all raised with saline water (3 PPT). Food conversion worked out to be 1.94 which is quite good for stripers under pond conditions. Field test continued on use of LHRHa, spawned 6 females with 24 males and obtained 3,300,000 eggs and stocked out 806,000 fry. There was no need to inject females to cause ovulation.

In 1992 the last six ponds were renovated, the new holding house was placed into operation. Each holding tank (500 gals.) is supplied with three different water supplies, pond, fresh water well or saline water well. Fingerling production hit a record for single crop at 1,446,370. A small batch of fingerlings (22,000) was held in a holding house tank from early June until mid August when inventoried they weighed out at 56.6 per pound with an average length of 3.5 inches. The Phase II stripers (102,645) were raised in eleven ponds in our saline water. All ponds had no algae problems and we had a poundage of 1,100 pounds per acre. In this the third year of LHRHa experiments we used 8 females, obtained 2,937,500 eggs and stocked out 2,690,000 fry.

January of 1993 found the manager at Hilton Head, S.C. presenting a paper at the World Aquaculture conference. Phase I production amounted to 871,900 while Phase II numbers again broke the record with 253,888 harvested and delivered to North Carolina coastal waters. A shipment of Phase I fingerling striped bass, the first since 1974, was shipped via Aeroflot to Moscow, Russia. After spawning female stripers under 8 lbs for a number years with little viable results we have concluded that they are first time spawners and give very little positive results. Here after only females in the ten pound range and above will be used for spawning.

In 1994 the hatchery brought American Shad back on station, after an absence of almost 50 years. Adult shad were successfully transferred from pound nets located at the mouth of the Chowan River to round six foot diameter holding tanks. This was a first step toward obtaining eggs by tank spawning and the use of LHRHa. All STB fry used on the station this year came from hatchery spawned females using LHRHa. There were 3,300,000 eggs spawned with 1,900,000 fry stocked into ponds. Phase I produced, 1,079,397. We completed another successful shipment to Russia. This was the last year of growing Chesapeake restoration stripers. Total Phased II stripers produced for the fall 93 stocking was a record 258,901.

Before the 1995 spring run of American Shad a small pilot spawning and hatching facility was constructed. During the run we were able to transport, inject (LHRHa) adult shad, tank spawn, collect and hatch eggs. A small number of viable fry were stocked into one of our 0.3 acre ponds. Eight Roanoke River STB broodfish were injected with LHRHa spawned 2,700,000 eggs which gave us 1,223,000 stockable fry. Phase I stripers (728,371) were produced for both N.C. and S.C. Another shipment of Phase I stripers was sent successfully to Moscow. Phase II stripers (188,434) were all stocked into N.C. coastal waters. The Neuse River and the Tar-Pamlico are the two major restoration river both are having nutrient and *Pfiesteria piscicida* problems.

In 1996 the station injected 55 American Shad with a reduced dosage of LHRHa down to 75 micro gram per kilogram from the previous years of 150 micro grams per pellet. Using females that were more than a month from natural spawning we obtained over 50,000 eggs and after hatching were able to stock out, and grow Phase I shad. 814,113 Phase I stripers were grown out for N.C., S.C. and the Gulf coast. Phase II numbered 142,219 and were stocked into N.C. coastal waters. White bass were grown for the first time on the station. The request for fish this year from Moscow asked for White bass as well as striped bass. No shipment was made because of our inability to obtain a shipping date from the Russian airline Aeroflot.

The year 1997 finds us continuing Phase I culture of striped bass with a the station only producing 397,931 for the year. A mandate to mark all hatchery stocked fish with oxytetracycline (OTC) proved to create survival problems. Marking methods for this year have been modified. Phase II numbers of 142,219 were sufficient for stocking of both the Neuse and Tar-Pamlico systems. Shad culture work resulted in 16,000 American shad fingerlings released into Albemarle Sound waters. A cooperative agreement between this hatchery and N.C. Inland Fisheries was developed to aid in a seven year restoration project on the Roanoke river. The first years goal will be 1,500,000 fry released into the Roanoke River at Roanoke Rapids.

Hatchery Managers

Steven G. Worth	1900-1916
Edward M. Hayes	1916-1922
William S. Vincent	1922-1936
William C. Bunch	1936-1954 1958-1964
Nathan A. Powell	1964-1970
Lawrence J. Wirtanen	1970-1973
Henn Gruenthal	1973-1975
Ronald Majors	1975-1976
Elliott A. Atstupenas	1976-

References

Anderson, J. C. 1966, Production of striped bass fingerlings. *Progressive Fish Culturist* 28:162-164.

Annual Reports, Edenton National Fish Hatchery, 1918-1997.

Atstupenas, Elliott A., 1993, Induction of Striped Bass, *Morone Saxatilis*, spawning with Implanted Gonadotropin Releasing-Hormone Analogue (GnRHa) and injected Human Chorionic Gonadotropin (hCG). Abstract: U.S. Chapter, World Aquaculture Conference.

Smith, Hugh M. , 1907, Vol. II, The Fishes of North Carolina.

Stickney, Robert R., 1996, Aquaculture in the United States.

Striped Bass-Report on the Development of Essential Requirements for Production, 1967, 1968, 1969, 1970, Bureau of Sport Fisheries and Wildlife, Division of Fish Hatcheries.

Egg collections.

NOTE: Striped bass shown herein were taken and hatched at the Weldon, N. C. sub-station operated seasonally under the Edenton Station.

Year	Species	Eggs collected	Eggs planted	Eggs hatched (fry)
1900	Shad	10,404,000		6,590,000
1901	Shad	75,400,000		51,280,000
1902	Shad	37,987,000		24,662,000
1903	Shad	36,320,000		25,549,000
1904	Shad	10,276,000	4,560,000	1,315,000
1905	Shad	6,748,000		3,848,000
1906	Shad Striped bass	25,771,000	495,000	17,883,000 2,191,000
1907	Shad Striped bass	23,644,000	235,000	16,085,000 3,680,000
1908	Shad Striped bass	55,866,000	760,000	41,178,000 3,061,000
1909	Shad Striped bass	59,685,000	266,000	38,354,000 4,518,000
1910	Shad Striped bass	69,233,000 4,566,000	1,360,000	48,262,000 2,669,000
1911	Shad	74,630,000		52,631,000
1912	Shad Striped bass	115,617,000	2,623,000	78,556,000 5,356,000
1913	Shad Striped bass White perch	138,912,000	3,394,000	95,589,000 7,234,000 3,270,000
1914	Shad Striped bass	42,885,000 17,290,000		29,431,000 11,699,000
1915	Shad Striped bass White perch	39,040,000		23,070,000 8,594,000 4,500,000
1916	Shad Striped bass White perch	16,084,000 1,200,000		9,765,000 10,071,000 850,000

Year	Specie	Eggs collected	Eggs planted	Eggs hatched (fry)
1917	Shad	7,625,000		6,060,000
	Striped bass	19,049,000		16,137,000
	White perch	41,925,000		32,625,000
1918	Shad	4,223,000		2,859,000
	Striped bass	17,660,000		14,999,000
1919	Shad	31,323,000		23,690,000
	Striped bass	17,942,000		13,540,000
	White perch	3,100,000		2,035,000
1920	Shad	21,667,000		16,286,000
	Striped bass	19,358,000		16,474,000
1921	Shad	21,710,000		16,046,000
	Herring	55,130,000		43,815,000
	Striped bass	24,600,000		20,184,000
1922	Shad	34,201,000		25,749,000
	Herring	116,920,000		82,600,000
	Striped bass	48,745,000		37,530,000
1923	Shad	250,000		200,000
	Herring	313,000,000		150,000,000
	Striped bass	22,084,000		16,341,000
1924	Shad	7,855,000		7,070,000
	Herring	222,000,000		95,000,000
	Yellow perch	5,460,000		2,450,000
1925	Shad	502,000		480,000
	Herring	336,000,000		92,000,000
	Yellow perch	7,385,000		7,000,000
1926	Herring	123,840,000		55,000,000
	Yellow perch	1,600,000		1,500,000
1927	Shad	827,000		600,000
	Herring	5,160,000		2,000,000
1928	Shad	8,111,000		7,050,000
	Herring	223,444,000		55,000,000
	Striped bass	9,415,000		7,230,000
	Yellow perch	11,540,000		10,760,000
1929	Shad	7,711,000		5,000,000
	Herring	37,740,000		11,500,000
	Striped bass	13,786,000		9,661,000
	Yellow perch	1,495,000		1,200,000

Year	Species	Eggs collected	Eggs planted	Eggs hatched (Fry)
1930	Shad	3,382,000		2,425,000
	Herring	30,700,000		10,000,000
	Yellow perch	2,940,000		2,300,000
1931	Shad	781,000		650,000
	Herring	104,715,000		50,000,000
	Striped bass	13,370,000		9,500,000
1932	Herring	117,220,000		55,000,000
	White perch	13,700,000		7,000,000
	Yellow perch	6,700,000		4,500,000
	Striped bass	2,095,000		1,676,000
1933	Shad	1,520,000		1,200,000
	Herring	84,826,000		25,000,000
	White perch	5,400,000		3,350,000
	Yellow perch	7,370,000		5,750,000
1934	Shad	5,457,000		3,500,000
	White perch	1,600,000		900,000
	Yellow perch	6,430,000		4,000,000
1935	Shad	4,283,000		2,774,000
	White perch	2,400,000		1,920,000
	Yellow perch	8,245,000		6,600,000
1936	Shad	4,776,000		2,800,000
1937	Shad	7,275,000		6,240,000
	Herring	24,220,000		14,500,000
	Striped bass	1,160,000		641,000
	Yellow perch	3,100,000		2,500,000
1938	Shad	10,481,000		7,110,000
	Herring	2,960,000		1,370,000
	Striped bass	646,000		515,000
	White perch	3,100,000		2,500,000
	Yellow perch	1,950,000		1,371,000
1939	Shad	11,134,000		7,136,000
	Herring	8,140,000		Ex Hatché
	Striped bass	3,413,000		1,793,000
	White perch	8,300,000		4,300,000
	Yellow perch	1,170,000		998,000
1940	Shad	20,347,000		13,350,000
	Herring	717,000		170,000
	White perch	4,000,000		2,800,000
	Striped Bass	8,075,000		5,917,000
	Yellow perch	1,885,000		1,360,000

Year	Species	Eggs collected	Eggs planted	Eggs hatched (fry)
1941	Shad	7,355,000		4,420,000
	White perch	2,900,000		2,300,000
	Yellow perch	2,330,000		1,646,000
	Striped bass	635,000		469,000
1942	Shad	416,000		290,000
	White perch	1,447,000		47,000
	Yellow perch	2,641,000		1,746,000
1943	Shad	210,000		122,000
	White perch	21,900,000		16,000,000
	Yellow perch	5,060,000		3,750,000
	Striped bass	2,515,000		1,563,000
1944	Striped bass	11,168,000		7,618,000
	White perch	31,200,000		12,600,000
	Yellow perch	1,430,000		795,000
1945	Shad	850,000		260,000
	Striped bass	465,000		279,000
	White perch	2,750,000		1,035,000
	Yellow perch	2,036,000		1,540,000