The Status of Striped Bass in Scotia-Fundy Region

by

B.M. Jessop
Biological Sciences Branch
Department of Fisheries and Oceans
P.O. Box 550
Halifax, Nova Scotia
B3J 2S7

Abstract

Migrant striped bass of Canadian/US origin (the proportions of each origin are unknown, but most are believed to be Canadian) range the Bay of Fundy and Atlantic coasts of Scotia-Fundy Region. Spawning stocks occur in three rivers - the Saint John in New Brunswick, and the Shubenacadie-Stewiacke and Annapolis in Nova Scotia. The occurence of spawning stocks is limited by the geomorphological suitability of rivers to spawning and rearing (moderate size, low gradient, large estuary, etc.). All suitable rivers occur in the Bay of Fundy area. Acid precipitation effects may limit the spawning success of striped bass stocks in the Saint John and Annapolis rivers.

The low abundance (and minimal reproduction in two rivers) of striped bass in Scotia-Fundy Region indicates that fish should not be harvested until they reach a size at which they have reproduced at least once (600 mm FL would ensure that a large proportion of females spawn at least once; males mature 1-2 years earlier than females). The larger the spawning stock, the higher the probability of achieving a successful year-class in spite of environmental limitations, and the greater the number of options for harvesting plans. Harvesting should not be permitted on or near spawning areas, nor during the spawning season, when stocks are low.

Striped bass stocks in the Annapolis and Saint John rivers are severely depressed; Shubenacadie River striped bass reproduce successfully. Potential production levels and sustainability of production, under existing environmental conditions, are unknown but are believed to be low or negligible in the Saint John and Annapolis rivers. Historical catch records suggest that average annual production did not exceed several thousand fish in the Shubenacadie River. No rivers can be considered to have a surplus to spawning requirements.

Recommendations are made for management action and research programs.

Résumé

Des bars rayés originaires les uns du Canada et les autres des Etats-Unis (sans connaître les proportions respectives de poissons de chaque origine, on estime que la majorité d'entre eux est canadienne) migrent dans la baie de Fundy et le long de la côte atlantique de la région de Scotia-Fundy. On en trouve des stocks reproducteurs dans un fleuve et deux rivières, soit le fleuve Saint-Jean, au Nouveau-Brunswick et les rivières Annapolis et Shubenacadie-Stewiacke en Nouvelle-Ecosse. La présence de stocks reproducteurs dépend de l'existence dans les rivières de conditions géomorphologiques favorables au frai et au grossissement (grandeur moyenne, faible pente, vaste estuaire, etc.). Toutes les rivières qui satisfont à ces critères se trouvent dans la baie de Fundy. Précisions, cependant, que les effets des pluies acides peuvent nuire au frai des stocks de bar rayé dans le fleuve Saint-Jean et dans la rivière Annapolis.

En raison de sa faible abondance dans la région de Scotia-Fundy (et de sa reproduction minimale dans deux rivières de la région) le bar rayé ne devrait pas être récolté avant d'avoir atteint une taille à laquelle il est plausible qu'il ait frayé au moins une fois (une bonne partie des femelles de 600 mm de longueur à la fourche auront frayé au moins une fois; les mâles parviennent à maturité de un à deux ans avant les femelles). Plus le stock reproducteur est gros, plus l'on est susceptible d'obtenir une bonne classe annuelle en dépit des contraintes environnementales et plus on étend le champ d'options des plans de récolte. On devrait interdire la récolte dans les frayères ou à proximité de celles-ci ainsi que durant la saison du frai, alors que les stocks sont bas.

Les stocks de bar rayé de la rivière Annapolis et du fleuve Saint-Jean sont décimés. Dans la rivière Shubenacadie, en revanche, l'espèce se reproduit bien. Bien que l'on ne connaisse pas les niveaux de production possible et la viabilité d'une production soutenue dans les conditions environnementales actuelles, on estime qu'ils sont faibles, voire négligeables, pour les stocks du fleuve Saint-Jean et de la rivière Annapolis. En ce qui concerne la rivière Shubenacadie, les relevés de prises antérieures semblent indiquer que la production annuelle moyenne ne dépasse pas quelques milliers de poissons. Aucun de ces réseaux hydrographiques n'a de surplus par rapport aux besoins de géniteurs.

On recommande ici l'adoption de mesures de gestion et de programmes de recherche.

Introduction

Striped bass (*Morone saxatilis*) are of relatively minor recreational and commercial importance in Scotia-Fundy Region, primarily because of their low abundance and scattered distribution. Their historical abundance exceeded their present abundance (Knight 1867; Perley 1852) and some stocks may still be in decline. The challenge to fishery management is to determine the causes of such declines and to identify and implement remedial measures. The information necessary to understand striped bass stocks includes stock-recruitment characteristics, life history, and history of exploitation. This document summarizes available information on the life history of anadromous striped bass in the Scotia-Fundy Region, their current stock status and important influencing factors, and identifies major areas of research necessary for effective management.

Distribution and Migration

Distinct stocks of striped bass occur naturally along the Atlantic coast of North America between the St. Johns River, Florida, and the St. Lawrence River, Quebec. North of Cape Hatteras, the most important stocks are from Chesapeake Bay and the Hudson River (Kohlenstein 1981; Boreman and Lewis 1987; Smith and Wells 1977). The population structure of striped bass that seasonally migrate along the Atlantic coast between Cape Hatteras, the Gulf of Maine and Bay of Fundy, and the Atlantic coast of Nova Scotia is confused, although most fish in American waters are believed drawn from the Chesapeake Bay and Hudson River stocks, with a small contribution from North Carolina stocks (Borman and Lewis 1987; Anonymous 1989), while Canadian stocks probably contribute most to their abundance in Canadian waters.

In Atlantic Canada, distinct stocks occur in the Gulf of St. Lawrence and in the Bay of Fundy. Melvin (1978) conjectured that segregation was ensured by the cold water mass off Cape Breton, but Hogans (1984) confirmed that striped bass migrate between Chesapeake Bay and the Gulf of St. Lawrence coast of New Brunswick. It is unknown whether these fish were of Canadian origin and migrated south where they became infected with regionally-specific parasites or whether they were fish of American origin migrating northward. The same uncertainty applies to recaptures of striped bass that were tagged at ages greater than one year or at locations and times other than the spawning grounds during spawning season. One tagged adult striped bass released in the Kouchibouguac River during March was recovered in a Maryland river 33 days later (Hogans and Melvin 1984). Other tagging studies confirm that striped bass of Canadian and US origin intermix in coastal waters north of Cape Hatteras. Striped bass tagged in New Brunswick and Nova Scotia waters have been recaptured along the US coast from Rhode Island to North Carolina, while fish tagged in Chesapeake Bay and the Hudson River have been recaptured in Bay of Fundy waters

(Rulifson et al. 1987). Dadswell et al. (1986) summarize historical release and recapture data for migrant striped bass associated with the Bay of Fundy. Whether such migrants are of US or Canadian origin is unknown. Although most recoveries of striped bass tagged and released in recent years in Nova Scotian waters have been local, striped bass tagged and released in American waters have, in the past, been recovered along the lower Fundy coast of New Brunswick and Gulf of Maine coast of Nova Scotia (Boreman and Lewis 1987).

Within the Scotia-Fundy Region, reproducing stocks of striped bass are known from the Saint John River in New Brunswick, and the Annapolis and Shubenacadie-Stewiake rivers in Nova Scotia. Striped bass reported in the estuaries of other rivers are believed to be seasonal migrants, of local or perhaps American origin, depending partly upon their size. Striped bass are coastal fish, seldom moving more than about 6-8 km offshore except during seasonal migrations (fish younger than 2 years old do not usually migrate). Most coastal migrants are female; larger fish migrate the farthest distances. The large migrants found along the Atlantic coast of Nova Scotia are of unknown, but probably American, origin. Dadswell (1976) concluded, based on life history and tagging data, that striped bass from the Saint John River have two origins: (1) a local population that spawns within the river system and moves seasonally between the upper and lower portions of the estuary and (2) a migratory, possibly Hudson River origin, stock that inhabits the lower estuary during late spring and summer and moves southward along the Atlantic coast in autumn. The seasonal stock structure of striped bass in the Annapolis River also suggests that one component is of migratory, probably US, origin (Jessop and Doubleday 1976; Harris and Rulifson 1988). Limited tagging results (Jessop, unpublished data) are uninformative regarding this hypothesis, because of the 9 and 44 adult striped bass angled, tagged, and released in 1975 and 1976, respectively, at the Annapolis River causeway only two were recovered, both in the Annapolis River (one fish was tagged in 1975 and recovered in 1976). M. Dadswell (1981, Dept. Fisheries and Oceans (DFO), pers. comm.) released 37 tagged striped bass (range 568-1000+ mm FL) in the Annapolis River in the spring of 1981, from which one fish was recovered in the same river in October of that year. B. Sabean (1981, Nova Scotia Dept. of Lands and Forests, pers. comm.) released 12 striped bass (range 315-470 mm FL) in the Gaspereau River estuary, Kings County, in June of 1981, of which one fish was recovered by an angler in Minas Basin in late August of 1982. Between release and recapture, the 3-yr-old (at release) fish grew 175 mm. Studies by Rulifson et al. (1987) indicate that small (<400 mm FL) striped bass in Minas Basin are probably of Shubenacadie River origin and remain within the basin, while some fish >400 mm FL may migrate south as far as New Jersey.

Reproduction, Age, and Growth

Striped bass undergo three major developmental stages: larval, juvenile, and adult. Of all the biological processes associated with the relationship between stock and recruitment for striped bass, perhaps those of most importance to fishery management are the high fecundity of striped bass, the higher maturation rate of males than of females, and their age- and sex-dependent migratory behaviour (Cooper and Polgar 1981). Most important to year-class success are the effects of environmental factors on egg and larval survival. Spawning success is associated with specific ranges of hydrographic and meteorological conditions.

Spawning of striped bass occurs mostly in silt-laden, turbid rivers of moderate to large size. In Scotia-Fundy Region, spawning of striped bass has been documented in the Saint John River (Dadswell 1976), Shubenacadie-Stewiake rivers (Leim and Scott 1966; Jessop, unpublished data; Pond 1985), and the Annapolis River (Williams et al. 1984), where it occurs on an intermittent basis between mid-May and late June at water temperatures extending from 11 °C (Dadswell 1976) to 18 °C (Williams et al. 1984).

Fecundity of striped bass has been infrequently and unthoroughly examined in Scotia-Fundy stocks. Williamson (1974) found a poor relationship between fish length and fecundity for nine striped bass from the Saint John River, in which fecundity ranged from 38,400 eggs in a 560 mm fish to 1.06 million eggs in a 960 mm fish. The fecundity of Scotia-Fundy striped bass stocks is presumably similar to that of other stocks for fish of comparable sizes.

The dominant year-class phenomenon is a notable part of striped bass life history and does much to explain the historical variability in striped bass abundance (Cooper and Polgar 1981). Stock size is independent of spawner density for striped bass because spawning success is more dependent on environmental conditions than on parental stock size, as long as some minimum stock size is present. Larval survival is believed most critical since year-class strength is established before the juvenile stage, in the first 3-4 weeks of life (Setzler et al. 1980; Goodyear et al. 1985). Mortality is a decreasing function of size. A dominant year-class has not been reported in Scotia-Fundy rivers since the early 1970s (Dadswell 1976; Jessop and Vithayasai 1979; Jessop 1980).

Little is known about growth of larval striped bass in Scotia-Fundy rivers because survival has been poor, with none collected from the Saint John River by Dadswell (1976), and only three caught in the Annapolis River after extensive sampling (Williams et al. 1984). Studies of the Shubenacadie River system have not examined the presence or growth of larval striped bass although survival must occur because numerous under-yearling fish were seined in the

tidal zone in the mid-1970s (Jessop, unpublished data). Rulifson et al. (1987) suggest that young-of-the-year striped bass (about 80 mm FL) caught in Cobequid Bay in late September-early October were of Shubenacadie River origin. Immature striped bass are most often found in bays or river estuaries while larger, mature fish occur along the coast, except during the spawning season when they move into the rivers (Smith and Wells 1977). Few fish of less than 2 years old are believed to move far from their river/estuary of origin.

Adult female striped bass mature between ages 4-7 in the Saint John River (where about 80% mature by age-6) and Annapolis and Shubenacadie rivers (Jessop and Vithayasai 1979). Males mature at an earlier age, typically 3-6 years. Mean lengths at maturity (ages 4-7) ranged from about 400 to 620 mm for female striped bass from all three rivers, although age and size at maturity varied somewhat between stocks. Sex ratios of striped bass varied widely amongst rivers, depending upon the status of the stock. Male sex composition in the Annapolis River ranged from 20% to 6% and declined during the mid-to-late 1970s (Jessop 1980); in the Saint John River, about 23% were male (Williamson 1974), and in the Shubenacadie River, about 35% were male.

Morphometric and meristic characteristics are similar for striped bass from the Saint John, Shubenacadie, and Annapolis rivers but protein analysis enables a partial separation of Saint John and Shubenacadie river stocks (Williamson 1974; Melvin 1978). Meristic and morphometric studies of other Atlantic coast striped bass stocks have typically yielded resolutions of 70-80% but the severity of the potential bias due to variation in meristic counts among years within stocks relative to variations among stocks has not been resolved (Waldman et al. 1988). Additional details of the general life history of the striped bass in Bay of Fundy waters can be found in Scott and Scott (1988) and the references previously cited; Bigelow and Schroeder (1953), Smith and Wells (1977), Setzler et al. (1980), and Bain and Bain (1982) provide comprehensive coverage of striped bass along the Atlantic coast.

Stock Status

The abundant stocks of striped bass which once occurred throughout their Atlantic coastal range have declined in most areas since the early 1970s (Boreman and Austin 1985; Anon. 1989). In Scotia-Fundy Region, serious declines in abundance have occurred in the Saint John and Annapolis rivers, while the Shubenacadie River population appears more stable (Dadswell 1976; Jessop and Vithayasai 1979). A lack of regular monitoring data on these stocks has delayed awareness of the seriousness of the problem and minimal corrective action has been taken in Scotia-Fundy Region. The present low levels of striped bass stocks have forced recognition by fishery managers and the interested public that a serious situation exists for this declining resource.

Substantial US research activity over the past 10 years has indicated that two hypotheses - overfishing and toxic contaminants - best explain the decline in stocks (Anon. 1989). Striped bass are now known to be highly vulnerable to ambient water conditions such as discharge level, lowered pH, and elevated aluminum levels, and to excessive exploitation rates by sport and commercial fisheries. The impact of each stressor varies among stocks. Consequently, determining the effects of interacting factors on a stock is complicated by a lack of experimental control, by natural variation in distribution and abundance, and by the natural processes of stock regulation. The coastal migratory nature of striped bass requires that interjurisdictional solutions be found.

Environmental effects on striped bass abundance are typically less easily controlled than is exploitation. The decline in US striped bass stocks has resulted in the imposition of stringent controls on exploitation of striped bass in recent years in all coastal states under the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Striped Bass Management Plan, with the goal of ensuring maintenance of striped bass spawning stocks and rebuilding of depleted stocks. Regulations enacted in 1982 required a reduction in fishing mortality sufficient to ensure that 95% of the females of the year-classes from 1982 onwards had an opportunity to reproduce at least once. Commercial fishing was banned in some states and sport fishing was further restricted. Minimum length limits in recent years have been set at 838 mm (33 in) TL. The reduction in exploitation was thought essential to stock recovery in view of environmental effects on reproduction; without it, stock recovery was considered unlikely. Consideration is now being given to reopening in 1990 the commercial fishery (with strict quota limits) in several states because the 1989 Maryland juvenile striped bass abundance index reached a level, previously agreed upon, to trigger reconsideration of the commercial fishery closure.

Saint John River

Recent (within the past 5 years) biological information is unavailable on the striped bass stock of the Saint John River. Construction of the Beechwood Dam in 1957 prevented access by those small (<2 kg) feeding migrant striped bass that once ascended the river at least as far as the Tinker Dam on the tributary Aroostook River. Construction of the Mactaquac Dam in 1967, and imposition of daily fluctuations in water level due to electrical generation patterns, have evidently reduced the suitability of the historic spawning areas around the islands between the dam and Fredericton (Adams 1873). The numbers, size composition, and run timing of striped bass entering the Mactaquac fishlift has substantially changed over the years. In 1968, over 800 striped bass entered the fishlift at the Mactaquac Dam, but in recent years less than 25 fish have usually entered (Smith 1979; Ingram 1980, 1985; Ingram, DFO, pers. comm.). In 1968, numbers of large, mature striped bass were caught in the fishlift between late May and late June, with

peaks in abundance of smaller fish (typically <3 kg) occurring in late July and August. From 1969 onwards, run peaks of smaller fish occured in August or early September (some fish >5 kg have been noted in recent years). The implication is that the spawning run to this section of the river has been destroyed.

In the mid-1970s, Dadswell (1976) concluded that the "local population is at a very low ebb and may be threatened with extinction...", and that the last successful year-class occurred in the late 1960s because 1-2 year old bass were abundant as late as 1969. Reproductive failure due to a high incidence of egg membrane break-up and embryo mortality was attributed to the high levels of organochloride (DDT, PCB) residues in eggs of striped bass from the Belleisle Bay area. Survival of striped bass larvae has been shown to decrease with increasing concentrations of chlorinated hydrocarbons in the eggs (Westin et al. 1985). A small year-class may have been produced in the Saint John River during 1979 because some yearling fish were caught in 1980 (Dadswell 1982, DFO, pers. comm.).

Summer (May-September) pH values of the lower Saint John River tend to be above 7.0 (Metcalfe et al. 1976), with moderate alkalinity and hardness due to the geology of the river basin (Smith 1966), although periodic episodes of lower pH occur (to 6.3) in Belleisle Bay. The sensitivity of striped bass to lowered pH and aluminum toxicity decreases with age; pH's of less than 6.5 will substantially reduce the survival of larval striped bass in poorly buffered fresh water in the presence of dissolved aluminum concentrations as low as 25 $\mu g \cdot L^{-1}$ (Buckler et al. 1987). Waters of the lower Saint John River estuary are not poorly buffered and the threat of aluminum toxicity should be reduced. However, surface water quality may temporarily degrade following heavy rainfall, and transitory low pH events may increase larval striped bass mortality (Hall et al. 1987). The cause of striped bass egg and larval mortality in the Saint John River is not positively known, but the combination of organochloride and periodic low pH effects is believed most important. Certainly, the low stock size provides little opportunity to take advantage of favourable spawning conditions.

Angling for striped bass was more active in the past than today, consequent to stock decline and habitat alteration. The angling fishery downstream of the Tinker Dam on the Aroostook River no longer exists nor does the Fredericton-area fishery, and angling in the Saint John area is minor. No season or bag limits apply to angling for striped bass in New Brunswick. A commercial gill-net fishery for striped bass occurred during winter months in the Belleisle Bay area before 1978 when the fishery was closed by regulation in response to low stock abundance. Annual catch variability was substantial between 1896 and 1978, with periodic peaks in catch every 7-14 years (Figure 1; Dadswell 1976; Dadswell et al. 1984). The three largest harvests occurred in 1959, 1966,

and 1970 at 20, 22, and 11 tonnes, respectively, after which catches steadily declined to less than 1 t by the late 1970s. Small bycatches of striped bass, which may be retained and marketed, occur in the gaspereau and shad fisheries of the lower estuary.

Shubenacadie River

Recent data of a comprehensive nature are unavailable for the striped bass population of the Shubenacadie River. The river is undammed, thereby permitting free seasonal movement for striped bass between the estuary and Shubenacadie Lake, a headwater lake in which some fish overwinter. A moderate sport fishery by anglers of primarily local origin occurs for striped bass during May and June in the upper estuary (Jessop and Vithayasai 1979) as well as during late summer in Shubenacadie Lake. DFO angling statistics for 1951 indicate a similar pattern, with angling occurring between April and September and peak catches in June and July. Between 1951 and 1974, annual catches of striped bass averaged 370 fish (range, 60-1,010 fish), of which about 50% were angled on the Stewiacke River during June. Recent angling statistics are unavailable. The estuarine/tidal zone angling fishery consists of two segments: a shore-based fishery that catches mostly smaller fish (mean of 290 mm FL in 1976; Jessop and Vithayasai 1979) and a boat-based fishery harvesting larger fish (mean of 420 mm). The summer fishery in Shubenacadie Lake, as represented by the records of the 1984-1986 Herald Fishing Derby, caught a total of 178 striped bass, of which 117 were sampled for biological data (B. Sabean 1987, Nova Scotia Dept. Lands and Forests, pers. comm.). Numbers of fish per age-group declined sharply after age 7; fish 8 years and older comprised 21% of the total. The catch of age-2 to age-7 (modal age 6; n = 93) averaged 462 mm FL (range, 235-660 mm) while the older group (n = 24) averaged 717 mm FL (range, 590-919 mm). The daily bag limit for striped bass in Nova Scotia, in locations other than the Annapolis River, is five fish per day.

A commercial fishery for striped bass is prohibited in Nova Scotia by the Fishery Regulations, but a modest fishery operates under cover of the drift-net fishery for American shad which occurs downstream of the Highway 102 bridge crossing the Stewiacke River. The fishery takes advantage of the provision (Section 18(1)) that "striped bass that are unintentionally caught in nets, traps or weirs set for other fish may be retained and marketed." A small-scale drift-net fishery for shad in the Avon River estuary of Minas Basin also takes striped bass as bycatch. Striped bass landings in Fishery Statistical District (FSD) 43 (Shubenacadie River) between 1977 and 1989 ranged irregularly from unrecorded or zero to 3 t, with landings in recent years being lowest. The Avon River (FSD 42) striped bass fishery was active during the 1950s, when the catch averaged about 4 t. The shad fishery declined during the 1960s but no catch data are available for striped bass. In the 1970s, both fisheries declined further and irregularly occurring catches of striped bass typically were less than 0.5 t. More

recently, landings in FSD 42 were 1 t in 1977, 2 t in 1988, and 1 t in 1989.

Muscle-tissue mercury levels increase with increasing length and weight in striped bass in Scotia-Fundy rivers (Jessop and Vithayasai 1979). Most fish caught in the Shubenacadie River are sufficiently small that total mercury content does not exceed the permissible limits of 0.5 ppm. Striped bass exceeding about 650 mm FL contain mercury concentrations higher than 0.5 ppm and their consumption should be limited. Mercury concentrations derive from natural bioaccumulation because few sources of mercury pollution exist in the Maritimes (Wilson and Travers 1977).

Striped bass in the Shubenacadie-Stewiacke River system are the only stock in Scotia-Fundy Region in recent years to reproduce successfully on a continuing basis (Jessop and Vithayasai 1979; Jessop 1980). One factor contributing to the successful reproduction in the Shubenacadie River is the relatively low organochloride levels in the ovaries of the 2.5-5.0 kg females that contribute most of the egg deposition (Jessop and Vithayasai 1979). More important is the interaction of low pH, dissolved aluminum level, and water hardness (Buckler et al. 1987). Water quality in the Shubenacadie River at the site (Pine Grove) sampled by Parker (1984) (May 27-August 8) closest to where spawning occurs averaged 90 $mg \cdot L^{-1}$ hardness, 0.21 $mmhos \cdot cm^{-2}$ conductivity, 300 $\mu g \cdot L^{-1}$ aluminum, and pH values from 6.4 to 7.8. The hardness of the water (due to the geology of the river basin, in which substantial deposits of gypsum occur) substantially reduces the toxicity of the high aluminum level at the observed pH levels (Buckler et al. 1987). Spawning in the Shubenacadie River occurs within several km upriver of the saline limit and the drift of eggs and larvae into slightly (2-5 ppt) saline waters would further enhance their survival (Mehrle et al. 1987). Recent research indicates that any reduction in egg viability due to PCB effects, or of direct effects of river contaminants on egg or larval mortality, may be offset by a large spawning biomass (Anon. 1989). The Shubenacadie-Stewiacke river system is currently believed to have the largest spawning biomass of any river in Scotia-Fundy region, but its size is unknown.

Annapolis River

Investigation of the biology and status of striped bass has been more active in the Annapolis River than in other rivers in the Scotia-Fundy Region. The most recent information on this stock is the survey of the sport fishery by Harris and Rulifson (1988), which examined changes in the stock since the creel survey of 1978 (Jessop 1980) and provides baseline data, for future creel surveys, following the opening of the tidal power plant at the Annapolis Royal causeway in 1985. No commercial fishery exists for striped bass in the Annapolis River, but small bycatches of striped bass occur occasionally in the herring weirs (presently three) that are active in the Annapolis Basin.

The angling fishery for striped bass in the Annapolis River is the largest and most popular of the striped bass fisheries in the Scotia-Fundy Region. Creel surveys documented the status of the fishery and the stock between 1972 and 1980 (Penney 1973; Jessop and Doubleday 1976; Jessop and Vithayasai 1979; Jessop, unpublished data), and in 1987 (Harris and Rulifson 1988). Although difficulties (due to differences in survey methods and length and time of survey period) in comparing results of different surveys should be recognized, it can be concluded that, between 1972 and 1980, fishing effort and catch during the periods surveyed steadily declined (from about 9,800 h and 478 fish in 1975 to 1,500 h and 40 fish in 1980; Table 1), stock abundance (as reflected by angling catch) decreased, and mean age composition and fish size increased (from 6.0 yr and 559 mm FL to over 12 yr and 850 mm FL; Table 2). In 1987, an influx of younger (4 yr old) fish produced slightly increased catches (190 fish) and lowered the size and age composition of the catch (to 703 mm FL and 6.3 yr). A substantial portion of the striped bass angled in the Annapolis River exceed the 650 mm FL size at which tissue mercury levels average more than 0.5 ppm. The large catches (25,000-58,000 fish) reported in the DFO angling statistics of 1969 to 1975 are believed to be greatly overestimated (Jessop and Doubleday 1975; Jessop and Vithayasai 1979), yet uncritical acceptance of such large catches still occurs (Harris and Rulifson 1988).

Before the recognition, in the late 1970s, of the declining status of the striped bass stocks of the Annapolis River, regulations restricted the angling fishery to a daily bag limit of five fish. Closure of the angling fishery upriver of the causeway to protect the spawning stock was implemented by variation order in 1977 and maintained until regulations were amended in 1982. The regulation changes imposed a closure of the fishery between April 1 and June 30 in the spawning area and reduced the daily bag limit to two fish. Enforcement of these regulations has been minimal, both in the late 1970s (Jessop, personal observation) and recently (Harris and Rulifson 1988).

Although striped bass aged by Harris and Rulifson (1987) were about 2 years younger, at similar size, than fish aged by Jessop (1980) (a discrepancy that is unresolved), the implication is that some young fish have recruited to the Annapolis River. Young striped bass could be from adjacent rivers, such as the Shubenacadie, because the available evidence suggests minimal or no survival of larval striped bass in the Annapolis River (Jessop 1980; Parker and Doe 1981; Williams et al. 1984).

Water quality values from sites near Paradise, within the spawning zone of striped bass (Williams et al. 1984), ranged from pH's of 6.6-7.3, hardness of 16-20 $mg \cdot L^{-1}$, alkalinity of 7-10 $mg \cdot L^{-1}$, and aluminum concentrations of 60-210 $\mu g \cdot L^{-1}$ in 1979 (Parker and Doe 1981) to pH's of 6.4-7-3, a mean hardness of 25 (range, 15-40) $mg \cdot L^{-1}$, a mean alkalinity of 13 (range, 7-20) $mg \cdot L^{-1}$, and mean

aluminum concentrations of 90 (range, 25-250) $\mu g \cdot L^{-1}$ in 1980 (Parker 1984). The effects of potential interactions of pH, hardness, aluminum concentration, and salinity decrease with larval age, but are such that mortality of striped bass in the Annapolis River could range from moderate to total, depending upon the combination of parameter values at a particular time (Hall et al. 1985; Buckler et al. 1987; Hall et al. 1987; Mehrle et al. 1987; Uphoff 1989). Increased survival of larval striped bass due to reduced aluminum toxicity at higher salinity levels (Palawski et al. 1985; Mehrle et al. 1987) is less likely in the Annapolis River than in the Shubenacadie River because of the stable halocline/thermocline in the Annapolis River downstream of the spawning zone and consequent increase in distance that must be traversed before salinity effects occur. Organochloride (PCB, $\sum$DDT) concentrations in the ova of large striped bass are sufficiently high to warrant concern about potential egg and larval mortality (Jessop 1980). Mean seasonal and abrupt changes in water temperature during spawning are also known to affect the survival of eggs and prolarvae (Cooper and Polgar 1981; Hall et al. 1989; Uphoff 1989).

Eggs spawned in the Annapolis River are viable and have a high hatching rate when held in water of suitable quality from sources other than the Annapolis River (Wiles 1979; Jessop 1980; Parker and Doe 1981; Jessop, unpublished data). Larvae from these eggs can be successfully reared to sizes of 60-80 mm with minimal mortality, other than due to cannibalism resulting from inappropriate rearing practices, and almost 600 striped bass fingerlings of Annapolis River stock were released into the river in September of 1981 (Jessop and Anderson, unpublished report).

Small angling fisheries for striped bass occur at other coastal sites, including the Passamaquoddy Bay area of New Brunswick and, in Nova Scotia, along the Noel Shore and Gaspereau River estuary of Minas Basin, in the Bear River estuary of the Annapolis Basin, in the Tusket River estuary, and in the LaHave River estuary and Porters Lake area along the Atlantic coast (Figure 2).

Management and Research Requirements

The long life and wide migration range of striped bass require long-term studies over broad geographic ranges if a good understanding of striped bass biology is to be obtained. Answers to many biological questions of interest to researchers and fishery managers in Scotia-Fundy Region will come from studies by American researchers working within the guidelines and funding of the federal-state cooperative Anadromous Striped Bass Restoration Program. Answers to stock-specific problems within Scotia-Fundy Region can only be provided by appropriate research in this region.

If agreement were reached that stock status is sufficiently depressed to warrant restorative actions, the three major

approaches are regulation of harvest, habitat improvement, and artificial rearing. Regulation of harvest is most readily achievable and justification exists to eliminate the bycatch of striped bass in the shad and gaspereau fisheries of the region. Consideration could also be given to declaring the striped bass a sport fish. Habitat improvement, particularly reduction in pH effects, is less easily achieved. Capability for artificial rearing of striped bass on the scale needed for stock restoration does not exist in Scotia-Fundy Region or in the Maritime Provinces, and serious obstacles of funding and knowledge exist for its development.

Important questions about striped bass biology requiring answers in Scotia-Fundy Region include: (1) the relative composition (native -non-native) of striped bass stocks and the contribution of each segment to fisheries and spawning, (2) the effects of environmental variation and contaminants on recruitment success, (3) the effects on stock abundance of changes in harvest regulations, and (4) if artificial culture and stocking are to occur, information necessary for ecologically sound, effective stocking policies must be developed and the techniques required for and factors affecting striped bass culture in this area must be understood. The US Striped Bass Research Plan (Anon. 1989) provides a framework for striped bass research that is broadly applicable to the Scotia-Fundy Region; the difficulty will be in deciding which regional problems are most in need of research and in obtaining the resources necessary to conduct that research.

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Table 1. Estimated striped bass catch, effort, and catch/effort statistics, by creel survey, Annapolis River causeway.

Survey[1]	Duration	Total effort (h)	Total catch	Av. fish per h
1975	May 13-Sept 11	9,799	478	0.05
1976	Jun 18-Sept 17	7,261	351	0.05
1978	May 15-Sept 8	5,618	116	0.02
1980	Jun 3-Sept 2	~1,500	~40	0.01
1987	Jun 1-Oct 22	3,757	190	0.05

[1]1972 survey data incomplete.

Table 2. Mean age, fork length (cm), and weight (kg) of striped bass examined in the creel surveys of 1972, 1975, 1976, 1978, 1980, and 1987 (after Jessop (1980), Jessop (unpublished data), and Harris and Rulifson (1987)).

Year	n	Length	n	Weight	n	Age
1972	232	55.9	232	2.70	182	6.0
1975	215	66.0	191	3.95	204	7.8
1976	160	76.3	155	5.89	159	9.4
1978	131	80.2	126	6.38	130	10.9
1980	24	77.1	24	6.25	-	-
1987	49	70.3	49	4.23	35	6.3

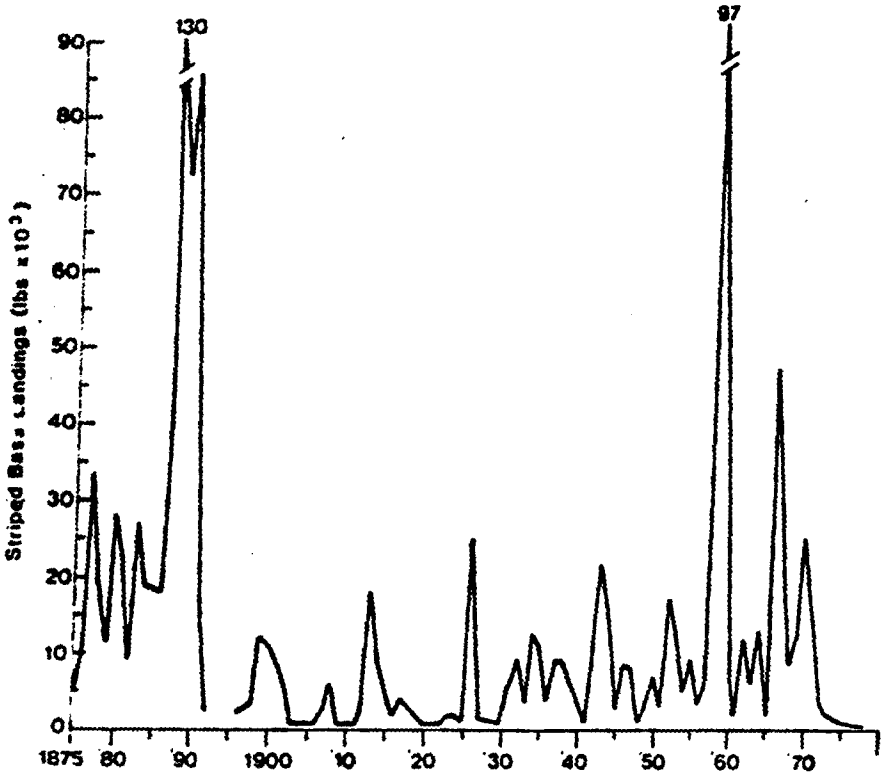

Figure 1. Striped bass commercial landings for the Saint John estuary, 1875-1975. From Dadswell et al. (1984).

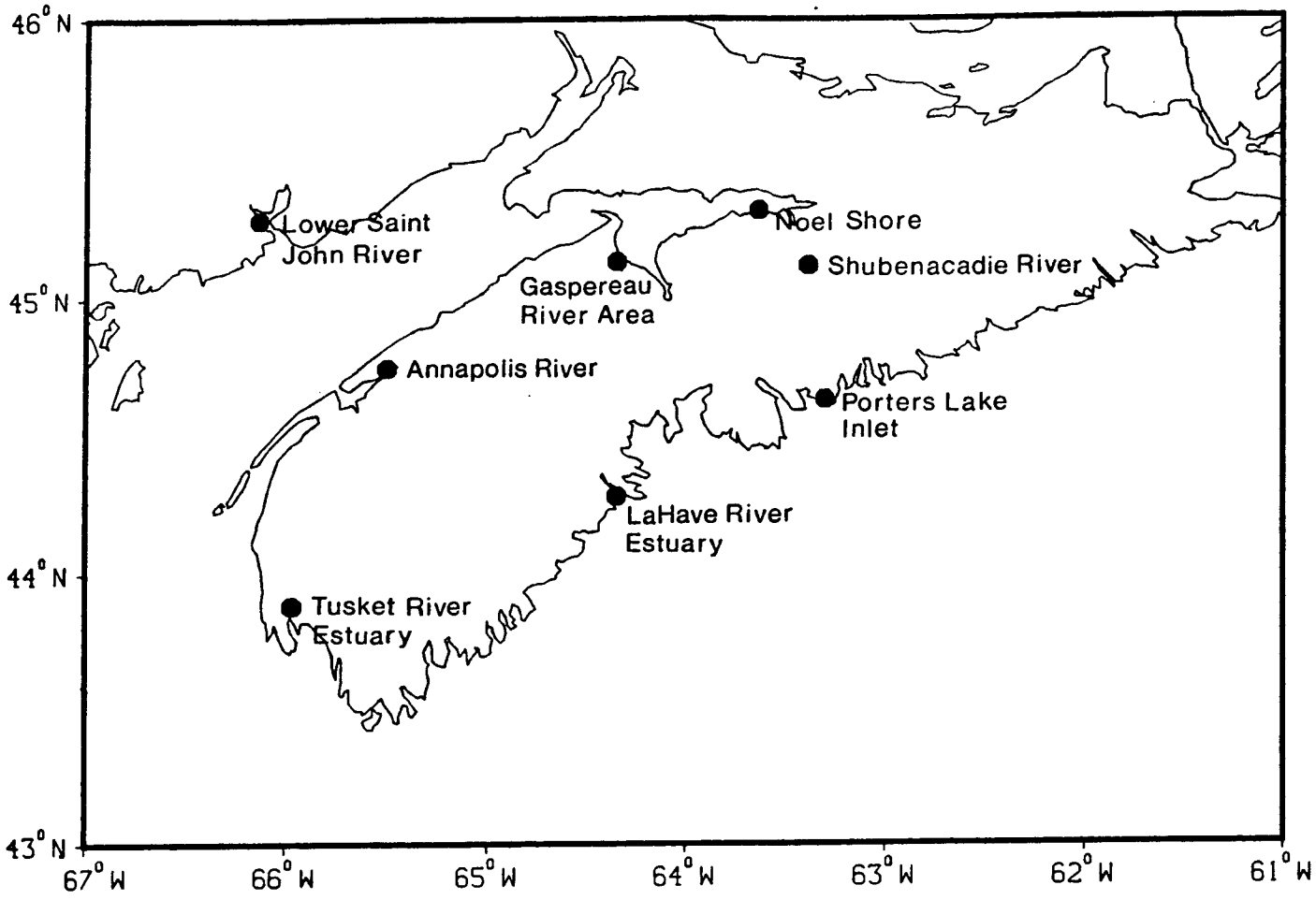

Figure 2. Striped bass angling locations, Scotia-Fundy Region.