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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/053

RECOVERY POTENTIAL ASSESSMENT FOR THE BAY OF FUNDY STRIPED BASS (*MORONE SAXATILIS)* DESIGNATABLE UNIT

Source: DFO

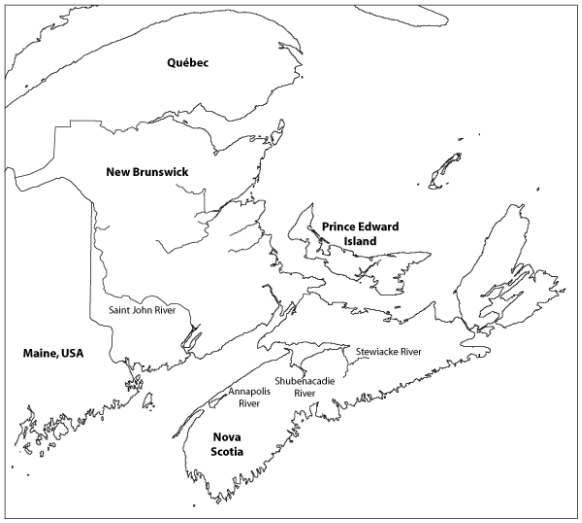

Figure 1. Map showing the location of the Bay of Fundy Striped Bass Designatable Unit and the spawning rivers within.

Context:

The *Committee on the Status of Endangered Wildlife in Canada* (*COSEWIC*) *has designated the Bay of Fundy (BoF) Striped Bass Designatable Unit (DU) as 'at risk' on two occasions, the first as Threatened in in 2004 (COSEWIC 2004) and most recently as Endangered in 2012 (COSEWIC 2012). Declining demographic status resulting from loss of spawning populations and unmitigated threats to extant spawning populations were the most significant factors contributing to the 'at risk' designations.*

When COSEWIC evaluates an aquatic species as 'Threatened' or 'Endangered', Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the Species at Risk Act (SARA), is required to undertake a number of actions. Formulation of scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. A RPA was completed in 2006 in response to the Threatened designation. The BoF Striped Bass DU is presently under consideration for listing as Endangered on Schedule 1 of Canada's SARA.

This Science Advisory Report is from the February 10-11, 2014, Recovery Potential Assessment for Striped Bass (Morone saxatitis), Bay of Fundy Designatable Unit. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated the Bay of Fundy (BoF) Striped Bass Designated Unit (DU) as 'at risk' on two occasions, most recently as Endangered in 2012.
- The BoF DU is considered to be comprised of three spawning populations: the Saint John River population in New Brunswick, the Shubenacadie River, and Annapolis River populations in Nova Scotia.
- The BoF DU presently consists of a single known spawning population in the Shubenacadie River, Nova Scotia. There is a possible spawning population in the Saint John River, New Brunswick, but there has been no direct evidence of spawning activity there in the last 30 years. Striped Bass in the BoF DU also historically spawned in the Annapolis River, Nova Scotia. While Striped Bass continue to feed in this river, no viable spawning has occurred since 1976.
- Evaluation of the status and area of occupancy of the BoF Striped Bass DU is confounded by the presence of US migrants within the BoF and Gulf of Maine.
- There are indications that the spawner abundance in the Shubenacadie River may have increased since 2002.
- Striped Bass populations exhibit significant variability in recruitment, the consequence of variable spawner success and survival past the early life-history. Survival through the first winter is dependent on body size. Individuals with pre-winter body sizes of smaller than approximately 10 to 11 cm fork length by the fall are less likely to survive.
- Based on presence of eggs, larvae, and ripe and running adult males and females, the tidal portion of the Stewiacke River lying 0 km to 6 km upstream of the confluence with the tidal Shubenacadie River is the only extant spawning site known to be used annually by the BoF Striped Bass DU.
- Genetic data acquired since the 2006 RPA supports the presence of a spawning population in the Saint John River; however, there has been no documented spawning activity in more than 30 years.
- Viable spawning by Striped Bass has not been observed in the Annapolis River since 1976. Although eggs have been collected from the river as late as 1990, survival beyond the egg stage is, therefore, thought to be very low to negligible.
- Age 1+ year and Age 2+ years juvenile Striped Bass possessing the genetic traits of the Shubenacadie River population have been detected within the Saint John River, indicating that the range of the Shubenacadie River population includes a large portion of the coastal and estuarial areas of the BoF.
- Most Age 0+ year Shubenacadie River Striped Bass appear to over-winter in tidal brackish water, although the specific over-wintering sites are not known.
- There are no life stages of Striped Bass that are thought to use a dwelling-place that meets the criteria for being declared a residence, as described in the *Species at Risk Act* and DFO draft guidelines.
- Due to the insufficient historical and present abundance data, it is not possible to establish abundance targets for either the BoF DU or the individual river populations at this time. However, there is no indication of a continued loss of spawning populations from within the DU and, therefore, of a further decline in general status.

- The primary threats facing the extant spawning population in the Shubenacadie River system are direct mortality through directed recreational angling and Food, Social and Ceremonial fisheries and, to a lesser extent, illegal fishing (poaching) and bycatch in commercial fisheries.
- There is an association between the decline in the Annapolis River Striped Bass population, the construction of the Annapolis Royal Causeway in 1960, and the subsequent construction of the Annapolis Tidal Station starting in 1980. The headpond is located downstream of the known spawning site on the Annapolis River and its alteration has had direct impacts on the quality of and access to this habitat.
- A reduced status for native Saint John River Striped Bass has been attributed to habitat degradation and loss, although direct cause-effect evidence for this specific population has not been gathered. Construction of the large Mactaquac hydroelectric dam upstream of a suspected important historical spawning ground is believed to be the single greatest factor contributing to the decline in the native population. The construction of the dam in 1967 may have significantly modified the spawning, egg incubation or larval habitats of the Saint John River population.

BACKGROUND

Rationale for Assessment

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) evaluates an aquatic species as 'Threatened' or 'Endangered', Fisheries and Oceans Canada (DFO), as the responsible jurisdiction under the *Species at Risk Act* (SARA), is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, population, or designatable unit (DU), threats to its survival and recovery, habitat needs, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes, including listing decisions and recovery planning.

COSEWIC has designated the Bay of Fundy (BoF) Striped Bass DU as 'at risk' on two occasions, the first as Threatened in 2004 (COSEWIC 2004) and most recently as Endangered in 2012 (COSEWIC 2012). Declining demographic status resulting from loss of spawning populations and unmitigated threats to extant spawning populations were the most significant factors contributing to the 'at risk' designations. These were reported as:

- COSEWIC 2004: "Repeated spawning failures led to the disappearance of the Annapolis and Saint John River populations. These disappearances are thought to be due to changes in flow regime and poor water quality. In the Shubenacadie River population, the presence of the introduced chain pickerel in over-wintering sites may constitute a threat. Another threat to the population is bycatch from various commercial fisheries."
- COSEWIC 2012: "…this large-bodied fish occurs at only a single known spawning location where it continues to be susceptible to exploitation from recreational fishing, by-catch in commercial fisheries, and from poaching. Habitat degradation continues in areas of historical spawning populations which limits recovery potential."

The BoF Striped Bass DU is presently under consideration for listing as Endangered on Schedule 1 of Canada's SARA. Of three recognized DUs, the BoF DU is the only one designated as being at greater risk in 2012 than in 2004. The designation for the St. Lawrence

River DU changed from Extirpated to Endangered, and the designation for the southern Gulf of St. Lawrence DU changed from Threatened to Special Concern.

Bay of Fundy Designatable Unit

Striped Bass (*Morone saxatilis*) is an anadromous percoid (spiny-finned fish) that spawns in estuaries along the eastern seaboard of North America from the St. Lawrence River in Québec, Canada, to the St. John's River in Florida, United States (US) (Scott and Scott 1988). Highest concentrations of Striped Bass occur in the middle of the species range, specifically in the Chesapeake Bay and the Delaware River areas of the State of Maryland and the Hudson River, New York. Striped Bass are an important high order predator in the coastal and estuarine zones wherever they occur.

In the Maritime provinces, Striped Bass are common in coastal and estuarine waters, as well as in certain freshwater bodies. They support important, directed, recreational fisheries and Aboriginal Food, Social and Ceremonial (FSC) fisheries. Migrant Striped Bass from spawning populations occurring along the eastern seaboard of the US and Striped Bass originating from BoF spawning populations occur in the BoF and along the Atlantic coast of Nova Scotia. The spawning populations that occur within the Canadian portion of the BoF represent one of the three Canadian DUs of Striped Bass defined in 2004 by COSEWIC (COSEWIC 2004). The BoF DU is considered to be comprised of three spawning populations: the Saint John River population in New Brunswick, the Shubenacadie River, and Annapolis River populations in Nova Scotia (Figure 1).

A RPA completed in 2006 in response to the Threatened designation defined a recovery target for the DU based upon area of occupancy, namely to reestablish annual spawning in at least one of the locations known historically to have supported spawning (DFO 2006). Neither the severity of stated threats nor the specific mechanisms contributing to the reported loss of the Annapolis River and Saint John River populations were known (DFO 2006).

ASSESSMENT

Status and Trends

The BoF DU presently consists of a single known spawning population in the Shubenacadie River, Nova Scotia. There is a possible spawning population in the Saint John River, New Brunswick, but there has been no direct evidence of spawning activity there in the last 30 years. Striped Bass in the BoF DU also historically spawned in the Annapolis River, Nova Scotia. While Striped Bass continue to feed in this river, no viable spawning has occurred since 1976.

In addition to being found in their spawning rivers, Striped Bass can also be found in the estuaries of other rivers within the DU and in the coastal waters of the BoF. Striped Bass frequenting the Minas Basin and Cobequid Bay in the summer months are thought to consist of a mixture of individuals that belong to the BoF DU and migrants from spawning populations from the eastern seaboard of the US. Evaluation of the status and area of occupancy of the BoF Striped Bass DU is confounded by the presence of US migrants within the BoF and Gulf of Maine.

Data relevant to assessing the current abundance and distribution of the BoF Striped Bass DU are scant and not well suited to quantitative assessment. However, a decline in the number of populations, the number of spawning locations, or the distribution within the DU since the first DU-wide assessment by Douglas et al. (2003) is not anticipated. The information available for each of the three populations is summarized in the following section.

Shubenacadie River Population

The Shubenacadie River Striped Bass population is the only population within the BoF DU that is confirmed to be reproductively active annually.

Adult Abundance

Spawner abundance was estimated in 2002, when the abundance of Age 3+ years and older fish was estimated at 15,000, including 7,000 that were Age 4+ years and older. This estimate is considered a conservative minimum estimate because only Striped Bass descending in the spring from Shubenacadie-Grand Lake, Nova Scotia, a known freshwater over-wintering site, were included in the census. Reported bycatch in commercial Shad and Gaspereau fisheries occurring in the Shubenacadie River indicates that Shubenacadie River Striped Bass spawner abundance may have increased since 2002. Available data indicate that even though juveniles have been produced annually since 1999, higher spawner abundance has not resulted in increased recruitment in the Shubenacadie River.

Juvenile Abundance

Shubenacadie River Age 0+ year Striped Bass abundance and distribution have been assessed annually since 1999, except for 2008. Inter-annual variation in year-class strength is apparent (Figure 2), in part due to climate variability and its impact on spawning success and/or survival of early life stages (i.e., eggs and larvae).

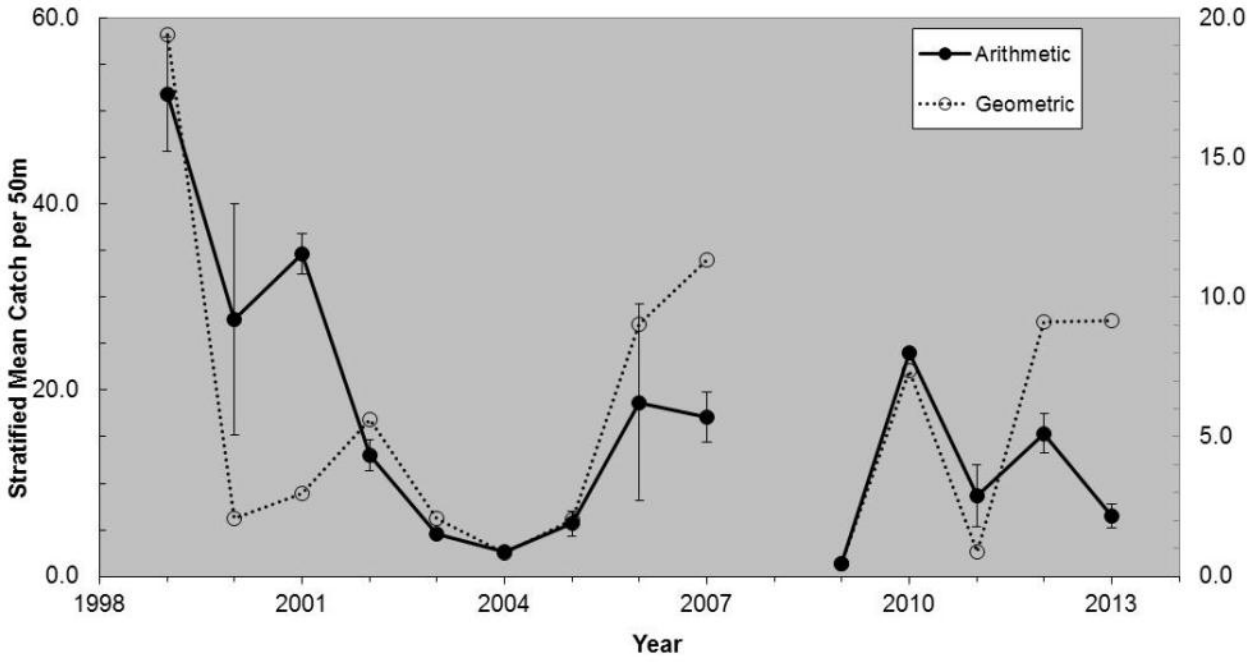

Figure 2. Arithmetic (±standard deviation) (left axis) and geometric (right axis) stratified mean annual catch (per 50m sweep) of Shubenacadie River Age 0+ year Striped Bass from beach-seine surveys for the years 1999-2007 and 2009-2013.

Distribution

Available information indicates that the extent of occurrence for the Shubenacadie River population includes all of the BoF. Genotyping (11 microsatellite loci) of 810 Striped Bass sampled from the Saint John River between 1999 and 2008 (Bradford et al. 2012) identified the

presence of Shubenacadie River fish in the river during every year of sampling. Striped Bass tagged while descending during May-June from an over-wintering site in Shubenacadie-Grand Lake have been recaptured in the coastal waters of the State of Maine (Bradford et al. 2012).

Saint John River Population

Genetic data acquired since the 2006 RPA (DFO 2006) supports the presence of a spawning population in the Saint John River (Bradford et al. 2012); however, there has been no documented spawning activity in more than 30 years. The search effort for spawning activity has been low and generally infrequent.

Local knowledge suggests that Striped Bass once spawned in several locations in the Saint John River (e.g., Belleisle Bay and Grand Lake), with the main spawning site at the head of tide in the vicinity immediately downstream of the Mactaquac Dam and Fredericton New Brunswick. Since 1967, spawning has been recorded only once.

Genotyping (11 microsatellite loci) of 810 Striped Bass sampled from the Saint John River between 1999 and 2008 (Bradford et al. 2012) identified the presence of both Shubenacadie River and US origin fish, as well as the inter-annual presence of a genetically discrete contingent that could not be assigned to a population of known origin. Both juvenile and adult fish were represented within this contingent, which exhibits greater genetic similarity to the southern Gulf of St. Lawrence DU and Shubenacadie River populations than to any of the populations of US origin that were included in the analysis (Bradford et al. 2012). These data lend support to the suggestion that native Striped Bass may still be present within the Saint John River; however, there is currently insufficient evidence outside of the genetic analysis to conclusively demonstrate the persistence of a spawning population of Striped Bass in the river.

Annapolis River Population

Native Annapolis River Striped Bass are considered to be extirpated. The continued presence of migrant Striped Bass in the estuary upstream of the Annapolis River causeway indicates that the river continues to function as foraging and perhaps over-wintering habitat.

Surveys of recreational Striped Bass fishers in the Annapolis River suggest that the population declined significantly from 1975 to 2000. Biological data collected during this period were consistent with low recruitment; the average length, weight and age increased, while the proportion of young fish sharply declined. Viable spawning by Striped Bass has not been observed in the Annapolis River since 1976. Although eggs were collected from the river as late as 1990, survival beyond the egg stage is thought to be very low to negligible.

There has been no attempt to collect and genotype adult Striped Bass in the Annapolis River since Douglas et al. (2003). Sampling has instead focused on attempting to locate early life-history stage Striped Bass in the river, the presence of which could indicate ongoing spawning activity. All monitoring of the early life-history stages of Striped Bass in the Annapolis River and Basin during 2001, 2002, 2009, and 2010 failed to detect any evidence of spawning activity.

Life-History Parameters

In Canada, Striped Bass are exclusively anadromous, meaning that they spawn in freshwater and spend a portion of their lives at sea. Spawning occurs during May and June in tidal freshwater upstream of the freshwater-saltwater interface in estuaries, with the possible but unconfirmed exception of the non-tidal portion of the lower Saint John River lying between Mactaquac Dam and the City of Fredericton. Significant numbers of Striped Bass over-winter in

freshwater in both the Saint John and Shubenacadie rivers, although it is not clear to what extent this behaviour is obligate.

Spawning activity is initiated by an increase in water temperature to about 15°C, and is generally considered to occur at dusk. This may not be the case for Shubenacadie River Striped Bass, which frequently exhibit observable and intense spawning activity during daylight. Spawning occurs at or near the surface, and it may persist for several weeks. Eggs and milt are broadcast simultaneously into the water column. Female Striped Bass are highly fecund, producing approximately 50,000 eggs per kg of total body weight. Eggs per female estimates for the Shubenacadie River population range from 41,000 eggs for a 45 cm fork length (FL) fish to 2.1 million eggs for a 91.0 cm FL fish.

Fertilized eggs float freely and hatch after two to three days, dependant on water temperature and environmental conditions. Larvae exhaust their yolk reserves in 5 to 10 days, and then move to the near-shore shallows of the estuary, where they feed on zooplankton. The larval stage can last 35 to 50 days, over the course of which the larval diet shifts from smaller to larger zooplankton.

Age of first spawning among Canadian Striped Bass populations is generally 3 to 4 years for males and 4 to 6 years for females, at body lengths of about 32 cm FL for males and 50 cm FL for females. Striped Bass can remain reproductively active for 20 years or more, although not all fish will spawn annually. Generation time for the BoF Striped Bass DU has been estimated to be 4 years.

Striped Bass populations exhibit significant variability in recruitment, the consequence of variable spawner success and survival past the early life-history. Year class dominance is, therefore, a common trait of adult populations.

Canadian populations of Striped Bass exhibit a higher intrinsic rate of somatic growth than many US populations. This is thought to help offset the negative effect of short summer growing seasons at higher latitudes on end of season body size of Age 0+ year individuals. Survival through the first winter is dependant on body size. Individuals with pre-winter body sizes of smaller than approximately 10 to 11 cm FL by the fall are less likely to survive. Size-dependent over-winter survival depends on stored energy reserves and temperature and salinity conditions for osmoregulation.

Unlike adult Striped Bass, which withstand significant variations in salinity, temperature, pH, and turbidity, eggs and larvae are sensitive to minor changes in environmental variables. Survival of eggs to hatching is closely tied to the physical and chemical properties of the incubation habitat, particularly temperature, salinity, dissolved oxygen and the presence of a moderate current, which keeps the eggs suspended in the water column. Survival of the larvae, like the eggs, depends on physical variables, including temperature, dissolved oxygen and salinity. The eggs, larvae and juveniles of the Shubenacadie River population exhibit several traits indicative of local adaptation to the highly dynamic environment (Bradford et al. 2012). Traits include large water-hardened diameters (3.67 mm ± 0.10 mm), large diameter oil globules (0.83 mm ± 0.02 mm), low specific gravity (1.0018 $g \cdot cm^{-3}$) (Bergey et al. 2003) and tolerance of a broader range of salinity (2 ppt – 20 ppt) than is typical for populations occurring elsewhere (Cook et al. 2010). Yolk-sac larvae up to 7 days post hatch tolerate salinities of up to 30 ppt and can tolerate temperature decreases that are lethal to other populations (Cook et al. 2010).

Habitat Considerations

The SARA defines critical habitat as, “the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species’ critical habitat in the recovery

strategy or in an action plan for the species." The *Act* requires that critical habitat be identified to the extent possible based on the best information available in the recovery strategy or action plan for all 'Threatened', 'Endangered' or 'Extirpated' species, or a schedule of studies be included that, when completed, would allow the species' critical habitat to be identified.

While this Science Advisory Report does not identify critical habitat, it provides information to support the identification of critical habitat in a future recovery document. National guidance suggests that critical habitat is comprised of several components: biophysical functions, features and attributes, and geographic location.

Functions – Critical habitat serves a biological function, which is the capacity to support a life-cycle process requirement of the listed species. A function is the result of a biophysical feature and its attributes**,** which together provide the capacity for the function to occur.

Features – Features are the biophysical components of the habitat (e.g., eelgrass beds, macrophytes, riffles, pools, and acoustic environment). Features are the aspects of the habitat that support the functional capacity for life-cycle processes necessary for survival or recovery. Features must be described in terms of their temporal use and/or availability.

Attributes – Every feature is comprised of many attributes, such as temperature, water depth, velocity, gravel size and oxygen level, that operate within optimal ranges and together provide the functional capacity of the feature to support a life-cycle process. Attributes are measurable and indicate why one feature is essential whereas another similar feature is not. Only those attributes deemed essential to a feature and the function it supports should be described.

Geographic location – Can be identified through a variety of approaches, including the Bounding Box Approach, in which the function and features of the habitat can be described but their exact location cannot.

A summary of features, functions, attributes, and geographic location of Striped Bass habitat in the BoF DU are summarized in Table 1 and discussed below.

Spawning Sites

Spawning sites are used by adults for the release of eggs and milt, for incubation of eggs, and by post-hatch larvae for development and feeding through to metamorphoses. The known spawning sites are geographically discrete and appear to represent the only specific habitat areas on which Bay of Fundy Striped Bass are dependent for fulfilment of life-history functions.

Locations

Based on the presence of eggs, larvae, and ripe and running adult males and females, the tidal portion of the Stewiacke River lying 0 km to 6 km upstream of the confluence with the tidal Shubenacadie River is the only extant spawning site known to be used annually by the BoF Striped Bass DU. There is anecdotal evidence that spawning has occurred within the tidal Shubenacadie River in an area upstream of the confluence with the Stewiacke River in recent years.

There is a possibility that other spawning locations exist within the BoF DU, most notably in the lower Saint John River. However, spawning activity in this river has not been confirmed in recent decades. Similar criteria identify the portion of the Annapolis River lying between Lawrencetown and Bridgetown as an historical spawning location that is no longer in use.

Features

There are few, if any, features (e.g., vegetation, substrate, stream flow) common to all known or suspected BoF Striped Bass spawning areas. This reflects the lack of dependence of

reproduction on physical structures. Spawning, egg incubation, and larval development through to first feeding and to metamorphoses are all completed within the water column. The presence of a moderate current to maintain eggs in suspension appears to be a required feature for Striped Bass in general.

Attributes

Oxygenated water above 5 mg/l is a general requirement. Shubenacadie River Striped Bass eggs produced during the 2000 and 2001 spawning seasons were predominantly (75^{th} Quantile) associated with water temperatures of ≤19^{o}C (minimum = 13^{o}C; maximum 24^{o}C) and salinity of ≤1 ppt (minimum = 0 ppt; maximum = 20 ppt). Larvae were predominantly associated with water temperatures of ≤23^{o}C (minimum = 15^{o}C; maximum 26^{o}C) temperature and salinity of ≤6 ppt (minimum = 0 ppt; maximum = 18 ppt).

Rearing Habitat

Rearing habitat is defined as areas outside primary spawning habitats that are used by juvenile Striped Bass for feeding and growth. There are indications that rearing habitat for BoF Striped Bass is not limiting,

Locations

The geographic extent of occurrences of Saint John River and Annapolis River Age 0+ year Striped Bass are not known. By the end of the first growth season, Shubenacadie River Striped Bass occupy the tidal portions of the Shubenacadie and Stewiacke rivers, the shoreline of Cobequid Bay and much of the shoreline of the Minas Basin. The consistent absence of Age 0+ year Striped Bass in beach seined collections of fish at a site located near Parrsboro, Nova Scotia, indicates the Minas Passage may not provide important habitat for this life-stage. However, recent captures of Age 0+ year Striped Bass in a research trapnet installed near the head of tide in the Petitcodiac River, New Brunswick, may indicate that the area of occupancy and, therefore, the locations of available habitat for young Shubenacadie River Striped Bass may be greater than previously thought.

The geographic range of Age 1+ year and older juvenile Shubenacadie River Striped Bass is not fully understood. Some ascend the Shubenacadie River during May and June. They are a regular component of collections acquired with a beach seine at standard sites located within the tidal Shubenacadie River, Cobequid Bay, and seaward to the Five Islands area of the Minas Basin. Age 1+ year Striped Bass of unknown origin have been sampled with a trapnet installed near the head of tide in the Petitcodiac River. Age 1+ year and Age 2+ years juvenile Striped Bass possessing the genetic traits of the Shubenacadie River population have been detected within the Saint John River, indicating that the range of Shubenacadie River Striped Bass juveniles includes a large portion of the coastal and estuarine areas of the BoF.

Features

Juvenile Shubenacadie River Striped Bass use a variety of shallow shoreline habitats, in both tidal and non-tidal waters, as rearing habitat. The viability of the population is likely not dependent upon any specific habitat feature (e.g., vegetation, substrate, stream flow).

Attributes

Oxygenated water above 5 mg/l is a general requirement. Age 0+ year Shubenacadie River Striped Bass sampled from the time of metamorphoses in June through to late July within the tidal Shubenacadie River were predominantly (75^{th} Quantile) associated with water temperatures of ≤20^{o}C (minimum = 17^{o}C ; maximum 20^{o}C) and salinities of ≤7 ppt (minimum = 0 ppt; maximum = 31 ppt).

A June to September beach seine survey conducted in most years since 1999 at fixed sampling sites in Minas Basin, Cobequid Bay, and the tidal portion of the Shubenacadie River indicates Age 0+ year Striped Bass were predominantly (75^{th} Quantile) associated with water temperatures of ≤24^{o}C (minimum =16^{o}C; maximum 28^{o}C) and salinities of ≤28 ppt (minimum = 0 ppt; maximum = 31 ppt).

Foraging

Foraging habitat includes all habitat where all post-larval Striped Bass feed irrespective of age or state of maturity. As such, rearing habitat and foraging habitat are synonymous for juvenile Striped Bass but may differ for adult fish. There are no indications that foraging habitat is limiting for BoF Striped Bass.

Larval and recently metamorphosed Striped Bass forage on zooplankton and other small invertebrates, although cannibalism is known (R.B. Bradford *personal observation*). Following metamorphoses into juveniles, their diet becomes increasingly diverse with time as they increase in body size and may include the following prey items: mysids, crangon, polychaetes, crabs, Rainbow Smelt, Atlantic Silverside, Alewife, Blueback Herring, American Shad, Atlantic Herring, Atlantic Tomcod, and American Eel.

Post-spawned adults, Age 1^{+}year, and older juveniles can partake in a coastal feeding migration that lasts for the summer and autumn. Striped Bass are generalist predators, consuming both macro-invertebrates and fish.

Over-wintering Habitat

Locations

Most Age 0+ year Shubenacadie River Striped Bass appear to over-winter in tidal brackish water, although the specific over-wintering sites are not known. Many Age 2+ years and older Striped Bass over-winter in Shubenacadie-Grand Lake on the Shubenacadie River. Striped Bass possessing the genetic traits of the Shubenacadie River population have been detected in samples collected from Belleisle Bay on the Saint John River during early spring. Additional freshwater over-wintering sites are possible.

The extent to which over-wintering in fresh-brackish water is obligate for BoF Striped Bass is not clear. Lethal low marine temperatures (colder than the freezing point (-1.5^{o}C) of unprotected blood) can occur within the BoF, but these are not an interannually consistent feature of the hydrography of the bay. Over-wintering in marine waters may occur at least in some years, as has been recently shown in Minas Passage (Keyser et al. 2013).

There are no indications that over-wintering habitat is limiting for BoF Striped Bass.

Features

Overall, the features of over-wintering habitat are not well described. Known freshwater over-wintering sites are lakes that are relatively large and deep when compared to other accessible lakes, e.g., Shubenacadie-Grand Lake, Nova Scotia and Belleisle Bay, New Brunswick.

Attributes

Over-wintering sites generally occur where water temperatures remain warmer than the freezing point of unprotected fish blood (<1.5^{o}C), which includes all freshwater habitats, but there is recent evidence that marine waters within the inner BoF may meet this requirement in most years (see spatial extent of over-wintering habitat).

Table 1. Summary of features, functions, and attributes of Bay of Fundy Striped Bass habitat.

Population	Geographic Location	Age from egg deposition	Function	Features	Attributes
Shubenacadie River	Stewiacke River 0 km to 6 km from confluence	Adults	Spawning (May-June)	Saltwater/Freshwater interface	Temperature: 13°C - 24°C Salinity: ≤ 1 ppt Water velocity: moderate current Dissolved oxygen: >5mg/l
		Eggs (0-3 days)	Incubation of pelagic eggs (May-June)	Saltwater/Freshwater interface Current to maintain eggs in suspension	Temperature: 13°C - 24°C Salinity: ≤ 1 ppt Water velocity: moderate current Dissolved oxygen: >5mg/l
		Larvae (0-7 days to first feeding)	Early development (May)	Saltwater/Freshwater interface Current to maintain eggs in suspension	Temperature: 15°C - 26°C Salinity: ≤ 6 ppt Dissolved oxygen: > 5mg/l Prey: zooplankton
		Larvae and recently metamorphosed juveniles (8-30 days)	Metamorphoses (May-July)	Waters under tidal influence in the Stewiacke and Shubenacadie rivers.	Temperature: 15°C - 26°C Salinity: < 10 ppt 8-17 days, 1-30 ppt 18-30 days. Dissolved oxygen: > 5mg/l Prey: zooplankton
	Tidal waters of the inner BoF	Age 0+ year (31-150 days post-hatch)	Growth (May-October)	Food availability	Temperature: ≤ 22°C Dissolved oxygen: > 5mg/l Prey: zooplankton
			Migration (May-December)	Corridor to/from winter habitat and spawning habitat	Temperature: ≤ 22°C Dissolved oxygen: > 5mg/l Corridor free of obstructions that prevent/delay migration
			Over-wintering (October–May)	Inner portions of estuaries	Temperature: ≥ -1.5°C Dissolved oxygen: >5mg/l Water circulation that promotes retention
	Tidal waters of BoF including Saint John River, Shubenacadie	All Age 1+ year and older	Growth (April-October)	Food availability	Dissolved oxygen: > 5mg/l Prey: mysids, crangon, polycheates, crabs,

Population	Geographic Location	Age from egg deposition	Function	Features	Attributes
	River and lakes				small, medium, and large fishes
			Migration (October-November)	Corridor to/from winter habitat	Temperature: ≥ -1.5°C (tidal waters) Dissolved oxygen: >5mg/l
			Overwintering (October–May)	Marine/estuarial	Temperature: ≥ -1.5°C Dissolved oxygen: > 5mg/l Water circulation that promotes retention
				Freshwater	Lakes/embayments with low susceptibility to flushing Dissolved oxygen: > 5mg/l
		Adults Males: Age 3+ years and older Females: Age 5+ years and older females	Spawning	See 'Eggs'	Temperature: ≥ 15°C (onset of spawning activity) Light: generally at dusk See 'Eggs'
				Corridor to spawning grounds	Free of obstructions that prevent/delay migration Dissolved oxygen: > 5mg/l
			Migration (October-November)	Corridor to/from winter habitat	Temperature: ≥ -1.5°C (tidal waters) Dissolved oxygen: > 5mg/l
			Overwintering (October-May)	Marine/estuarine	Temperature: ≥ -1.5°C Dissolved oxygen: > 5mg/l Water circulation that promotes retention
				Freshwater	Lakes/embayments with low susceptibility to flushing Dissolved oxygen: > 5mg/l
DU Saint John River Annapolis River Non-specific locations within BoF		Spawners Eggs Larvae	Spawning	Estuarine	Large estuaries that share the features identified for Shubenacadie River Striped Bass Temperature: ≥ -1.5°C Dissolved oxygen: > 5mg/l

Residence Requirements

The *Species at Risk Act* defines a residence as:

> *"A dwelling-place, such as a den, nest or other similar area or place that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating."*

The draft Operational Guidelines for the Identification of Residence and Preparation of a Residence Statement for an Aquatic Species at Risk (DFO, unpublished report) uses the following four conditions to determine if an aquatic species uses a residence:

- there is a discrete dwelling-place that has structural form and function similar to a den or a nest; and
- an individual of the species has made an investment in the creation or modification of the dwelling-place; and
- the dwelling-place has the functional capacity to support the successful performance of an essential life-cycle process such as spawning, breeding, nursing and rearing; and
- the dwelling-place is occupied by one or more individuals at one or more parts of its life cycle.

At this time, there are no life stages of Striped Bass that are thought to use a dwelling-place that meets the criteria for being declared a residence as described in SARA and DFO draft guidelines.

Range and Distribution

Genetic assessment and mark-recapture data (Bradford et al. 2012) indicate the range of BoF Striped Bass extends from the Gulf of Maine to the southern Atlantic coast of Nova Scotia. Striped Bass are common in coastal and estuarial waters. Spawning is currently limited to the Shubenacadie River, Nova Scotia and potentially the Saint John River, New Brunswick.

Recovery Targets

Recovery targets for BoF Striped Bass can be defined using two components: an abundance target and a distribution target.

Abundance Targets

Due to the insufficient historical and present abundance data (i.e., number, biomass, or attributes of mature spawning age animals), it is not possible to establish abundance targets for either the BoF DU or the individual river populations at this time. However, there is no indication of a continued loss of spawning populations since the time of the 2004 COSEWIC assessment and, therefore, of a further decline in general status (Table 2).

Table 2. Abundance of mature animals attribute (updated from DFO 2006). (NA = not applicable)

Attribute	Achievability
AI – Recovery objectives defined	No, and cannot be defined with existing data. See Table 3
AII – Expectation of recovery within ten years (by 2024)	NA (no recovery target)
AIIa - Under present conditions	NA See Table 3
AIIb - If fisheries related mortalities are reduced	NA Higher abundance expected
AIIc - If other human-induced mortality factors are reduced	NA Higher abundance expected

Distribution Targets

The distribution targets for the BoF Striped Bass DU (Table 3) were previously defined by DFO (2006) using an index area of occupancy scaled to spawning habitat. The aim is,"... successful spawning in one of two historical locations of the Bay of Fundy DU where there has been no evidence of spawning during the last ten years" (DFO 2006).

Table 3. Area of occupancy attributes based on spawning locations (updated from DFO 2006). Timeframe refers to the estimated length of time that would be required for an attribute to be met (NA = not applicable).

Attribute	Achievability
DI – Maintain spawning in the DU	The DU presently meets this attribute. The Shubenacadie River population continues to spawn annually.
DII – Spawning re-established annually in a portion of the locations lost within the DU	The DU potentially meets this attribute. A spawning population may exist in the Saint John River (COSEWIC 2012), but this requires confirmation. Timeframe: Unknown, > ten years
DIII – Spawning annually at all historic locations of the DU	The DU does not meet this attribute. Spawning has not been detected in the Annapolis River. Timeframe: Unknown, > ten years

Threats and Limiting Factors

Specific levels of mortality cannot be quantified with available data. Threats are accordingly assigned a relative rank as was the case during the previous RPA (DFO 2006). Threats to BoF Striped Bass were previously assessed by DFO (2006) and COSEWIC (2012).

Threats are described separately below for the Annapolis, Saint John and Shubenacadie rivers. Significant threats that are common to all populations within the DU are then described. The full suite of threats during the RPA and the effect to be mitigated are compiled in Appendix 1 by attribute (Direct Mortality, Water Quality, Water Quantity, Impacts on Habitat), along with present mitigation, options to reduce effect, monitoring and research requirements and the rank effect on the status of the DU.

Threats to Individual Populations

Shubenacadie River Population

The primary threats facing the extant spawning population in the Shubenacadie River system are direct mortality through directed recreational angling and FSC fisheries, as well as illegal fishing (poaching) and bycatch in commercial fisheries. While the level of removals is not known for each of these sources, the total number of authorized removals is potentially high. Despite these threats, the limited information available suggests that the Shubenacadie River Striped Bass population has increased substantially in recent years, most likely the result of strong year-classes during the 1999 and 2000 spawning years. Preliminary estimates of annual survival for adult members of the Grand Lake population (i.e., those that over-winter in Grand Lake, Nova Scotia) have been acquired using acoustic telemetry. The estimates varied between 47% and 74% survival rate for the years 2008 to 2010, although the estimates were only for spawning fish that spent the summer in the Minas Basin. Handling mortality during the first summer post-tagging was observed (53% to 74%); however, survival was estimated to be consistently ≥ 80% thereafter and without a significant seasonal effect.

Annapolis River Population

There is an association between the decline in the Annapolis River Striped Bass population, the construction of the Annapolis Royal Causeway in 1960, and the subsequent construction of the Annapolis Tidal Power Generating Station starting in 1980 (began operation in 1984). The headpond is located downstream of the historical known spawning site on the Annapolis River, and its alteration has had direct impacts on habitat quality. The circulation changes resulting from the construction of the causeway and tidal station are considered the only potential source of high mortality for the population. Operation of the turbine may result in the release of suspended sediment and physical scouring along downstream channels and shorelines, resulting in further alterations to potential habitat. Striped Bass may also be subject to direct mortality as a result of entrainment in the Annapolis Tidal Station's turbine.

Recent measures of river pH indicate that acid toxicity may not be a significant factor (Freeman 2013) suggesting that low pH may not have contributed to the loss in spawning viability, as had been previously hypothesized.

Saint John River Population

A reduced status for native Saint John River Striped Bass has been attributed to habitat degradation and loss, although direct cause-effect evidence for this specific population has not been gathered. Construction of the large Mactaquac hydroelectric dam upstream of a suspected important historical spawning ground is believed to be the single greatest factor contributing to the decline in the native population. However, suspected spawning in the main stem of the river has never been confirmed with collections of eggs or larvae. The construction of the Mactaquac Dam in 1967 may have significantly modified the spawning, incubation or larval habitats of the Saint John River population. According to local knowledge, the main spawning site is believed to have been at the head of tide in the vicinity of the Mactaquac Dam and Fredericton, New Brunswick.

It is not possible to quantify the loss in productivity of this population that may have resulted from elimination of access to formerly free-flowing river habitat above Mactaquac Dam and potential loss of spawning habitat below the dam.

High levels of PCBs and DDT, both a potential threat to a high trophic level predator such as Striped Bass, occurred during the 1970s in the Saint John River. However, water quality of the Saint John River has improved as municipalities and industries have installed wastewater treatment systems. Water quality continues to be impacted by human activities and, most notably, dissolved oxygen is considered low in portions of the Mactaquac Dam headpond, which are not presently known to be occupied by Striped Bass.

Common Threats Irrespective of Population of Origin

The primary source of human-induced mortality of BoF Striped Bass is considered to be the directed recreational angling fishery that occurs in both tidal and non-tidal waters. Participation in the fishery, as estimated from the national survey of licenced anglers in the Provinces of New Brunswick and Nova Scotia, is thought to have exceeded 5,000 anglers in the years since 2000. However, the estimate is considered to be low because provincial angling licences are not required to fish tidal waters. Therefore, not all anglers would be subject to selection for survey. Reported removals of Striped Bass by anglers vary from about 2,000 to approximately 13,000 per year. The number of Striped Bass reported to be hooked and released by anglers is typically on the order of 100,000 fish per year and is, therefore, a potentially significant source of incidental mortality. The mortality of Striped Bass caught and released can vary widely from a low of 3% to a high of 74% depending on the water temperature, salinity, and type of tackle used. The catch-release mortality rate for Southern Gulf of St. Lawrence Striped Bass is assumed to be 10% (DFO 2011).

Twelve First Nations have signed Aboriginal Fisheries Agreements with DFO that include provisions for the harvest of Striped Bass for FSC purposes. These agreements include negotiated daily allocations for each licence but are not subject to a total take.

The retention of one Striped Bass greater than 68 cm total length per day is authorized for several inshore commercial fisheries operating within the BoF. The total removal as bycatch per year is not known but potentially high given the large number of licence holders fishing for at least several weeks of the year.

Illegal fishing of Striped Bass is considered to be a low threat. Enforcement is considered to be effective at minimizing retention of bycatch and illegal harvest.

Fisheries on forage species for Striped Bass generally occur throughout the BoF, but their impact on Striped Bass is considered low. The forage base for Striped Bass is diverse, widely available, and includes both freshwater and marine fish and invertebrates.

Ecosystem Change

A warming trend in sea surface temperature has occurred in the BoF over the past 3 decades (Hebert et al. 2013). Higher winter marine temperatures have the potential to alter the dynamics of Striped Bass during the over-wintering period by providing increased spatial extent of suitable over-wintering habitat, or altering metabolic demands during this period. The overall net impact of warming winter temperatures remains unclear.

Spatial Configuration Constraints

The Mactaquac Dam on the Saint John River, New Brunswick prevents migration of Striped Bass to the 175 km portion of the river lying between the dam site and Grand Falls, a natural barrier to upstream passage. The quantity of potential forage habitat lost to native Saint John

River fish and migrant Shubenacadie River fish is low relative to the total available freshwater habitat lying below Mactaquac.

Fishing gear, principally dip net stands built to harvest Gaspereau from the Shubenacadie River during May to June, may delay the downstream migration of Striped Bass from their over-wintering site in Grand Lake to tidal waters. There are indications that the migrant fish become susceptible to harassment from recreational anglers and unauthorized activities (e.g., poaching).

Saltmarsh habitat that has been converted to agricultural land through the construction of dykes along the tidal sections of the Shubenacadie and Stewiacke rivers may have reduced the amount of forage habitat available to Age 0+ year Shubenacadie River Striped Bass.

Mitigation and Alternatives

Several measures are already in place to attempt to address the threats to Striped Bass identified in Appendix A, although the effectiveness of these measures has not been evaluated. An inventory of additional potential mitigation measures and alternatives to address threats assigned relative rank effects of 'High' or 'Medium' to BoF Striped Bass are outlined below. It is anticipated that implementation of many of these approaches would require collaboration among multiple departments, agencies, and groups. Prioritization of these mitigation options has not been attempted.

Threats Related to Direct Mortality

Potential mitigation measures to address direct mortality-related threats include:

Directed Recreational Angling Fishery – High Threat

- Close the recreational fishery, or move to a hook-and-release fishery by instituting prohibitions on the retention of BoF Striped Bass.
- Consider additional targeted closures to protect Striped Bass during migration or spawning.
- Reduce the bag limit or expand period/range of no-retention (catch and release only) restriction.
- Implement a maximum size (slot limit) to protect large spawners being removed from the population.
- Implement licencing for recreational fishing in tidal waters.
- Implement further gear restrictions (e.g., circle hooks when fishing with baited lines) to reduce catch-and-release mortality.

Illegal Fishing – High Threat (Saint John River population only)

- Increase targeted monitoring efforts to better identify incidents of illegal fishing.
- Implement stricter penalties.
- Maintain and improve reporting mechanisms.

Bycatch in Commercial Fisheries – High (gillnet, intertidal weir, trapnet) and Medium (trawl) Threat

- Enhance enforcement of existing bag limits for retention of Striped Bass captured as bycatch.
- Implement a maximum size (slot limit) to protect large spawners from being removed from the population.

- Enforce targeted seasonal/location closures of fisheries with potential for bycatch.
- Implement more restrictive bycatch limits in other fisheries.
- Implement additional gear restrictions.

Bycatch in Recreational Angling Fisheries – High Threat (tidal water)

- Implement licencing for recreational fishing in tidal waters.
- Enhance enforcement of existing bag limits for retention of Striped Bass captured as bycatch.
- Implement a maximum size (slot limit) to protect large spawners from being removed from the population.
- Enforce targeted seasonal/location closures of fisheries with potential for bycatch.
- Implement more restrictive bycatch limits in other fisheries.
- Implement additional gear restrictions.

FSC Fishery – High Threat

- Negotiate new FSC licenses that could involve new retention limits, seasonal and area closures, or other modifications to minimize removal of Striped Bass in areas and during times of concern.
- Implement maximum size limits to protect large spawners.
- Work towards defining take limits, determining the demand and level of interest in use of the species, and understanding the importance of the fish to the communities.

Entrainment in Flow-Through Turbines – High Threat (Annapolis River population only)

- Make modifications to fish passage to encourage use by Striped Bass and other species.
- Improve fish passage upstream and downstream.

Ecotourism and Recreation (Outboard Motoring) – Medium Threat (Shubenacadie River population only)

- Restrict use of outboard motors at times and in locations used by Striped Bass for spawning.

Scientific Research – Medium Threat (Shubenacadie River population only)

- Ensure that individuals authorized to sample wild Striped Bass for scientific research purposes are trained in proper handling techniques, and ensure that harm to fish collected for these purposes is minimized.
- Limit collections and retentions of fish through conditions of licencing.
- Ensure that all scientific work is justified and has a benefit for the long-term understanding and management of the species, and use it as an opportunity for education about the species.

Threats Related to Water Quantity

Potential mitigation measures to address water quantity-related threats include:

Altered Hydrology Resulting from Construction of Barriers (Annapolis River Causeway, Mactaquac Dam) – High Threat (Saint John River Population and Annapolis River Population)

- Install additional fish passages or flow-through to improve access to and from habitat considered to be important to the completion of life-history functions (i.e., spawning, over-wintering in the Annapolis River).
- Manage flows through the barriers to restore the functions of spawning, egg incubation, and larval development within the portion of Annapolis River estuary lying upstream of the causeway.
- Modify timing of release of water from reservoirs to prevent adverse downstream effects, especially during spawning.
- Evaluate effectiveness of existing up and downstream fish passages, and determine ways to improve passage.

Presence of In-stream Barriers that Impede Migration and Increase Susceptibility to Harassment – Medium Threat (Shubenacadie River population only)

- Enforce compliance with regulations on width of river channels that are to remain open.
- Explore options to maintain the required open channel width as river width varies with river discharge.

Threats Related to Impacts on Habitat

Potential mitigation measures to address threats related to impacts on habitat are described below.

Ecosystem Change – Medium Threat

- Incorporate consideration of ecosystem change into stock assessments to better understand and manage change in natural mortality of Striped Bass

Population Projections

Population projections cannot be calculated with existing data.

Allowable Harm

The maximum allowable harm that the DU can sustain and not jeopardize survival or recovery cannot be quantified in the absence of information on trends in abundance.

Available data indicates that the extant spawning population in the Shubenacadie River continues to produce new individuals annually and that current levels of direct and indirect mortality are not threatening survival. Activities that result in losses from the Shubenacadie River population are not likely to impede survival or recovery of either the Saint John River or Annapolis River populations. In the event that abundance data shows a declining trend in Shubenacadie River population abundance, allowable harm levels will need to be revisited.

The presence of dams on the Saint John and Annapolis rivers are currently not impacting survival on the fish at a level that can be detected, but dams are considered to be preventing achievement of the recovery distribution targets.

Scope for harm will require re-assessment in the event of confirmation of the re-establishment or persistence of spawning populations in either the Annapolis or Saint John rivers. The re-assessment will require consideration of scope for harm throughout these population distributions (i.e., BoF).

Sources of Uncertainty

Current sources of uncertainity include:

- There are no current estimates of the sex ratio, size/age structure, and abundance of adult Shubenacadie River Striped Bass.
- The rate of replacement (recruitment) for the Shubenacadie River population is not known.
- The total number of removals annually from authorized activities is not known.
- Neither the status of the Saint John River population nor the locations of habitat, including habitat above the Mactaquac Dam important for sustaining a viable Striped Bass population in the river, are known.
- It is not clear at the present time how changes in the potential availability of marine over-winter habitat will affect either the demographics or productivity of Striped Bass populations within the DU.
- It is uncertain whether the negative impacts of the Annapolis River Causeway and the Mactaquac Dam can be mitigated.

MANAGEMENT CONSIDERATIONS

Because a license is not required for recreational angling within tidal waters, there is currently no platform for collecting accurate effort, catch and retention data. Similarly, fisheries-independent creel survey data have not been collected in recent decades.

SOURCES OF INFORMATION

This Science Advisory Report is from the February 10-11, 2014, Recovery Potential Assessment for Striped Bass (*Morone saxatilis*), Bay of Fundy Designatable Unit. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX

Appendix 1. Summary of threats considered during the RPA, organized by attribute, the effect of the threat, populations affected, location of the effect and which abundance (A) and distribution (D) recovery targets are potentially impacted (see Tables 2 and 3 for the abundance and distribution recovery targets).

Attribute	Human Induced Threats	Effect of Threat	Effect Under Current Management Strategies			
			Populations Affected	Level of Impact on Individuals	Location of Effect	Recovery Target
Direct Mortality	Directed recreational angling fishery	Direct mortality of adults (retention or handling mortality in catch and release)	Shubenacadie Saint John	High	Tidal and non-tidal Shubenacadie River system. All tidal waters of the Bay of Fundy. Tidal[1] and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIa DI, DII
Direct Mortality	Illegal fishing	Mortality as a result of illegal retention of Striped Bass (i.e. without a general angling license, during closures, below size limits or above bag limits)	Shubenacadie Saint John	Low for Shubenacadie and Saint John	Tidal and non-tidal Shubenacadie River system. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIa DI, DII
Direct Mortality	Bycatch in commercial fisheries (gillnet, intertidal weir, trawl, trapnet, dipnet)	Mortality as a result of handling or retention of Striped Bass as bycatch in commercial fisheries targeting other species	Shubenacadie Saint John	High (gillnet, intertidal weir, trapnet) Medium (trawl) Low (dipnet)	Tidal and non-tidal Shubenacadie River system. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIa DI, DII
Direct Mortality	Bycatch in recreational fisheries (angling)	Mortality as a result of handling or retention of Striped Bass as bycatch in recreational fisheries targeting other species	Shubenacadie Saint John	High for tidal water Low for freshwater	Tidal and non-tidal Shubenacadie River. All tidal waters of the Bay of Fundy. Lower Saint John River (tidal and non-tidal).	AIIa DI, DII

[1] Tidal is defined for the Saint John River as waters under tidal influence rather than relative to the definition of tidal waters contained in regulations.

Attribute	Human Induced Threats	Effect of Threat	Effect Under Current Management Strategies			
			Populations Affected	**Level of Impact on Individuals**	**Location of Effect**	**Recovery Target**
Direct Mortality	Food, Social, and Ceremonial Fishery	Mortality as a result of handling or retention of Striped Bass by Aboriginals fishing under a Food, Social or Ceremonial fishery licence	Shubenacadie Saint John	High (the cumulative annual communal requirement is potentially high)	Tidal and non-tidal Shubenacadie River lying below Grand Lake. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIa DI, DII
Direct Mortality	Entrainment in flow-through turbines (Annapolis Tidal Power Generating Station)	Direct mortality or injury, cavitation	Shubenacadie Annapolis	Low for Shubenacadie High for Annapolis	Annapolis River Causeway at Annapolis Royal	AIIb DI, DII, DIII
Direct Mortality (and fish health)	Ecotourism and recreation	Disturbance of fish aggregations and introduction of petroleum products and byproducts through boat and recreational vessel use	Shubenacadie Saint John	Low	Spawning areas Stewiacke River (Shubenacadie) Undetermined (Saint John)	AIIb DI, DII
Direct Mortality (and fish health)	Ecotourism and recreation	Potential for direct injury to adult Striped Bass resulting from propeller strikes	Shubenacadie	Low	Spawning and staging sites for adults within the tidal Stewiacke River	AIIb
Direct Mortality (and fish health)	Scientific research	Handling related mortality, increased stress and disease transfer; obstruction of natural migrations and behaviour; introduction of petroleum products and byproducts	Shubenacadie Saint John	Medium for Shubenacadie Low for Saint John	Tidal and non-tidal Shubenacadie River below Grand Lake. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam	AIIb DI, DII
Direct Mortality	In-stream tidal power	Possible future installation of in-stream	Shubenacadie Saint John	Unknown	Minas Channel (FORCE test site)	AIIb DI, DII

Attribute	Human Induced Threats	Effect of Threat	Effect Under Current Management Strategies			
			Populations Affected	Level of Impact on Individuals	Location of Effect	Recovery Target
	generation stations [Potential]	turbines, which could represent a source of direct mortality				
Direct Mortality	Fisheries on prey species	Reduction of prey species populations through directed fisheries, leading to Striped Bass mortality as a result of lost prey stocks	Shubenacadie Saint John	Low	Tidal and non-tidal Shubenacadie River lying below Grand Lake. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIa DI, DII
Fish Health/Population Fitness	Striped Bass aquaculture	Releases from private Striped Bass aquaculture facilities result in introgression with wild individuals	Shubenacadie Saint John	Low	Tidal and non-tidal Shubenacadie River. All tidal waters of the Bay of Fundy. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.	AIIb DI, DII
Water Quantity, Water Quality, and Impacts on Habitat	Altered hydrology resulting from construction of barriers (Annapolis River Causeway, Mactaquac Dam)	Alterations of estuarial circulation and flow regimes; reduced access to habitat above partial or complete barriers, and alteration of spawning habitat below dam and above and below causeway due to changes in flow regime	Shubenacadie Saint John Annapolis	Low for Shubenacadie Uncertain for Saint John High for Annapolis	Annapolis River Causeway at Annapolis Royal Saint John River at Mactaquac Dam	AIIb DI, DII, DIII
Water Quantity, Water Quality, and Impacts on Habitat	Presence of in-stream barriers that impede migration and increase their susceptibility to harassment	Potential obstruction to migration of fish including foraging fish	Shubenacadie Saint John Annapolis	Low for Shubenacadie Uncertain for Saint John High for Annapolis	Annapolis River Causeway at Annapolis Royal Saint John River at Mactaquac Dam	AIIb DI, DII, DIII
Water Quantity	Presence of in-stream barriers	Increased authorized and unauthorized	Shubenacadie	Medium	Non-tidal portion of Shubenacadie River below	AIIa,b

Attribute	Human Induced Threats	Effect of Threat	Effect Under Current Management Strategies			
			Populations Affected	**Level of Impact on Individuals**	**Location of Effect**	**Recovery Target**
	that impede migration and increase their susceptibility to harassment	removals (mortality) resulting from greater susceptibility to exploitation; potential increase in physiological stress			Grand Lake	
Water Quantity	Presence of in-stream barriers that impede migration and increase their susceptibility to harassment	Potential increase in physiological stress	Shubenacadie	Uncertain	Non-tidal portion of Shubenacadie River below Grand Lake	AIIa,b
Water Quantity	Dyked lands that eliminate access to potential forage habitat along tidal river margins	Loss of potential forage for Age 0+ year	Shubenacadie	Low	Tidal portions of Shubenacadie and Stewiacke rivers	AIIb
Water Quality	Municipal and industrial wastewater	Degraded water quality (e.g., low pH, low DO, toxic chemicals) and degraded sediment quality (e.g., accumulation and redistribution of toxic chemicals), heat, direct wastewater input	Shubenacadie Saint John Annapolis	Low	Tidal and non-tidal Shubenacadie River Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam. Tidal and non-tidal Annapolis River above causeway	AIIb DI, DII, DIII
Water Quality	Agricultural run-off	Degradation of water quality (e.g., migration of nutrients, pesticides, animal waste) resulting in lowered DO, toxic substances, increase in plant growth.	Shubenacadie Saint John Annapolis	Low	Tidal and non-tidal Shubenacadie River. Tidal and non-tidal portions of the lower Saint John River system below Mactaquac Dam.Tidal and non-tidal Annapolis River above causeway	AIIb DI, DII, DIII

Attribute	Human Induced Threats	Effect of Threat	Effect Under Current Management Strategies			
			Populations Affected	**Level of Impact on Individuals**	**Location of Effect**	**Recovery Target**
Water Quality	Acid precipitation (especially during periods of snow melt)	Low pH precipitation leading to reduction of surface water-body pH levels, potentially affecting survival of Striped Bass.	Annapolis	Low	Tidal freshwater portions of the Annapolis River lying below the confluence of the Nictaux River	AIIb DI, DII, DIII
Water Quality	Development of underground bulk storage facilities (e.g., for natural Gas Storage) Project [Potential]	Release of brine into striped bass habitat during development of underground natural gas facilities [Potential]	Shubenacadie	Unknown	Tidal portions of Shubenacadie and Stewiacke rivers in their area of confluence.	AIIb DI
Impacts on Habitat	Aggregate Mining [Potential]	Dredging of mineral sands (e.g. titanium) in tidal waters would involve the removal of substrate that could result in the alteration of Striped Bass habitat. [Potential]	Shubenacadie Saint John	Unknown	Tidal Shubenacadie River and Cobequid Bay.	AIIb DI
Impacts on Habitat	Invasive Species (Chain Pickerel in Shubenacadie and Muskellunge in Saint John River)	Loss of forage base for Striped Bass as a result of increased competition for forage. Predation on young Striped Bass. Competition for habitat.	Shubenacadie (Chain Pickerel) Saint John (Muskellunge)	Low	Grand Lake, NS Saint John River	AIIb DI, DII
Impacts on Habitat	Ecosystem Change	Change in water temperatures results in altered key life-history functions (spawning, overwintering)	Shubenacadie Saint John Annapolis	Medium	Spawning sites within the tidal Stewiacke River (Shubenacadie), over-wintering areas in tidal portions of the Bay of Fundy (Shubenacadie, Saint John, Annapolis)	AIIb DI, DII

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