Fisheries and Oceans Canada | Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 99/007

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 99/007

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# Striped Bass Stocking Programs in the United States: Ecological and Resource Management Issues

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ISSN 1480-4883
Ottawa, 1999

Canada

## ABSTRACT

The striped bass (*Morone saxatilis*) has been an important commercial, recreational and socio-economic resource along the U.S. eastern seaboard since earliest colonial times. The first colony resource laws, written in 1639, addressed conserving the striped bass resource. Concerns about population declines in the late 1800s resulted in the first attempts to culture striped bass in a manner similar to that for American shad, *Alosa sapidissima*. The Roanoke River population in North Carolina served as the original strain for culture beginning in 1884, and for many years eggs, fry and fingerlings of Roanoke origin were stocked in watersheds throughout the eastern seaboard and along the Gulf of Mexico. These fish were used for stock enhancement and for stock restoration programs. In the 1980s, concern about collapse of populations throughout the range, and preserving any remaining genetic integrity of striped bass populations, led the *Atlantic States Marine Fisheries Commission* (ASMFC) to endorse a large culture and stocking program of Age 0 fish. Brood fish from "natal rivers" were used, with progeny returned to the watershed of the brood parentage. However, the 100+-year-old practice of cross-stocking young and adults, and the continued practice of cross-stocking at the state level, have resulted in the introgression of non-endemic genetic strains to many striped bass populations along the east and Gulf coasts. Effects of this long-standing practice remain undocumented and unquantified. This manuscript documents the use of these strains for population rebuilding and maintenance programs, and addresses issues concerning survival of stocked fish, implications of ecological incompatibility of cross-stocked fish, and management problems associated with these issues.



## RÉSUMÉ

Le bar rayé (*Morone saxatilis*) constitue une importante ressource commerciale, récréative et socio-économique, le long de la côte Est des États-Unis depuis le début des colonies. Les premières lois traitant des ressources des colonies, écrites en 1639, traitaient de la conservation de cette espèce. Des inquiétudes soulevées par le déclin des populations vers la fin des années 1880 ont donné lieu aux premières tentatives d'élevage de ce bar en procédant d'une façon semblable à celle utilisée pour l'alose d'Amérique, *Alosa sapidissima*. La population de Roanoke River, de la Caroline du Nord, a servi de souche aux travaux d'élevage amorcés en 1884 et, pendant un grand nombre d'années, des œufs, des alevins et des jeunes ont été ensemencés dans des bassins versants de toute la côte Est et de celle du golfe du Mexique. Ces poissons ont été utilisés à des fins de mise en valeur et de rétablissement de stocks. Au cours des années 1980, des inquiétudes ayant trait à l'effondrement possible de populations dans toute l'aire de répartition et à la disparition de ce qui restait de l'intégrité génétique des populations de bar rayé ont amené la *Atlantic States Marine Fisheries Commission (ASMFC)* a appuyer un important programme d'élevage et d'ensemencement de poissons d'âge 0. Des géniteurs provenant de rivières « natales » ont été utilisés et leur progéniture a été remise dans les bassins versants d'origine. Mais la pratique, datant de plus d'un siècle, de pratiquer des ensemencements croisés de jeunes et d'adultes et le maintien, au niveau de l'État, de cette pratique ont donné lieu à une introgression de souches non-endémiques affectant plusieurs populations de la côte Est et du Golfe. Les effets de cette longue pratique demeurent inconnus et inquantifiés. Le présent manuscrit documente l'utilisation de ces souches à des fins de rétablissement et de maintien de populations et traite de questions ayant trait à la survie des poissons ensemencés, aux incidences de l'incompatibilité écologique des poissons ayant fait l'objet d'ensemencements croisés et aux problèmes de gestion qui en découlent.

## INTRODUCTION

Historical Perspective on Striped Bass Importance, 1600s to 1900s

The striped bass, *Morone saxatilis*, is considered an anadromous species; that is, it utilizes a life history strategy of living in the ocean in the adult phase, but relies on migration to fresh waters for spawning in order to complete the life cycle (Dadswell et al. 1987). Striped bass must have water movement at, and downstream of, the spawning site strong enough to keep the eggs in suspension, but not so strong that survival to the hatching stage is jeopardized (Manooch and Rulifson 1989). All striped bass populations throughout the species' range employ this strategy, but there are two distinct sub-strategies: one that utilizes movements of tidal waters, and the other employing flow of fresh waters from the upstream watershed with no tidal influence present. Populations north of Cape Hatteras, North Carolina, are considered fully anadromous (Setzler et al. 1980), but those populations south of Cape Hatteras are considered endemic riverine; i.e., use of ocean habitats in the adult phase is restricted or non-existent (McIlwain 1980; Rulifson et al. 1982a). Striped bass populations along the North American Pacific coast were introduced by stocking yearling fish of Navesink River and Shrewsbury River (New Jersey) origins into San Francisco Bay in 1879 and 1881 (Raney et al. 1952).

Considerable confusion exists about terms used to describe striped bass populations on local and regional levels. The term "stock" is used here to identify a fishery management unit within a defined geographic area. Populations from the Roanoke River northward through Maine are considered to be the "Atlantic coastal migratory stock". The contribution of Canadian fish to this stock is unknown; the contribution of U.S. fish to Canadian populations may be considerable (Wirgin et al. 1995). South of the Roanoke River, populations of striped bass are considered to be non-migratory, and the terms "stock" and "population" are interchangeable. Fishery agencies often refer to the "Chesapeake Bay stock", the "Hudson stock", the "Albemarle-Roanoke stock", and the "Santee-Cooper stock". Unfortunately, the term used in this manner connotes genetic subgroups, and we avoid the use of the term in this context when possible. Populations (and stocks) are comprised of different "strains", a term used here to mean a genetic subgroup of a population. Historical documents refer to striped bass populations of the eastern seaboard to be of one "race"

– the “Atlantic strain” – to differentiate those from the endemic populations in states along the Gulf of Mexico; i.e., the “Gulf strain” (Barkaloo 1970). These two terms are still used by state and federal fisheries agencies, particularly in southern and Gulf coast states in reference to stocking practices.

Reasons for Decline of the Stocks

Since the time of North American colonization, anthropogenic alterations to the environment have had considerable negative impact on populations of striped bass and other anadromous fish species (Rulifson et al. 1982b, 1994). In Canada and New England, primary contributors to declining populations include dams, inadequate fishway facilities, and poor control of water release from reservoirs. South of New England, dams and lack of fishways are important but other factors resulting in poor water quality are more numerous: thermal effluents, low oxygen, sewage, sedimentation, turbidity, and non-point source pollution (Rulifson 1994). Activities responsible for water quality changes include, but are not limited, to: channelization, dredge and fill, and road and residential construction. These changes, combined with high utilization of the fishery resource, are thought to be responsible for large reductions in population size in the late 1800s (N.C. Board of Agriculture 1881) and again in the late 1970s (ASMFC 1990).

Alternative Ways to Reverse Trends

**Restoration of Lost Habitats.** Loss of access to historical spawning grounds, and degradation of spawning grounds and nursery habitats, began in Colonial times and continues today. Before electricity, wooden dams spanning rivers and streams at the Fall Line commonly were constructed for meeting mechanical power demands of mills for grinding grain and sawing lumber. Often these wooden structures contained fish trapping devices for harvesting anadromous species (e.g., fish slides and boxes). Blockage of migrating fish to upstream habitats virtually eliminated many anadromous spawning runs, especially in New England, by 1800. In 1879, North Carolina Commissioner of Agriculture L.L. Polk lamented that the state had allowed “…citizens exclusive privileges and emoluments...” to “… erect dams or other obstructions… for his own use, thereby excluding the thousands of citizens further in the interior and contiguous to such stream from its benefits.” He continues, “By the traps fixed in these dams, not only are the adult shad [*Alosa sapidissima*] caught in their efforts to reach the spawning grounds, but many are so constructed as to destroy vast numbers of young shad in their exit to the ocean” (NC General Assembly 1879). Additional problems of pollution associated with the Industrial Revolution also restricted upstream migration of anadromous species (e.g., Philadelphia pollution block in the Delaware River, see ASMFC 1998) and damaged nursery areas.

Early attempts to restore lost habitat occurred when concrete dams for electrical generation replaced wooden structures. Fishways often were constructed to facilitate passage, but ingenuity was ahead of scientific knowledge; the lack of understanding about fish hydromechanics, behavioral differences among species, and correct positioning of fishway entrances to attract fish, usually resulted in no fish passage (Clay 1995).

Currently, dams of many Atlantic coastal rivers are being retrofitted for fish passage structures that work, or are being removed entirely if no longer needed, to restore access by anadromous fish to critical upstream habitats (Joseph 1998).

Another issue with hydropower production is the substantial change in river flow patterns experienced downstream of hydroelectric facilities (Zincone and Rulifson 1991). Electrical generation at these facilities often occurs to meet daily peak demand in electrical usage. The advantage to such a power system is the nearly instantaneous response by the power company to meet increased electrical demands, yet the result is a tremendous change in water velocity, water depth, and water quality downstream of the dam (Rulifson and Manooch 1993). Since Fall Line hydropower facilities (i.e., where the upland watershed and coastal watershed join) are common, they represent the most upstream location available for spawning by anadromous species if no functional fish passage is provided. Daily peaking in electrical production causes continual change on the spawning grounds, and efforts are underway in the Roanoke River to return to pre-impoundment historical flow regimes or more appropriate flows for improving the chances of anadromous populations to rebuild to benchmark levels (Manooch and Rulifson 1989; Rulifson and Manooch 1990, 1991, 1993).

**Regulation of the Fishery.** The first fisheries legislation in the American colonies was directed to protecting the striped bass resource. In 1639, the Massachusetts Bay Colony passed legislation outlawing the use of striped bass as fertilizer. In 1670, an act of the Plymouth Colony levied a tax on several fisheries, including that for striped bass, to provide funds for establishing the first public schools and to provide the earliest form of "social security" for "widows and orphans of men formerly engaged in service to the Colony" (Setzler et al. 1980). Federal responsibility for stewardship of the U.S. fishery resources was initiated in 1871 with the Congressionally established position of U.S. Commissioner of Fish and Fisheries. This position was created to address the decline of domestic food fish supplies (U.S. Fish and Wildlife Service 1993).

A myriad of regulations concerning commercial and recreational striped bass fisheries have been passed by all eastern seaboard states until the present day, but coordinated interstate compacts of fisheries regulations were initiated with the formation of the Atlantic States Marine Fisheries Commission (ASMFC) in 1942. This interstate commission, formed of representatives from the 15 eastern seaboard states, the Potomac River Fisheries Commission, and the District of Columbia, was founded to address fishery management within the three-mile limit of state jurisdiction; regulations beyond three miles are federal. The ASMFC routinely assesses the status of recreationally and commercially harvested fish and shellfish species, and provides recommendations for strategies to restore populations of species in decline. One of the first species targeted was the striped bass (ASMFC 1981).

First attempts to manage striped bass on a regional basis were by the U.S. Fish and Wildlife Service based on research in the 1930s and recommendations by William Nevelle (1942, cited in ASMFC 1981), but few states adopted the recommendations.

Record commercial harvests in the early 1970s, followed by drastic declines in population sizes during the late 1970s and 1980s, resulted in the ASMFC taking strong measures to protect the remaining resource. An interstate fisheries management plan (FMP) for striped bass was implemented in 1981. In this plan, management recommendations focused primarily on imposing size limits and spawning period closures, which individual states could implement to enhance the status of east coast striped bass populations. Regulations must come from the states since the ASMFC does not have regulatory authority over individual state fisheries (ASMFC 1987). The initial FMP was deemed insufficient to protect remaining populations, so amendments to the original plan were written in 1984 and 1985 to address more stringent limitations for exploitation. At the same time, the U.S. Congress passed the Atlantic Striped Bass Conservation Act (PL 98-613), which released federal funds for research to ascertain causes for declining populations and also allowed for a federal imposition of a harvest moratorium in states failing to comply with ASMFC recommendations for management (ASMFC 1987).

In the late 1980s, a coordinated coastwide stocking program was considered as a feasible alternative to assist with population restoration (ASMFC 1989) even though this alternative was considered not feasible just several years earlier (ASMFC 1981)**.** A revised plan known as Amendment 4, effective on January 1, 1990, addressed stocking as one measure for rebuilding and managing striped bass populations (ASMFC 1993). The ASMFC acknowledged that socio-economic pressures had caused a number of states to initiate stocking programs. The Commission believed that coastwide coordination and cooperation were critical, and that state programs should adhere to specific guidelines to ensure genetic integrity of wild populations and protection from potential problems introduced through stocking of hatchery fish (Table 1).

**Stock Enhancement Programs.** Protecting and enhancing the striped bass resource through stocking programs were initiated more than 120 years ago in the State of North Carolina and represent the beginning of stocking young striped bass in non-natal streams, a practice that was referred to as “stock transfer” or “cross-stocking” in the 1980s. North Carolina established the Department of Agriculture by an Act of the General Assembly (March 12, 1877). The Act required the North Carolina Board of Agriculture, Immigration and Statistics “at once to provide for stocking all available waters of the State with the most approved breeds of fishes.” Early attempts included “California salmon”, trout, and American shad. In May 1877, hatcheries were established on the Neuse River in the vicinity of New Bern for rearing shad. The Neuse River had the largest shad population south of Chesapeake Bay at the time, but was showing signs of population decline. The watershed already had been stocked by the U.S. Fish Commission in 1873 (43,000 fry) and in 1876 (170,000 fry). Many of the fry produced were stocked in Albemarle Sound rivers, primarily the Roanoke and Chowan, but the long travel time to release sites necessitated the building of a hatchery facility in the Albemarle Sound region (NC General Assembly 1879). The Avoca facility, located at the confluence of the Roanoke and Chowan rivers, soon became the site for early attempts to produce striped bass in a manner proven effective for American shad culture.

Because the striped bass was an important food source, the U.S. Fish Commission was committed to “arresting its alarming decrease.” (Worth 1884). The Roanoke River had the largest spawning run of striped bass south of Chesapeake Bay, and it was in 1874 that Marcellus G. Holton performed the first successful artificial fertilization and hatching of striped bass eggs on the banks of the Roanoke River near the town of Weldon (Holton 1874). In 1878, Stephen G. Worth was appointed state Fish Commissioner. Working at Avoca, Worth considered the feasibility of establishing a striped bass hatchery at Weldon (NC Board of Agriculture 1881). Experiments in 1883 resulted in the establishment in 1884 of a hatchery housed in a temporary building near the flume of a local mill at a point in the river where mature adult striped bass could be obtained. In the first year, six fish collected from the Roanoke by skim nets and fish traps were used to provide 2,420,000 eggs, 1,535,000 of which were fertilized successfully and returned directly to the river along with 280,500 fry (Worth 1884).

The Roanoke striped bass hatchery was the only one in the nation until the 1960s, operated almost continuously first by Federal fisheries agencies and then by the North Carolina Wildlife Resources Commission (Harrell et al. 1990). Production records for the Weldon facility are available, but stocking records have not been located. It is believed that most of the production from the late 1800s and early 1900s was stocked into the Roanoke River with subsequent stockings into adjacent North Carolina watersheds in later years. During the period from 1937 to 1957, a total of 166,820,000 eggs were brought into the Weldon hatchery resulting in production of 106,679,000 fry (Braswell 1983). By the 1960s Roanoke strain striped bass were being shipped all over the U.S. and foreign countries for research, stock enhancement, and restoration or establishment programs (Geddings 1971). The Edenton National Fish Hatchery (NFH) also was involved in striped bass production using Roanoke fish and served as a major source of Roanoke striped bass to other federal and state hatcheries, as well as overseas requests (Table 2). By 1971, Roanoke fingerling striped bass had been distributed to North Carolina, Virginia, South Carolina, Georgia, Florida, Tennessee, Alabama, Oklahoma, Michigan, New York, and Russia. By the mid-1960s the State of South Carolina established the Moncks Corner hatchery. Major breakthroughs in striped bass culture were accomplished there, including successful spawning of non-ripe females using hormone injection (Stevens 1966, 1967; Bayless 1972), which resulted in the construction and operation of many striped bass hatcheries in the United States (Harrell et al. 1990). In 1973, the State of Virginia established the Brookneal striped bass cultural station on the banks of the Staunton (Roanoke) River to take advantage of an upstream Roanoke population landlocked in 1950 with the construction of the Kerr Reservoir. The Brookneal facility became a second major contributor of Roanoke strain striped bass, most of which were stocked into Virginia watersheds discharging to Chesapeake Bay (Table 3).

By the 1970s a number of federal and state hatcheries had been established, and many states had striped bass stocking programs. The Roanoke and the Santee-Cooper (Moncks Corner Hatchery) were not the only sources of fry; additional sources included fry with origins from watersheds in New York, Maryland, Virginia, Georgia, Florida, and Louisiana (Table 4). From 1965 until the early 1980s, over 65 million striped bass were stocked in coastal tributaries of the Gulf of Mexico to enhance the sport fishery (Rulifson 1987). Less than one percent of stocked fish were of Gulf of Mexico origin. It was believed that the migratory nature of Chesapeake Bay strains would result in Gulf populations utilizing coastal rivers for spawning but ocean coastal habitats as adults, thereby increasing potential population size and enhance the striped bass sport fishery. Cross-stocking in the Gulf of Mexico was only moderately successful in part because northern strains had difficulty adjusting to the warmer water temperatures (Rulifson 1987). In the north, Maine instituted a stocking program to enhance the recreational fishery (Table 5). From 1982-1991, Maine stocked 260,000 Phase II (175-250 mm TL) juvenile striped bass of Hudson River origin into the Kennebec/Androscoggin Rivers and tributaries to develop a self-sustaining population (Flagg and Squiers 1992). A similar restoration program for the Navesink River population was initiated in New Jersey (Baum 1992). The source of origin for fish to be used in the Navesink restoration was debated; offers to ship fish from California were made but the general consensus was that West Coast striped bass likely would not resemble their Navesink River origin after 100 years and multiple generations. Instead, Navesink restoration was accomplished (Table 5) using Roanoke fish of Weldon and Brookneal origin (Peter Himchak, New Jersey Division of Fish, Game, and Wildlife, personal communication). Figure 1 depicts watersheds of the U.S. Atlantic coast that received, or still receive, hatchery-reared striped bass.

Concern about the need for coordinated efforts of stock enhancement and restoration resulted in the States cooperating with the U.S. Fish and Wildlife Service to establish cooperative stocking programs with criteria established by the ASMFC (Table 1). States from Maine through North Carolina began reporting coastal stockings to the ASMFC (Table 2) with an attempt to stock fry and fingerlings back to native coastal waters. During the 1990-1995 period, a total of 22 of the 77 federal hatcheries were producing striped bass: Alabama (1 hatchery), Arkansas (1), Florida (1), Georgia (2), Louisiana (1), Massachusetts (1), Missouri (1), Mississippi (2), North Carolina (2), Ohio (1), Pennsylvania (1), South Carolina (2), Texas (3), Virginia (1), and West Virginia (1). Total striped bass production by federal hatcheries during this period was 830,000 eggs and 51,920,772 fish (U.S. Fish and Wildlife Service fish and egg distribution reports for 1990-1995).

## Present Stock Status

All components of the Atlantic coastal migratory stock are considered recovered to recent historic levels (1960s and early 1970s). The Chesapeake Bay stock was declared recovered on January 1, 1995, and the Albemarle-Roanoke stock was declared recovered in November 1997. The Delaware stock was considered recovered in late 1998. The Hudson River stock never was considered to be in a state of collapse and therefore was not targeted for restoration efforts.

At present, the U.S. Fish and Wildlife Service Fisheries Program involvement with striped bass is limited to the production of fish for restoration of non-migratory populations that reside in South Atlantic and Gulf of Mexico drainages. Edenton NFH, NC, is producing phase I striped bass of the Santee-Cooper strain for the State of South Carolina; these fry will come from the SC state hatchery at St. Stephens (formerly Moncks Corner). Edenton is also producing phase I and phase II Roanoke River striped bass from fry provided by the Watha State Fish Hatchery (NC) for stocking into the Neuse River, NC, and upstream reservoirs on the Roanoke River as partial mitigation for dam construction. Gulf of Mexico strain striped bass fry are being produced at Welaka NFH, FL, Marion State Fish Hatchery, GA, and Blackwater River (state) Fisheries Research and Development Center, FL, for growout to phase I and/or phase II at five federal hatcheries: Welaka NFH, Private John Allen NFH, MS, Natchitoches NFH, LA, Inks Dam NFH, TX, and Warms Springs NFH, GA. These fish are destined for stocking in Gulf of Mexico drainage basins.

Rationale for stocking programs

**Increase commercial harvest.** Stocking of the late 1800s was an attempt to stop the decline of food value fisheries in coastal areas (Worth 1884), and clearly the intent was to maintain or increase commercial harvests. In the 1900s, the peak in commercial harvest in 1972 followed by the precipitous drop in landings spurred states to address the situation through stocking efforts rather than implement harvest restrictions. Indeed, the strict ASMFC-coordinated management recommendations of 1981, and the moratorium of harvest in Chesapeake Bay beginning in 1985 were designed for recovery of the fisheries, both commercial and recreational, with a goal of an unidentified recovery level to be determined at a later time (John Field, ASMFC, personal communication).

**Protect/enhance recreational fishing.** The monetary value of striped bass for sport fishing along its range was, and continues to be, one of the most lucrative of the recreational fisheries. In many of the southern states where striped bass populations were smaller, the striped bass sport fishery was much more valuable than a commercial fishery and stock restoration efforts of the 1960s and 1970s were directed to enhancing the economic value of the fishery (Rulifson et al. 1982a).

**Public visibility in fixing the problem**. Because of the extreme popularity of striped bass as a food fish and sport fish, the striped bass resource was perceived by the public as a barometer of the general well-being of our Nation’s coastal resources. The dramatic decline of the 1970s brought outcry from the public, from commercial and sport fishermen, from environmental groups, and from fishery managers themselves. Chesapeake Bay was the center of activity surrounding the striped bass issue, and outcry brought action by the U.S. Congress to release federal funds to study the decline. The Emergency Striped Bass Study (ESBS), initiated in 1982, launched investigations by numerous scientists to identify problems associated with striped bass decline. While researchers “grasped at straws”, ranging from acid rain and toxic chemicals to general decline in water quality, others believed that the stocking of fingerling-sized striped bass would overcome the environmental problems being experienced by the wild striped bass eggs and larvae. Also, a large stocking program was a visible signal to the public that the striped bass problem was being addressed. If overharvest was part of the problem, the 1980s plan by the ASMFC for reducing fishing mortality was not mandatory until 1984 (J. Field, ASMFC, personal communication).

Issues

**Does stock enhancement work?** Whether stock enhancement "works" depends upon the goals of the stocking program, and the criteria used to evaluate enhancement efforts. The recent (1985-1995) ASMFC stocking program was undertaken "...to determine the feasibility of using artificial propagation as a restoration tool for rebuilding Atlantic coast striped bass stocks" (Upton 1993, 1996; Upton and Mangold 1996). The ASMFC program's indicators of success were: 1) the return of marked and stocked striped bass to the spawning grounds as brood fish; 2) the change or failure of change in young-of-the-year indices; 3) changes in the viability of eggs and larvae; 4) changes in the ratio of juvenile marked hatchery fish to unmarked fish in collections made by beach seine, gill nets, pound nets and electrofishing; and 5) the contribution of hatchery fish to recreational and commercial fisheries (the latter criterion was added in the later years of the study, see Upton 1996, p. 10). Evaluation of the stocking program is still ongoing with sampling programs for detecting the presence of binary coded wire tags (BCWTs) in stocked fish. However, stocking has largely terminated (as of 1994) and some preliminary conclusions are evident (Upton 1996, Upton and Mangold 1996). The stocking of large numbers of juveniles in order to increase the numbers of sub-adult and spawning fish appears to have been successful, at least in some tributaries (i.e., Patuxent River, see next section). Stocked fish are now contributing to the spawning population (1-3% in larger systems). The young-of-year index in Chesapeake Bay has on average increased since initiation of stocking; however, it is impossible to link this trend with introduction of hatchery fish due to the large size of the Chesapeake Bay wild population (Upton 1996). As noted below, the Patuxent River is an exception, since there appears to be a significant hatchery contribution to the spawning population and viable fry. With regard to production of viable fry, hatchery-reared females that were recaptured on the spawning grounds in Maryland were successfully spawned in captivity. The ratio of hatchery and wild juvenile striped bass is dependent on the number of hatchery fish stocked and the strength of a given year class. Collections in the Patuxent River documented hatchery fish comprising as much as 85% to as low as 1% of the fish present. Production of dominant year classes in recent years was taken as an indication that recovery is taking place and that in most cases, supplementation with hatchery fish appears unnecessary (Upton 1996). Surveys of Maryland commercial and recreational fisheries from 1991 to 1993 showed a consistent bay-wide hatchery fish contribution of 4.5 to 7.5%. It should be noted that a moratorium imposed on striped bass harvest by the Chesapeake Bay states in 1985, and the subsequent production of dominant year classes in 1993 and 1994, are considered to be greater factors in recovery of the coastal migratory stock than the stocking program itself.

Another significant issue in the evaluation of stocking programs is the benefit versus the cost, especially when the program is supported using public funds. Upton and Mangold (1996) include a preliminary analysis and evaluation of the costs and benefits of the Chesapeake Bay stocking program. They divided program costs into four categories: 1) acquisition and construction of facilities and equipment; 2) collection of brood stock, spawning, care of larvae, tagging and transport; 3) maintenance and operation of hatchery facilities for grow out; and 4) evaluation of the striped bass program. Stock enhancement programs for striped bass are not cheap, with costs of about twenty cents each for phase I (20-35 mm TL "fingerling") fish and one dollar each for phase II (175-250 mm TL) fish (Elliot Atstupenas, Edenton NFH, U.S. Fish and Wildlife Service, personal communication). Cost of individual fish production for the Chesapeake Bay striped bass stocking program ranged from 0.42 cents to $4.28, depending on the facility and the phase of fish produced (Upton and Mangold 1996). Total costs for rearing 7.8 million striped bass at U.S. federal hatcheries and power company hatcheries during the period 1985-1995 were estimated at $7,135,839. Total costs of any stocking program, including start-up costs if infrastructure such as new hatchery facilities are required, should be weighed against the benefits in terms of the economic value of recreational or commercial fisheries to be restored and/or enhanced, as well as the ecological value derived from reestablishing biodiversity or community structure. No such study has been conducted for stocking programs involving migratory striped bass.

A last, somewhat philosophical issue is: Why stock if a wild, self-sustaining population can be maintained through controlled harvest? Stocking is expensive as noted above, requiring extensive use of limited funding available for fisheries management, and has other associated problems (maintaining appropriate genetic diversity, etc., see below). In theory, wild populations should sustain themselves at no cost to society as long as spawning stock biomass is sufficiently high. However, good management requires constant monitoring to collect and analyze data to ensure that sufficient spawning stock biomass is maintained, and such monitoring also is expensive. We are not aware of any studies that compared the costs of these two management approaches and reached a conclusion as to which is most cost-effective for sustaining public trust resources. Grimes (1998) recently reviewed the historical development of marine stock enhancement and discussed the rationale for attempting to enhance marine populations using hatchery-reared progeny; the same issues apply to discussion of anadromous stock enhancement. Grimes noted that artificial enhancement of natural populations, if it can be accomplished, would be an attractive solution to fishery managers who are desperate to recover depleted populations. But, he also raises the issue of whether marine stock enhancement is simply "techno-arrogance", our belief that we can avoid making the difficult decisions necessary to conserve natural populations and the ecosystems that produce them through the techno-fix of enhancement (Grimes 1998). He concludes that, although the scientific basis for marine stock enhancement has significantly advanced, "...it is not yet possible to conclude that marine stock enhancement is or is not biologically and economically feasible", and noted that the desirability of stock enhancement for recovering populations must be weighed against the far less expensive, but more politically difficult, traditional management approaches such as size limits, catch quotas, gear restrictions, and harvest refugia. Our sentiments lie with maintaining the wild populations because so many genetics pitfalls are avoided under that alternative as well.

**What age is best-suited for stocking?** Size of striped bass used for stocking is somewhat dependent upon the goals of the program. Use of either phase I or phase II fish bypasses the sensitive egg and larval stages and in theory gives the fish a "jump start" toward survival as adults (unless of course predators learn to forage near the hatchery truck during release, as has been documented in at least one case). If cost is a big factor, phase I fish cost less to produce than phase IIs. One or the other phase may be more desirable depending upon the proposed release site, presence of known predators in the system, time of year, or other factors. Studies with largemouth bass in reservoirs indicate that the survivability of the stocked juveniles may be very dependent upon the numbers released at a given site (fewer is better) and the habitat at the release site (appropriate nursery habitat)(James R. Jackson, Department of Zoology, N.C. State University, personal communication). Few studies have been done in which rates of return of different aged fish at release were compared, in part because of the difficulty in controlling such variables as the condition of the fish upon release. However, of the studies reviewed, stocking larger fingerlings resulted in higher survival (Eager 1991, Sutton et al. 1998). Van Den Avyle (1998) examined post-stocking survival of striped bass in the Savannah River, Georgia-South Carolina and determined that recruitment to the adult population was optimized by stocking fewer, larger, more costly phase II fish.

Upton and Mangold (1996) evaluated the use of phase I (40-50 mm) and phase II (150-200 mm) striped bass in the Chesapeake Bay enhancement program. They noted that use of phase I has the advantage of lower production costs due to the shorter period required in the hatchery, and that larger numbers of fish can be produced at a given facility because of their smaller size at stocking time. Cost of phase II production has been estimated to be five times greater (Dorazio et al. 1991). The off-setting disadvantage of using less costly phase I fish is dependent on the relative survival of phase I and phase II releases in the wild. Phase I fish are subject to natural mortality for four to five months before phase II fish are stocked. Predation by adult striped bass within days of release can be a significant factor in mortality (Andreasen 1995). Results of comparing the rates of return of phase I and phase II fish were somewhat inconclusive. For some years, rates of recovery were about the same for both sizes (1989) and in others, phase II fish were recovered at rates two to four times greater (1988). Upton and Mangold concluded that stocking of phase I fish is a viable option given that recovery rates were about the same and production costs much lower.

**Do fish survive and contribute?** The coastwide tagging studies combined with other evidence shows that hatchery-reared fish survive stocking, contribute to the wild population, and eventually participate in spawning runs of the wild populations. Upton and Mangold (1996) documented that intense stocking of small watersheds, combined with low abundance of the wild population, resulted in as much as half of the population comprised of stocked fish. An example was the Patuxent River in Chesapeake Bay. Fishery independent surveys were conducted each year on the Patuxent River spawning grounds. The population was being supplemented by hatchery-reared fish. In 1987, an increased stocking effort resulted in nearly 400,000 hatchery-reared juvenile striped bass placed into the system. In 1987, the juvenile survey index was only 2.94 (low since 1985 was 0.28 in 1990). The resultant 1987 year class recovered during Patuxent spawning ground surveys from 1992 to 1995 was comprised of 26% to 49% of hatchery-origin fish. However, the contribution of hatchery-reared striped bass to populations in larger coastal surveys (e.g., New York haul seine) and Chesapeake Bay were about 5% during the initial stock-rebuilding period (H.F. Upton, personal communication). In the Savannah River, Georgia-South Carolina, hatchery-produced fish now account for about 70% of all fish in the system; the current moratorium on harvest was implemented in 1988 (Carl Hall, GA Department of Natural Resources, personal communication).

Inland stocking has considerable survival, and evidence indicates that hatchery-reared fish stocked in upstream reservoirs can move downstream through dams to coastal streams. Memos written by North Carolina Wildlife Resources Commission (NCWRC) personnel during the late 1960s documented the development of recreational striped fisheries in inland reservoirs not stocked by the NCWRC. Chapman (1969a) provided a list of “reliable reports” of striped bass caught in 1968 and 1969 in Badin Lake, a Pee Dee River watershed reservoir not stocked by the Commission. Fish ranged in size from 0.75 lb. to over 12 lb. Chapman (1969a) stated that “these fish migrated downstream from High Rock Lake, since Badin Lake has never been stocked with striped bass”. High Rock Lake was a target system for inland striped bass stocking since the early 1960s. A second memo from Chapman (1969b) provided evidence that Yadkin River reservoirs were experiencing the same phenomenon. Photographs accompanied both memos. Recent studies conducted by North Carolina State University indicate that some striped bass stocked in Lake Gaston passed through the dam and entered the adjacent downstream Roanoke Rapids Reservoir as long as a year after initial tagging. Others tagged and released in Lake Gaston passed through both downstream dams and entered the coastal watershed of the Roanoke River and eventually Albemarle Sound immediately after handling (J. Hightower, U.S. Geological Survey, Biological Resources Division, NCSU, personal communication).

**What should be used as broodstock?** Adult striped bass collected from wild populations should be used in hatcheries to maximize genetic diversity. However, we caution that, based on the history of cross-stocking along the eastern seaboard, we can no longer assume that adult broodfish captured on the spawning grounds are in fact of a strain or strains endemic to that stream. This aspect has been documented through tagging programs described elsewhere in this manuscript. If the intent is to enhance a fishery and conserve the genetic integrity, then genetic testing of individual brood fish before spawning is recommended.

**What effect does stocking have on genetics of the population?** The overriding consideration when stocking to supplement wild populations is the potential loss of genetic diversity and reduced fitness of the wild population including, but not limited to, reduced fidelity to natal streams, reduced disease resistance, and reduced availability to adapt to prevailing environmental conditions. These phenomena have been studied in great detail for salmonids but not striped bass. See articles by Danzmann et al (1989), Altukhov and Salmenkova (1990), Gauldie (1991), Skaala et al. (1990), Waples et al. 1990, Allendorf (1991), Hindar et al. (1991), Ryman (1991), and Schramm and Piper (1995).

One possible problem involves a phenomenon known as “bottlenecking”. The term “bottleneck” refers to a population experiencing a severe reduction in the effective number of breeding adults. This phenomenon can occur in nature when the population drops to a threshold level beyond which natural recovery may not be possible. Loss of genetic diversity for the population occurs when only a few individuals are involved in spawning. This diversity is lost to all future generations unless it is regained through mutation, a process that cannot occur in real time. Loss of genetic diversity is one of several reasons why it is difficult to restore a natural resource with hatchery-produced populations (Tave 1993). Stocking programs can exacerbate this problem when only a few adults are used to produce hundreds of thousands of fish for wild stock supplementation. Inbreeding occurs when a small number of broodstock are used, and the result could be beneficial if the culturist has selected for enhanced growth, feeding, age at maturity, etc., but at the same time cause the appearance of deleterious recessive phenotypes seldom observed in wild populations. Problems that can occur after only one generation of sibling mating include reduced growth rate, lower survival, poor feed conversion, and increased numbers of deformed larvae (Piper et al. 1982). For stocking programs, fish culturists are encouraged to use as many adults as possible in order to conserve the greatest amount of genetic diversity.

At first glance, the concept of stocking fish in non-natal streams seems a good strategy, because cross-stocking could, in effect, negate the potential for bottlenecking caused at the hatchery. Allowing fish of different origins to reproduce at random on the spawning grounds could produce hybrid vigor, especially in growth and disease resistance (Piper et al. 1982). However, it could be counterproductive because introgression fundamentally alters the “native gene pool” by disrupting co-adapted gene complexes thereby reducing fitness of the population, a phenomenon known as “outbreeding depression”.

**Ecological compatibility of the strain to the habitat**. Hatchery-reared fish cross-stocked into other watersheds can utilize the resources and compete with the wild population for habitat, food, etc., but may be ecologically unfit to reproduce successfully during spawning because the critical life stages of eggs and larvae are not compatible with the watershed environment (Philipp et al. 1993). This means that the maturing hatchery-reared fish may be incapable of producing progeny that can recruit successfully to the forming year class, which results in an expensive put-and-take fishery program. Beyond that, hatchery-reared fish surviving to maturity will breed with native fish resulting in offspring less fit to cope with the unique ecological conditions of the watershed.

Therefore, in developing stock enhancement and restoration programs, it is important to consider the type of watershed habitat to be stocked, and determine the most appropriate source of fish to be used in the stocking program; i.e., the genetic code conserved under the unique set of environmental conditions for one watershed should be similar to that of adjacent and similar watersheds. An extreme example is the extensive stocking effort of “Atlantic strain “ striped bass into watersheds along the Gulf of Mexico. Since the intent was to enhance the sport fishery, and since the habitats were limited in size, the idea was to expand habitat availability by stocking striped bass that exhibit migratory behavior out of the watershed into coastal waters. However, these stocking efforts were of limited success in part because of temperature differences between regions. Another example is the Roanoke River, where stockings included fish of Maryland origin. Several striped bass populations in Chesapeake Bay are known for having more buoyant eggs to remain in the water column of slow moving watersheds of the Eastern Shore. Roanoke River striped bass have a heavier egg to remain within the channel of the floodplain watershed. Buoyant eggs may be transported to the floodplain during high water events, thereby reducing chances of successful reproduction of the Maryland lineage. In theory, the “Roanoke population” without stocking should eventually return to a genetic lineage, or set of lineages, ecologically compatible with the watershed (i.e., survival of the fittest). Alternatively, Roanoke strain fish stocked in slow-moving waters may have eggs too heavy to remain suspended, so stocking Roanoke fingerlings in Eastern Shore watersheds of Maryland or in the Upper Chesapeake Bay would not be a prudent decision.

In Canada, striped bass in the Shubenacadie watershed of Nova Scotia experience a tidal bore twice daily, which causes a potentially harsh set of environmental conditions for spawning. If the Shubenacadie striped bass population is being considered as a brood source for stock enhancement and restoration programs, then understanding how this population has evolved to cope with this unique set of environmental conditions is critical before such programs are initiated (Rulifson and Tull 1999, in press).

Stocking Methods

**Early stocking practices.** Major spawning populations were the sites used for early stocking efforts. The Roanoke population had a large, well-defined and easily accessible spawning run which was conducive for early fish culture. Young fish could be trapped and transported to other locations (e.g., the Navesink, New Jersey fish transported by rail car to California); however, early culture efforts used wild adults in spawning condition and fertilized eggs or fry were returned directly to the natal stream. Improvements in hatchery techniques for rearing, handling and transporting allowed for fry to be put into adjacent watersheds. Because early efforts were directed to reversing the decline of food value fisheries, stocking young fry and fingerlings produced at a central location into adjacent watersheds was of a practical necessity.

**Interstate regulatory changes for stocking practices**. As discussed earlier, concerns for protecting remaining populations and new awareness of possible importance in maintaining genetic integrity led to a set of specific recommendations from the ASMFC about how coastal stocking of striped bass should be conducted

(Table 1). A number of coastal states revised their methods of collecting brood stock for hatchery production, collecting from coastal streams rather than utilizing a single population. However, changes to coastal stocking protocols did not apply to inland stocking programs, which continued to rely on brood fish caught from a single population, or kept on station.

**Present stocking strategies**. At the interstate level, a coordinated federal-state stocking program is nearly non-existent at the present time primarily because the striped bass stocks are considered to be restored. The Striped Bass Stocking Committee of the ASMFC has not met in nearly 4 ½ years because estuarine stocking is now considered a non-viable activity for stock restoration (John Field, ASMFC, personal communication). Any coastal stocking currently underway is being conducted under ASMFC guidelines (Table 1), and any future coastwide stocking programs likely would follow the same guidelines. Coastal monitoring programs by state and federal agencies continue to scan for coded wire tags (CWTs) implanted in the 1980s and early 1990s. At the state level, stocking programs are primarily inland reservoirs with little effort directed toward coastal populations. One exception is the Savannah restoration effort. The Savannah River striped bass population crashed in the late 1980s. Restoration efforts used Ogeechee River adults as brood, but now inland reservoir fish of Savannah, Ogeechee, and Gulf origins are used for the coastal stocking program. Amendment 4 of the striped bass management plan passed in 1989 opened the coastal migratory stock to modest commercial and recreational fishing pressures. Striped bass were considered fully restored based upon a spawning stock biomass (SSB) model developed by Lou Rugelo of Maryland. The SSB model used the Maryland Juvenile Abundance Index (JAI) and grew the fish up through time, accounting for emigration from the system. The units were relative SSB units irrespective of age structure. The strong 1993 year class in Chesapeake Bay was important in making the SSB units increase dramatically to the benchmark population levels of 1960-1972. Based on Rugelo's model, the Commission declared the Chesapeake Bay population recovered on January 1, 1995.

## Management Implications

**Re-examination of current stocking practices.** The idea that "wild adult fish", taken from spawning grounds for hatchery production, may NOT be the "original" endemic strain is relatively new and may be discounted by some culturists and fishery managers. However, consider the following scenario. Typically, capture of wild brood occurs early in the spawning season to ensure that enough fish are available for meeting hatchery production needs for the year. If the river population was enhanced by stocking a striped bass strain that spawns at lower water temperatures than the endemic strain, the annual hatchery production could be based on the non-endemic strain collected at lower water temperatures, rather than the endemic strain that has not yet arrived because water temperatures are too cool. If the non-endemic strain has additional characteristics incompatible with its new watershed, such as perhaps the wrong egg buoyancy, the strain will be perpetuated in the system through stocking efforts. If the population was left to natural production, over several generations (decades) Darwin's "survival of the fittest" theory should eventually eliminate any cross-stocked lineages ecologically incompatible with the watershed.

**What contribution are hatchery fish now making to "restored stocks"?** During initial stocking efforts, the relative contributions of young hatchery-reared striped bass to the year class were considerable, as much as 30-50% in smaller systems with low population size (Upton and Mangold 1996). However, as populations rebuild the relative contribution of hatchery-reared fish decreases. After time, the signal of hatchery-contributed fish is obscured and eventually may disappear. At the present time, data from the annual New York haul seine survey indicate that hatchery fish comprise about 1% of the coastal population off New York. On the other hand, a very high JAI of 100 in the Patuxent River in 1993 caused speculation that the hatchery-reared females of the 1985 and later year classes were returning and contributing to the spawning stock (H.F. Upton, personal communication).

**Mixed stock analyses for ocean harvest.** Considerable effort and expense have been directed to identifying a foolproof method that can distinguish unique populations of striped bass during the coastal ocean phase of the life cycle, but the large, extensive coastwide stocking programs documented here potentially has "mongrelized" most, if not all populations and therefore results of mixed stock analyses should be interpreted carefully.

Early methods used to identify populations have employed meristic and morphometric techniques and biochemical techniques. A review of these methods was provided by Waldman et al. (1988). Studies conducted prior to the 1970s may have had an unknown level of accuracy assuming that striped bass exhibit fidelity to natal streams. However, none of these studies identified population markers that consistently and accurately assigned individual fish to particular populations, and none of the studies considered the effects of cross-stocking on the analyses.

In recent years efforts to discriminate among striped bass populations have employed genetics since they appear to work for other species, especially salmon species (e.g., Waples 1990), yet these studies ignore the issue of cross-stocking. Several recent striped bass studies have removed the Roanoke population from mixed stock analyses because tagging studies suggest that Roanoke fish do not contribute to the coastal migratory stock. Yet, Roanoke fish have been stocked extensively and, presumably, the genetic signal remains. Similar conditions should exist for other genetic signals as well including the Hudson, "Chesapeake", and Santee-Cooper. It follows that mixed stock analyses may provide an indicator of the contribution of genotypes to the mixed stock frequency, but it would be impossible to identify if "Hudson River" fish were from the Hudson River, the Kennebec River, or any another river having a population enhanced or restored using fish of Hudson River origin.

Until the genetic variability of individual populations is carefully described, efforts to develop mixed stock analyses are meaningless. Stellwag et al. (1994) carefully described the heterogeneity of the Roanoke River population by sampling female striped bass throughout the spawning season for two years, as opposed to other studies using the "grab sample" technique of collecting fish within several days. Using this sampling protocol and several additional nucleotide cutters, six distinct genotypes were identified in the population as opposed to another study conducted in the same year describing the population as genetically homogeneous (Wirgin et al. 1990). Stocking records document that the river has received fish from at least four sources including the Santee-Cooper, "Maryland", and the upper Roanoke population from Virginia above Kerr Reservoir, so results indicating a heterogeneous population are reasonable. Until similar studies are conducted to fully describe intra-population variability (i.e., population heterogeneity) on temporal and spatial scales for all populations, mixed stock analyses should be considered confounding and subject to multiple interpretations.

**Law enforcement problems tracking illegally harvested fish**. By mutual agreement of the jurisdictions party to the ASMFC's Amendment 5 to the striped bass management plan (ASMFC 1995), all migratory striped bass legally taken in commercial fisheries from North Carolina through Maine are to be individually tagged for identification purposes. Tags can, however, be counterfeited, or more likely, reused on fish to allow harvest in excess of specified quotas. In addition, fish taken illegally after seasons are closed or from closed areas can be shipped to inland markets (e.g., Chicago, Illinois) in states which are not members of the ASMFC and which do not enforce tagging requirements.

Given that poachers would not likely tag fish anyway, law enforcement agents must be able to document that fish originated from the particular water body where illegal harvest occurred. Unless the fish are literally watched by agents (via videotape) and their journey documented from the source water body to the market destination, other methods are required for identification. Use of distinct proteins present in tissues has been perfected as a means of discriminating cultured red drum (*Sciaenops ocellatus*) from wild populations; however, such techniques are not yet available for striped bass insofar as we are aware. Lack of coordination between jurisdictions with regard to tagging requirements, and the timing of harvest seasons is a final problem which makes enforcement and control of illegal harvest difficult. If one jurisdiction has an open season while others are closed, a legal outlet is provided for illegally harvested fish (T. Bennett, Senior Resident Agent, Law Enforcement, U.S. Fish and Wildlife Service, personal communication). Another recent issue is the poaching of gravid females, from which eggs are removed, fertilized and then hatched and the resultant fry and/or fingerlings shipped to Asian and Latin American countries for use in the aquaculture industry (Mike Elkins, Deputy Assistant Regional Director-Law Enforcement, FWS, Atlanta, GA).

Technology is currently available to insert a genetic marker into hatchery-reared fish. If the mark was different for each river targeted for stocking, then the genetic marker could be used for law enforcement purposes as the mark slowly enters the wild population from hatchery-marked fish eventually participating in annual spawning activity.

Ecological Implications

**Gene pool conservation of the species.** The primary literature documents the critical need for conserving the genetic diversity of a species to maximize the chances that future generations can adequately cope with the constant shift in environmental conditions. There are two components to overall genetic diversity: 1) within-population variation, which can be lost through inbreeding at a small population size; and 2) among-population diversity, which can be lost through mixing of populations. Stocking programs can severely reduce genetic diversity, especially restoring populations of few remaining individuals, as documented elsewhere in this manuscript (e.g., Philipp et al. 1993). However, severe fishing pressure, especially targeted to spawning populations, may have a similar effect through differentially removing the older and heterozygous individuals from the virgin stock as documented for the orange roughy, *Hoplostethus atlanticus* (Smith et al. 1991). Severe fishing pressure on the spawning populations must be eliminated to conserve the remaining genetic integrity of the population.

**Is there STILL such a thing as "stock integrity" or "discrete stocks"?** Experts disagree on the extent to which endemic striped bass populations may have been disrupted by cross-stocking. On one side, some fishery managers and geneticists insist that stocked fish represents only a minor contribution to the population, and survival likely was poor, so there is no problem. However, until the compilation of the stocking records presented in this document, there was no comprehensive information about hatchery contributions. Others believe that the problem is severe, perhaps causing a reduction in fitness of the population and causing migratory adults to wander into the wrong river system. Unfortunately, these trends are difficult to document *a posteriori* and so the question remains debatable and likely unsolvable.

Clues to addressing this debate may lie in the remaining striped bass populations at the northern end of the range, i.e., the Shubenacadie and Miramichi populations. These populations have not been stocked, and careful documentation of the natural genetic variability of each population (in time and space), combined with similar care in describing each component of the life history through field studies and tagging experiments, may provide information about what U.S. populations were like prior to the 1880s.

One additional problem is finding a genetic technique to describe lineal and population variability. As described earlier, a number of non-genetic techniques have been used, and recent efforts have involved mitochondrial DNA (mtDNA) and nuclear DNA. Results of these studies are not as straightforward as they appear (Danzmann et al. 1989, Paula et al. 1989, Birt et al. 1990, Billington and Hebert 1991,). The method of characterizing the mtDNA D-loop genome by the restriction fragment length polymorphism (RFLP) technique initially was believed to be a good identifier among populations, but recent studies indicate that it is a highly unstable marker, even among siblings (King et al. 1998). Until a reliable and stable marker is identified to address this problem, the issue will remain unresolved.

**Homing versus wandering**. Recoveries of tagged hatchery-reared fish suggest that wandering among river systems is common, but more importantly, hatchery-stocked fish can be found on the spawning grounds of non-natal rivers. Upton and Mangold (1996) reported considerable mixing between Chesapeake Bay and the Delaware river system. U.S. Fish and Wildlife Service tag return data documented that commercial and recreational fishermen in Delaware Bay were recapturing internal anchor-tagged juvenile striped bass of hatchery origin released into Chesapeake Bay waters; it is hypothesized that these fish moved through the Chesapeake and Delaware (C&D) Canal within the first year of stocking. This trend continued throughout the reporting period. Ample evidence from tag returns suggests that Chesapeake-stocked fish eventually started participating in spawning runs within the Delaware River. Whether these fish spawned and produced progeny that recruited to the forming year class is undocumented. The Delaware spawning grounds independent fisheries survey conducted each year recovered a total of 31 hatchery-tagged (CWT) fish through 1995. Chesapeake Bay/Maryland hatchery-released fish accounted for 30 out of the 31 recovered on the spawning grounds, and 24 of those 30 fish were from Upper Chesapeake Bay releases. Within Chesapeake Bay itself, mixing of hatchery-reared striped bass among the rivers is common. Fishery independent surveys of the spawning grounds conducted from 1991 through 1995 indicated total mixing (not random) among all systems surveyed; Nanticoke-stocked fish were found on spawning grounds of the Choptank River, Patuxent-stocked fish were found on upper Bay spawning grounds (where the Susquehanna River enters the Bay), etc. Hatchery-reared fish also were recovered from spawning grounds of rivers not stocked such as the Potomac and Chester rivers.

## Conclusions and Recommendations

Based on review of the literature that addresses existing migratory striped bass stock enhancement programs in the United States, as well as the broader review of marine stock enhancement issues prepared by Grimes (1998), it is apparent that there is no definitive answer at this time with regard to the effectiveness, from either an ecological or economic perspective, of such stock enhancement efforts. Definitive answers await further rigorous testing using sound scientific design. In the interim, management of striped bass populations should be conducted conservatively with a view toward maintaining present genetic diversity, sustainability and ecological function.

**Recommendations on Enhancement**. We generally concur with the conclusion of Upton and Mangold (1996) that "...stocking solely for the purpose of put-and-take fisheries is not advisable given the current success and relatively low costs of wild fishery management." Grimes (1998) reaches essentially the same conclusion that the desirability of marine stock enhancement as a management tool "...must be weighed against far-less-expensive, but more politically difficult, traditional approaches...." In our view, the conservative approach for enhancement of wild, endemic stocks is to impose sufficient regulatory measures to ensure adequate protection, conservation and sustainability for future generations.

Should stock enhancement be chosen as a management measure in the face of documented uncertainties, then we strongly recommend a thorough review and adoption of the measures recommended in Upton (1996). That report finalizes recommendations which should be incorporated into any migratory striped bass stocking program. The recommendations pertain to seven major areas and are repeated here in their entirety, with minor editing to reflect application to Canadian stocks:

1) Disease considerations:

- Striped bass tested and proven to be carriers of the IPN virus should not be stocked anywhere and especially not into waters with salmonids.

- To reduce the spread of disease, any striped bass designated for stocking or transport into provinces that culture salmonids should be screened for IPN and other pathogens. It is incumbent upon potential striped bass shippers, including private culturists, to be aware of each province's policies and regulations on disease screening prior to shipping to that province.

- Provinces receiving striped bass may require screening for pathogens. Screening requirements and authorization to ship fish is the prerogative of the receiving province.

- Provinces should report shipping and disease screening requirements for striped bass to the DFO so that this information can be readily disseminated.

- Additional research is needed on the potential of disease transfer among striped bass, other anadromous species, and warmwater species.

2) Tagging programs:

- If fish are to be stocked in coastal waters, a sufficient number must be marked to allow determination of survival and percentage of contribution to natural (endemic) stocks. All fish should be marked in cases where hatchery-reared striped bass could confound juvenile survey indices.

- Development and use of genetic tags will provide a means to ascertain the true contribution of hatchery fish to spawning and year class success.

- All fish should be marked if one million or less are stocked.

- If more than one million are to be stocked, then the percentage to be marked should be calculated based on the number of fish released and the estimated number in the natural (endemic) stock.

- Binary coded wire tags should be used to mark fingerlings to be released in all coastal waters. Other tagging methods which also differentiate release sites and date might be substituted under certain circumstances.

- Binary coded wire tag codes should contain information sufficient to identify each lot of fish stocked.

- Under certain circumstances hatchery fish of sufficient size should be marked with tags recognizable to fishermen so that individuals may report recoveries.

3) Restoration criteria: (see below)

4) Genetic and hybrid concerns:

- Genetic integrity of Atlantic Coast striped bass should be maintained within river basins, including specific rivers of bays and estuaries. This could be accomplished by delineating conservation management units that identifies the genetic strain.

- Only progeny from endemic brood stock, when available, should be stocked in river basins and coastal waters.

- Progeny from brood stock of adjacent rivers or hydrologically similar systems should be used if endemic brood stock do not exist. If non-endemic fish are to be stocked these activities should be reported to the DFO.

- Brood stock requirements such as the number of females needed for hatchery production from a specific system, detection of striped bass-hybrid backcrosses, and the use of hatchery-reared fish as brood stock should be further investigated, especially if any new stocking initiative is to take place. Interim policy dictates a conservative approach by using as many females as possible and avoiding the use of hatchery-reared females or males, or re-use of males for more than one mating, to prevent over-representation from a particular gene pool.

- Hybrids should be restricted to inland freshwater reservoirs or to other systems in which escapement and reproduction is not possible. Any inland reservoir stocking programs should employ purebred strains of striped bass endemic to the river system being stocked.

- Neither striped bass nor hybrids should be stocked by culturists into coastal or inland waters without prior notification and approval of the proper and official provincial fishery agencies.

- Commercial aquaculture operators must understand that escapement of hybrids and non-endemic striped bass will not be allowed, and that concerned agencies should be alerted to this policy. Sterile fish should be used for aquaculture operations.

5) Stocking strategies:

- In areas with or without natural reproduction, phase I or phase II fish should be stocked as long as they are marked to avoid confounding young-of-year surveys.

- Juvenile and adult surveys should be continued to determine the most cost effective release strategies including age at release and optimal release conditions such as salinity, temperature, and time of day for future potential stocking programs.

6) Provincial coordination:

- Programs among and within provinces should be coordinated by adhering to recommendations made by a coordinating committee.

- Each province should take appropriate regulatory or statutory action to insure that striped bass stocked by private entities into coastal waters be in accordance with recommendations of the coordinating committee.

- Stocking and evaluation activities should be reported to the committee to allow for the dissemination of information to other interested parties.

7) Evaluation:

- The tagging program should be coordinated on a coast-wide basis in order to avoid duplication of tag codes, and to make sure that resources such as wand tag detectors are used to the fullest possible extent.

- A central database and archive for the binary coded wire tags and data should be maintained by the committee and the DFO so that standardization and sharing of data will be facilitated. This should allow for a flow of information among provincial and federal agencies, and interested parties.

- Binary coded wire tags should be placed only in the left operculum.

- Stocking strategies should be further investigated and evaluated in order to maximize benefits achieved through stocking.

- Long-term evaluation of stocking success would be improved with development and use of genetic tags.

- The purpose of stocking and planned evaluation must be documented before further stocking programs are initiated.

- The evaluation program should be budgeted at a value equal to the coast of the stocking program.

**Recommendations on Restoration.** When natural colonization from straying individuals of nearby endemic strains is absent, then stocking is the only alternative for restoring extirpated populations. The example of the Patuxent River in Maryland demonstrates that stocking can be successful for reestablishment. In that regard, Upton (1996) offers the following recommendations:

- Continue to evaluate the return of adult females to the spawning grounds for all studies in which significant numbers of hatchery fish were marked.

- Continue research concerning larval and juvenile mortality and abundance for improved understanding of factors affecting recruitment and possible calibration of juvenile indices.

- Any stocking for enhancement purposes should be terminated except in those systems where striped bass have been absent or when the adult population and reproduction have been at low levels for several years as measured by juvenile and spawning surveys.

- Continue to survey recreational and commercial fisheries in order to quantify benefits of stocking programs to both pre-migratory and coastal populations.

- Stocking of hatchery-reared fish should be recognized as only one tool available to resource managers and the appropriateness of this tool will vary with circumstances.

- Stocking should be at the discretion of the province in cases where agreements between power companies and a given state are in effect (for mitigation of impingement/entrainment impacts).

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Table 1. The ASMFC Amendment 4 guidelines for acceptable striped bass hatchery and stocking programs (ASMFC 1989).

1. Disease Certification Programs
    - 1.1 Hatchery-reared striped bass which are to be released into any open system should be screened for IPN virus to prevent spread and dispersion of that virus.
    - 1.2 Additional research should be conducted to determine the pathogenicity of the IPN virus isolated from striped bass to other warmwater and marine species, such as flounder, menhaden, shad, largemouth bass, and catfish.
    - 1.3 Researchers and managers should fully review the known facts about the pathogenicity and life history of suspected disease organisms in known hosts before attributing loss of fish to the presence of that organism in new hosts.
2. Tagging Programs
    - 2.1 A sufficient number of fish to be stocked in coastal waters should be marked to allow for determination of survival and percentage contribution to natural stocks.
    - 2.2 Binary coded wire tags are the preferred means of marking hatchery-reared fish to be released into coastal waters.
    - 2.3 All fish should be marked if one million or less are stocked; for greater numbers, the percentage to be marked should be calculated based on the number of fish released and the estimated number in the natural stock.
    - 2.4 Tag codes should contain information sufficient to identify each lot of fish stocked.
3. Evaluation of Stocking Programs
    - 3.1 Continue the stocking and evaluation program long enough to allow for maturation and return of adult females.
    - 3.2 Continue to conduct research to determine the limiting factors affecting recruitment; this research should not be contingent upon the success or failure of the hatchery program.
    - 3.3 Terminate stocking if restoration is successful as judged by return of young-of-year indices for a period of three years to levels determined to be acceptable, and by a decline in the ratio of marked hatchery fish to unmarked native fish*.
    - 3.4 Terminate stocking if marked and stocked fish fail to return as brood fish*.
    - 3.5 Terminate restoration program if fish return as brood fish but progeny fail to survive due to poor anthropogenic-related environmental conditions on the nursery grounds*.
    - 3.6 The evaluation program should be established as part of any stocking program and should be budgeted at a value equal to that of the stocking program.
    - 3.7 Monitoring of coded-wire tagged [CWT] striped bass should be incorporated into all major existing fishery-dependent and fishery-independent monitoring programs. Attempts should be made to recover, decode and report CWTs to a centralized repository administered by the U.S. Fish and Wildlife Service. Percent composition of coded-wire tagged fish within samples should also be recorded. Special studies should also be conducted to assess survival, growth and distribution of hatchery-reared striped bass.
4. Genetic Integrity
    - 4.1 Genetic integrity of Atlantic coast striped bass should be maintained within river basins.
    - 4.2 Only the progeny from native brood stock, when available, should be stocked in river basins and coastal waters.
    - 4.3 Progeny from brood stock from adjacent rivers or hydrologically similar systems should be used if native brood stock do not exist.
    - 4.4 Stocking of hybrids should be restricted to inland freshwater reservoirs or to other systems in which escapement and reproduction can, and will, be controlled.
    - 4.5 Neither striped bass nor hybrids should be stocked in coastal or inland waters without notification and approval of the proper and official state agencies.
5. Stocking
    - 5.1 Stocking of hatchery-reared fish should be recognized as only one tool available to resource managers and that the appropriateness of this tool will vary with circumstances.
    - 5.2 Either Phase I or Phase II fish are acceptable for stocking provided all fish are tagged.

6. Coordination of State Programs
    6.1 Programs should be coordinated among and within states by adherence to these guidelines.
    6.2 Each state should take appropriate regulatory or statutory action to insure that striped bass stocked by private entities into coastal waters be in accordance with these guidelines.
    6.3 To avoid duplication, tagging program involving potentially migratory stocks of striped bass should be coordinated on a coast-wide basis.
    6.4 A central database should be established for all tags used in coastal stocking programs.
    6.5 Coded wire tags should be placed only in the left operculum.

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*Decision on time for termination of a non-restoration program should be made by the state agency having jurisdiction over the program.

Table 2. Stocking and shipping record of the Edenton National Fish Hatchery from 1978-1991, summarized by location in latitudinal order. Strains of fish stocked or shipped not confirmed at this time. Broodstock at Edenton during 1970-1989 included Roanoke River (Weldon), Roanoke River (Dan), Nanticoke River, "Maryland", Hudson River, Monks Corner, and WeldonXMonks Corner.

| | Location | Period | Number of yrs | Number of pounds | Number of fish |
|---|---|---|---|---|---|
| Massachusetts | | | | | |
| | Mar.Fish.Res. | 1981 | 1 | 200.0 | 20 |
| | Mar.Res., MA | 1982 | 1 | 1.0 | 500 |
| | MA Mar. Res. | 1983 | 1 | | 5,000 |
| Connecticut | | | | | |
| | CT Mar.Res. | 1982 | 1 | 42.0 | 630 |
| | CT-NMFS | 1984 | 1 | 46.0 | 600 |
| New Jersey | | | | | |
| | NJ (Swimming River) | 1985-88 | 4 | 252.6 | 142,713 |
| | Navesink R., NJ | 1989 | 1 | 42.3 | 50,000 |
| Maryland | | | | | |
| | Sassafras, MD | 1985 | 1 | 1,817.0 | 12,874 |
| | MD | 1987 | 1 | 105.0 | 15 |
| Virginia | | | | | |
| | VA to Edenton | 1979 | 1 | 154.0 | 104,000 |
| | Anna Lake, VA | 1981 | 1 | 209.9 | 160,349 |
| | VA | 1979-85 | 6 | 1,136.6 | 1,540,234 |
| North Carolina | | | | | |
| | NC Stocking | 1978 | 1 | 66.9 | 96,741 |
| | NC | 1990 | 1 | 243.8 | 181,361 |
| | Chowan R. | 1982 | 1 | 348.2 | 4,631 |
| | Union Camp | 1986 | 1 | 514.9 | 5,149 |
| | Albemarle Sound, NC | 1978-90 | 13 | 52,061.7 | 1,394,299 |
| | Smith Mtn. Res. VA | 1981 | 1 | 171.5 | 235,350 |
| | Gaston Res. | 1978-89 | 4 | 520.3 | 420,992 |
| | Roanoke Rapids Res. | 1981-91 | 4 | 258.1 | 224,066 |
| | Roanoke R. | 1990 | 1 | | 240,000 |
| | Mattamuskeet L. | 1978-90 | 9 | 16,156.0 | 252,395 |
| | Pamlico Sound | 1982-83 | 2 | 2,695.0 | 151,753 |
| | Tar-Pamlico | 1979-87 | 3 | 2,016.1 | 137,144 |
| | Neuse R. | 1979-90 | 9 | 17,973.3 | 660,308 |
| | New R. | 1983-84 | 2 | 98.1 | 146,011 |
| | White Oak R. | 1983-84 | 2 | 42.0 | 71,932 |
| | Cape Fear R. | 1980-90 | 4 | 2,007.5 | 594,036 |
| | Warm Springs - Cape Fear R. | 1983 | 1 | 1,221.0 | 6,374 |
| | Warm Springs-Cape Fear | 1983 | 1 | 1,246.0 | 7,027 |
| South Carolina | | | | | |
| | Greenwood Lake, SC | 1978-79 | 2 | 422.2 | 372,000 |
| | Lake Murray, SC | 1979 | 1 | 860.0 | 93,000 |
| Florida | | | | | |
| | Pensacola, FL | 1980 | 1 | 66.6 | 400 |
| Fish Hatcheries | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Bowden NFH, WV | 1987-91 | 4 | 877.8 | 1,085,696 |
| | Cheraw NFH (to Marion, AL) | 1980 | 1 | 484.0 | 65 |
| | Harrison Lake NFH, VA | 1981-88 | 3 | 249.0 | 329,135 |
| | Lamar NFH, PA | 1991 | 1 | 161.5 | 139,184 |
| | Mammoth Springs NFH, GA | 1978 | 1 | 225.0 | 60 |
| | Marion, AL | 1985 | 1 | 188.0 | 94 |
| | McKinney Lake NFH, NC | 1988-89 | 2 | 87.8 | 75,884 |
| | Millen NFH (to Marion, AL) | 1980 | 1 | 297.0 | 33 |
| | Senecaville NFH | 1981 | 1 | 6.0 | 600,000 |
| | Transfer-Marion Mammoth Spring | 1983 | 1 | 167.7 | 4,001 |
| | Cedarville SFH, MD | 1985 | 1 | 6,842.0 | 70,974 |
| | Manning SFH, MD | 1986-90 | 5 | 32,483.0 | 390,400 |
| Research Labs | | | | | |
| | Aurora, NC | 1990 | 1 | 131.0 | 1,195 |
| | Baltimore-Nat.Aquar. | 1981 | 1 | 2.5 | 250 |
| | Columbia Res.Lab. | 1981 | 1 | 1.0 | 100,000 |
| | Columbia Res.Lab. | 1981 | | 75.0 | 7 |
| | Comm.Res.Lab | 1981 | | 66.8 | 400 |
| | Disease Biologist | 1985 | 1 | 536.0 | 240 |
| | Howard Kerby | 1986-87 | 2 | 221.5 | 3,115 |
| | Johns Hopkins Univ. | 1982 | 1 | 67.0 | 1,000 |
| | Leetown, WV | 1981-84 | 4 | 1,776.6 | 7,828 |
| | Long Island, NY | 1978 | 1 | 750.0 | 20,000 |
| | Milford, CT | 1983 | 1 | 26.5 | 600 |
| | Milford, CT Lab | 1980 | 1 | 68.9 | 400 |
| | Milford, CT (NOAA) | 1978 | 1 | 40.0 | 300 |
| | Nat. Fish. Lab. | 1986 | 1 | 25.0 | 20,000 |
| | NC Marine Resources Aquar. | 1980-82 | 3 | 14.0 | 100 |
| | NCSU | 1981-91 | 3 | 467.2 | 5,504 |
| | Norfolk Airport, Multi-Aquacul. Systems | 1978 | 1 | | 200,000 |
| | Oxford, MD | 1978 | 1 | 3.0 | 2,000 |
| | SUNY-Stoneybrook | 1991 | 1 | | 3,000 |
| | U.MD | 1983 | 1 | 8.4 | 200 |
| | Wash.NC Law Enf. | 1984 | 1 | 4.5 | 15 |
| Foreign | | | | | |
| | Moscow, USSR | 1981 | 1 | | 6,000 |
| | National Airport, DC | 1978 | 1 | | 200,000 |
| | Total shipped or stocked, 1978-91 | | | 149,349 | 10,579,583 |

Table 3. Numbers of Roanoke striped bass stocked in Virginia (1975-98) and North Carolina (1967-97) by state agencies.

| | | | Roanoke strain | | "Chesapeake strain" | |
|---|---|---|---|---|---|---|
| State | Watershed | Drainage | Period | Number | Period | Number |
| Virginia | | | | | | |
| | Potomac | Chesapeake Bay | 1977-91 | 155,136 | | |
| | York* | Chesapeake Bay | 1980-92 | 98,579 | 1995-98 | 33,492 |
| | New | Mississippi | 1975-98 | 1,071,222 | 1996 | 36,037 |
| | James | Chesapeake Bay | 1975-97 | 2,489,008 | 1995-98 | 1,284,091 |
| | Meherrin | Albemarle Sound | 1975 | 5,000 | | |
| | Roanoke | Albemarle Sound | 1975-98 | 38,016,195 | | |
| | | Total Virginia | | 41,835,140 | | 1,353,620 |
| North Carolina | | | | | | |
| | Roanoke | Albemarle Sound | 1975-97 | 2,780,399 | | |
| | Tar | Pamlico Sound | 1973-97 | 1,886,212 | | |
| | Neuse | Pamlico Sound | 1974-97 | 854,945 | | |
| | New | New River | 1973-74 | 25,400 | | |
| | Cape Fear | Cape Fear | 1979-94 | 167,010 | | |
| | Yadkin | Pee Dee (SC) | 1967-97 | 4,121,290 | | |
| | Catawba | Santee-Cooper (SC) | 1967-97 | 4,057,202 | | |
| | | Total North Carolina | | 13,892,458 | | |

*Includes Mattaponi and Pamunkey Rivers, both used as source of brood stock for "Chesapeake" production

Table 4. Striped bass stocked in coastal waters from National Fish Hatcheries (fingerlings to 8-inch fish), and coastal streams and reservoirs from state hatcheries. Data sources 1975-1981 from Rulifson et al. (1982). Blanks indicate data not located at this time.

| | | National Fish Hatcheries | | State hatcheries | | | |
|---|---|---|---|---|---|---|---|
| | | Coastal stocking only | | Coastal stocking | | Inland stocking | |
| State | Year | Source of fry | Number stocked | Source of fry | Number stocked | Source of fry | Number stocked |
| New York | 1975 | MD | 90,000 | | | | |
| North Carolina | 1967 | | | | | NC | 19,120 |
| | 1968 | | | | | NC | 299,264 |
| | 1969 | | | | | | |
| | 1970 | | | | | NC | 92,979 |
| | 1971 | | | | | | |
| | 1972 | | | | | | |
| | 1973 | | | NC | 120,000 | NC | 25,000 |
| | 1974 | | | NC | 183,833 | NC | 84,000 |
| | 1975 | NC | 300,000 | NC | 2,124 | NC | 387,395 |
| | 1976 | VA | 240,000 | NC | 18,074 | NC | 423,050 |
| | 1977 | NC | 255,000 | NC | 29,380 | NC | 276,398 |
| | 1978 | NC | 405,000 | NC | 30,336 | NC | 478,405 |
| | 1979 | NC | 401,000 | NC | 90,000 | NC | 469,000 |
| | 1980 | VA | 585,876 | NC | 12,410 | NC | 126,000 |
| | 1981 | | | NC | 21,463 | NC | 601,000 |
| | 1982 | | | NC | 0 | NC | 507,620 |
| | 1983 | | | NC | 28,000 | NC | 507,620 |
| | 1984 | | | NC | 2,000 | NC | 231,787 |
| | 1985 | | | NC | 0 | NC | 514,421 |
| | 1986 | | | NC | 0 | NC | 313,418 |
| | 1988 | | | NC | 0 | NC | 699,661 |
| | 1989 | | | NC | 0 | NC | 772,942 |
| | 1990 | | | NC | 0 | NC | 605,426 |
| | 1991 | | | NC | 0 | NC | 125,938 |
| | 1992 | | | NC | 0 | NC | 643,138 |
| | 1993 | | | NC | 48,000 | NC | 845,261 |
| | 1994 | | | NC | 1,911,358 | NC | 931,815 |
| | 1995 | | | NC | 0 | NC | 15,288 |
| | 1996 | | | NC | 139,450 | NC | 430,126 |
| | 1997 | | | NC | 28,022 | NC | 607,363 |
| South Carolina | 1975 | SC | 500,000 | | | | |
| | 1976 | SC | 200,000 | | | | |
| | 1977 | SC | 588,000 | | | | |
| | 1978 | SC | 85,000 | | | | |
| | 1979 | SC | 397,000 | | | | |
| | 1980 | SC | 296,000 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Georgia | 1975 | NY | 100,080 | NY | 34,988 | GA | 21,540 |
| | 1976 | | | GA | 18,228 | GA | 18,125 |
| | 1977 | SC | 90,000 | | | GA | 4,494 |
| | 1978 | | | GA | 109,690 | GA | 217,123 |
| | 1979 | GA | 70,400 | GA | 312,110 | GA | 490,297 |
| | 1980 | GA | 10,025 | GA | 111,799 | GA | 434,285 |
| | 1981 | GA | 36,898 | | | | |
| Florida | 1975 | MD | 600,000 | | | | |
| | 1976 | SC | 150,000 | | | | |
| | 1977 | GA | 622,000 | | | | |
| | 1978 | FL | 205,000 | | | | |
| | 1979 | FL | 450,000 | | | | |
| | 1980 | FL | 132,000 | | | | |
| Alabama* | 1975 | SC | 50,000 | ? | 366,297 | | |
| | 1976 | SC | 289,000 | ? | 382,535 | | |
| | 1977 | FL | 259,000 | ? | 399,337 | | |
| | 1978 | GA | 300,000 | ? | 273,415 | | |
| | 1979 | NC | 314,000 | ? | 346,414 | | |
| | 1980 | SC | 300,000 | ? | 508,110 | | |
| | 1981 | | | ? | 793,456 | | |
| Louisiana | 1967 | | | SC | 758,700 | | |
| | 1972 | | | MD | 15,036 | | |
| | 1973 | | | MD | 205,600 | | |
| | 1974 | | | VA | 45,105 | | |
| | 1975 | | | SC | 227,504 | | |
| | 1976 | LA | 80,000 | SC | 479,420 | | |
| | 1977 | LA | 1,635,697 | SC | 240,181 | | |
| | 1978 | LA | 1,478,000 | SC | 330,412 | | |
| | 1979 | LA | 784,000 | SC | 238,889 | | |
| | 1980 | | | SC | 310,000 | | |
| Mississippi** | 1974 | | | SC | 21,144 | | |
| | | | | MD | 25,121 | | |
| | | | | VA | 8,992 | | |
| | | | | MD | 647 | | |
| | | | | VA | 563 | | |
| | 1975 | SC | 50,000 | SC | 6,424 | | |
| | 1976 | SC | 314,000 | SC | 179,749 | | |
| | | | | NY | 27,421 | | |
| | 1977 | SC | 406,000 | SC | 122,782 | | |
| | | | | NC | 7,794 | | |
| | | | | MS | 18,808 | | |
| | 1978 | SC | 300,000 | SC | 232,586 | | |
| | | | | MS | 145,000 | | |
| | 1979 | SC | 298,000 | SC | 137,159 | | |
| | | | | NC | 28,154 | | |

| | | | | | |
|---|---|---|---|---|---|
| | | | MS | 56,666 | |
| 1980 | VA | 168,000 | VA | 222,800 | |
| | SC | 205,000 | SC | 204,000 | |
| | FL | 16,687 | | | |
| 1981 | | | SC | 292,473 | |
| | | | VA | 43,876 | |
| Total stockings: | | 14,056,663 | | 10,953,835 | 12,219,299 |

*Includes anadromous rivers of the Atlantic coast and certain streams contiguous with the Gulf of Mexico.
**Coastal stockings from fish reared at the Gulf Coast Research Laboratory.

Table 5. Coastal striped bass stocking activities reported to ASMFC, 1985-1992 (after Upton 1993).

| State | Watershed | Size | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | Total by watershed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maine | Kennebec[1] | Phase II | | 26,676 | | 51,501 | 58,935 | 58,497 | 9,893 | | 205,502 |
| | Androscoggin[1] | Phase II | | 3,641 | | 15,442 | 8,600 | 6,736 | 1,049 | | 35,468 |
| | Eastern[1] | Phase II | | 1,000 | | | | | | | 1,000 |
| New York | Hudson | 3" | 284,578 | 529,563 | 324,800 | 48,611 | 202,069 | 234,387 | 256,631 | | 1,880,639 |
| | Hudson | Phase II | | | | | | | | 210,815 | 210,815 |
| New Jersey | Navesink[2] | Phase I | | 13,300 | 18,320 | 29,393 | 30,967 | | | | 91,980 |
| | Navesink[2] | Phase II | | 13,650 | | | | | | | 13,650 |
| Pennsylvania | Conowingo Pool[3] | Phase I | | 54,000 | 226,000 | 200,000 | 210,025 | 155,400 | 54,000 | | 899,425 |
| | Conowingo Pool | Phase II | | | | 21,400 | | | | | 21,400 |
| Delaware | C&D Canal | Phase II | | | | 10,941 | | | | | 10,941 |
| | Delaware | Phase II | | | | | 36,134 | 92,547 | | 40,702 | 169,383 |
| Maryland | Choptank | Phase I | | | | | | | 108,130 | | 108,130 |
| | Choptank | Phase II | | | 324,529 | 422,036 | 256,251 | 54,814 | 52,252 | | 1,109,882 |
| | Nanticoke | Phase I | | | | 22,133 | | | | 98,067 | 120,200 |
| | Nanticoke | Phase II | 58,186 | 15,841 | 79,524 | 33,042 | 3,100 | | | 236,072 | 425,765 |
| | Patuxent | Phase 1 | 100,261 | 10,125 | 15,806 | 100,435 | 101,987 | | 105,915 | 283,195 | 717,724 |
| | Patuxent | Phase II | 125,612 | 293,566 | 377,242 | 171,693 | 196,355 | 356,758 | 240,432 | 271,283 | 2,032,941 |
| | Upper Bay | Phase II | 60,474 | 59,282 | 31,129 | 198,622 | 426,846 | 403,884 | | | 1,180,237 |
| | Matapeake | Phase II | | | | 11,812 | | | | | 11,812 |
| Virginia | Mattaponi | Phase I | | | | | | | 36,088 | | 36,088 |
| | Mattaponi | Phase II | | | | 21,978 | 4,830 | 173,554 | 128,580 | 133,213 | 462,155 |
| | Pamunkey | Phase II | | | | | | 31,056 | 82,994 | 153,744 | 267,794 |
| North Carolina | Albemarle Sound | Phase II | | 118,345 | 15,435 | 5,000 | 3,289 | 2,000 | 2,994 | 2,465 | 149,528 |
| | Pamlico | Phase II | | | 17,993 | | | | 30,801 | | 48,794 |
| | Neuse | | | | | | | | | 138,540 | 138,540 |
| | Cape Fear | | | | | | 77,242 | 77,242 | | | 154,484 |
| Total reported coastal stocking: | | | 629,111 | 1,138,989 | 1,430,778 | 1,364,039 | 1,616,630 | 1,646,875 | 1,109,759 | 1,568,096 | 10,504,277 |

[1] All Maine stockings 1985-1991 were fish of Hudson River origin.

[2] All New Jersey stockings 1984-1989 were Roanoke fish of Weldon (Edenton NFH) and Brookneal origin.

[3] Conowingo stockings in 1987 - 26,000 were from Georgia and 200,000 from Maryland.

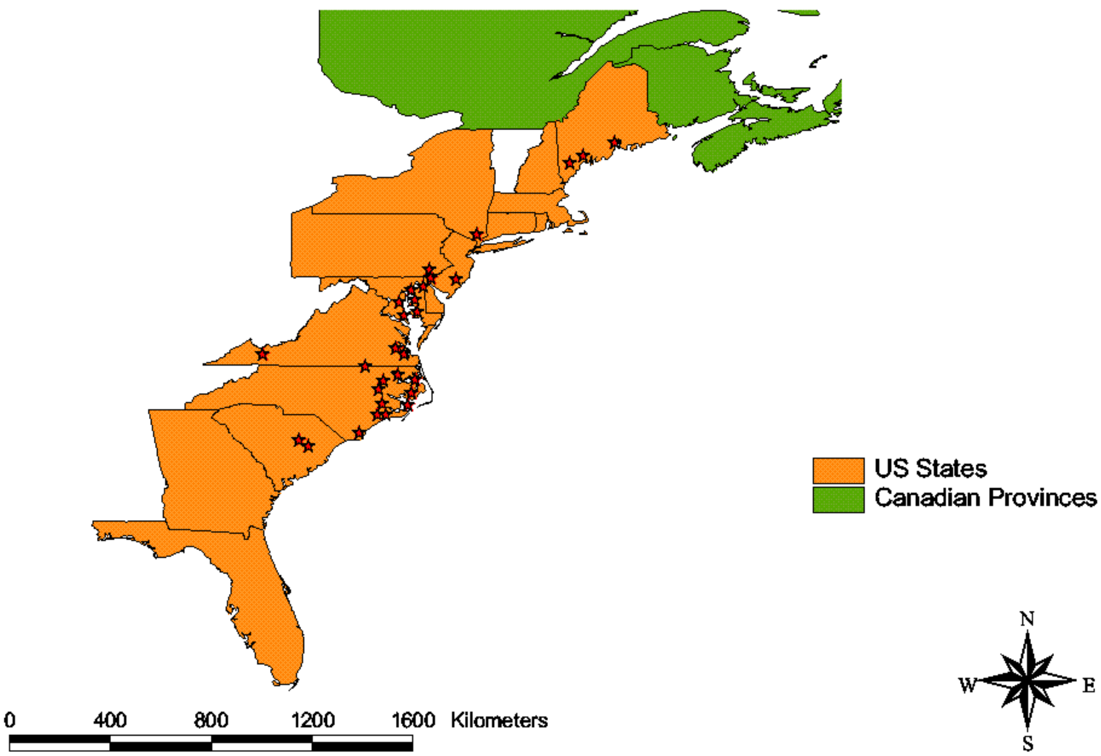


Figure 1. Watersheds of the U.S. Atlantic coast that received, or still receive hatchery-reared striped bass.