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Assessment of Status and Recovery Potential for Striped bass (*Morone saxatilis*) in the Southern Gulf of St. Lawrence

Évaluation de la situation et du potentiel de rétablissement du bar rayé (*Morone saxatilis*) dans le sud du golfe du Saint-Laurent

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ABSTRACT

The COSEWIC's recommended "Threatened" listing for striped bass in the southern Gulf required that DFO's Section 73 permitting framework be applied to determine if incidental harm would jeopardize survival or recovery of the species. Three primary indicators were explored to determine the status of striped bass in the southern Gulf. First, mark-recapture experiments conducted on striped bass returning to the Northwest Miramichi River to spawn indicated an average of 22,000 mature individuals each year since 2001. This represented a modest increase from a low of approximately 4,000 annually in the 1998-2000 period but not as high as the peak level of 50,000 spawners observed in the mid 90's. Secondly, analyses of the striped bass bycatch in the gaspereau fishery of the Northwest Miramichi River indicated an average of 84 bass per net per day over the last 5 years and closely correlated with estimates of population size derived from mark-recapture experiments. Lastly, spawning success measured from catches of young-of-the-year in the fall open-water smelt fishery (1991-1998) and beach seine surveys (2001-2005) were weakly correlated with spawner abundance estimates and suggests that year-class success can be determined by environmental factors. Secondary indicators of status such as the truncated and unchanged age and size distributions for spawning striped bass since the early 90's supported the high natural mortality estimate of 0.54-0.59 derived for this population after the commercial fishery closure in 1996. Tagging studies continue to define the whole of the southern Gulf as the area of occupancy for this population of striped bass.

A discrete life history model was used to propose reference levels for recovery of the southern Gulf population. The recovery objectives parallel the precautionary approach benchmarks of critical, cautious, and healthy zones. We propose an S_{opt} value of 21,600 spawners as the recovery limit for southern Gulf striped bass and the 50%SPR value of 31,200 spawners as the recovery target, the latter being the value for managing any directed fisheries. The S_{eq} value (spawners at replacement in the absence of fisheries) was estimated at 63,000 fish. We discuss the need to implement compliance rules and suggest that a 6 year sliding window may be appropriate with the objective of exceeding the recovery limit in 5 of 6 years. Under present conditions, including bycatch of YOY and continued illegal removals of adult bass, there is a low probability (18%) that the southern Gulf striped bass will be above the recovery limit by 2015. If the total mortality on adults is reduced to $Z = 0.6$ from the current condition of $Z = 0.8$ and YOY bycatch is eliminated, there is a greater than 95% chance that the population will be above the recovery limit by 2015.

The Northwest Miramichi River remains the only confirmed spawning location for striped bass in the southern Gulf. Because striped bass occupy all of southern Gulf but yet continue to show high fidelity to the Northwest Miramichi, the colonization or establishment of new spawning locations may not be a realistic recovery objective.

Quantitative estimates of mortality were not possible for each of the major threats believed to be limiting the rebuilding of this population. Illegal harvests are believed to be the single greatest cause of mortality for the population. Total accumulated mortality does not seem to jeopardize the survival, but under present conditions, recovery above the proposed limit is unlikely.

Mitigation measures are discussed. Recovery efforts for southern Gulf striped bass should focus on reducing adult mortality and YOY bycatch and protecting the striped bass habitat and spawning grounds of the Miramichi system.

RÉSUMÉ

La recommandation du COSEPAC d'inscrire le bar rayé du sud du Golfe sur la liste des espèces « menacées » exigeait l'application du cadre d'autorisation du MPO en vertu de l'article 73 afin de déterminer si la survie ou le rétablissement de l'espèce risque d'être compromis par une activité qui la toucherait de manière incidente. Trois indicateurs principaux ont été examinés afin d'établir la situation du bar rayé dans le sud du Golfe. Premièrement, des expériences de marquage et de recapture menées sur les bars rayés remontant la rivière Miramichi Nord-Ouest pour frayer ont donné une moyenne de 22 000 poissons matures, chaque année, depuis 2001. Ce total représente une modeste hausse par rapport au creux d'environ 4 000 par année pendant la période de 1998 à 2000, mais il n'est pas aussi élevé que le sommet de 50 000 géniteurs observé au milieu des années 1990. Deuxièmement, des analyses des prises accidentelles de bars rayés au cours de la pêche du gaspareau dans la rivière Miramichi Nord-Ouest ont indiqué une moyenne de 84 bars par filet par jour au cours des cinq dernières années; ces résultats ont été reliés à l'estimation de l'effectif de la population à partir des expériences de marquage et de recapture. Enfin, on a établi une faible corrélation entre le succès de la ponte, mesuré à l'aide des prises des jeunes de l'année au cours de la pêche de l'éperlan d'automne en eau libre (1991-1998) et des relevés à la senne de rivage (2001-2005), et l'estimation de l'abondance des géniteurs; ces résultats semblent montrer que le succès des classes d'âge peut être déterminé par des facteurs environnementaux. Les indicateurs secondaires de la situation, tels que la répartition tronquée et inchangée selon l'âge et la taille des bars en frai depuis le début des années 1990, appuient l'estimation élevée du taux de mortalité naturelle de 0,54 à 0,59 établie pour cette population après la fermeture de la pêche en 1996. Les études de marquage continuent de définir l'ensemble du sud du Golfe comme la zone occupée par cette population de bar rayé.

Un modèle discret du cycle biologique a été utilisé afin de proposer des niveaux de référence pour le rétablissement de la population du sud du Golfe. Les objectifs de rétablissement correspondent aux points de référence de l'approche de précaution pour les zones essentielles, prudentes et saines. Nous proposons une valeur S_{opt} de 21 600 géniteurs comme limite de rétablissement pour le bar rayé du sud du Golfe et une valeur de 31 200 géniteurs représentant 50 % des géniteurs par recrue comme cible de rétablissement, celle-ci étant la valeur utilisée pour la gestion de toute pèche dirigée. La valeur de S_{eq} (géniteurs de remplacement en l'absence d'exploitation) a été estimée à 63 000 poissons. Nous examinons la nécessité d'appliquer des règles de conformité et proposons une fenêtre mobile de 6 ans comme appropriée, l'objectif étant de dépasser la limite de rétablissement en 5 ou 6 ans. Dans les conditions actuelles, y compris les prises accidentelles de jeunes de l'année et le prélèvement illégal continu de bars adultes, il subsiste une faible probabilité (18 %) que le bar rayé du sud du Golfe dépasse la limite de rétablissement d'ici 2015. Si le taux de mortalité totale des adultes est réduit à Z = 0,6 par rapport à la situation actuelle de Z = 0,8 et que les prises accidentelles de jeunes de l'année sont éliminées, la probabilité que la population dépasse la limite de rétablissement d'ici 2015 serait de plus de 95 %.

La rivière Miramichi Nord-Ouest demeure la seule frayère confirmée du bar rayé dans le sud du Golfe. Puisque le bar rayé occupe tout le sud du Golfe, mais continue néanmoins d'afficher une grande fidélité à la Miramichi Nord-Ouest, la colonisation ou l'établissement de nouvelles frayères n'est peut-être pas un objectif de rétablissement réaliste.

Il n'a pas été possible de faire une estimation quantitative de la mortalité pour chacune des principales menaces au rétablissement de cette population. Les prises illégales constitueraient la plus grande limitation au rétablissement de cette population. La mortalité totale cumulative ne

semble pas menacer la survie de la population, mais, dans les conditions actuelles, le rétablissement au-delà de la limite proposée est peu probable.

Les mesures d'atténuation sont décrites. Les efforts de rétablissement du bar rayé du sud du Golfe devraient porter principalement sur la réduction de la mortalité des adultes et des prises accidentelles de jeunes de l'année et sur la protection de l'habitat du bar rayé et des frayères dans le réseau de la Miramichi.

RATIONALE

The 2002 review of striped bass (*Morone saxatilis*) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) resulted in the division of 3 “designatable units” (DU) with listings of extirpated for Quebec’s St. Lawrence population and threatened for those of the southern Gulf of St. Lawrence (southern Gulf) and the Bay of Fundy (COSEWIC 2004). If the Governor in Council accepts COSEWIC’s recommendations, striped bass will be listed on, and afforded protection under, Canada’s *Species at Risk Act* (SARA) by May/June 2007.

Section 73 of the SARA authorizes competent Ministers to permit otherwise prohibited activities affecting a listed wildlife species, any part of its critical habitat, or the residence of its individuals but only after certain preconditions have been met. DFO Science has developed the framework to evaluate these preconditions and determine whether or not incidental harm permits should be issued (DFO, 2004a). The results from the application of this framework to striped bass in the southern Gulf is presented in this document and forms part of the “Recovery Potential Assessment” (RPA) for the population.

The organization of this document reflects a series of questions that were posed in the remit for the striped bass RPA held in Moncton, between November 30 and December 2, 2005 (Appendix A). The series of questions were developed to address the requirements of the Section 73 permitting framework and were divided into 3 phases. Phase I covered an update of the species status and trends, an evaluation of recovery for the population and a general time frame to reach it. Major potential threats and possible mitigation measures were discussed in Phase II and III, respectively.

LIFE HISTORY

Mitochondrial and nuclear DNA analyses indicated that striped bass in the southern Gulf are distinct and isolated from neighbouring striped bass populations in the Bay of Fundy and the USA (Wirgin et al. 1993, Wirgin et al. 1995; Diaz et al. 1997; Robinson et al. 2004). Because the genetic make-up of Quebec’s St. Lawrence population was not determined prior to their extirpation (Beaulieu 1985), their relatedness to striped bass in the southern Gulf remains unknown.

Further evidence indicating the isolated nature of the southern Gulf population stems from conventional tagging studies initiated in the early 1980s. With the exception of one reported recapture from the Chesapeake Bay area (Hogans and Melvin 1984), no southern Gulf tagging study has produced a recaptured striped bass from outside of the region. Tags have been returned from as far north as Percé, Quebec (Bradford and Chaput 1996), and tags placed on striped bass in the Margaree River Cape Breton, have been recaptured on the spawning grounds of the Northwest (NW) Miramichi. None of the nearly 10,000 tags applied to southern Gulf bass have been returned from waters of the Bay of Fundy. Recent recaptures from locations in Gulf Nova Scotia are updated in the “Secondary Indicators of Status” section under “Area of Occupancy”.

Striped bass in the southern Gulf are anadromous and return annually to the NW Miramichi River to spawn. Despite recent attempts to locate additional spawning grounds (Robinson et al. 2001; AVC Inc. 2003), the NW Miramichi River remains the only location in the southern Gulf where striped bass eggs and larvae have been collected (Robichaud-LeBlanc et al. 1996). During an early study of striped bass in the southern Gulf, Hogans and Melvin (1984) report on a spawning population in the Kouchibouguac River situated in southeastern New Brunswick. Their conclusion of a spawning population was based on the observation of presumed spawning activity for 3 days during the second week in May but was not confirmed with the collection of eggs or larvae. Furthermore, 8 striped bass tagged during early May of the same study were recaptured only weeks later during the spawning run to the Miramichi system (Hogans and Melvin 1984). Finally, without evidence of eggs or larvae, Rulifson and Dadswell (1995) speculated on 4 southern Gulf rivers (besides the Miramichi) believed to sustain a spawning population of striped bass: Nepisiguit, Tabusintac, Kouchibouguac, and Richibucto.

Age to sexual maturation for southern Gulf bass is believed to occur at ages 4 to 5 for females and earlier for males at ages 3 to 4. Fecundity analyses of southern Gulf striped bass have been limited to a single study involving 8 females captured during the early spring of 1983 in the Kouchibouguac River (Hogans and Melvin 1984). From these data, a female striped bass with a fork length of 50 cm would produce about 96,000 eggs, similar to about 89,000 eggs that a Shubenacadie-Stewiacke bass of the same length would produce (Paramore 1998). The high fecundity of striped bass is critical to compensate for the high mortality incurred by the eggs after release. Spawning occurs in early June only weeks after ice out when river temperatures are nearing 15^{o}C (Scott and Scott 1988). A gradual increase in water temperature is believed to promote spawning and sudden drops in water temperature can have devastating effects on egg and larval survival (Rutherford and Houde 1995). Many researchers believe that striped bass recruitment is largely dependant on the conditions experienced by eggs and larvae during the first weeks after spawning (Rutherford and Houde 1995; McGovern and Olney 1996; Ulanowicz and Polgar 1980).

Spawning occurs near the head of tide and at the surface of the water. The spawning act is obvious and can vary from a gentle swirling motion of several fish, to an aggressive behaviour that splashes water high into the air. The eggs and milt are broadcast simultaneously by the females and males respectively, and fertilization occurs in the water column. The eggs are semibuoyant and need to remain in suspension until hatching is complete. Depending on water temperatures and conditions, eggs require 48 to 72 hours to hatch (Peterson et al. 1996; Scott and Scott 1988). Robichaud-LeBlanc et al. (1996) found the highest concentration of striped bass eggs and larvae directly upriver of the salt wedge in the NW Miramichi.

Young-of-the-year (YOY) striped bass remain in the mid-channel portion of the NW Miramichi until the end of June (Robichaud-LeBlanc et al. 1998). Larval yolk reserves get exhausted within 14 days post-hatch at which time exogenous feeding begins. By early July, underyearling bass have moved to nearshore habitats of the estuary where they will remain and grow rapidly during the summer, attaining lengths between 8 and 20 cm by October (this document). Young-of-the-year exhibit a downstream range extension throughout the summer, and by late July, can be captured along coasts both north and south of the Miramichi system (Robichaud-Leblanc et al. 1998; Douglas et al. 2003; Robinson et al. 2004). Underyearling bass of Miramichi origin are abundant in many estuaries of the southern Gulf by the end of their first growing season.

After summer feeding migrations, both YOY and adult striped bass either remain or return to estuaries in the fall to spend the winter. Striped bass of every age and size are known to overwinter in many southern Gulf estuaries. The winter season is considered stressful as these fish remain under the cover of ice and fast during that time. It appears that YOY striped bass in the southern Gulf which do not attain a fork length of 11cm during their first growing season have poor overwinter survival (Bernier 1996).

FISHERIES MANAGEMENT

Striped bass in the southern Gulf are managed as a single unit. The sale of striped bass bycatch from commercial fisheries was prohibited after 1996 and when the interim conservation requirement of 5,000 female striped bass was not achieved between 1997 and 2000, recreational and First Nation fisheries were suspended. Those regulations remain in effect.

1 – INDICATORS OF STATUS

Three primary and five secondary indicators of status were explored for southern Gulf striped bass. Deviations and updates from the last assessment (Douglas et al. 2003) are discussed.

PRIMARY INDICATORS OF STATUS

1. Spawner abundance – Mark and recapture estimates

The gaspereau (*Alosa aestivalis* and *Alosa pseudoharengus*) fishery of the Northwest Miramichi has been used to assess the spawning run of striped bass to that river since 1993. Detailed sampling protocols are available from previous assessments (Bradford et al. 1995; Bradford and Chaput 1998; Douglas et al. 2001) but can be briefly summarized by efforts to mark adult striped bass early in the year prior to spawning (mid May) and the subsequent monitoring of their bycatch throughout the remainder of the gaspereau fishery. Biological characteristics of the population including fork length (nearest mm), age, and sex were also collected annually during gaspereau trapnet monitoring.

Two indicators of stock status from this monitoring program include a spawner abundance estimate based on mark-recapture and another on catch per unit effort (CPUE). Start dates for mark-recapture experiments have been similar throughout the time series while end dates were chosen on the basis of a decline in overall striped bass catches, a decline in the number of recaptured striped bass, and an increase in the number of spent fish (Table 1.1).

Peak spawner abundance was estimated at 50,000 fish in 1995 but fishery harvests during that same year accounted for most of the decrease into 1996 (Bradford and Chaput 1997) (Fig. 1.1). The collapse between 1995 and 1996 and the low spawner abundance estimates during the 1998-2000 period prompted closures of the commercial, recreational, and Aboriginal fisheries. The complete closures of all fisheries have likely helped the population stabilize to an average of 22,000 fish in each of the last five years (2001-2005) (Table 1.2). Strongest contributions to the spawning run of striped bass in recent years have been from the 2001 year-class (Fig. 1.2). The contribution of the 2002 year-class in 2005, primarily as males, was weak and provides little hope for a strong showing of the female component of this year-class in 2006 and beyond (Fig. 1.2).

2. Spawner abundance – CPUE-commercial gaspereau fishery

An annual index of abundance was derived using a general linear model treating striped bass catch per 24 hours per trapnet as the response variable and year as the explanatory variable. The log link was used because a Poisson distribution was assumed for the response variable (Venables and Ditchmount 2004). The analysis was performed using PROC GENMOD in SAS and the variance of the estimates was generated using a Pearson chi-square correction for overdispersion (SAS 2005). This is an alternate treatment from that presented in Douglas et al. (2003) and is considered more appropriate for CPUE data (Maunder and Punt 2004).

Striped bass catches are highest in late May and early June and decline rapidly by mid June after spawning is complete (Fig. 1.3). There has been limited control on the timing of the collection of the fishery data relative to the striped bass spawning period in the NW Miramichi but it is assumed that the peak spawning period was encompassed in all years. We explored three groupings of the data: 1) data from the entire sampling period, 2) data constrained to end on the date used for the mark-recapture experiment, and 3) data constrained to the period encompassing the upper quartile of the catch rates (Table 1.1). The third option was considered because of the interest in estimating the maximum abundance of spawners and the difficulty in collecting abundance data for that time period only.

The abundance of bass in the gaspereau fishery of the NW Miramichi has important within season and annual variability (Table 1.3; Fig. 1.3). Regardless of the method used to group the data, peak abundance was estimated for the years 1994, 1995 and 2001 to 2003 and the lowest abundance in 1993 and the 1996 to 2000 time period (Fig. 1.4). The median annual catch rate (CPUE) was positively correlated with the spawner estimates derived from mark-recapture experiments (Fig. 1.5) with 1995 being an outlier year. When the 1995 data point is excluded, the correlation is greater than 0.8.

Sources of Uncertainty

Mark recapture estimates of spawner abundance for the period 2004-2005 are considered to be conservative. It is believed that many striped bass had moved through the fishing area and were on the spawning grounds before a large number of tags could be applied. Fewer striped bass were recaptured in 2004 and 2005 than in previous years which resulted in wider confidence intervals than the previous 3 years (Table 1.2).

Striped bass of all sizes were harvested in the gaspereau fisheries of the Miramichi system between 1993 and 1995 (Table 3 in Bradford and Chaput 1998). Neither the mark and recapture estimate nor the abundance index estimate has been corrected for removals from the fishing area in those years.

Estimates of spawner abundance only reflect the number of adult striped bass returning to the NW Miramichi to spawn and do not represent the entire biomass of the population. Not all adult striped bass return to the NW Miramichi to spawn on a yearly basis. Adult striped bass have been sampled in the Hillsborough River PEI (AVC Inc. 2003) and the Kouchibouguac River (Hogans and Melvin 1984) during May and June and fishery officers report striped bass in spring gaspereau fisheries of Kent Co., the Tracadie, Pokemouche, and Margaree rivers, Pictou harbour, and Wallace Bay, NS (Chiasson et al. 2002). Results from an acoustic tracking survey in 2003-2005 indicated that 6 of 26 striped bass that overwintered in the Miramichi system left soon after ice out and did not return to spawn later in the season (this document) (Table 1.4).

3. Young-of-the-year abundance as index of spawning success

Indices of YOY in the fall and in the summer have been obtained over different time periods in the Miramichi. An abundance index of YOY in the fall was obtained from sampling the bycatch of the commercial open-water rainbow smelt (*Osmerus mordax*) fishery of the Miramichi estuary during 1991 to 1998. A summer beach seine index has been adopted since 2001.

Fall YOY Index

Details of the sampling procedure for the fall smelt fishery were described in Bradford et al. (1997b). Sampling in 1991 commenced later and was less intense than subsequent years. Sampling ceased after 1998 following a change in management which delayed the opening of the smelt fishery in the Miramichi to November 1, a measure which was considered by the fishermen to have been a direct consequence of the science related activities to monitor bycatch. An annual index of abundance was derived using a general linear model treating the catch per 24 hour per net as the response variable and year as the explanatory variable. The log link was used because a Poisson distribution was assumed for the response variable (Venables and Ditchmount 2004). The analysis was performed using PROC GENMOD in SAS and the variance of the estimates was generated using a Pearson chi-square correction for overdispersion (SAS 2005).

Catches of YOY in the smelt fishery declined through the season in some years but showed important annual variability (Fig. 1.6). Peak abundance was estimated for the years 1995 and 1996 with the lowest abundances in 1993, 1997 and 1998 (Fig. 1.6). The mean annual catch rate (CPUE) is positively correlated ($R = 0.66$) to the female spawner estimates derived from mark and recapture and less so for the total spawner abundance (Fig. 1.7). When female spawner abundance was at or above 5,000 fish, there was a high YOY index in the fall smelt fishery, as previously indicated by Bradford and Chaput (1997). This observation supports the premise that spawner abundance is an important component of recruitment to the fall YOY stage of striped bass.

Summer Beach Seining Index

Beach seining at index sites of the Miramichi began late in the 2000 season and only complete surveys between 2001 and 2005 were used in the analysis. The same five or six beaches were seined on a weekly basis during the months of July and August in all 5 years. Sites covered the Miramichi estuary from nearly complete freshwater of the upper estuary to sites with salinities around 20 ppt of the lower estuary at Loggieville where the river widens into Miramichi Bay. The seine was fabricated of 6.4mm mesh, measured 30m long x 1.8m deep, and was equipped with a cone shaped bag in the centre that measured 1.8x1.8x1.8m. Single sweeps were made at each site during day light hours and high tide was often targeted. When conditions permitted, half of the seine was pulled into the water perpendicular to shore then swept in an arc formation back to shore.

Catch per unit effort analyses were restricted to the July surveys only because 1) YOY are readily captured in nearshore habitats of the Miramichi by this time, 2) most YOY have not yet extended their distribution outside of the Miramichi system, and 3) catches of YOY by beach seine in the Miramichi substantially decrease by August.

Mean CPUE estimates were highly variable between years ranging from a high of 139 YOY per sweep to a low of 4 YOY per sweep in 2003 and 2004, respectively. Captures of YOY striped bass in 2004 were so few that plans to collect 2,000 individuals for the St. Lawrence estuary (Quebec) restocking initiative were cancelled, while collections were completed in 2002, 2003 and 2005. Further evidence of a very low abundance of YOY (year-class failure) in 2004 were provided from the DFO sponsored Community Aquatic Monitoring Program (CAMP) which reported the capture of only one YOY outside of the Miramichi system during region wide beach seine surveys (J. Weldon DFO pers. comm.).

Several more years of beach seine data will be required to determine the correlation between YOY and spawners but the limited data set indicates that environmental factors may play an important role in year-class success. Good numbers of female spawners in 2002 and 2004 produced the lowest YOY CPUE estimates of the time series (Fig. 1.8). Furthermore, the poor YOY index in 2002 appears to have manifested itself with the poor recruitment of 3 year old fish in 2005 (Fig. 1.2). These data would agree with several US studies that have demonstrated that recruitment is largely determined in the first few days after spawning as a result of variable environmental conditions affecting survival (Richards and Rago 1999).

SECONDARY INDICATORS OF STATUS

1. Size structure

Fork lengths of adult striped bass sampled on the spawning grounds of the NW Miramichi have not changed during the 1993-2005 monitoring period (Table 1.5). Striped bass with fork lengths of 40-50 cm are most abundant in Miramichi samples and similar to fork lengths reported by Chaput and Robichaud (1995) from samples collected at Millbank (Miramichi) between 1975-1982, and from samples collected in the Kouchibouguac River during the early 80's (Hogans and Melvin 1984). Occasionally striped bass with fork lengths between 65 and 75 cm are sampled and only rarely from fish > 75 cm. Complete fishery closures in the 1996-2000 period have not produced an increased length or age distribution.

2. Sex ratio

Male striped bass have nearly always outnumbered female striped bass on the spawning grounds of the NW Miramichi (Table 1.2). This phenomenon can be partly explained by the earlier maturation schedule of males at age 3 versus females at age 4. Furthermore, striped bass that are not ripe enough to expel either milt or eggs at the time of sampling are considered to be female. The proportion of males declines with age and males are rare beyond age 6 years (Table 1.6).

3. Age structure

The age structure of striped bass sampled during their spawning migration to the NW Miramichi between 1994 and 2005 is predominantly comprised of 3 to 5 year old bass (Table 1.7). The closure of fisheries between 1996-2000 has had little effect on the age distribution of this population of striped bass. Striped bass greater than age 6 are rare and those over age 10 are negligible.

4. Mortality estimates

<u>Adult (age 3 and older) mortality</u>

Scales collected from adult striped bass during their spawning migration between 1994 and 2005 were interpreted for ages. Field sampling during the week prior to the main run of gaspereau was considered to be the most representative of the age and length composition because fishermen were often contracted to provide access to striped bass with the agreement that complete catches could be sampled. For years 1998-2005, only ages interpreted from scales taken during the initial sampling events were used to determine proportion at age. For 1994 to 1997, proportion at age was determined using age-length keys from data taken throughout the sampling season applied to the lengths taken during the initial sampling events.

The numbers of spawners at age were calculated using the proportion at age and the spawner abundance as estimated either by mark-recapture or CPUE analysis (see Primary Indicators of Status above). The instantaneous mortality rate (Z) was calculated from the standard equation described by Ricker (1975):

$$Z = -Ln\left(\frac{N_{t,i}}{N_{t-1,i-1}}\right)$$

where $N_{i,t}$ = abundance of spawners at age i in year t

Annual survival (range 0 to 1) is calculated as e^{-Z} and annual mortality is $1 - S$.

Although the commercial fishery has been closed since 1996, mortality estimates after that date contain an important but undetermined amount of fishing mortality (F). Illegal harvests of striped bass are believed to be substantial throughout the southern Gulf (see Phase II below). Because there are no legal directed fisheries on striped bass adults, we consider the mortality estimates presented here as equivalent to natural mortality and indicative of the underlying conditions of recent years.

Numbers at age derived from spawner abundance estimated either by mark-recapture or CPUE produced similar mortality rate estimates (Table 1.8). Positive values of Z ranged from a low of 0.07 to a high of 3.41, corresponding to annual rates of 7% to 97% (Table 1.8). Negative estimates of Z were frequent at age 3 and were not unexpected given the presumed maturity schedules for male and female bass at ages 3 to 5. There was a consistent bias in the spawner abundance estimates of 2000-2001 and 2004-2005 as evidenced by the negative Z values along the diagonals of the age by year-class matrix (Table 1.8). This bias is the result of either an underestimate of spawners for 2000 and 2004, an overestimate in 2001 and 2005, or both. Alternatively, proportionally more fish at age may have recruited to the spawning grounds in 2001 and 2005 relative to the previous years. Similar bias was noted for the CPUE series (Table 1.8).

Based on the average abundance at ages 3 to 7 years over the period 1997 to 2005, the mortality of adult striped bass is in the order of 0.5 to 0.6 (Z = 0.8 to 0.9; Fig. 1.9). Mortality estimates of recent years were as high as those during the period 1994-1996 when striped bass were commercially exploited (Fig. 1.10). Recruitment of strong year-classes is obvious at age 3 and often increases the following year when the age 4 female component returns to spawn for the first time. By age 5, year-class abundance is diminishing rapidly and nearly nonexistent after age 7. The high mortality estimates are consistent with the observed truncated age and length distributions of spawners in the NW Miramichi.

Natural mortality factors

The southern Gulf of St. Lawrence striped bass is the most northern spawning population in North America (Douglas et al. 2003). Environmental conditions of the southern Gulf are characterized as relatively warm in the summer with cold winters defined by extensive ice cover inshore and offshore and complete ice cover in rivers and estuaries for upwards of four months (December to March). These conditions pose particular challenges to striped bass populations in Canada that are not experienced by populations along the eastern seaboard of the United States. Adult and juvenile bass overwinter in the upper portions of estuaries where feeding is believed to cease when temperatures fall below 10^{o}C in October-November (Robichaud-LeBlanc et al. 1997). The overwinter survival depends upon obtaining sufficient energy reserves before the period of fasting and upon suitable temperature/salinity conditions for osmoregulation (Hurst and Conover 1998). Both juvenile and adult bass are subjected to overwinter mortality. YOY striped bass (13.2 - 15.1cm) were retrieved from frozen-over holes drilled in the ice during a winter tracking study in late winter 2004; the cause of their death or an explanation of the circumstances that lead to their entrapment in an 8 inch auger hole is unknown. Kills of striped bass associated with the loss of a thermal refuge in the cooling tail race of a generating station in Trenton (Nova Scotia) during the winter of 2004 provide evidence of the susceptibility of all size groups of bass to sudden changes in conditions and exposure to lethal temperatures in the winter. Adult bass mortalities have been reported from some southern Gulf estuaries shortly after ice-out in the spring.

The overwintering period may represent a specific constraint on survival of striped bass. The causes of overwinter mortality could include starvation, size-dependent predation, or physiological intolerance to reduced temperatures (Sogard 1997). It has been suggested that the survival of young-of-the-year striped bass in the first winter may be conditioned by the size attained at the end of the first growing season (Chaput and Robichaud 1995), as was observed in white and yellow perch (Johnson and Evans 1991). Preliminary work provided evidence in support of size-based overwinter survival in striped bass of the Miramichi River (Bernier 1996), with few bass less than 10 cm fork length at the end of the first year of growth (quantified by back-calculation from scales) estimated to have been present in the survivors sampled at two years of age. Chaput and Robichaud (1995) presented back-calculated size at age for male and female striped bass in which few fish were estimated to have been less than 10 cm fork length at the end of their first year. Environmental conditions which would therefore affect size of YOY into the first winter are of interest.

Winter conditions

High discharge events during the winter period (December to March) have presumably displaced juvenile bass downstream to locations in Miramichi Bay which they would normally not inhabit during those months (Hanson and Courtenay 1995). This displacement may expose bass to sub-zero temperatures and osmoregulatory stressful conditions. Mean winter air temperatures (Nov. to March) in the Miramichi area ranged between -8 to -4ºC during 1961 to 2003 (Fig. 1.11; Appendix B). The warmest period of the time series was observed in 2001/02 resulting from a succession of four winters of warmer conditions commencing in 1997/98 (Fig. 1.11). Mid-winter (Jan. to March) daily peak flows in the Miramichi are generally less than 100 $m^3 s^{-1}$ with very high flow events (>= 400 $m^3 s^{-1}$) recorded in 7 of 42 winters between 1962 and 2003, four of these were recorded between 1996 and 2000, corresponding to the warmer recent period (Fig. 1.11). The potential to displace bass into cold and stressful osmoregulatory conditions was particularly acute in the recent decade.

There is a significant negative correlation between mean winter air temperature and the number of days of ice cover in the Miramichi River; an increase in mean air temperature of 1ºC reduces the duration of ice cover by about one week (Fig. 1.12; Appendix B). There is large annual variability in the duration of ice cover, ranging from a low of 102 days in 1999/2000 to a high of over 170 days during 1972/1973 (Fig. 1.12). Duration of ice cover was somewhat higher in the 1960s and 1970s than in the recent decade. Years of shorter ice duration may not necessarily be positive for striped bass survival as increases in water temperatures may result in a more rapid depletion of energy reserves. A number of studies have shown that size-dependent survival may be expressed during intermediate winter conditions rather than during mild or extremely severe winters (Sogard 1997 and references within). The association between overwintering conditions and survival of southern Gulf striped bass is unknown.

Preliminary studies on size dependent overwinter survival of striped bass from the southern Gulf suggest that few YOY striped bass less than 10 cm fork length survive their first winter (Bernier 1996). An analysis of the length distributions of YOY bass in the fall compared with back-calculated lengths of the survivors at age 2 years of the same cohort show a shift in size distribution pre and post winter in two of the three years with no observed shift in the size distributions of the 1991 cohort which was large bodied (Fig. 1.13). Assuming that only size-dependent mortality was occurring in the first winter, the relative losses of the cohorts ranged from 0% for 1991, to over 80% in 1992 and 1993. Based on the observed length frequency distributions of YOY bass between 1991 and 1998, the additional size-dependent mortalities over the first winter would have been most important for the 1992, 1993, and 1996 cohorts and least important for the large-bodied 1991, 1995, 1998, and 1999 cohorts (Fig. 1.14).

Summer conditions

The size of YOY striped bass at the end of the growing season is largely determined by the conditions favourable to growth. Growth is strongly correlated to water temperature (Dey 1981; Secor et al. 2000). An index of growth potential for striped bass YOY was developed using the air temperature time series from Chatham (Miramichi). Indices based on mean summer temperature and degree days (June to September) are strongly correlated (Fig. 1.15). The mean summer temperature for the period 1960 to 2003 was 17.0ºC, within a range of 14.9ºC in 1986 to a high of 18.7ºC in 1999. The modal length of juvenile bass in the fall of 1991 to 1999 is positively correlated to the mean air temperature and degree day indices with the large bodied 1999 cohort associated with the maximum mean temperature and degree days indices of the time series (Fig. 1.15). Faster growth and larger body size are expected to be positive for survival of bass during their first year.

Early life stage survival

The high fecundity, early age at maturity and iteroparity features of striped bass are adaptive traits indicative of high early life stage mortality. Year-class variability in striped bass has been observed to be high and largely determined during the egg and larval stages and influenced by environmental factors (see references within Richards and Rago 1999). Instantaneous daily rates of mortality ($M\ d^{-1}$) between the egg and the 8mm larval stage have been estimated to vary between 0.11 and 0.34 with survival after 20 days varying between 0.03% and 11% (Rutherford et al. 1997). Rutherford and Houde (1995) indicated that spawning success of striped bass in eastern U.S. was largely dependent on water temperatures. They reported that a storm which lowered river temperatures below 12ºC caused complete mortality of eggs and larvae and eliminated more than 50% of the season's production. Larval growth was positively correlated to water temperatures. There is minimal information with which to examine early life stage survival variability in the Miramichi River. A cooling event in late May 2004 on the spawning grounds is suspected of having contributed to high mortality of eggs and early larvae and subsequently a low index value of YOY abundance in the summer beach seine survey (Fig. 1.8).

Parasites disease

Philometra rubra is a common nematode occurring in striped bass in the southern Gulf (Hogans 1984). It is possible that striped bass weakened or compromised by infection of *P. rubra* can succumb when subjected to other stresses such as secondary bacterial or viral infection, unusually cold water or pollution (J. Melendy DFO parasitologist pers. comm.).

Three dead YOY and two adult striped bass were collected before or just after ice out from the Miramichi estuary. DFO's fish health unit positively identified the North American strain of the viral hemorrhagic septicaemia virus (VHSV) and nodavirus in all five fish. VHSV could not be confirmed as the cause of death for these fish.

Lymphocystis is a common chronic and usually non-fatal infection caused by an iridovirus that results in uniquely hypertrophied cells of the skin and fins. The condition is much like that of warts in that the lesions are macroscopic, occur mostly in the periphery of the vascular system and have a cauliflower appearance. Transmission of the disease is facilitated by increased fish density, trauma during spawning, netting or tagging practices, pollution, or disruption of the protective mucous layer by external parasites. Striped bass infected with lymphocystis are common in the southern Gulf and infection rates of 1% to 8% have been noted in May on the spawning grounds of the NW Miramichi between 2001 and 2005.

5. Area of occupancy (Fig. 1.16)
Douglas et al. (2003) presented tagging information that indicated striped bass utilized the entire southern Gulf. Tagging studies of southern Gulf striped bass have shown no mixing with the Bay of Fundy populations and a distribution of recaptured fish between Percé, Quebec and the Margaree River in Cape Breton (Fig. 1.16). More recently, 3 of 57 striped bass tagged in Wallace Bay, NS in the fall 2001 were recaptured on the spawning grounds of the NW Miramichi in June 2003 (n=2) and June 2004 (n=1). Additionally, 1 of 29 bass tagged in East River, Pictou Co. NS during the autumn of 2002 and 2003 was recaptured in each of the 2003 and 2004 spawning runs to the NW Miramichi.

Recent surveys in the Kouchibouguac and Richibucto rivers (Robinson et al. 2001), the Tabusintac River (DFO unpublished) and the Hillsborough River in PEI (AVC Inc. 2003) have failed to find evidence of striped bass eggs and larvae. The only confirmed spawning location for striped bass in the southern Gulf remains the NW Miramichi.

Recent studies tracking the movements of spawners in the Miramichi provide further evidence of the discrete spawning site in the southern Gulf. Eight striped bass implanted with acoustic pingers monitored on the spawning grounds of the NW Miramichi between May 29 and June 21 were subsequently detected off the coast of Val Comeau (north of the Miramichi) between June 18 and July 3, 2004. The northward post-spawning migration from the Miramichi corroborates all of the information (published and anecdotal) on the presence of striped bass in northern areas in early summer but discounts the notion of spawning at any of those locations (Rulifson and Dadswell, 1995). One of the eight striped bass detected at Val Comeau was detected approximately one month later in Bay of Chaleur on July 15 during a simultaneous Atlantic salmon (*Salmo salar*) smolt tracking study (P. Brooking ASF pers. comm.).

YOY continue to move out of the Miramichi system only weeks after spawning and occupy much of the southern Gulf by the end of their first growing season. In 2003, YOY striped bass were captured by beach seine in the surf off Miscou Island and at the mouth of the Little Buctouche River by mid August in northern and southern New Brunswick, respectively (Fig. 1.16).

RECOVERY

ISSUE
The striped bass population in the southern Gulf met COSEWIC's criteria (Appendix C) for Endangered B2ac(iv), but was designated as threatened, B2ac(iv); D2, and "because of the high degree of resilience evident in recent spawner abundance estimates" (COSEWIC 2004). COSEWIC's threatened designation was largely attributed to the single spawning location for striped bass in the southern Gulf which is well below the "Threatened" criteria of <10 and the "Endangered" criteria of < 5 (Appendix C). Additionally, the large number of striped bass confined to the Miramichi system each spring, increases their susceptibility to "the effects of human activities or stochastic events and becoming highly endangered in a very short period of time" (COSEWIC 2004). Fluctuations in the number of mature individuals (Criterion B2c(iv)) also factored into their assessment.

SMALL DISTRIBUTION
There is presently no information that would indicate that there is, or was, more than one spawning location for striped bass in the southern Gulf. Hogans and Melvin (1984) and Rulifson and Dadswell (1995) speculate on other spawning populations in the southern Gulf based on

the presence of adults and juveniles in various estuaries other than the Miramichi. The presence of adult or YOY striped bass alone in southern Gulf estuaries is insufficient evidence for multiple spawning areas. Recent studies have shown that underyearling bass extend their distribution out of the Miramichi River and into neighbouring estuaries soon after hatching (Robinson et al. 2004; Douglas et al. 2003) and adult striped bass tagged throughout the southern Gulf have been recaptured on the spawning grounds of the NW Miramichi (this document). Adult striped bass are found throughout the year in many southern Gulf estuaries but no spawning has been documented outside of the NW Miramichi. Directed monitoring for striped bass eggs and larvae has been limited (Douglas et al. 2003).

Striped bass have colonized new areas, either naturally (since the last ice age) or through human intervention (Scofield 1931). Striped bass continue to demonstrate high fidelity to the NW Miramichi despite their presence in, and potential colonization of many estuaries of the southern Gulf. The establishment of several new spawning locations in the southern Gulf is not likely a realistic recovery objective for this population of striped bass. An experiment is presently taking place to re-introduce striped bass into the St. Lawrence River. Should the experiment be successful, it will provide evidence that where habitat is appropriate, striped bass from the southern Gulf have retained the capacity to establish self-sustaining populations. Since the stock for the re-introduction program is from the Miramichi, this would provide a second spawning location for the southern Gulf striped bass unit.

The single spawning location for southern Gulf bass will always meet COSEWIC's "Endangered" criteria for Small Distribution (Appendix C). COSEWIC assessed the shortnose sturgeon (*Acipenser brevirostrum*) with its similar limited distribution and single spawning location in the Saint John River, New Brunswick (COSEWIC 2005). The COSEWIC criteria for small distribution were not strictly adhered to for the shortnose sturgeon and the species' was designated as one of "Special concern" (COSEWIC 2005).

FLUCTUATION IN MATURE INDIVIDUALS

Large fluctuations in abundance of striped bass on the spawning grounds in the southern Gulf during 1993 to 2005 are, in part, associated with the removal of over 30,000 animals during the 1995 and 1996 fishing seasons. Year-class variability has been observed to be high in this species, determined largely within the first few weeks during the egg and larval stages and influenced by environmental factors (see references within Richards and Rago 1999). It has been acknowledged that recovery of juvenile production is not guaranteed by increased spawning stock, but in the Chesapeake Bay experiment, increases in spawning biomass resulted in improvements in recruitment. The high levels of spawners were considered to have been a major factor in the establishment of above average year classes in two of the eight years (Richards and Rago 1999).

RECOVERY DEFINITION

A national workshop was recently held to consider the issue of what comprises "recovery" for aquatic species (DFO 2005). The intent of the workshop was to develop guidelines to help science advisors in the provision of consistent interpretations of recovery in the development of recovery plans. The SARA does not define recovery but expert groups must reach a consensus on the biological characteristics which would constitute recovery of the species or populations. The workshop participants concluded that the "precautionary framework" consisting of three zones (healthy, cautious, critical) appears suitable as a starting framework for incorporating recovery definitions. The discussions of the workshop centered around where the recovery definition would be placed relative to the precautionary framework zones as well as the biological attributes which might be used to characterize recovery. There was a strong consensus from the workshop that recovery would be well above the level which would ensure that COSEWIC considers the population neither Threatened nor Endangered. The qualitative conclusion from the workshop appears to have been that recovery plans which aim to increase abundance, for example, to the cautious-healthy boundary in the precautionary framework would most likely be acceptable as a definition of recovery by species assessment committees such as that of the COSEWIC (DFO 2005).

The attributes used to define recovery and assess status relative to the recovery objective should be defined in terms of quantities which can be monitored. The workshop considered that direct measures of abundance and total range occupied would be the preferred currencies for specifying recovery objectives because these correspond to COSEWIC assessment criteria and to reference objectives used in fisheries management. Supplementary attributes could include fragmentation or recovery of habitat, age and size composition, and genetic diversity.

Defining when a species or population is recovered also requires a compliance rule, i.e. how consistently the attribute(s) remains in the recovered state. Requiring that the attribute(s) always be above the recovery level before the species or population can be considered "recovered" is synonymous with treating the reference level as a limit. The compliance rate in these situations has to be very high, i.e. a very low probability (<5%) of the attribute falling below the limit. On the other hand, if it is acceptable that the attribute be sometimes above or sometimes below the reference level without a trend, then that is a candidate for a target, i.e. an objective to aim for with a probability of attainment of about 50%. It could be argued that recovery as a limit may be the point where a population or species is assessed as being above threatened or endangered whereas recovery as a target would be when the status is assessed to be above "special concern". A desirable feature of the recovery objective and its compliance rule is that the species status assessment be robust to uncertainty in assessments and dynamics and have sufficient inertia to preclude rapid and frequent changes in status.

In the eastern United States, recruitment overfishing was implicated as a factor in the decline of striped bass and an intensive fisheries management plan was put in place to restore the populations (Richards and Rago 1999). Projection models indicated that a fishing mortality (F) target of F= 0.25 was required for stock rebuilding and measures were introduced to reduce the fishing rates (Richards and Rago 1999). The plan had the defined objective of protecting 95% of the females of the 1982 and subsequent year classes until 95% had an opportunity to spawn at least once. A recovery attribute was defined based on an index of juvenile recruitment. The populations of striped bass were to be considered recovered (end point decision rule) when the juvenile index, calculated as the three-year running average, exceeded the approximate long-term average (1954 to 1984) of 8.0 fish per unit of effort (Richards and Rago 1999). The definition of a clear decision rule was critical in the implementation of the management plan but the decision rule had some shortcomings. It was realized later that the populations could be considered recovered after a single annual index of 24 was measured even if the two preceding indices were zero (Richards and Rago 1999). As well, there was no accounting of the precision of the index itself. An example of an alternative decision rule could have been a recovery value of the annual index other than the mean (for example, the median or a lower percentile) and a decision rule, for example, that would have required that the annual index be above a value for three consecutive years (Fig. 2.1). This would have been a more cautious rule to ensure that recovery status was not based on the presence of a single strong year class.

RECOVERY OBJECTIVES FOR SOUTHERN GULF STRIPED BASS

The potential and time frame for recovery were examined using a discrete life history model (Appendix D). Mortality, fecundity, and stock and recruitment dynamics were modeled using general life history information of the species and observed or assumed values specific to the southern Gulf striped bass. The choice of parameter values in the model were governed by observations on characteristics of the population and balancing of life stage abundances. The characteristics of the southern Gulf population of particular interest included:

- prior information on abundance of adult bass and spawners,
- relative age structure of the spawners, and
- sex ratio of spawners.

Specific assumptions and functional relationships are described in Appendix D.

Perceptions of historical abundance

The maximum recorded annual landing of southern Gulf striped bass was 61.4 metric tons in 1917 with the maximum in the most recent 30 years (1968 to 1996) of 47.1 metric tons (LeBlanc and Chaput 1991; Douglas et al. 2003). Landings were recorded from a large number of statistical districts and seasons. The annual mean weight of adult striped bass on the spawning grounds between 1994 and 2005 has varied from a low of 1 kg in 1994 to a high of 1.9 kg in 1996. This range of average weights was combined with a range of exploitation rates between 0.3 to 0.5 to estimate historical abundances of adult bass in the southern Gulf. High exploitation rates have been documented previously for southern Gulf bass when removals between May 1995 and May 1996 were in excess of half of the 1995 spawning stock (Bradford and Chaput 1997).

Using the historical maximum landing of 61.4 t, the abundance of adult-sized (3 year and older) striped bass in the southern Gulf was between 65,000 and 200,000 fish. The maximum recorded harvest of the last three decades would suggest a range of 50,000 to 160,000 fish. Estimates of the total abundance of bass age 3 years and older are not available for the southern Gulf because only the abundance on the spawning grounds in the NW Miramichi is estimated and only a portion of the striped bass aged 3 years and older are considered to be on the spawning grounds.

Estimates of the spawning stock

Estimates of the abundance of spawners in the Northwest Miramichi are available for the period 1993 to 2005. A peak abundance of over 50,000 bass was estimated in 1995 with a low of 3,400 fish in 1998 (Table 1.2).

Relative age distribution of spawners

During 1994 to 2005, the most abundant age groups on the spawning grounds have been age 3 and 4 year olds with 99% of the fish aged 3 to 7 years (Table 1.7). The oldest fish sampled was interpreted at 13 years old. This constricted age distribution for spawners is indicative of a high mortality rate. For this stock, the average instantaneous mortality of bass age 3 and older over all the years sampled is estimated at about 0.8 annually (Fig. 1.9). A rate of $M = 0.6$ applied to a stable age distribution starting at age 3 results in less than 2% of the population alive at age 11.

Sex ratios on the spawning ground

Sampling on the spawning grounds has consistently shown a disproportionate number of males relative to females (Table 1.6). Confirmed male bass (by extrusion of milt) have represented between 37% and 94 % of sampled fish. Confirmed female bass (as determined by extrusion of eggs or residual fluids) were generally low with the highest proportion (8 to 11%) of all samples in 2004 and 2005. The bias toward males on the spawning grounds is consistent with earlier maturation schedule for males and partial recruitment of females at all ages. Differential mortality among males and females may also produce this biased sex ratio but this dynamic was not explored in the discrete model.

Recovery objectives

We ran the life history model without stochasticity (Fig. 2.2) over a range of egg depositions to derive four spawning stock reference levels: spawners at equilibrium in the absence of fisheries (Seq), the spawning stock which produced the maximum gain (Sopt), spawning stock at a fishing rate which resulted in 50% and 30% spawning per recruit (50%SPR, 30%SPR). The mortality rate and life history parameters were assumed as:

S_0 = 0.001 and YOY_{cap} = 1.5 (million)
M = 1.5 for the six months of overwintering for YOY
M = 1 for age 1 bass
M = 0.6 for age 2 and older bass
Maturation schedule as in Appendix D
Fecundity as in Appendix D based on mean length, mean weight at age

The 30%SPR and Sopt have been defined as limit reference points (Mace 1994; Potter 2001). The 50%SPR level has been proposed as a precautionary reference point (Mace 1994). We propose Sopt as the recovery limit for the southern Gulf striped bass and spawners for 50%SPR as the recovery objective for directed fisheries. Under the equilibrium conditions, the loss in lifetime eggs due to fishing YOY in the fall occurs at an F value five times greater than the F value for fishing bass age one year and older (Figure 2.3).

Since the parameters for the Beverton-Holt compensatory function are not known, we ran the simulations under lower and higher average YOY production (1, 1.5, 2 million YOY capacity) and for lower and higher density independent survival (0.0005, 0.001, 0.002). Based on the prior expectation of adult abundance being in the range of 100,000 bass, the YOY production capacity of 1.5 million and the density independent survival rate of 0.1% were retained as suitable values for deriving the reference levels (Table 2.1). The S_{eq} value (spawners at replacement in terms of lifetime egg production) was estimated at 63,000 fish. The proportion female is 0.34.

We propose the S_{opt} value of 21,600 spawners as the recovery limit for the southern Gulf striped bass and the 50%SPR value of 31,200 spawners as the recovery target, the latter being the value for managing any directed fisheries (Table 2.2). We see no reason for using 30%SPR as the recovery limit because it involves higher fishing rates, lower abundance of both spawners and adult bass, and lower yield than S_{opt}.

COMPLIANCE RULES

The definition of a compliance rule was based on observed age structure on the spawning grounds and responsiveness to changes in status. In the context of a limit reference level, the compliance rule should respond rapidly but not necessarily to abundance falling below the limit. The rule would allow for rapid identification when the status falls below the limit but a slower response concluding that the resource is above the limit (see example in Fig. 2.1). A target reference level can be more responsive since it is an objective to aim for rather than a point to avoid (limit).

Based on the observed age structure on the spawning grounds (99% of spawners between 3 and 7 years), we suggest a six year sliding window to assess status. For the southern Gulf striped bass, we suggest that the reasonable compliance rule for the limit reference point be that the stock attribute is above the level in at least 5 of 6 consecutive years. The compliance rule for the recovery target is when the stock is above the target objective in at least 3 of 6 consecutive years. The status can be summarized using traffic lights (Caddy 2002) with the overall status of the resource determined first by its status relative to the limit reference point and secondly by the status relative to the target reference point conditional on the limit status.

Traffic light	Status	Compliance rule
Red	Below the recovery limit	Attribute < limit reference in > 1 of 6 years
Yellow	Above limit, below target	Attribute > limit reference in >= 5 of 6 years
		AND
		Attribute < target reference in > 3 of 6 years
Green	Above target	Attribute > limit reference in >= 5 of 6 years
		AND
		Attribute > target reference in > 2 of 6 years

The limit reference defines the border between the red and yellow traffic light zones. Red is assigned a value of 0, yellow a value of 1. The target reference level defines the border between the yellow and green zones with yellow a value of 1 and green a value of 2. The overall status is the product of the limit and target colour values with the red zone a product of 0, the yellow zone a product of 1, and the green zone a product of 2. An example of the application of this traffic light summary calculation is shown in Fig. 2.4.

Recovery attributes of abundance

Possible recovery attributes of abundance of striped bass in the southern Gulf include the number of spawners (see above), an index of the spawner abundance (CPUE index) and relative spawning success (juvenile indices). Additional attributes could include the age structure of the spawners (range of ages, relative contributions of year-classes).

Spawner abundance

Estimates of the spawning stock in the NW Miramichi are available for the period 1993 to 2005. A peak abundance of over 50,000 bass was estimated in 1995 with a low of 3,400 fish in 1998. Between 1994 and 2005, the spawner abundance has been consistently below the recovery limit. Based on the previous 5 years and the compliance rule, the stock will be below the recovery limit until at least 2009 (Fig. 2.4). Considering the uncertainty in the estimates of spawner abundance (Table 1.2), the lower confidence interval of the estimates (i.e. 97.5% chance that the abundance was greater than the lower interval) should be used to evaluate compliance relative to the recovery limit.

Sampling on the spawning grounds has consistently shown a disproportionate number of males relative to females. Bradford and Chaput (1998) indicated that the abundance of young-of-the-year striped bass as measured in the open-water fall smelt fishery increased dramatically when female spawner abundance was estimated to have been above 5,000 fish and this was subsequently suggested as an interim conservation level (Douglas et al. 2001). The interim conservation threshold of 5,000 females which has been used to close all directed fisheries on striped bass equates on average to about 15,000 spawners. As the estimate of female abundance is even more uncertain than the estimate for total spawners, we recommend using the latter as the spawner attribute.

Index of spawner abundance

An index of spawner abundance was obtained from the commercial gaspereau fishery in the Northwest Miramichi. Details of the sampling procedure and analyses are described in the section on Primary Indicators of Status above.

The mean annual catch rate (Ln(CPUE)) is positively correlated to the spawner estimates derived from mark and recapture with 1995 being an outlier year (Fig. 2.5). When the observation for 1995 is excluded, the correlation is greater than 0.9. Using the reference levels for spawners derived previously, the equivalent index for S_{opt} would correspond to a catch rate value of 4.02 (LnCPUE) or 56 bass per trapnet per 24 hour period whereas 50%SPR spawner reference level would be demarcated by a catch rate value of 5.15 (LnCPUE) or 173 bass per trapnet per 24 hour period (linear regression of LnCPUE on spawner abundance excluding the 1995 data point).

Using the traffic light boundaries established for the spawner estimates, the boundary for the red/yellow zone could correspond to a catch rate value of 3.8 (LnCPUE) or 46 bass per trapnet per 24 hour period whereas the yellow/green zone would be demarcated by a catch rate value of 6.2 (LnCPUE) or 486 bass per trapnet per 24 hour period (linear regression of LnCPUE on spawner abundance excluding the 1995 data point) (Fig. 2.5).

Index of spawning success

Indices of young-of-the-year in the fall and in the summer have been obtained over different time periods in the Miramichi (see section on Primary Indicators of Status above). The fall index was obtained from bycatch sampling of the commercial open water rainbow smelt fishery for the period 1991 to 1998. The mean annual catch rate (CPUE) is positively correlated ($R = 0.66$) to the female spawner estimates derived from mark and recapture but less so for the total spawner abundance. When female spawner abundance was at or above 5,000 fish, there was a high young-of-the-year index in the fall smelt fishery (Bradford and Chaput 1997) which supports the premise that spawner abundance is an important component of recovery and maintenance of striped bass.

A summer beach seine index has been developed covering a shorter but more recent time period (see section on Primary Indicators of Status above). Several more years of the summer index and spawner abundance estimates will be required before the functional relationship can be described. However, the data thus far illustrates that survival in the early egg and larval stages can dramatically influence recruitment. This was evidenced in 2004 when the summer YOY index was very low relative to the estimated abundance of spawners that year (see section on Primary Indicators of Status above).

TIME FRAME FOR RECOVERY

Recruitment for striped bass is considered to be strongly influenced by environmental factors (Richards and Rago 1999). In the Chesapeake Bay stock, high recruitment indices were noted in only four of the nine years when spawning stock biomass was high (1989 to 1997; Fig. 7 in Richards and Rago 1999). Year class failures are also possible. Despite an above average abundance of spawners in 2004, the resulting year class is expected to be weak as a result of poor survival in the first few weeks after spawning when water temperatures cooled. We used the discrete life history model with stochasticity to describe the potential and the general time frame for recovery (Appendix D). The results of the simulations are specific to the assumptions regarding the stock and recruitment dynamic, survival, and maturation schedule.

With stochastic variation in survival and in the absence of directed fisheries on any life stage, the mean abundance of spawners reaches a ceiling of 60,000 fish with the median abundance of 55,000 fish (Fig. 2.6). The 2.5th percentile of the spawner abundance levels at about 25,000 spawners although the minimum value in any simulation occasionally falls below 10,000 fish. Individual simulation trajectories illustrate the annual variability in YOY abundance, spawner abundance, and 3+ adult bass abundance, expected from the life history model conditional upon the assumed parameters of the model (Fig. 2.6; Appendix D). The variability in abundance over time in any single simulation is quite broad, determined largely by the assumed variation in egg to YOY recruitment (Fig. 2.7).

In the absence of fisheries removals and assuming M at age as above, there is a greater than 90% chance that by 2011, the abundance of spawners will be greater than S_{opt} (21,600) in six consecutive years (Table 2.3). There is a 90% chance that the abundance will be greater than S_{opt} in 5 of 6 consecutive years by 2010. There is a 92% chance that the abundance of spawners will be above the limit and above the target (in GREEN) during the next ten years (Table 2.4).

There continues to be losses of striped bass as legal bycatch of young-of-the-year striped bass and in illegal fisheries on adult bass (see Phase II below). We consider these current conditions to be the starting point for evaluating persistence and potential to recover. Average Z for ages 3 to 7 is 0.8 between 1997 and 2005 (Fig. 1.9) and consequently we ran the life history model with M = 0.6 and F = 0.2 for striped bass aged 2 years and older. We assumed full recruitment to the illegal fisheries for those ages. Young of the year bycatch was modeled at F = 0.1 on all bycatch fisheries in the summer and fall. Under these conditions, the population trajectory for spawners leveled out at a median value of just under 13,000 adults within a 2.5 to 97.5 percentile range of 4,000 to 38,000 fish (Fig. 2.8). The minimum value in any simulation is about 1,000 fish. Removals of adult bass are in the order of 7,300 fish (2.5 to 97.5 interval range of 2,200 to 24,000 fish) whereas losses in the YOY bycatch fisheries are in the order of 33,000 fish (2.5 to 97.5 interval range of 6,000 to 157,000 fish). The probability of the stock recovering above the limit of 21,600 spawners in at least 5 years out of 6 (YELLOW) between 2006 and 2015 is only 18% (Table 2.5).

If exploitation on adult bass was reduced to zero (with M = 0.6) and exploitation in the bycatch fisheries set at the 50%SPR reference level (F=0.444), there is a 44% chance that the spawner abundance will remain below the recovery limit (RED) if the 5 of 6 years compliance rule is used (Table 2.4, 2.6).

Directed fishing on adults at the 50%SPR rate (F = 0.089) will result in a 31% chance that the spawner abundance will remain below the recovery limit (RED) (Table 2.4, 2.7). Finally, fishing at the combined 50%SPR rates for young-of-the-year bycatch (F=0.220) and adults (F=0.044) is expected to result in a 37% chance that the spawner abundance will remain below the recovery limit between 2006 and 2015 (Table 2.4, 2.8).

Using the 5 of 6 years compliance rule, a very low bycatch mortality of juveniles (F = 0.1) and no increased mortality on adults may provide a 95% chance of the spawning stock recovering out of the RED zone between 2006 and 2015.

RESIDENCE AND CRITICAL HABITAT

Landings data, tagging data (conventional and acoustic), beach seine surveys, fishery officer reports, field observations, traditional ecological knowledge, and anecdotal information indicate that striped bass are widespread as adults, juveniles, and YOY throughout the southern Gulf.

With the exception of the freshwater habitat, striped bass are present at some time of the year in every estuary, lagoon, inlet, and coast of the southern Gulf.

Although the whole of the southern Gulf is crucial for striped bass life history events associated with feeding, rearing, and overwintering, it does not fall within the definition of "residence" described by the "den" and "nest" examples in the SARA s.2(1). The transient nature of striped bass during all life stages and the passive drift of eggs and larvae out of their area of production do not meet the criteria of containment. Although the southern Gulf as a whole must be technically disqualified as striped bass "residence", the Miramichi estuary to the head of the tide encompasses the only known spawning location for striped bass in the southern Gulf and as such is critical to the persistence of the population.

The Northwest Miramichi is presently the only known spawning location for striped bass in the southern Gulf (see Life History section). This phenomenon has been and continues to be demonstrated annually with conventional tagging studies (Douglas et al. 2003; this document) and unsuccessful attempts at finding spawned eggs and larvae in other southern Gulf estuaries during spring (Robinson et al. 2001; AVC Inc. 2003, DFO unpublished). The Miramichi estuary is habitually occupied each spring when the spawning migration of striped bass arrives.

The extent of the spawning grounds of the Northwest Miramichi was further refined in time and space through acoustic tracking studies in 2003 and 2004. Striped bass captured on the spawning grounds of the NW Miramichi were implanted with acoustic transmitters (N = 19 in 2003, N = 21 in 2004) and their movements monitored with stationary receivers placed throughout the Miramichi estuary and inner bay in 2003 and additionally in coastal waters off northern NB in 2004. Implanted striped bass spent an extended period staging at Strawberry Marsh, adjacent to the confluence of the Northwest and Southwest Miramichi rivers prior to spawning in early May. Striped bass activity was next highest during early June, between the areas of the Northwest Millstream and Cassilis on the NW Miramichi, an area traditionally known to encompass the spawning grounds. The time that implanted striped bass spent in this section of the river was assumed to represent spawning and was consistent with egg and larval density distributions during the 1992 spawning run (Robichaud-LeBlanc et al. 1996). Implanted striped bass made excursions up the Southwest Miramichi to the head of tide in both years but the amount of time spent in that branch was substantially less than that of the NW Miramichi. There was relatively little activity recorded on receiver arrays in the middle and lower sections of the estuary, and no detections were recorded at arrays anchored in the main shipping channels between the barrier islands (Fig. 2.9). In 2004, 8 implanted striped bass that exhibited spawning behaviour in the Northwest Miramichi were detected in coastal waters at Val Comeau and one was later detected in Chaleur Bay (Fig. 1.16). These data may provide managers with protection options that could include area and time closures targeted at staging and spawning bass.

The Miramichi estuary and specifically the Northwest Miramichi also proved to be an important overwintering area for implanted striped bass. Twenty-six of the implanted striped bass returned to the Miramichi estuary during late autumn in 2003 and 2004 (Table 1.4). Overwintering striped bass were monitored under the ice by stationary receivers anchored to the streambed. Again striped bass remained in the area of Strawberry Marsh until after ice cover during late December. In both years, there was a slow progressive movement up the Northwest Miramichi in tidal waters until they reached the same area where they had spawned only months previously.

Striped bass are known to overwinter in many estuaries of the southern Gulf (Rulifson and Dadswell 1995) but assessment of overwintering habitat has been limited to the Kouchibouguac

River (Bradford et al. 1997a). The relative importance of estuaries in terms of overwintering locations for striped bass is unknown. It has always been perceived that the choice of an overwintering location has been opportunistic and in response to cooling ocean temperatures encountered by migrating adult bass (Bradford and Chaput 1996). In years of high YOY abundance coupled with their annual widespread range extension out of the Miramichi, it is extremely likely that every estuary in the southern Gulf harbours striped bass through the winter months. It is believed that striped bass would chose alternate overwintering sites if conditions deteriorated but the sudden loss of many overwintering sites could be disastrous for southern Gulf striped bass.

2 - HUMAN – INDUCED MORTALITY

MAJOR POTENTIAL SOURCES OF MORTALITY / HARM

The list of threats put forward by COSEWIC (2004) for striped bass in the southern Gulf included "bycatch in various fisheries such as gaspereau, and rainbow smelt and illegal takes particularly during ice fishing". To the extent possible, we explore this list of limiting factors, as well as others in the southern Gulf. Little or no quantitative information exists to derive mortality estimates for each of the potential sources of harm and therefore we assigned qualitative ranks based on field observations by DFO Science and Conservation and Protection (C&P) staff, and discussions with commercial fishermen, First Nations, non-government organizations (NGO), and the public. Ranks used to characterize the potential sources of mortality were low, moderate, high, or uncertain. The rank of "no indication" (NI) was used when there was no evidence in support of striped bass mortality associated with the human induced factors explored as a requirement of the RPA exercise (DFO 2004b). Evidence in support of many of the assigned ranks were discussed below while all mortality factors and associated ranks were summarized in Table 2.9.

Directed fishing – high

Striped bass of the southern Gulf are managed under the *Canada Fisheries Act* and the *Maritime Provinces Fishery Regulations*. Current protection for the species prohibits the retention, possession, or sale of any wild striped bass in the region. Although legal fisheries for striped bass are currently closed, illegal fisheries and black markets for their sale are extensive. Striped bass angling, frequently under the guise of targeting other legal species in tidal waters, is widespread throughout the southern Gulf.

The worst accounts of illegal gillnet fisheries for striped bass originate from Kent County, NB. Credible reports of gillnetting striped bass by the thousands are common, especially from the mouths of the Kouchibouguac and Black rivers and at Rivière au Portage, during early May, when striped bass are leaving their winter refuges to begin their spawning migration to the Miramichi. The fish's nearshore schooling behaviour is easily exploited by individuals setting gillnets in water no deeper than that required to tend them with chest waders. Hogans and Melvin (1984) cautioned that if poaching continued at the high levels observed in the Kouchibouguac National Park in 1983-84, the population would decline.

Striped bass are gillnetted intensively again in the fall and through the winter under the ice, as they move into estuaries for the winter months. Much of the autumn gillnetting occurs in the Richibucto River system. In recent years, we have received reports of striped bass being offered for sale for $5.00 each and available throughout Kent county in any quantity desired (Kouchibouguac National Park warden pers. comm.). Furthermore, poaching with gillnets is extensive in the areas of Tabusintac, Tracadie and Pokemouche (e.g. one net was seized recently with 19 adult striped bass (DFO fishery officer, pers. comm.)). Credible accounts of severe poaching exist for the upper reaches of the Pugwash River, NS just before freeze-up. Given the widespread distribution of striped bass in the southern Gulf, it may be reasonable to assume that gillnetting occurs or has occurred in other locations of the southern Gulf.

Anglers either kill or cause harm to striped bass when they are hooked and released. US studies on hook and release of striped bass indicate that mortality generally increases with water temperature and type of bait (Wilde et al. 2000). The Atlantic States Marine Fisheries Commission currently assumes a hooking mortality rate of 8% (Diodati and Richards 1996) which infers that well over 1 million striped bass died along the US Atlantic coast between 1996 and 2000. Millard et al. (2005) suggest that a hook and release mortality rate closer to 16% in freshwater river systems may be more appropriate. There is no doubt that mortality associated with the hooked and released component of any striped bass recreational fishery is substantial and needs to be considered when managing the resource.

Angler accounts of hooking and releasing 75 bass per day are common during May at the confluence of the SW and NW Miramichi rivers, a location known as Strawberry Marsh, as well as 15km upstream, directly on the spawning grounds of the NW Miramichi. After a single patrol in May 2005, fishery officers reported 34 anglers in the Strawberry Marsh area hooking and releasing striped bass, and one individual was charged with the illegal retention of two bass (F. Butler, DFO C&P, pers. comm.). Although angling for striped bass is widespread throughout the southern Gulf, striped bass are particularly targeted in the staging areas only days before spawning and only meters away from the spawning grounds. Anecdotal accounts are made of increased catches along the coasts of New Brunswick as the bass leave the Miramichi after spawning and begin their summer coastal migrations.

Miscou Island is a well known striped bass angling area. DFO fishery officers estimate that a minimum of 1,000 striped bass are angled from Miscou beaches annually (Miscou C&P, pers. comm.). Evidence to corroborate these claims surfaced in 2003 when an angler from Miscou returned an acoustic pinger that had been implanted in the body cavity of a striped bass two months earlier. Reports from a reliable source indicate that one Miscou angler completed the 2005 season with a total take of 125 bass.

Angling for striped bass continues to occur regularly in many locations of the southern Gulf including: Bathurst harbour, the Tabusintac and Tracadie rivers, all of the tributaries and rivers of Kent Co., NB, Mabou harbour in Cape Breton, and the Hillsborough river in PEI. Offenders with striped bass angled from Pictou Harbour were charged in 2004.

Bycatch in gaspereau fisheries – moderate

Landings data prior to the commercial fishery closure in 1996, reveal that striped bass bycatch in the gaspereau fisheries of the southern Gulf can be substantial (LeBlanc and Chaput 1991). The highest level of striped bass bycatch is believed to exist in the gaspereau fishery of the Miramichi system and can be attributed to their annual spawning migration to the NW Miramichi. With the exception of the Miramichi, fishery officers reported that striped bass bycatch is minimal in the larger gaspereau fisheries of the Margaree, Buctouche, Richibucto, Kouchibouguac, Pokemouche, and Big Tracadie rivers, the Pictou and Pugwash harbours, and Wallace Bay (Table 7 in Chiasson et al. 2002). This list does not exhaust the locations of all potential effort and gear for gaspereau in the southern Gulf (Appendix E). For example, striped bass are intercepted annually in the Napan, Black (n=2), St. Louis, and Tabusintac rivers of NB, as well as, the Pisquid and Hillsborough rivers of PEI (AVC Inc. 2003). Given the widespread and roaming behaviour of striped bass in the southern Gulf, any gear set for gaspereau at any location has the potential of harming the species (Appendix E) (DFO 2000a; DFO 2001a; DFO 2002a).

The commercial fishery closure in 1996 eliminated the direct mortality of striped bass bycatch, but any interference with natural behaviour or migrations will cause harm to the species. Survival is believed to be high when striped bass are culled quickly and efficiently from catches of gaspereau. DFO Science has used the gaspereau fishery of the NW Miramichi extensively for striped bass assessment purposes and has yet to witness or report on mortality from improperly handled fish (see previous assessments). Whether the striped bass bycatch is treated similarly throughout the other southern Gulf gaspereau fisheries is unknown. One commercial fisherman from the Richibucto River was charged in 2003 with a poorly culled catch where approximately 40 juvenile bass were mixed in with the gaspereau.

Bycatch in rainbow smelt fisheries – high

The only quantitative bycatch study completed for the Rainbow smelt fishery was limited to the Miramichi estuary during the open-water season between October 15 and the end of November in 1994 and 1995. Bradford et al. (1997b) estimated that between 100-500 thousand YOY striped bass were captured as bycatch in the open water fall smelt fisheries of 1994 and 1995. The high bycatch levels of striped bass in the Miramichi were consistent with levels ranked by fishery officers for that same smelt fishery (Chiasson et al. 2002). Fishery officers also ranked striped bass bycatch as highest in the Tabusintac, and Wallace areas, and as moderate throughout Kent Co. NB, and in the East and West rivers of PEI (Chiasson et al. 2002). Fishery officers from the Neguac NB detachment commented that “after a rain in the fall there is nothing to see thousands of small striped bass in a single smelt net. Fishers try their best not to harm the small bass but when they lift the box or bag net, 50% of the bass are already dead due to the current pushing the small juvenile fish against the back of the net” (Chiasson et al. 2002).

There is a large amount of gear in the rainbow smelt fishery in the both the fall and winter seasons throughout the southern Gulf (Appendix F).

Culling efforts by fishermen using box and bag nets is generally considered to be poor and mortality is essentially 100% in gillnets. Fishers are often constrained by the timing of the tides and entire catches are loaded before culling begins. Frigid air temperatures that instantaneously freeze striped bass out of the water or gulls feasting on striped bass trying to escape provides little chance of survival.

Based on the estimates in Bradford et al. (1997b) for a portion of the smelt fishing activity, bycatch in the order of 100s of thousands, particularly when juvenile abundance is high, is entirely realistic. The proportion of the total juvenile stock intercepted in these fisheries remains unknown. Bycatch concerns in smelt fisheries date to the 1930s when Huntsman (1945) identified this fishery as having a particular negative effect on striped bass abundance.

Bycatch in American eel fisheries – moderate

Little is known about the level of bycatch in the American eel fishery of the southern Gulf (Bradford et al. 1995). Fishery officers ranked bass bycatch as minimal in eel fisheries of Cascumpec PEI, the Richibucto River system in NB, and Antigonish and Pomquet harbour in Gulf NS (Chiasson et al. 2002). Areas where striped bass bycatch was considered to be high and moderate were the Tabusintac River and Merigomish Harbour, respectively. Fishery officers report that striped bass bycatch didn’t occur in the eel fisheries of the Miramichi, Tracadie, or Pokemouche systems even though it is common knowledge that it does (Chiasson et al. 2002). With the exception of years with low spawner success, YOY striped bass are captured by beach seine along most coasts of the southern Gulf. It is reasonable to assume that the large amount of gear targeting eels in the southern Gulf captures several thousand striped bass annually (Appendix G) (DFO 2000c; DFO 2001c; DFO 2002c).

Bycatch in coastal fisheries – uncertain
Bradford and Chaput (1998) reported two tag returns from striped bass captured in the herring fishery off Escuminac, NB, in spring 1997. Herring gillnets in this fishery are often set in a few meters of water next to shore, so it is likely that striped bass undergoing their spring spawning migration to the Miramichi are intercepted more frequently than previously documented. Herring gear have small mesh and would be expected to have a larger impact on the younger age groups.

Bycatch in Aboriginal fisheries – high
Prior to 2000, First Nations retained striped bass for food, social, and ceremonial purposes. Allocations were suspended when the conservation requirement of 5,000 female spawners was not achieved for several consecutive years in the late 90's. Although the striped bass allocation was suspended, seasons and locations that coincided with traditional Atlantic salmon fisheries were not altered. Since gillnets do not select by species, striped bass continue to be killed and discarded during those fisheries that target Atlantic salmon. Aboriginal gillnet fisheries believed to have the greatest impact on striped bass survival include those near the spawning grounds on the NW Miramichi at Eel Ground and Red Bank. Striped bass returning to estuaries in the fall to overwinter are intercepted by Elsipogtog (formerly Big Cove) and Esgenoôpetij (Burnt Church) First Nation targeting late run Atlantic salmon in the Richibucto and Tabusintac rivers, respectively. Pictou Landing First Nation intercept striped bass in the East River of Gulf NS.

Reliable striped bass harvest statistics from any First Nation fishery have never been provided. One 24 hr gillnet catch sampled in June 2003 at Eel Ground yielded 80 adult striped bass and no other species of fish. Gillnets are generally tended once a day and it is unlikely that more diligent monitoring of the gear would improve the poor survival probability of striped bass enmeshed in gillnets.

Striped bass are intercepted by First Nation trapnets set for food, science, or commercial purposes (Table 2.10). When striped bass allocations were in place, First Nations often harvested striped bass captured in trapnets. Efficient culling practices in trapnet fisheries are believed to cause little mortality.

Habitat alterations under permit - low
There are no major habitat alteration issues believed to threaten bass in the southern Gulf. DFO Habitat is cognisant of the specialized spawning grounds for striped bass in the NW Miramichi and has recently refused permission for the construction of a wharf and marina in that area. Applications for large floating docks near the spawning grounds of the NW Miramichi have also been denied. Dredging activities are localized and generally of a low scale, directed at opening channels near community wharves for access by relatively small inshore fleets. Plans for any habitat alterations in the southern Gulf need to consider the widespread use of all estuaries by striped bass.

Power generating stations - uncertain
The effect of power generating stations (PGS) on striped bass in the southern Gulf is unknown. It is known, however, that large numbers of striped bass are drawn to the thermal effluent of the PGS at Trenton NS, Dalhousie and Belledune NB, during late fall and winter. Anglers target these warm water effluents because of the large concentrations of striped bass which continue

to feed at that time of year. Well over 1,000 striped bass were estimated to have died at the outflow of the Trenton PGS in February 2004. The cause of the fish kill was believed to be the result of an acute reduction in water temperature when the PGS went off line and the thermal discharge was turned off (C. MacInnis DFO, pers. comm.).

Industrial and municipal waste water - uncertain
Waste water effluents from industrial and municipal facilities are widespread throughout the southern Gulf, but their effect on striped bass or striped bass habitat is unknown. Sites of particular interest are those along the Miramichi River including UPM-Kymenne's pulp paper mills (both bleached kraft and ground wood) at Newcastle and Nelson (closed in 2004) respectively, and the 7 sewage treatment facilities between the head of tide at Red Bank and the inner Miramichi Bay (Robichaud-LeBlanc et al. 2000). The discharge from the UPM-Kymenne operation is in the Northwest Miramichi, in the Strawberry Marsh area, the location believed to function as the primary pre-spawning staging area for striped bass. This warm effluent produces a localized open water area even in the coldest months of the year. It is expected that millions of eggs, larvae, and free swimming YOY are exposed to a wide array of chemicals in the Miramichi environment. Many of the chemicals used in present day operations are known to contain endocrine disrupting compounds such as estrogens and testosterones that eventually make their way into rivers via effluents (Wayne Fairchild, DFO, pers. comm.). Burton et al. (1983) demonstrated significant mortality of striped bass larvae after a 72-h exposure to bleached kraft mill effluent. Environmental impact assessments for new industries in any estuary of the southern Gulf need to consider potential effects on striped bass and their habitat.

Other pulp and paper operations in the southern Gulf include Atholville (Restigouche River), Dalhousie and Bathurst (Chaleur Bay), and Pictou Harbour (Nova Scotia). The Pictou Harbour area is a well known overwintering site for striped bass and is located in the same embayment as the thermal power generating station at Trenton, NS.

Scientific research - low
Any scientific research program that requires fixed or mobile gear anywhere in the southern Gulf will harm striped bass. However, gear that traps fish instead of entangling fish has been shown to cause less mortality. Trapnets similar to those used in the gaspereau fisheries of the southern Gulf have been used by DFO, First Nations, and NGO's to assess different anadromous stocks throughout the region and all have recorded striped bass catches (Hayward 2001). Trapnets used for science based activities on a relatively consistent basis are listed in Table 2.10.

Extracting scales for ageing purposes and applying tags to striped bass as part of the annual DFO stock assessment activity disrupts the mucous membrane covering the fish and increases the likelihood of infections. There has been no evaluation of mortality from tagging procedures used on southern Gulf striped bass. Special striped bass research requests are often granted that have recently included a tracking study that required incisions into the body cavity of striped bass and fin clipping for genetic analysis.

Striped bass YOY are susceptible to injury or death from beach seining early in the growing season when fish are fragile, or if catches are large, or if the catch includes a lot of debris. DFO Science has developed a beach seine index of YOY striped bass in the southern Gulf that has entailed over 100 sweeps annually between 2000 and 2005. DFO Stewardship has recently started the Community Aquatic Monitoring Program (CAMP) where community groups throughout the southern Gulf beach seine approximately 5 sites per watershed each month between May and October. Effort in this program is not consistent but 100 beach seine sweeps annually throughout the region would be a reasonable estimate of effort with a maximum combined catch in the range of a few thousand individuals.

An action plan developed between DFO Gulf Region and the Province of Quebec to re-introduce striped bass to the St. Lawrence Estuary required the use of Miramichi progeny as seed stock. The approximately 2,000 YOY striped bass that have been removed from the Miramichi system in each of 1999, 2002, 2003, and 2005, have been either stocked directly into the St. Lawrence estuary or are being raised for broodstock.

CONCLUSION

Individual mortality estimates of the potential threats listed above are not possible at this time, but the cumulative mortality has the potential of being important. There is little doubt that poaching alone removes several thousand adult striped bass annually, conceivably half of the adult population each year. The extent of striped bass mortality associated with the rainbow smelt and American eel fisheries of the southern Gulf is poorly understood but it is reasonable to assume that hundreds of thousands, and in exceptional cases, a million YOY striped bass could be captured in these fisheries annually.

Although the aggregate mortality of all of these factors is high, striped bass in the southern Gulf have persisted, although at much lower levels of abundance than might be expected if anthropogenic related mortalities were reduced. Our analysis and perceptions indicate that the aggregate sum of the current mortality rates imposed on this population is well above the value which would allow abundance to increase and be maintained above the recovery objective. In the absence of any reductions in mortality, the abundance of spawners is expected to remain low and highly variable. Any additional mortality will preclude the recovery potential for southern Gulf striped bass.

3 - MITIGATION AND ALTERNATIVES

The persistent reports of thousands of bass being gillnetted and angled year-round in numerous estuaries and inshore coastal areas of the southern Gulf indicate to us that these illegal fisheries are the largest threat to recovery of the population. We suggest that efforts be focused, first, on substantially reducing the illegal and bycatch mortality on adult striped bass, followed by measures to reduce the bycatch of YOY bass in estuarine fisheries. Because of the large amounts of YOY available to capture, the bycatch which numbers in the hundreds of thousands appears to be impressive. The Spawner per Recruit (SPR) analysis presented in this document puts the relative losses in perspective; a loss of 300 thousand YOY bass in the bycatch fisheries has the same impact on lifetime production of eggs as the removal of 18,500 age one and older bass. These values are less than the realized removals of bass in these fisheries during the mid 1990s.

Although angling for striped bass occurs throughout the region, the elimination of angling on the staging and spawning grounds of the NW Miramichi in May and June should be operationally feasible as it entails the closure of a relatively small section of the Miramichi River. The acoustic tracking study demonstrated that striped bass staged in the area of Strawberry Marsh between the middle and end of May. Spawning for this population is generally during the first 10 days of June in the vicinity of the Northwest Millstream, upstream to Cassilis. The closure of these two areas in May and June each spring would substantially reduce mortality on the striped bass spawning component. “Hotspot” angling areas could also be targeted for special monitoring.

Coincident with the prohibition of angling in tidal waters in the time and area stated above, a delay in the opening of the Eel Ground First Nation gillnet fishery targeting Atlantic salmon in the Northwest Miramichi to possibly June 15 would substantially reduce the mortality on striped bass spawners during the peak spawning period of late May to early June. Delaying the season would reduce bycatch and eliminate handling of undesired fish in the gillnet fishery and possibly have minimal impact on overall catches of Atlantic salmon. Data from trapnets fished by the Eel Ground First Nation in the same area as the gillnets indicated that few Atlantic salmon were captured prior to June 15 and the peak of the early run never occurred before the first week in July (Hayward 2001).

Gaspereau fisheries in the Miramichi River, particularly those in the Northwest Miramichi, have the potential to intercept large numbers of bass spawners. In recent years, with the prohibition on retention and sale of all striped bass in these fisheries, the industry has delayed the opening of the gaspereau fisheries into late May to maximize their fishing opportunities for the target species, gaspereau. Handling practices have improved in these fisheries as science staff collaborate regularly with the fishermen for assessment and research purposes. Furthermore, there has been a concerted effort on the part of the fishermen to cull rapidly to reduce harm. Other than an outright closure on this fishery, we cannot think of any additional measures which would further reduce the low impact this fishery is currently having on striped bass spawners.

As a result of studies conducted on the spatial and temporal characteristics of the bycatch of YOY bass in the open water smelt fishery of Miramichi Bay, the season opening was delayed by two weeks, from Oct. 15 to Nov. 1, in 1999. This measure was estimated to potentially reduce the YOY striped bass bycatch in this fishery by as much as 50% (Bradford et al. 1997b). However, in the absence of similar detailed studies in other areas of the southern Gulf, the delayed opening of the season was restricted to the small study area in Miramichi Bay. Important bycatch issues remain in many other locations (Chiasson et al. 2002). At a minimum, precautionary approach principles would favour a delay in the opening of the season in all of these areas. This would be supported by targeted research to assess the spatial and temporal distributions of YOY bass to ascertain whether alternative or additional interventions would be required.

We suggest that mortality of striped bass at all life stages would be substantially reduced if fishers used gear that allowed for the live release of non-targeted species rather than entanglement gears (i.e. gillnets). In estuaries that are used extensively by striped bass in the fall and winter, several First Nation gillnet fisheries operate regularly. These fisheries occur in the estuaries of the Tabusintac, Kouchibouguac, Richibucto, Buctouche, Pictou Harbour, and Miramichi.

CONCLUSION

Because there are no baseline mortality estimates for striped bass bycatch in any fishery, the effect of implementing the mitigation measures described above will be difficult to gauge. We argue, however, that implementation of any mitigation measure can only improve this population's potential for recovery.

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Table 1.1. Sampling details and start and end dates for the three groupings of the CPUE data from the striped bass bycatch of the NW Miramichi gaspereau fishery. Sampling intensity refers to the proportion of catches sampled relative to the total number of catches landed during a sampling event.

Year	Sampling period		Catches sampled	Sampling intensity	Mark and recapture end date	Upper quartile dates	
	First	Last				First	Last
1993	28-May	18-Jun	46	7.7%		28-May	16-Jun
1994	24-May	18-Jun	50	7.7%	12-Jun	24-May	15-Jun
1995	24-May	21-Jun	60	7.7%	9-Jun	24-May	11-Jun
1996	24-May	19-Jun	72	8.3%	10-Jun	31-May	13-Jun
1997	4-Jun	20-Jun	60	8.2%	20-Jun	4-Jun	14-Jun
1998	21-May	17-Jun	83	8.4%	4-Jun	21-May	11-Jun
1999	21-May	18-Jun	139	8.0%	8-Jun	21-May	15-Jun
2000	25-May	21-Jun	102	9.0%	21-Jun	25-May	16-Jun
2001	25-May	20-Jun	32	11.0%	11-Jun	25-May	1-Jun
2002	23-May	19-Jun	56	9.4%	4-Jun	23-May	3-Jun
2003	24-May	23-Jun	75	9.3%	11-Jun	24-May	11-Jun
2004	24-May	25-Jun	86	9.0%	11-Jun	24-May	17-Jun
2005	24-May	24-Jun	85	9.6%	8-Jun	1-Jun	13-Jun

Table 1.2. Spawner abundance estimates for striped bass on the spawning grounds of the NW Miramichi. Estimates based on mark recapture experiments between 1993 and 2005.

	Spawner abundance estimates for year												
Estimate	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total spawners (mode)	5,500	29,000	50,000	8,090	8,000	3,400	3,940	3,900	24,000	29,000	21,000	15,000	20,000
95% confidence limit (lower)	4,550	23,000	35,000	6,275	5,800	2,900	3,450	2,850	18,000	25,500	17,000	10,000	11,500
95% confidence limit (upper)	7,300	47,000	175,000	13,370	17,500	4,800	4,430	5,250	33,000	32,500	27,000	24,500	45,500
Proportion mature males	0.94	0.92	0.63	0.37	0.69	0.83	0.69	0.64	0.77	0.58	0.51	0.69	0.40
Proportion mature females (minimum)	na	na	na	na	na	na	0.03	0.04	0.02	0.01	0.00	0.08	0.11
Proportion mature females (maximum)	0.06	0.08	0.37	0.63	0.31	0.17	0.31	0.36	0.23	0.42	0.49	0.31	0.60
Mature males (minimum)	5,170	26,680	31,500	2,993	5,520	2,822	2,719	2,496	18,480	16,820	10,710	10,350	8,000
Mature females (minimum)	na	na	na	na	na	na	118	156	480	290	0	1,200	2,200
Mature females (maximum)	330	2,320	18,500	5,097	2,480	578	1,221	1,404	5,520	12,180	10,290	4,650	12,000

Table 1.3. Mean annual catch per unit of effort (Ln(CPUE), standard error of Ln(CPUE) and back transformed median CPUE of striped bass in the NW Miramichi, derived from the general linear model, in three sampling periods. All season refers to the CPUE derived using the observations over the entire sampling period. Mark and recapture refers to the mean CPUE based on the sampling interval from the start of sampling to the end date of the mark and recapture experiment. Upper quartile is the mean CPUE derived using the period which encompassed the upper quartile of the CPUE observations annually. Samples where catch = 0 is the percent of all the samples for the entire sampling period when no bass were observed in the catches at the trapnets.

	Ln (CPUE)			CPUE			Samples
Year	All season	Mark and recapture	Upper quartile	All season	Mark and recapture	Upper quartile	where catch=0
1993	1.39	1.39	1.58	4	4	5	28.3%
1994	4.19	4.42	4.32	66	83	75	0.0%
1995	3.70	4.28	4.04	41	72	57	1.7%
1996	2.19	2.49	2.53	9	12	13	4.2%
1997	1.60	1.60	1.77	5	5	6	11.7%
1998	2.34	2.68	2.48	10	15	12	4.8%
1999	1.99	2.38	2.07	7	11	8	17.3%
2000	1.89	1.89	1.99	7	7	7	3.9%
2001	4.36	4.56	5.23	78	95	186	0.0%
2002	4.52	5.28	5.51	91	196	247	0.0%
2003	3.66	4.21	4.21	39	67	67	1.3%
2004	2.53	3.34	2.92	13	28	19	5.8%
2005	2.98	3.59	3.42	20	36	30	5.9%

	Standard error		
Year	All season	Mark and recapture	Upper quartile
1993	0.55	0.51	0.48
1994	0.13	0.13	0.12
1995	0.15	0.15	0.14
1996	0.29	0.32	0.28
1997	0.43	0.40	0.39
1998	0.25	0.26	0.23
1999	0.23	0.23	0.20
2000	0.29	0.27	0.26
2001	0.15	0.14	0.14
2002	0.10	0.11	0.10
2003	0.14	0.14	0.13
2004	0.23	0.25	0.20
2005	0.18	0.19	0.17

Table 1.4. Spawning and overwintering history for striped bass implanted with acoustic pingers in 2003 and 2004.

	2003			2004		
	Males	**Females**	**Total**	**Males**	**Females**	**Total**
Tagged in spring	7	12	19	9	12	21
Known removals	0	1	1	0	0	0
Tags available for detection	7	11	18	9	12	21
Overwintered in Miramichi (tagging year)	7	7	14	5	7	12
Overwintered in the Miramichi (tagging year) and spawned after ice out	4	6	10	4	6	10
Overwintered elsewhere and spawned after ice out	0	2	2	0	3	3
Consecutive spawns	4	8	12	4	9	13
Overwintered in the Miramichi and left after ice out	3	1	4	1	1	2
Missing	0	2	2	2	4	6

Table 1.5. Fork lengths at age for striped bass sampled during their spawning run to the NW Miramichi between 1994 and 2005.

Age		Year of sampling 1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	Mean			15.0			15.6	18.2		17.9		18.4	17.7
	Range			(14.4 - 15.9)			(11.5 - 24.3)	(16.1 - 19.8)		(16.8 - 19.1)		(16.2 - 21)	(17.1 - 18.3)
	N			7			6	10		5		41	2
2	Mean	25.4	26.4	26.7	29.2	25.7	27.8	31.0	29.8	29.8	32.6	30.8	29.6
	Range	(25.2 - 25.6)	(25.4 - 28.5)	(24.1 - 29.8)	(25.4 - 34.6)	(23.1 - 28)	(24.5 - 33)	(26.7 - 38.8)	(25.6 - 34.5)	(26.3 - 36.8)	(28.3 - 41.4)	(27.4 - 33.7)	(26.3 - 34.1)
	N	2	3	191	18	19	9	34	43	65	27	30	25
3	Mean	38.2	35.5	36.0	37.3	39.3	40.8	41.5	40.0	43.5	41.9	42.5	42.4
	Range	(30.7 - 46.1)	(32.9 - 40.3)	(27 - 38.7)	(31.6 - 44.1)	(34.2 - 45.4)	(30.3 - 48.5)	(31.5 - 48)	(296 - 49.3)	(29.4 - 48.3)	(35.2 - 51.2)	(36.8 - 48.9)	(38.8 - 45.4)
	N	754	164	11	95	152	467	131	160	551	133	178	16
4	Mean	46.4	43.8	42.7	45.9	45.6	47.4	49.2	43.2	48.7	49.7	50.2	49.1
	Range	(41 - 49.8)	(35.1 - 54.8)	(39.2 - 48.2)	(41.7 - 49.2)	(37.7 - 52.6)	(35.4 - 56.2)	(29 - 57)	(34.2 - 55)	(39.5 - 57.5)	(37.4 - 56.7)	(42.2 - 57.1)	(43.2 - 56.8)
	N	129	382	98	22	68	201	192	327	528	222	72	97
5	Mean	52.9	52.2	51.3	48.8	53.6	52.6	54.7	51.3	54.4	55.1	55.1	53.9
	Range		(43 - 59.2)	(43.7 - 59.9)	(47.4 - 49.9)	(46.5 - 61.3)	(35.7 - 64.4)	(47.9 - 63.8)	(40.1 - 60.5)	(45.9 - 62)	(45.9 - 65.8)	(39.7 - 63.3)	(42.6 - 60.2)
	N	1	86	350	4	31	93	58	84	211	85	34	36
6	Mean	58.5	57.8	56.6	54.2	61.3	56.5	60.5	57.2	60.1	60.6	61.9	61.1
	Range		(44.8 - 64)	(47.3 - 64.3)	(49.5 - 62.7)	(53.7 - 66.6)	(49 - 66.5)	(53.8 - 72.6)	(52.4 - 63.5)	(46.9 - 70.5)	(52.9 - 65.1)	(52.4 - 70.5)	(50.4 - 66.7)
	N	1	22	20	47	16	21	37	30	68	12	9	17
7	Mean	65.5	65.1			61.2	64.5	63.8	60.0	67.0	68.1	67.4	67.1
	Range	(65.5 - 65.5)				(52.3 - 69.5)	(58.9 - 69.8)	(53.8 - 68.6)	(55 - 66)	(63 - 70.7)	(56.7 - 72.4)	(65.5 - 69.5)	(57.2 - 72.4)
	N	2	1			20	9	6	14	9	4	4	7
8	Mean	69.9	65.2	66.2			65.4	66.3	64.7	72.0	69.2	75.8	
	Range		(60.5 - 69.8)				(57 - 82)	(51.5 - 74.9)	(61.2 - 67.2)	(65.5 - 76.1)	(60.2 - 76.5)		
	N	1	2	1			8	7	3	9	5	1	
9	Mean	74.2			74.9			71.9	71.6	75.3	76.1		
	Range							(63.2 - 80.5)	(63.5 - 77)	(73.5 - 77.6)	(74 - 78.3)		
	N	1			1			2	4	6	4		
10	Mean			72.7		72.4				77.5			82.9
	Range												
	N			1		1				1			1
11	Mean										80.7	73.2	86.1
	Range											(70.2 - 77.5)	(86.1 - 86.1)
	N										1	3	2
12	Mean		81.7		87.2		88.5			84.7			
	Range												
	N		1		1		1			1			
13	Mean									80.9			
	Range												
	N									1			

Table 1.6. Sex ratios at age for striped bass sampled during the spawning run to the NW Miramichi between 1995-2005.

Year	Age	Proportion at age Female	Male	Juvenile
2005	3	0.00	1.00	0.00
	4	0.55	0.45	0.00
	5	0.73	0.27	0.00
	6	0.88	0.13	0.00
	7	1.00	0.00	0.00
2004	2	0.00	0.11	0.89
	3	0.12	0.88	0.00
	4	0.61	0.39	0.00
	5	0.81	0.19	0.00
	6	1.00	0.00	0.00
	7	1.00	0.00	0.00
	11	0.00	1.00	0.00
2003	2	0.21	0.21	0.57
	3	0.24	0.76	0.00
	4	0.54	0.46	0.00
	5	0.78	0.22	0.00
	6	1.00	0.00	0.00
	7	1.00	0.00	0.00
	8	0.50	0.50	0.00
	9	1.00	0.00	0.00
2002	1	0.00	0.00	1.00
	2	0.00	0.08	0.92
	3	0.21	0.79	0.00
	4	0.54	0.46	0.00
	5	0.82	0.18	0.00
	6	0.92	0.08	0.00
	7	1.00	0.00	0.00
	8	1.00	0.00	0.00
	9	1.00	0.00	0.00
	10	1.00	0.00	0.00
	12	1.00	0.00	0.00
	13	1.00	0.00	0.00
2001	2	0.09	0.07	0.84
	3	0.08	0.90	0.03
	4	0.16	0.84	0.00
	5	0.42	0.58	0.00
	6	0.76	0.24	0.00
	7	0.67	0.33	0.00
	8	1.00	0.00	0.00
	9	0.75	0.25	0.00

Year	Age	Proportion at age Female	Male	Juvenile
2000	1	0.00	0.00	1.00
	2	0.00	0.06	0.94
	3	0.26	0.74	0.00
	4	0.37	0.63	0.00
	5	0.50	0.50	0.00
	6	0.72	0.28	0.00
	7	0.50	0.50	0.00
	8	1.00	0.00	0.00
1999	1	0.00	0.00	1.00
	2	0.00	0.00	1.00
	3	0.20	0.80	0.00
	4	0.49	0.51	0.00
	5	0.70	0.30	0.00
	6	0.86	0.14	0.00
	7	0.89	0.11	0.00
	8	0.88	0.13	0.00
1998	2	0.00	0.00	1.00
	3	0.25	0.75	0.00
	4	0.59	0.41	0.00
	5	0.63	0.38	0.00
	6	1.00	0.00	0.00
	7	1.00	0.00	0.00
1997	2	0.67	0.00	0.33
	3	0.92	0.08	0.00
	4	0.23	0.77	0.00
	5	0.75	0.25	0.00
	6	0.87	0.13	0.00
	9	1.00	0.00	0.00
	12	1.00	0.00	0.00
1996	1	0.00	0.00	1.00
	2	0.00	0.00	1.00
	3	0.82	0.09	0.09
	4	0.65	0.35	0.00
	5	0.82	0.18	0.00
	6	0.80	0.20	0.00
	8	1.00	0.00	0.00
	10	1.00	0.00	0.00
1995	2	0.00	0.00	1.00
	3	0.44	0.56	0.00
	4	0.23	0.77	0.00
	5	0.83	0.17	0.00
	6	1.00	0.00	0.00
	7	1.00	0.00	0.00
	8	1.00	0.00	0.00
	12	1.00	0.00	0.00

Table 1.7. Abundance estimates of striped bass at age in the spawning population of the Northwest Miramichi, 1994 to 2005. Estimates of abundance were based on mark-recapture experiments.

	Year of spawning											
Age	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**
3	1127	9651	6826	11490	5872	1240	2300	1977	4471	185	12462	24596
4	11268	3314	10318	11131	12272	1844	996	726	1035	1648	29027	4208
5	4225	1570	3283	4457	3049	484	456	341	188	5887	6535	33
6	2254	291	313	1373	1092	272	104	199	2212	336	1672	33
7	1127	116	104	190	452	30	45	156	0	0	76	65
8	0	0	104	190	113	30	40	0	0	17	152	33
9	0	0	52	106	151	0	0	0	47	0	0	33
10	0	0	0	21	0	0	0	0	0	17	0	0
11	0	58	0	0	0	0	0	0	0	0	0	0
12	0	0	0	21	0	0	0	0	47	0	76	0
13	0	0	0	21	0	0	0	0	0	0	0	0
Total	20000	15000	21000	29000	23000	3900	3940	3400	8000	8090	50000	29000

Table 1.8. Estimates of Z and corresponding M values for striped bass year-classes 1991-2001 based on two indicators of stock status.

Indicator		Age	Estimates of Z and M for year-class										
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mark-recapture													
	Z	3	-0.17	2.02	-1.72	1.82	0.69	0.22	-2.29	-0.64	0.11	0.72	-0.15
		4	1.60	2.17	1.11	0.46	0.72	-0.50	1.01	1.22	1.88	-0.24	
		5	0.98	-0.06	1.19	0.52	-0.81	0.80	2.66	2.42	-0.36		
		6	2.65	1.50	1.24	-0.51	1.75	2.58	0.99	-1.35			
		7	1.37	0.39	-1.32	0.87	0.60						
		8		-1.61	0.07	1.29							
		9		1.96									
	M	3	-0.14	0.86	-4.60	0.84	0.50	0.20	-8.90	-0.90	0.10	0.51	-0.17
		4	0.79	0.89	0.67	0.37	0.51	-0.65	0.64	0.71	0.85	-0.28	
		5	0.62	-0.06	0.70	0.40	-1.26	0.55	0.93	0.91	-0.44		
		6	0.93	0.78	0.71	-0.66	0.83	0.92	0.63	-2.88			
		7	0.75	0.32	-2.74	0.58	0.45						
		8		-3.98	0.06	0.73							
		9		0.86									
CPUE													
	Z	3	0.52	1.99	-0.86	-0.14	1.14	0.66	-3.13	-1.13	0.86	1.26	-0.12
		4	1.57	3.03	-0.84	0.92	1.16	-1.34	0.52	1.97	2.42	-0.21	
		5	1.84	-2.01	1.65	0.96	-1.65	0.31	3.41	2.96	-0.33		
		6	0.69	1.95	1.68	-1.34	1.26	3.33	1.53	-1.32			
		7	1.83	0.83	-2.15	0.37	1.35						
		8		-2.44	-0.43	2.04							
		9		1.47									
	M	3	0.41	0.86	-1.36	-0.15	0.68	0.48	-21.78	-2.10	0.58	0.72	-0.13
		4	0.79	0.95	-1.33	0.60	0.69	-2.80	0.41	0.86	0.91	-0.23	
		5	0.84	-6.47	0.81	0.62	-4.19	0.26	0.97	0.95	-0.38		
		6	0.50	0.86	0.81	-2.82	0.72	0.96	0.78	-2.74			
		7	0.84	0.56	-7.60	0.31	0.74						
		8		-10.46	-0.53	0.87							
		9		0.77									

Table 2.1. Recovery objectives for southern Gulf striped bass based on the discrete life history model.

	Density independent survival (S_o)	YOY_{cap} (millions) 1.0	**1.5**	2.0
Spawners at equilibrium eggs (S_{eq})	0.0005	26,400	39,300	52,100
	0.001	42,500	**63,300**	84,100
	0.002	50,500	74,500	100,100
Spawners for maximum gain of eggs (S_{opt})	0.0005	11,200	16,000	22,400
	0.001	14,400	**21,600**	28,800
	0.002	12,800	21,000	27,200
3+ abundance at S_{eq}	0.0005	45,100	67,300	89,500
	0.001	72,500	**108,500**	144,600
	0.002	86,200	129,000	172,100
3+ abundance at S_{opt}	0.0005	25,900	37,400	51,800
	0.001	47,300	**70,900**	94,600
	0.002	61,400	95,000	125,700

Table 2.2. Possible reference points for striped bass from the southern Gulf based on 50%SPR, S_{opt}, and 30%SPR. Reference levels are for values of S_0 = 0.001 and YOY_{cap} = 1.5 (Table 2.1).

Reference level	Spawners	F YOY	F Age 1+	Yield YOY (millions)	Yield Age 1+ (number)	Yield Age 1+ (weight, t)	Mid-year 3+ abundance
50% SPR	31,200	0.444	0.000	0.303	0	0.0	54,000
		0.000	0.089	0.000	18,500	15.7	64,200
		0.220	0.044	0.167	7,800	7.1	59,100
S_{opt}	21,600	0.640	0.000	0.336	0	0.0	37,400
		0.000	0.131	0.000	21,600	17.5	47,500
		0.320	0.064	0.195	8,400	7.4	42,000
30% SPR	20,000	0.695	0.000	0.341	0	0.0	34,000
		0.000	0.143	0.000	22,300	17.7	44,000
		0.345	0.069	0.199	8,400	7.4	39,000

Table 2.3. Status of the resource in 2005 and the probability of a change of status and the year when status changed for the period 2006 to 2015 under the conditions of no mortalities in any fisheries.

Compliance rule At least 6 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0.000
Frequency of status change	Probability of change over next ten years	
0	0.049	
1	0.923	
2	0.029	
Year first changed occurred		
2011	0.928	
2012	0.023	
2013	0.020	
2014	0.015	
2015	0.015	

Compliance rule At least 5 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0.000
Frequency of status change	Probability of change over next ten years	
0	0.017	
1	0.966	
2	0.016	
3	0.001	
Year first changed occurred		
2010	0.907	
2011	0.054	
2012	0.012	
2013	0.009	
2014	0.009	
2015	0.009	

Table 2.4. Traffic light summary of potential for recovery of striped bass from the southern Gulf for the period 2006 to 2015.

	Probability of being in zone during 2006 to 2015		
	RED Spawners <= 21,600 in > 1 of 6 years	**YELLOW** Spawners > 21,600 in >= 5 of 6 years AND Spawners <= 31,200 in > 3 of 6 years	**GREEN** Spawners > 21,600 in >= 5 of 6 years AND Spawners > 31,200 in >= 3 of 6 years
No directed fisheries	**0.017**	0.058	0.925
Assumed current conditions YOY (F=0.1) and adults (F = 0.2)	**0.820**	0.116	0.065
Fishing on YOY only (50%SPR F = 0.444)	**0.437**	0.252	0.312
Fishing on adults only (50%SPR F = 0.089)	**0.306**	0.238	0.456
Fishing at 50%SPR on YOY (F=0.22) and adults (F = 0.044)	**0.369**	0.248	0.383

Table 2.5. Status of the resource in 2005 and the probability of a change of status and the year when status changed for the period 2006 to 2015 under the assumed current fishing conditions on YOY in bycatch fisheries (F = 0.1) and on adult bass (F = 0.2).

At least 6 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.899	
1	0.053	
2	0.049	
Year first change occurred		
2011	0.571	
2012	0.101	
2013	0.118	
2014	0.106	
2015	0.105	

At least 5 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.820	
1	0.102	
2	0.077	
3 to 4	0.001	
Year first change occurred		
2010	0.418	
2011	0.219	
2012	0.104	
2013	0.096	
2014	0.084	
2015	0.079	

Table 2.6. Status of the resource in 2005 and the probability of a change of status and the year when status changed for the period 2006 to 2015 under the conditions of mortalities on young-of-the-year in bycatch fisheries at the 50%SPR rate (F = 0.444).

At least 6 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.572	
1	0.321	
2	0.107	
Year first change occurred		
2011	0.661	
2012	0.083	
2013	0.084	
2014	0.090	
2015	0.081	

At least 5 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.436	
1	0.455	
2	0.106	
3 to 4	0.003	
Year first change occurred		
2010	0.555	
2011	0.176	
2012	0.067	
2013	0.071	
2014	0.064	
2015	0.067	

Table 2.7. Status of the resource in 2005 and the probability of a change of status and the year when status changed for the period 2006 to 2015 under the conditions of directed mortalities on adult bass (age 1 and older) at the 50%SPR rate (F = 0.089).

At least 6 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.446	
1	0.437	
2	0.118	
Year first change occurred		
2011	0.718	
2012	0.070	
2013	0.073	
2014	0.072	
2015	0.068	

At least 5 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.306	
1	0.583	
2	0.108	
3 to 4	0.004	
Year first change occurred		
2010	0.621	
2011	0.165	
2012	0.057	
2013	0.056	
2014	0.051	
2015	0.051	

Table 2.8. Status of the resource in 2005 and the probability of a change of status and the year when status changed for the period 2006 to 2015 under the conditions of mortalities on young-of-the-year in bycatch fisheries and adult bass at the 50%SPR rate (F = 0.22, F = 0.044).

At least 6 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.506	
1	0.379	
2	0.116	
Year first change occurred		
2011	0.690	
2012	0.074	
2013	0.080	
2014	0.082	
2015	0.075	

At least 5 of 6 years > 21,600	Status in 2005 relative to compliance rule for the recovery limit	
	Below	Above
	1.000	0
Frequency of change of status	Probability of change over next ten years	
0	0.369	
1	0.521	
2	0.107	
3 to 4	0.004	
Year first change occurred		
2010	0.588	
2011	0.171	
2012	0.064	
2013	0.060	
2014	0.058	
2015	0.059	

Table 2.9. Summary of human induced mortality factors for southern Gulf striped bass, their associated relative rank, cause, effect and potential alternatives to the activity. The rank "NI" signifies no indication.

Potential sources of mortality/harm	Source	Relative rank	Cause	Effect	Alternatives or mitigation
<u>Domestic</u>					
Directed Fishing	Illegal (poaching)	High	Targeted captures	Direct mortality	Education, Increased enforcement
Bycatch in Fisheries	Commercial Gaspereau	Moderate	Incidental captures	Direct mortality, Handling related mortality	Season / area closures, Gear modifications, Best management practice in effect
	Commercial Rainbow smelt	High	Incidental captures, Inefficient culling	Direct mortality, Handling related mortality	Season / area closures, Gear modifications
	Commercial American Eel	Moderate	Incidental captures, Inefficient culling	Direct mortality, Handling related mortality	Season / area closures, Gear modifications
	Commercial Herring	Uncertain	Incidental captures in gillnets, Inefficient culling	Direct mortality, Handling related mortality	
	Recreational	Uncertain	Incidental captures	Direct mortality, Hook and release mortality	Season / area closures, Gear modifications

Table 2.9. (continued).

Potential sources of mortality/harm	Source	Relative rank	Cause	Effect	Alternatives or mitigation
Bycatch in Fisheries	Aboriginal (food, social, ceremonial)	High	Incidental captures, Inefficient culling	Direct mortality, Handling related mortality	Season / area closures, Gear modifications, Best management practices
Fisheries Impacts on Habitat	Illegal (poaching)	Low	Installation of fixed gear, Boat use	Obstruction of natural migrations and behaviour, Introduction of petroleum products and bi-products	Education, Enforcement
	Commercial	Low	Installation of fixed gear, Boat use	Obstruction of natural migrations and behaviour, Introduction of petroleum products and bi-products	Season / area closures, Gear modifications
	Recreational	NI	Boat use	Introduction of petroleum products and bi-products	Season / area closures, Gear modifications
	Aboriginal (food, social, ceremonial)	Low	Installation of fixed gear, Boat use	Obstruction of natural migrations and behaviour, Introduction of petroleum products and bi-products	Season / area closures, Gear modifications

Table 2.9. (continued).

Potential sources of mortality/harm	Source	Relative rank	Cause	Effect	Alternatives or mitigation
Direct Mortality Under Permit	NI				
Habitat Alterations Under Permit	Municipal, provincial, and federal dredging activities	Low	Dredging of navigation channels, wharf construction, and deposition of sediments	Mortality of benthos and habitat destruction	Select deposition sites which do not impact striped bass habitat, Forbid activities near essential habitats
	Municipal waste water treatment facilities, Pulp & paper mills, Power generating facilities	Uncertain	Discharge of effluents, (waste water, heat)	Mortality of all life stages	
Ecotourism and Recreation	Private companies and public at large	Uncertain	Boat and recreational vessel use	Mortality of eggs and larvae on spawning grounds, Disturbance of fish aggregations, Introduction of petroleum products and bi-products	
Shipping, Transport and Noise	Municipal, provincial, federal, and private transport activities (land and water based)	Low	Transport of hazardous materials, toxic substance spills Boat use	Mortality of all life stages, Introduction of petroleum products and bi-products	Best management practices

Table 2.9. (continued).

Potential sources of mortality/harm	Source	Relative rank	Cause	Effect	Alternatives or mitigation
Fisheries on Food Supplies	Commercial, recreational, Aboriginal fisheries for: Gaspereau, American shad, American eel, Rainbow smelt, Atlantic tomcod, Atlantic silverside, Mackerel, Herring, Crab sp. etc.	Low	Mortality of striped bass prey species	Mortality associated with starvation, reduced growth and/or reproductive effort	Management plans in place for directed fisheries
Aquaculture	Private shellfish culture companies	Uncertain	Introduction of excessive fecal matter Boat use	Mortality of benthos and habitat destruction, Introduction of petroleum products and bi-products	
Scientific Research	Government, university, community groups, First Nations	Low	Installation of fixed gear, use of mobile gear, Manipulation and collection of striped bass, Boat use	Handling related mortality, increased stress, and disease transfer, Obstruction of natural migrations and behaviour, Introduction of petroleum products and bi-products	Permitted activities under section 52 of *Fisheries Act*, Proper handling techniques, Education
Military Activities		NI			
Non-domestic		NI			

Table 2.10. Non-commercial fishing gear used on a regular basis throughout the southern Gulf known to intercept striped bass. The exception is Eel Ground FN who fish trapnets commercially for gaspereau early in the season but switch to food and science based activities by the end of June.

Organization	Watershed	Gear (target species)	Quantity	Activity
Dept. Fisheries & Oceans	Miramichi R.	trapnets (all species)	2-3	science
Dept. Fisheries & Oceans	Southern Gulf	beach seine (all species)	>100	science
Miramichi Salmon Assoc.	Miramichi R.	trapnets (salmon smolts)	1	science
Various NGOs	Southern Gulf	beach seine (all species)	>100	science
Eel Ground First Nation	Miramichi R.	trapnets (gaspereau, salmon)	3-5*	food, science
Eel Ground First Nation	Miramichi R.	gillnets (salmon)	11	food
Eel Ground First Nation	Miramichi R.	fyke nets (American eel)	1	food
Red Bank First Nation	Miramichi R.	fyke nets (American eel)	2	food
Red Bank First Nation	Miramichi R.	trapnets (salmon)	2	food, science
Red Bank First Nation	Miramichi R.	gillnets (salmon)	4	food
Burnt Church First Nation	Miramichi Bay / Tabusintac R.	trapnets (American eel)	10	food
Burnt Church First Nation	Miramichi Bay / Tabusintac R.	trapnets (salmon)	2	food, science
Burnt Church First Nation	Miramichi Bay / Tabusintac R.	gillnets (salmon)	41**	food
Burnt Church First Nation	Miramichi Bay / Tabusintac R.	box nets (rainbow smelt)	unlimited	food
Eel River Bar First Nation	Eel R.	trapnets (salmon)	3	food
Eel River Bar First Nation	Eel R.	gillnets (salmon)	30	food
Pabineau First Nation	Nepisiguit R	trapnets (salmon)	1	food
Big Cove First Nation	Richibucto R.	trapnets (gaspereau)	6	food, science
Big Cove First Nation	Richibucto R.	box nets (rainbow smelt)	6	food
Indian Island First Nation	Richibucto R.	fyke nets (American eel)	2	food
Indian Island First Nation	Richibucto R.	gillnets (salmon)	15	food
Indian Island First Nation	Richibucto R.	box nets (rainbow smelt)	6	food
Buctouche First Nation	Buctouche R.	fyke nets (American eel)	1	food
Buctouche First Nation	Buctouche R.	trapnets (trout)	1	food

* includes 1 partial counting fence at Big Hole Tract

** includes 3 gillnets for kelts

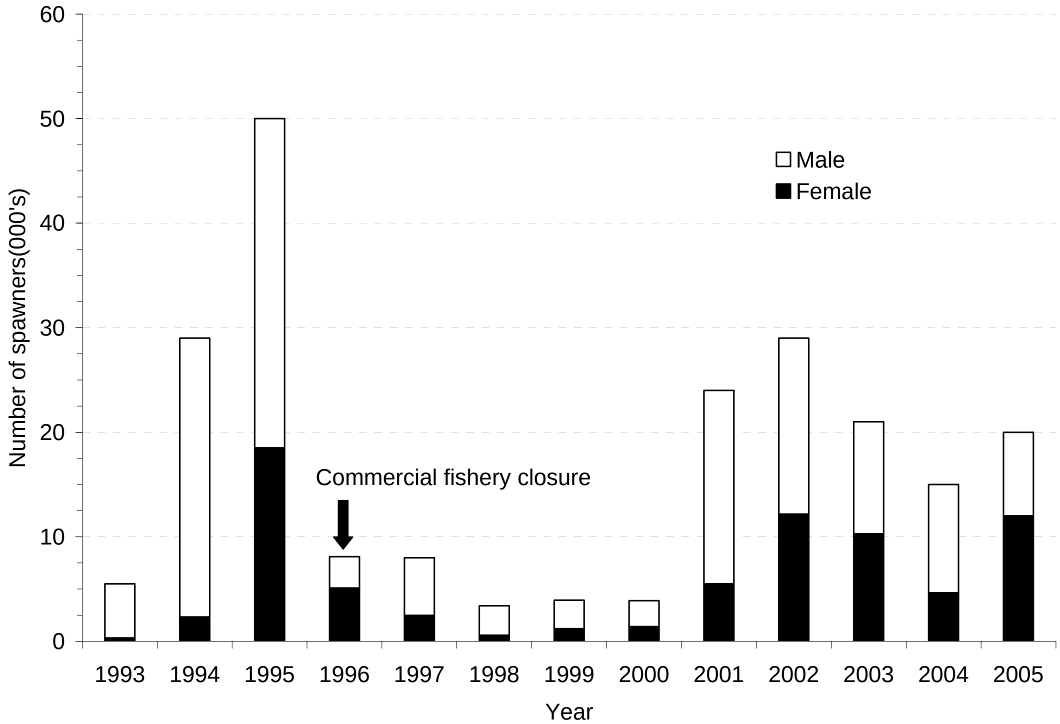


Figure 1.1. Spawner abundance estimates from mark-recapture experiments between 1993 and 2005 on the Northwest Miramichi River.

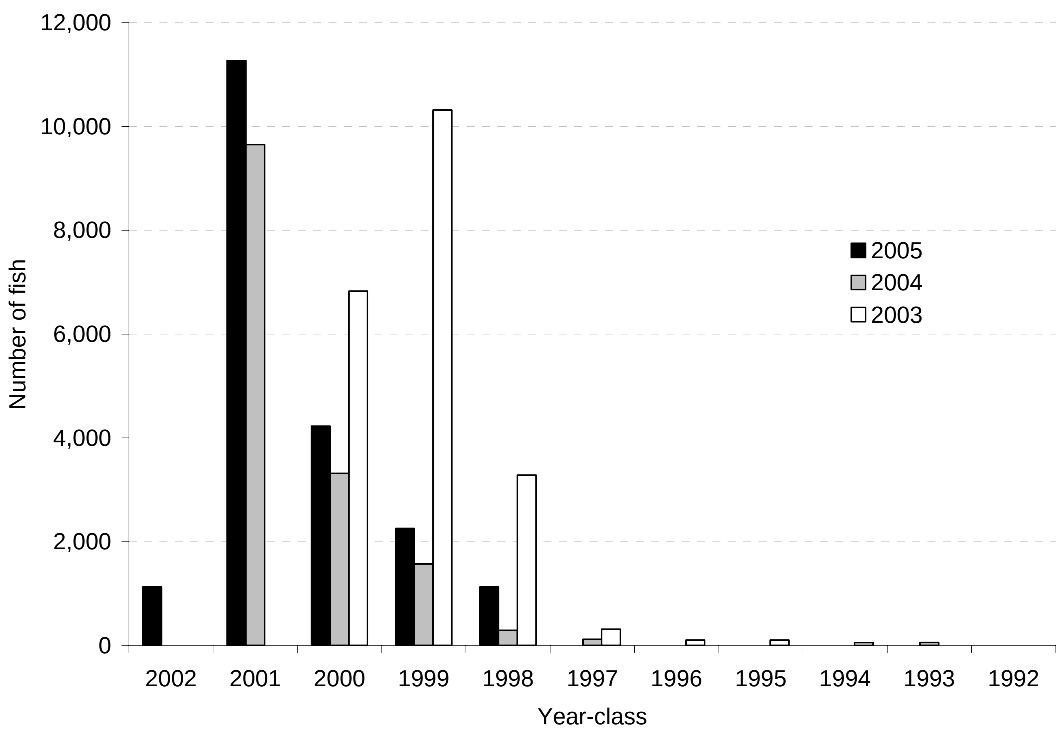


Figure 1.2. Year-class contributions to the spawning run of striped bass to the Northwest Miramichi between 2003 and 2005.

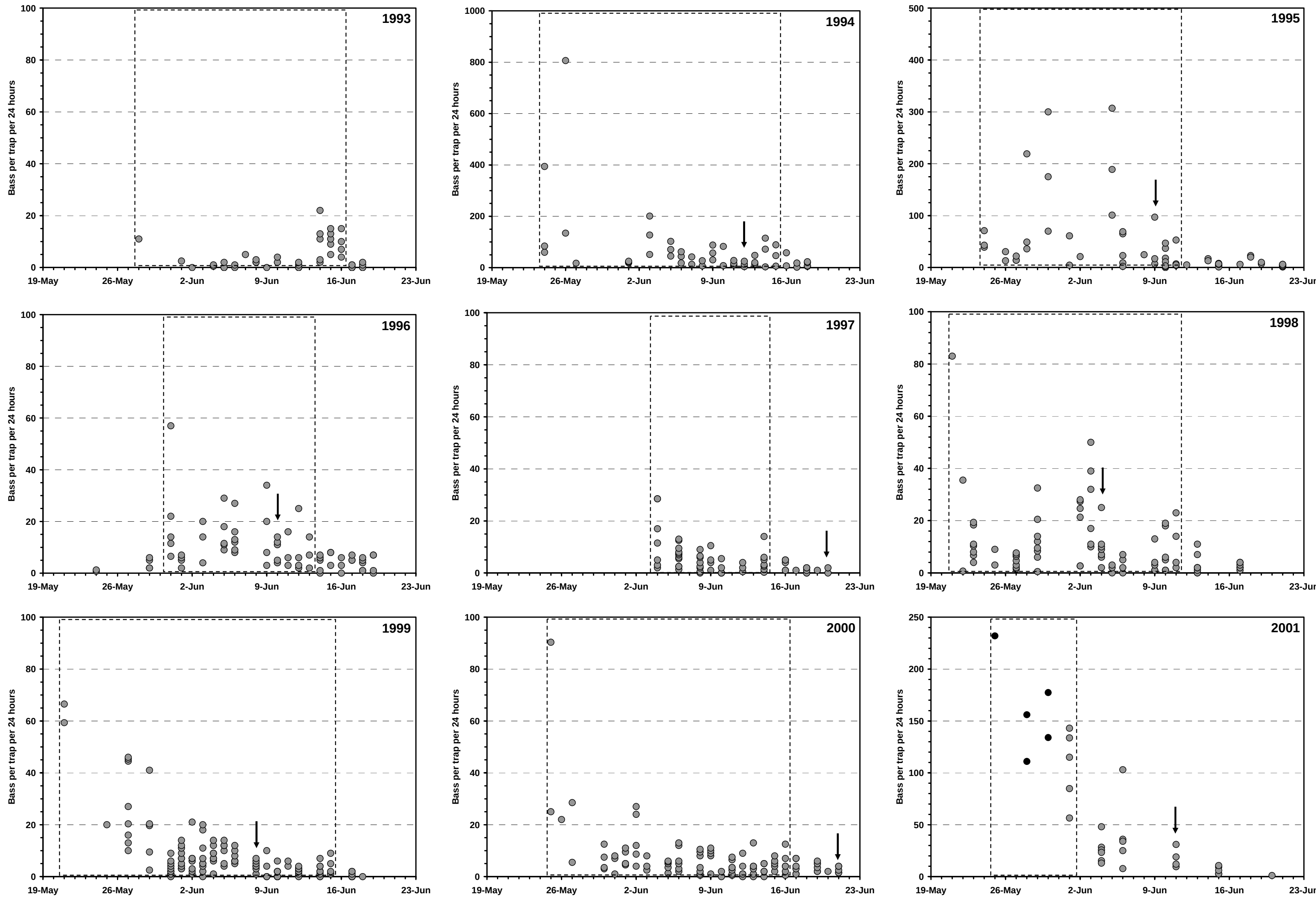


Figure 1.3. Catch of striped bass per net per 24 hour period in the gaspereau fishery of the Northwest Miramichi, 1993 to 2005. The arrow defines the date at which the mark and recapture experiment was considered complete. The dashed rectangle represents the period encompassing the upper quartile of the annual CPUE data. Darkened points represent catches on dates when an individual fisher was contracted to fish his gear specifically for marking purposes early in the season.

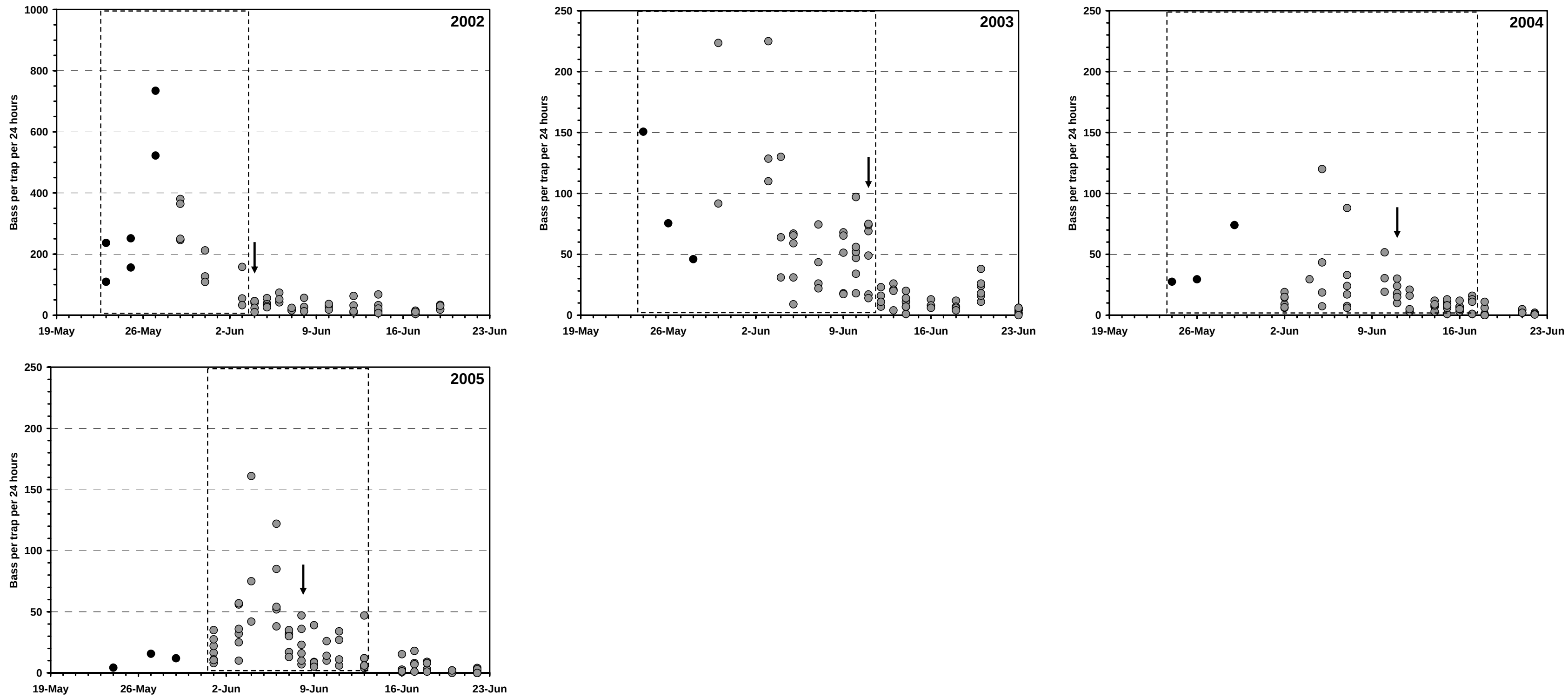


Figure 1.3 (continued). Catch of striped per net per 24 hour period in the gaspereau fishery of the Northwest Miramichi, 1993 to 2005. The arrow defines the date at which the mark and recapture experiment was considered complete. The dashed rectangle represents the period encompassing the upper quartile of the annual CPUE data. Darkened points represent catches on dates when an individual fisher was contracted to fish his gear specifically for marking purposes early in the season.

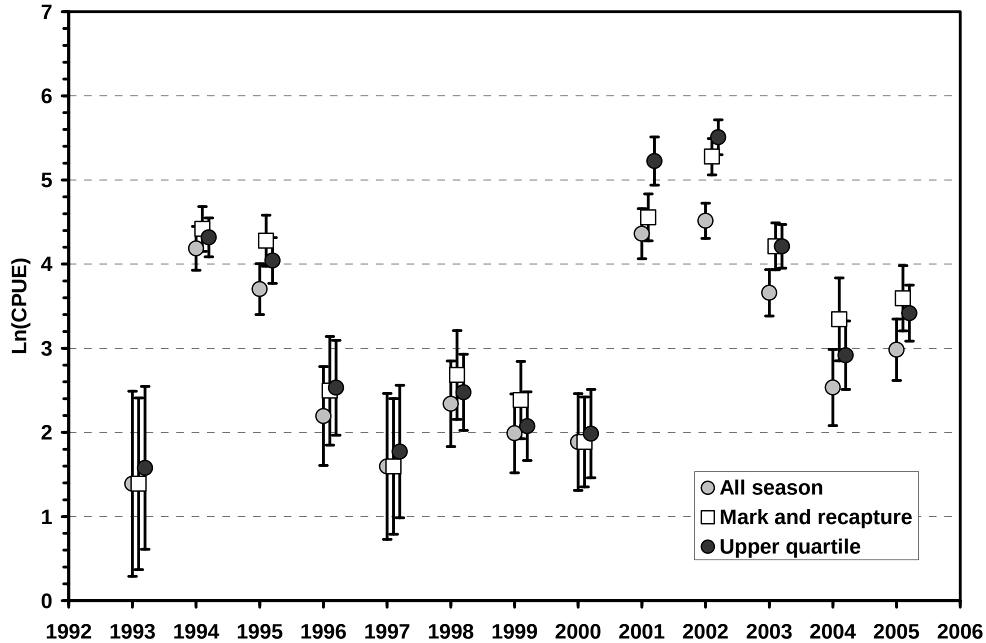


Figure 1.4. Abundance index (Ln(CPUE) mean +/- 2 standard errors) of striped bass spawners in the gaspereau trapnets of the Northwest Miramichi, 1993 to 2005. All season refers to the CPUE derived using the observations over the entire sampling period. Mark and recapture refers to the CPUE based on the sampling interval from the start of sampling to the end date of the mark and recapture experiment. Upper quartile is the CPUE derived using the period which encompassed the upper quartile of the CPUE observations annually.

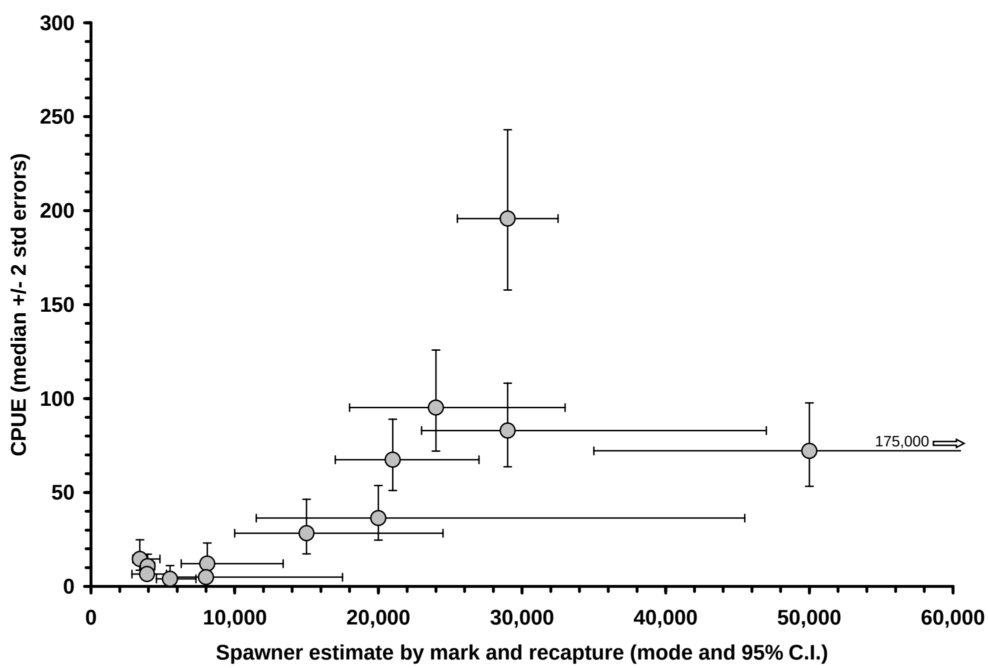


Figure 1.5. Association between spawner estimates from CPUE and mark-recapture for the same year. The CPUE estimate is based on catches during the mark-recapture experiment.

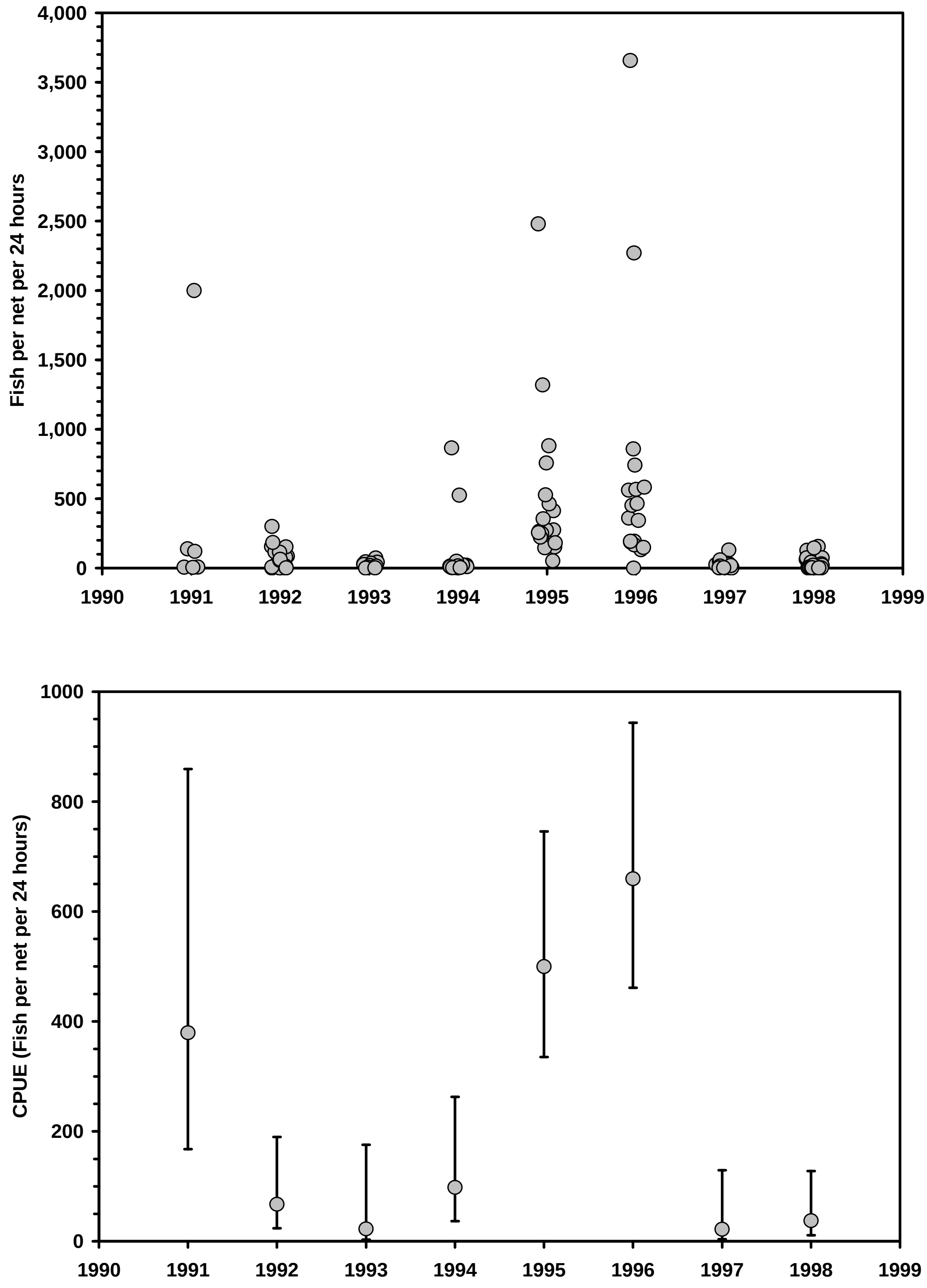


Figure 1.6. Fall abundance index of young-of-the-year striped bass as inferred from bycatch in the fall open water smelt fishery of the Miramichi River. The upper panel summarizes the observations by year (jittered by year to reduce overlap) and the lower panel illustrates the CPUE as derived from the General Linear Model analysis with only year as an explanatory variable.

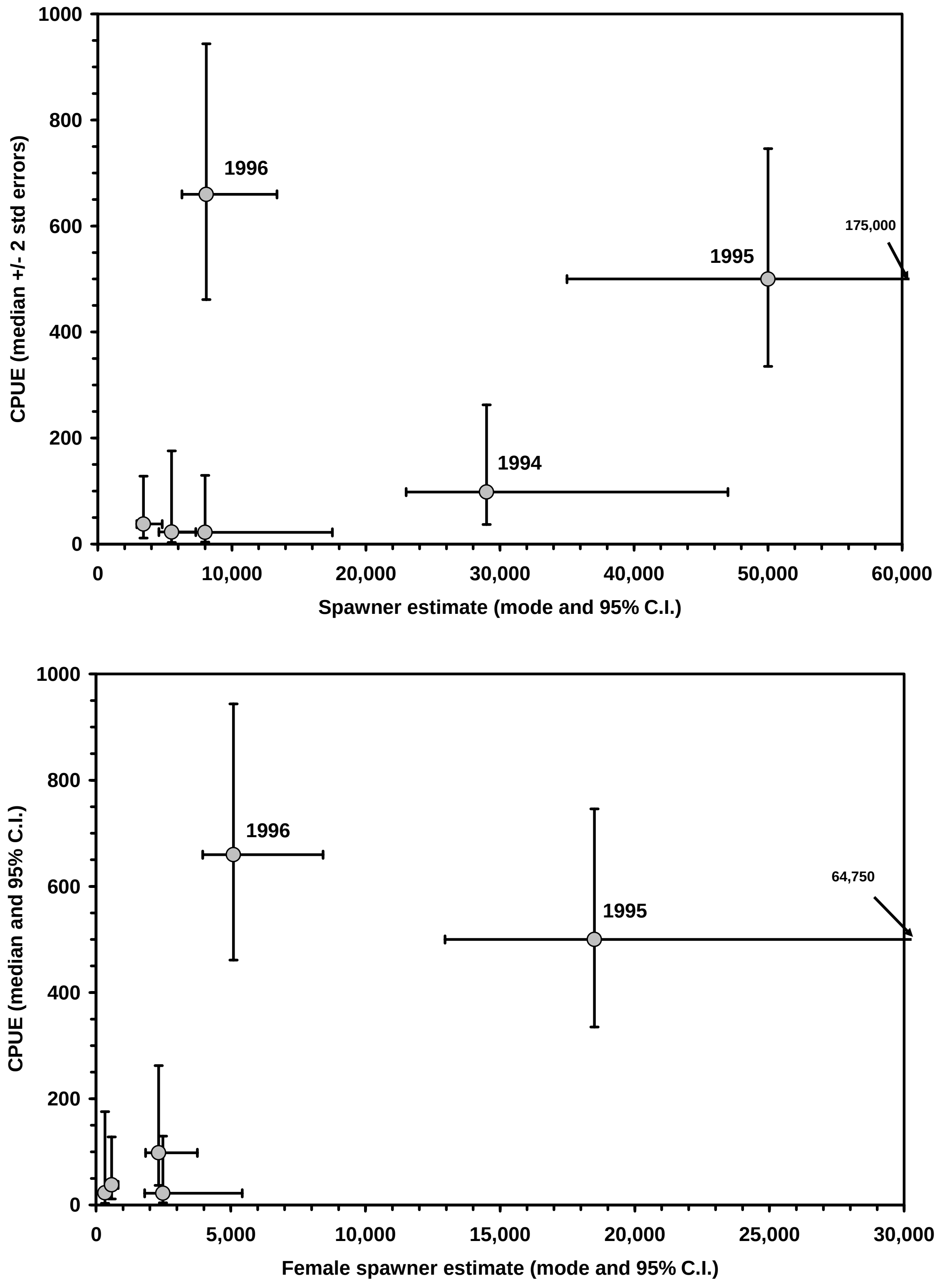


Figure 1.7. Association between the fall young-of-the-year abundance index (catch per net per 24 hours) and the estimated abundance of spawners (upper panel) and female spawners (lower panel) for the corresponding year.

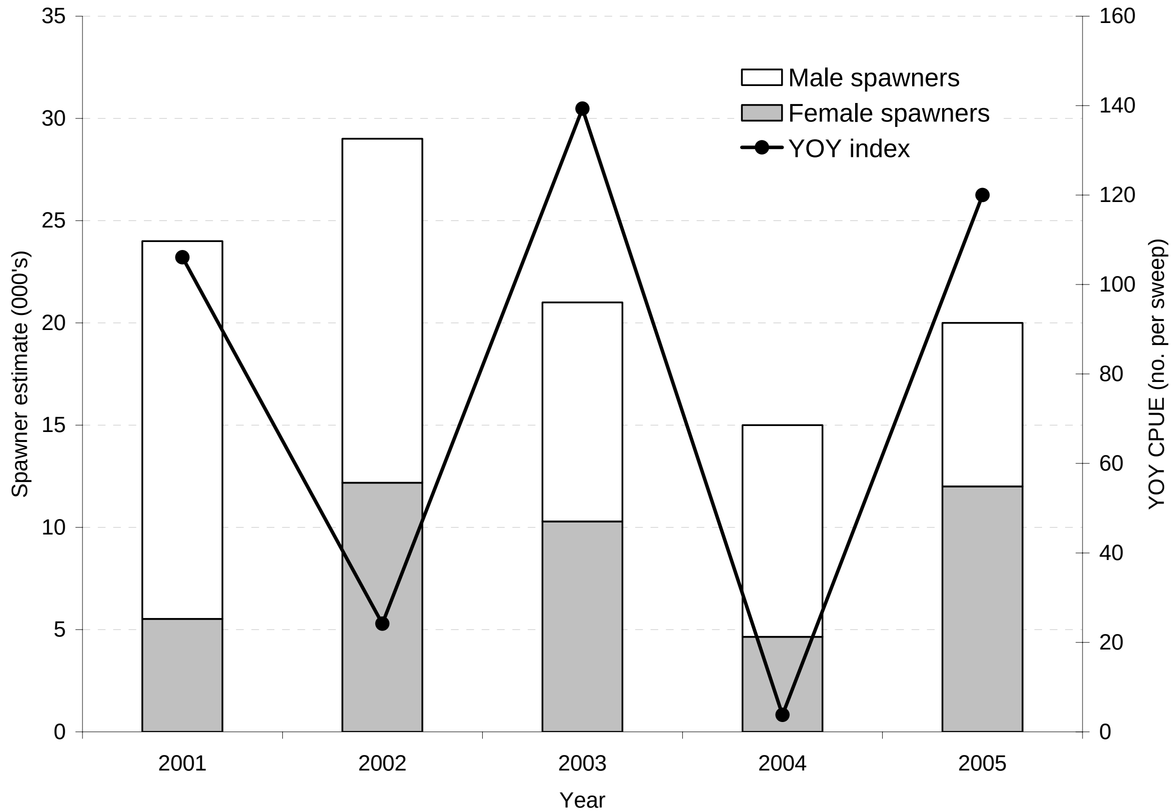


Figure 1.8. Relationship between YOY abundance derived from beach seine catches and spawner estimates based on mark recapture experiments.

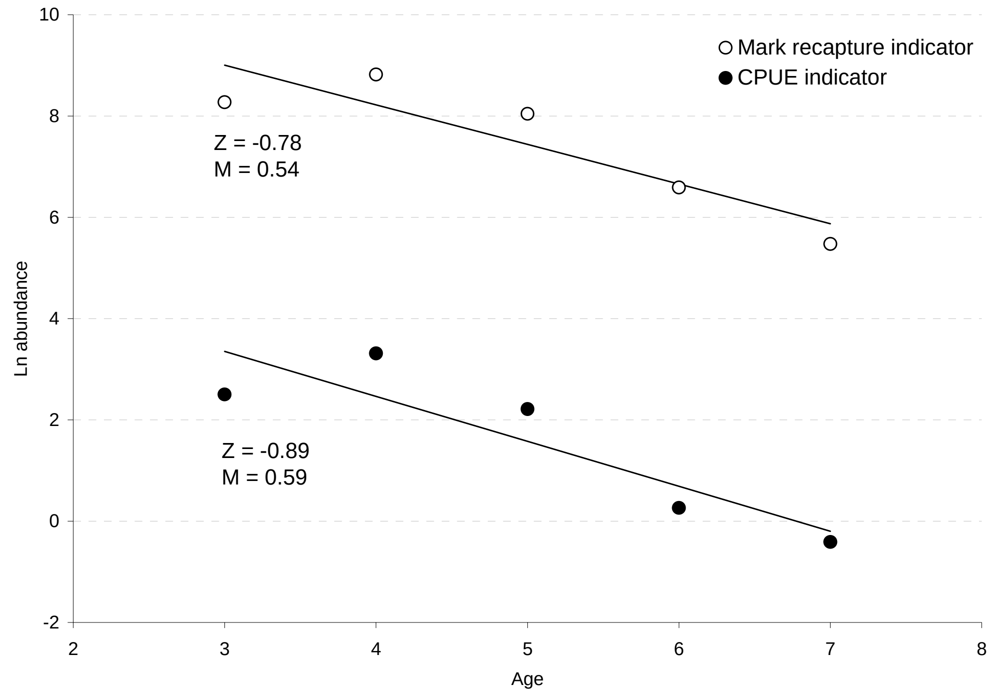


Figure 1.9. Average mortality of the southern Gulf striped bass using both the mark-recapture and CPUE spawner abundance indicators. Analysis includes only data collected from 1997 to 2005 after commercial fishing was closed.

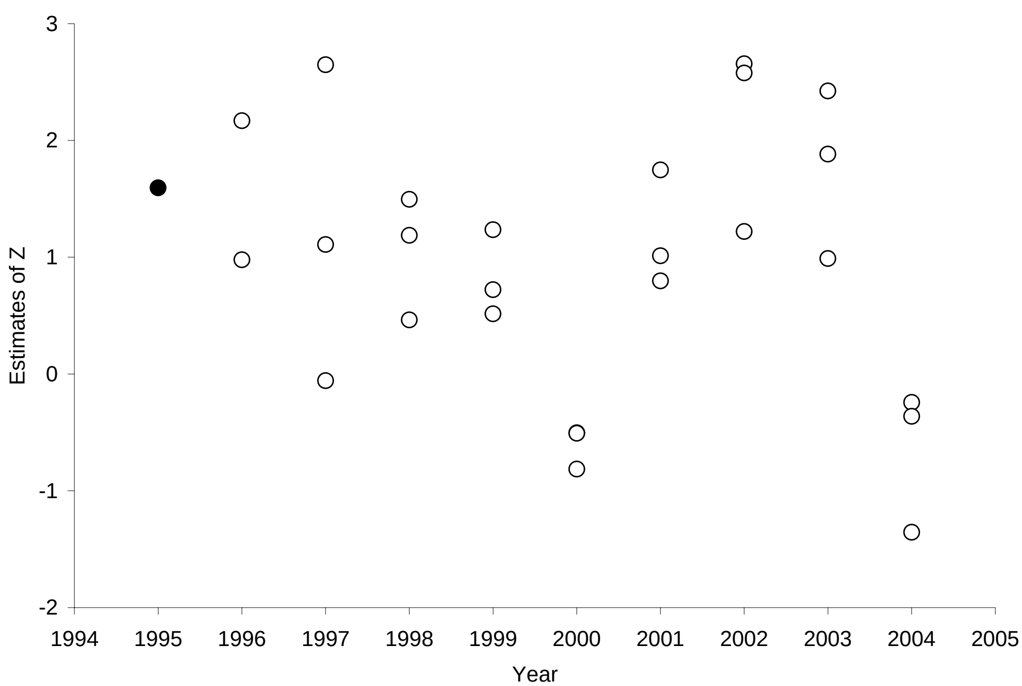
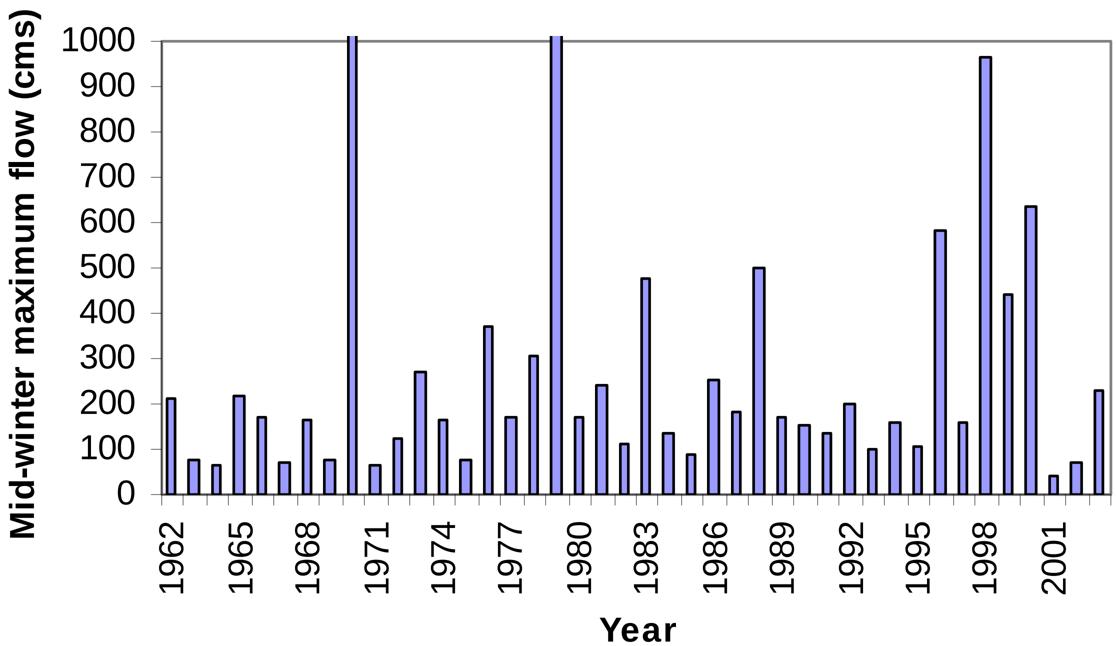


Figure 1.10. Individual Z estimates based on striped bass aged 4 to 6 only. Solid symbol indicates Z estimate when commercial harvesting was still permitted.



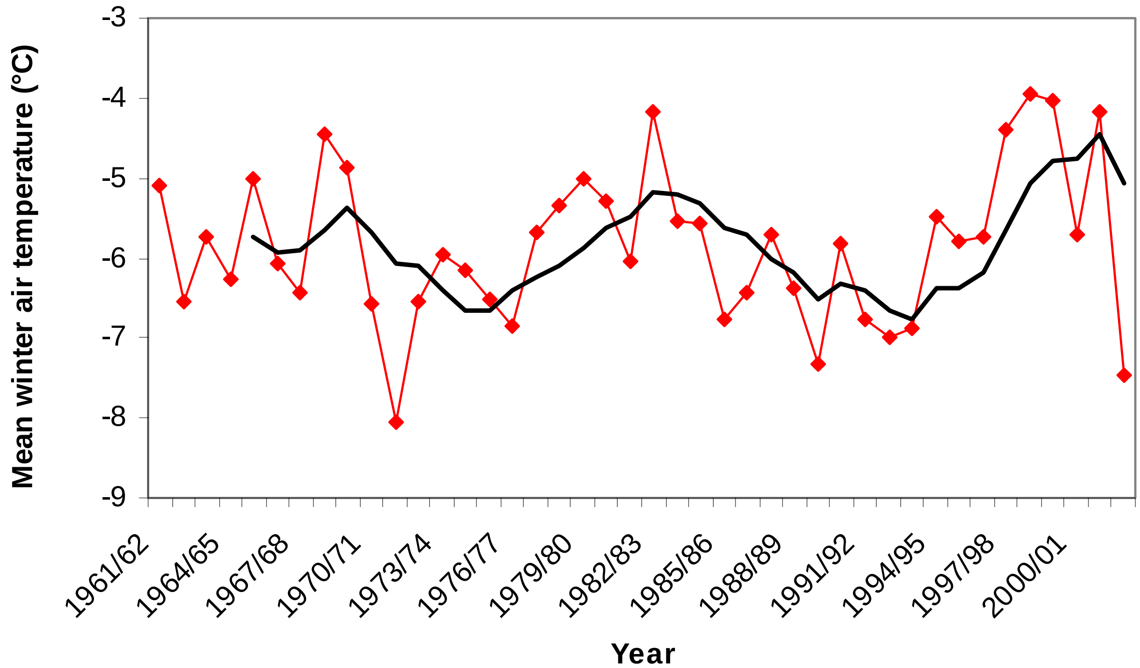


Figure 1.11. Maximum daily discharge in the winter months (Jan. to March) (upper panel) and mean winter air temperatures (Nov. to March) within the Miramichi area, 1961 to 2003 (lower panel). Solid line represents the 5 year running mean for winter air temperature.

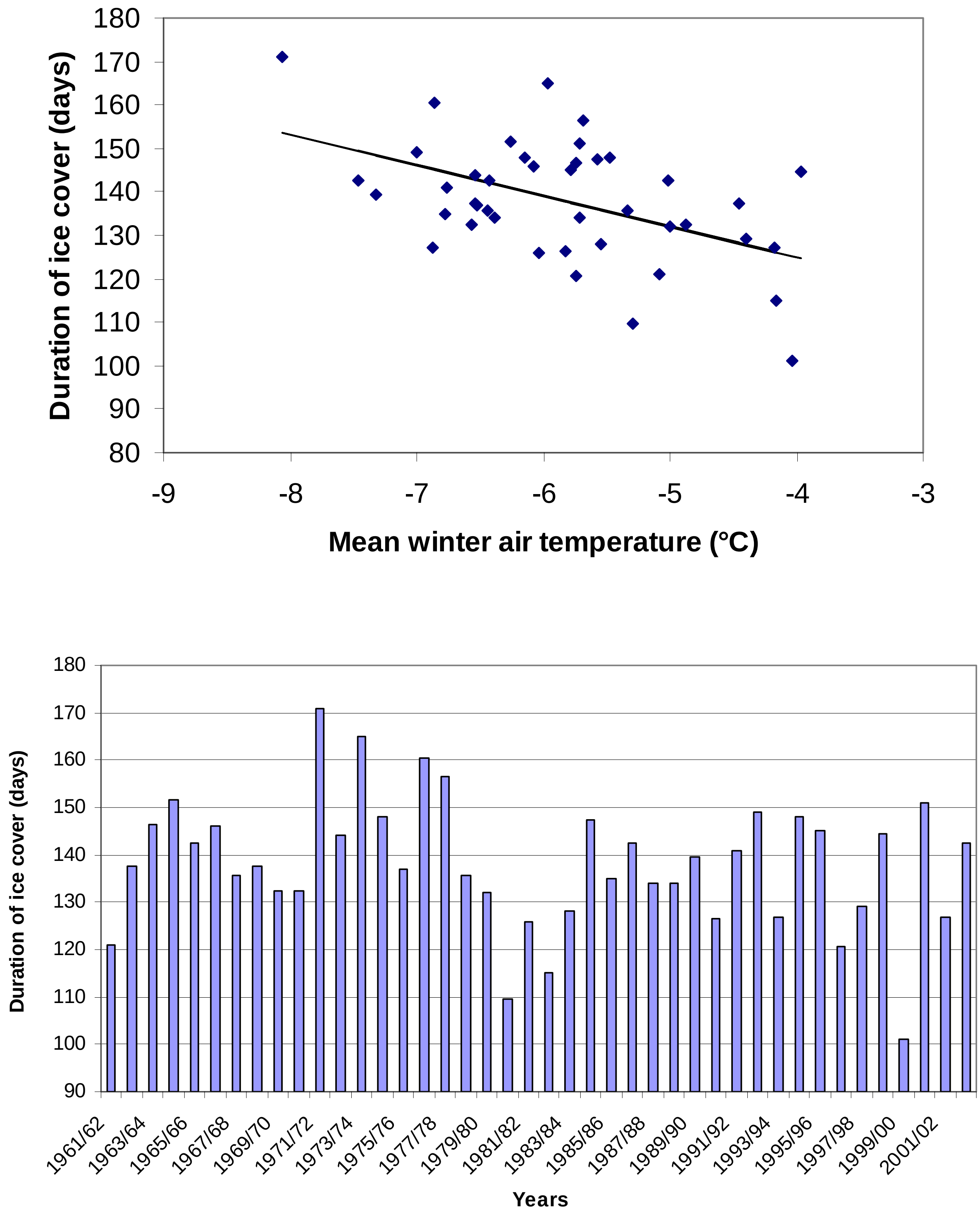


Figure 1.12. Mean air temperature in the winter (Nov. to March) versus duration of ice cover (days) (upper panel) and the duration of ice cover for the winters of 1961/62 to 2002/03 (lower panel) in the Miramichi area.

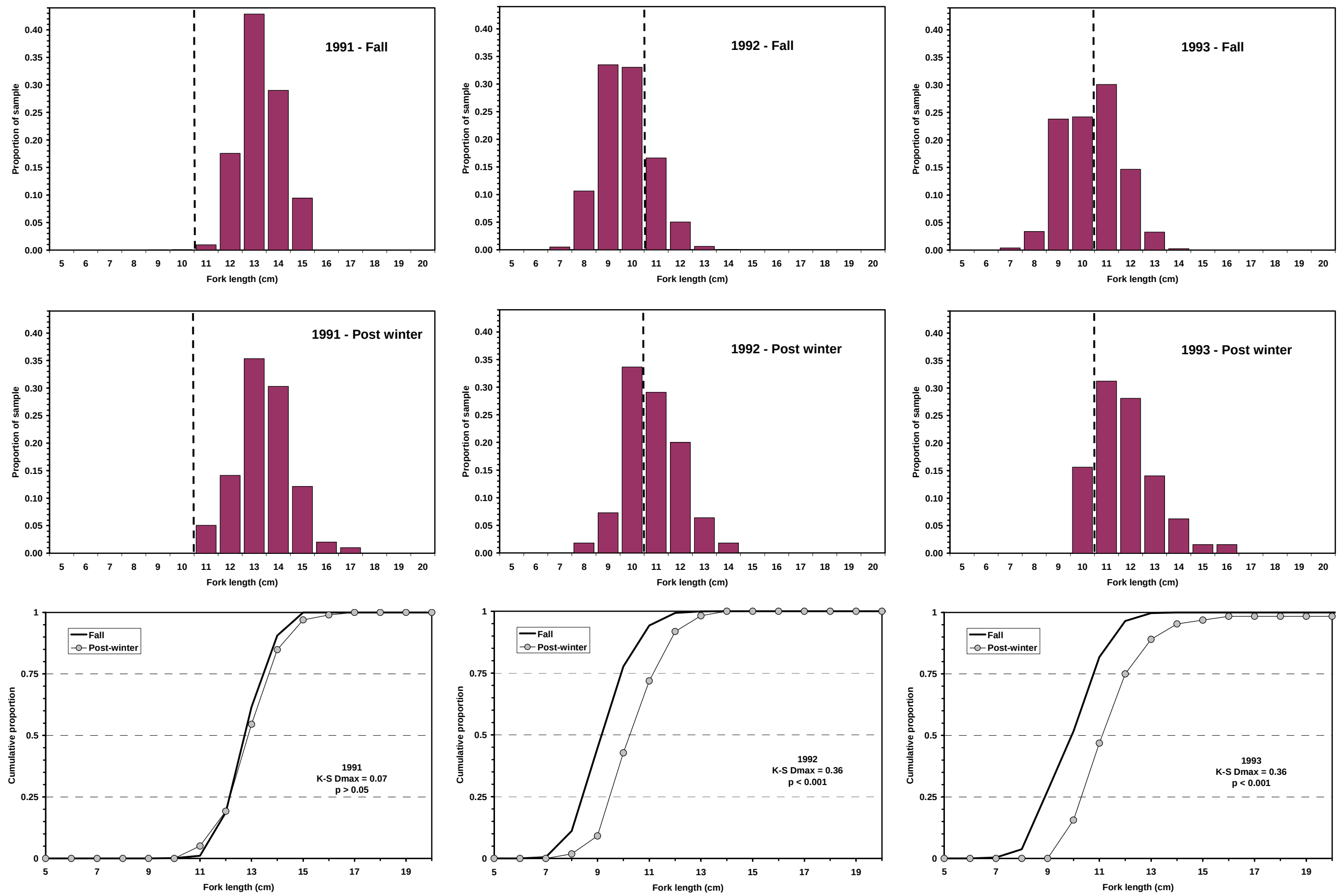


Figure 1.13. Length frequency distributions (4.5 to 5.4 = 5 cm group) of the 1991 to 1993 cohorts of juvenile striped bass in the fall open water smelt fishery of the Miramichi River (upper panels) and length frequency distributions of the survivors based on back-calculated size-at-age from the scales of striped bass sampled at age 2 years in 1993 to 1995 (middle panel) and cumulative distributions (lower panel). The vertical hatched lines were included for reference between the pre and post winter length distributions.

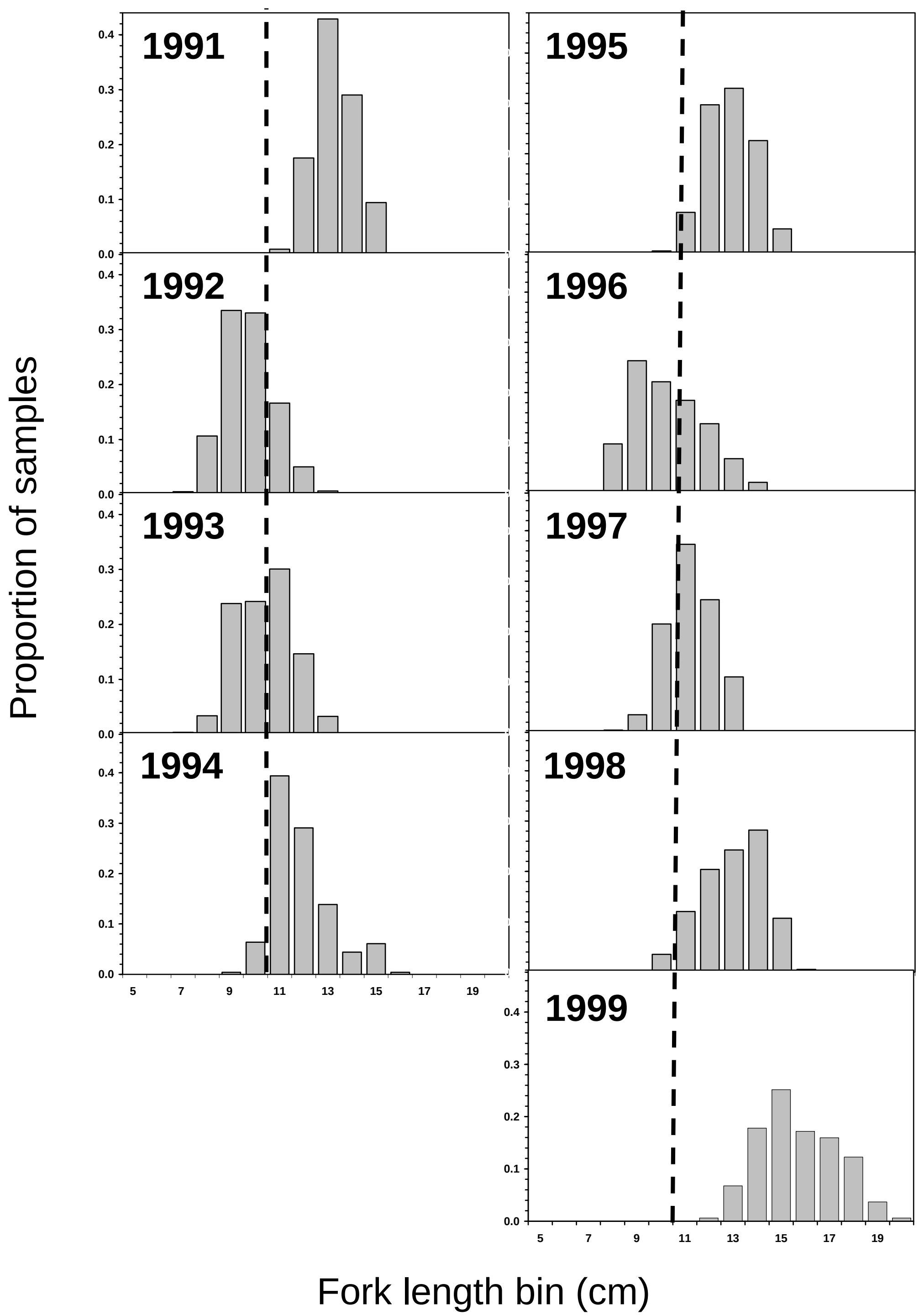
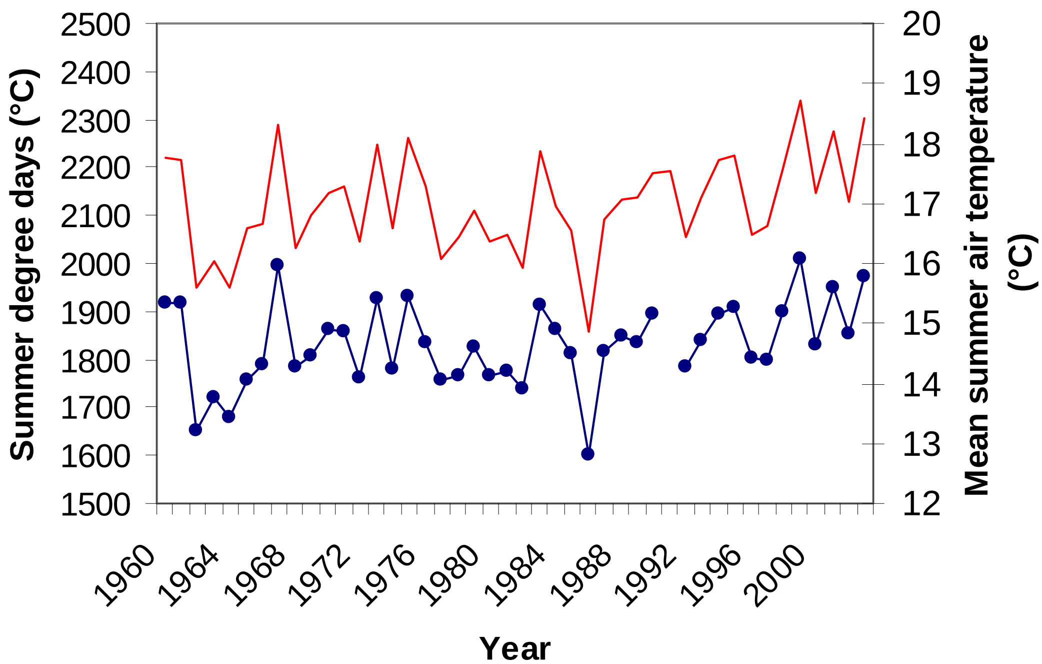


Figure 1.14. Length frequencies of young-of-the-year striped bass as sampled in the fall open-water smelt fishery of Miramichi Bay (1991 to 1998) and the Tabusintac estuary (1999). The vertical hatched lines were included to demonstrate the size variability among years.



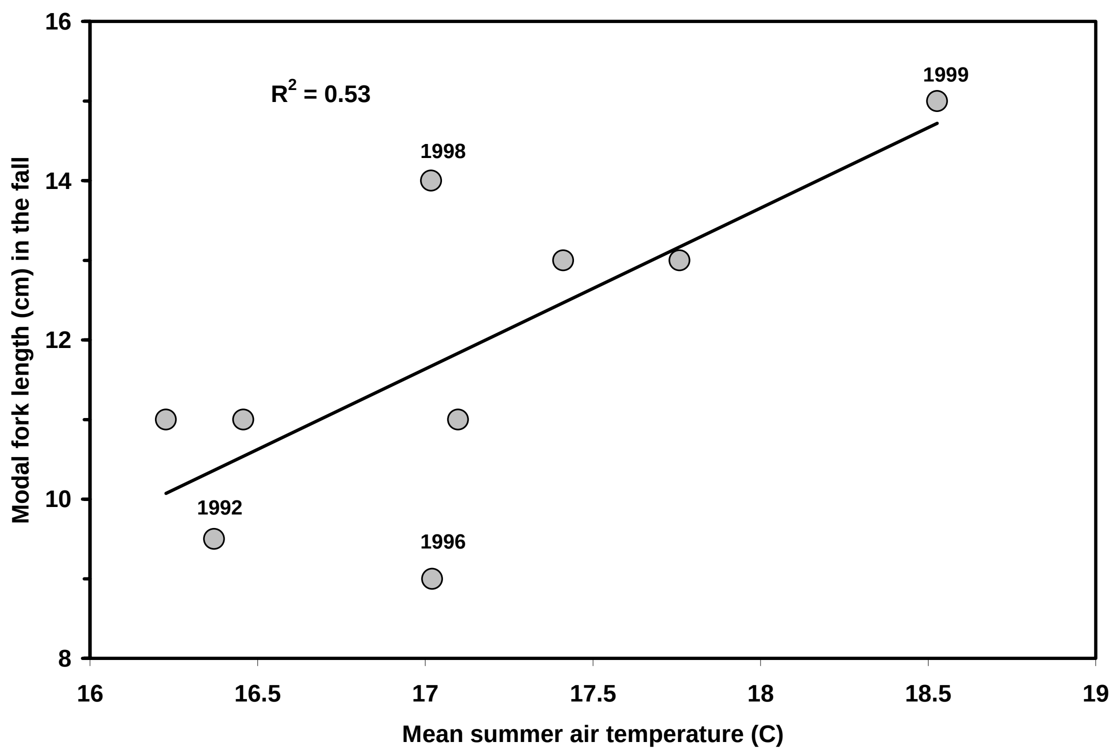


Figure 1.15. Degree days and mean summer air temperatures in Miramichi for 1960 to 2003 (upper panel) and association between modal length of YOY in the fall and mean summer air temperature for the 1991 to 1999 cohorts (bottom panel).

Figure 1.16. Place names of the southern Gulf of St. Lawrence indicating area of occupancy and locations where striped bass have been sampled.

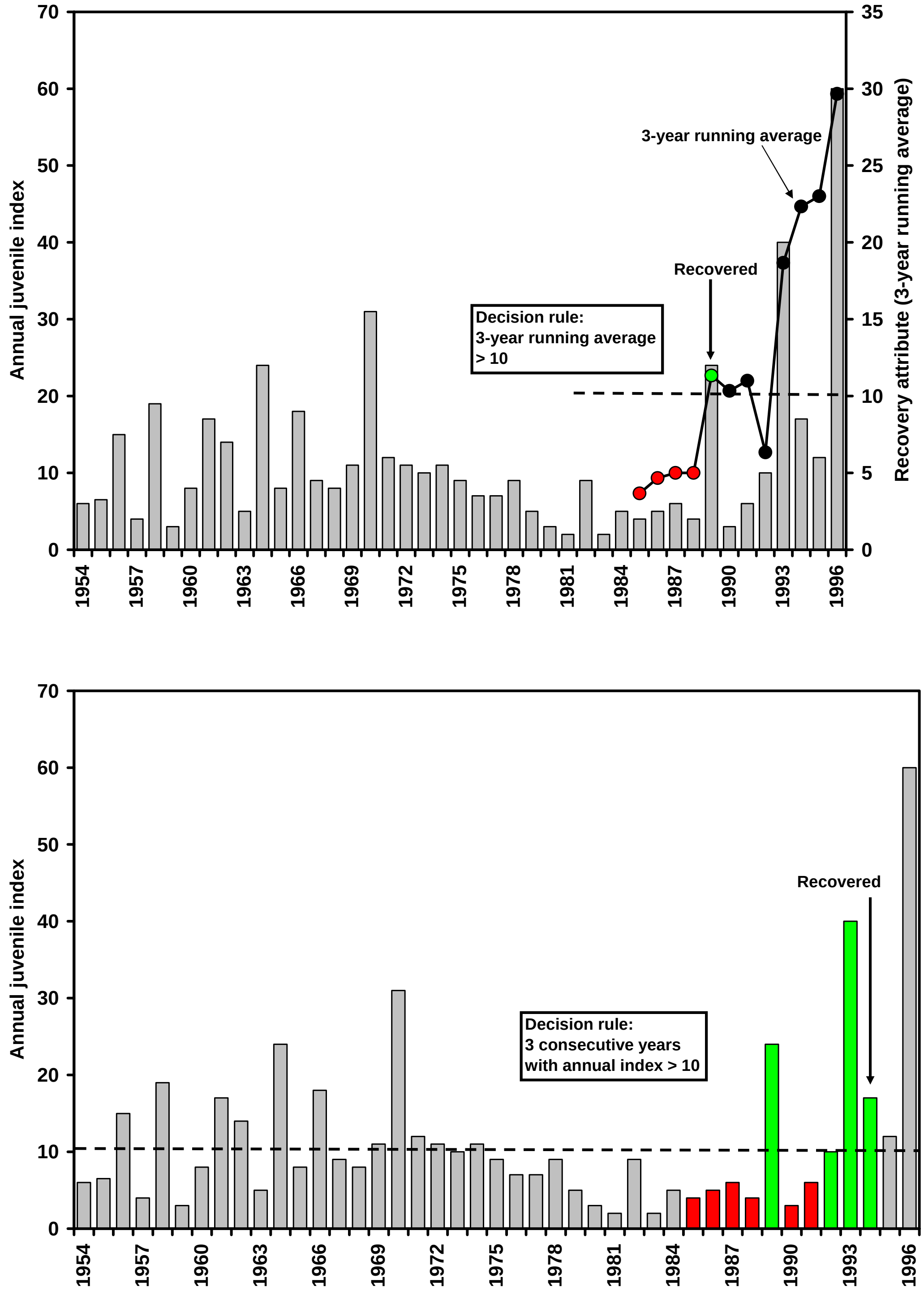


Figure 2.1. Illustrative examples of end point decision rules (or compliance rules) of stock recovery attributes and their application to the case of the Chesapeake Bay striped bass as described in Richards and Rago (1999). The upper panel illustrates the conclusion that the stock was recovered in 1989 based on the three-year running average of the annual index exceeding the long term average of the attribute. The lower panel illustrates an alternative end point decision rule which would have concluded that recovery occurred in 1994 after the annual index exceeded the recovery objective for three consecutive years.

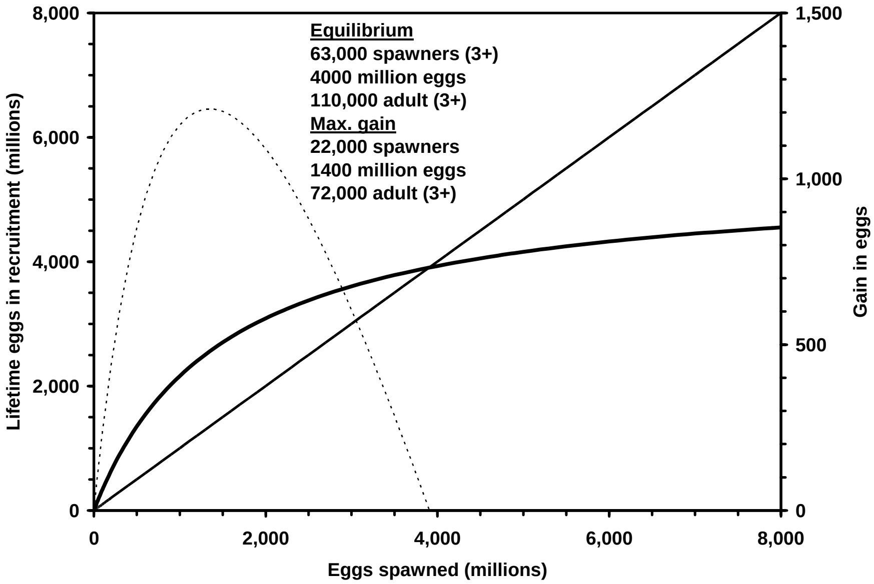


Figure 2.2. Beverton-Holt stock and recruitment relationship for striped bass eggs to young-of-the-year abundance in the fall based on density independent survival of 0.1% and young-of-the-year mean carrying capacity of 1.5 million fish. Also shown is the gain in eggs (lifetime egg production minus spawning eggs) line relative to eggs spawned.

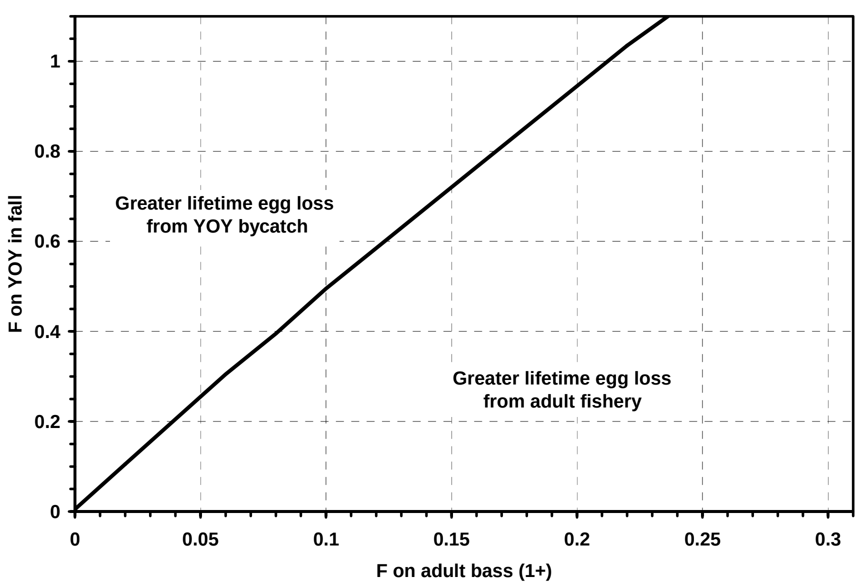
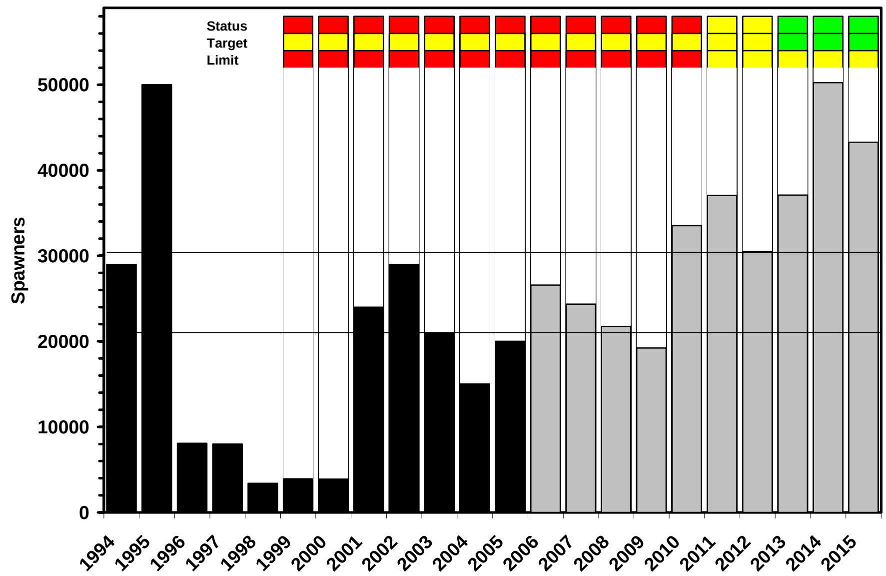


Figure 2.3. Lifetime egg loss equivalents of fishing YOY in the fall versus fishing bass age 1 and older. The diagonal line is the equivalence line for which lifetime egg loss is the same at the F described for YOY versus for age one and older bass. For YOY, overwinter survival (M) occurs over six months, of which one month occurs simultaneously with F. For age one and older bass, F is the same at all ages, occurs simultaneously with M, and all age groups 1 year and older are fully recruited to the fishery.



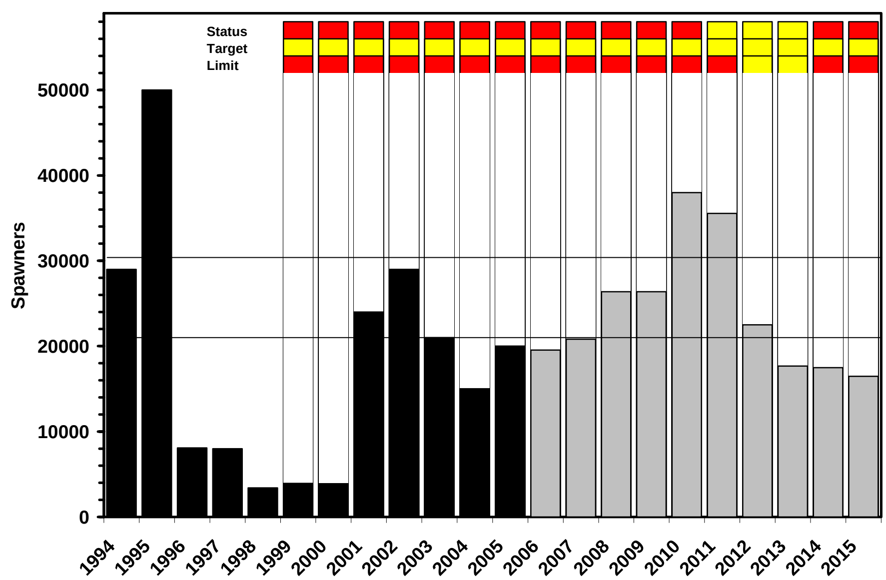


Figure 2.4. Application of traffic light summary to the spawner abundance attribute to illustrate status relative to the limit, the target and overall for striped bass from the southern Gulf. The graphs show two stochastic realizations under fishing on YOY (F=0.22) and adults (F = 0.044). The black bars are the modes of the estimated abundance of spawners based on mark and recapture experiments, 1994 to 2005. The grey bars are simulated values based on the simulations initiated using the spawner estimates for 1994 to 1996. The limit compliance rule is: red (0) spawners < 21,600 in more than one year out of six, yellow (1) otherwise. The target compliance rule is: green (2) if spawners > 31,200 spawners in 3 or more out of 6 consecutive years, yellow (1) otherwise. The status is evaluated as the product of the limit and target values.

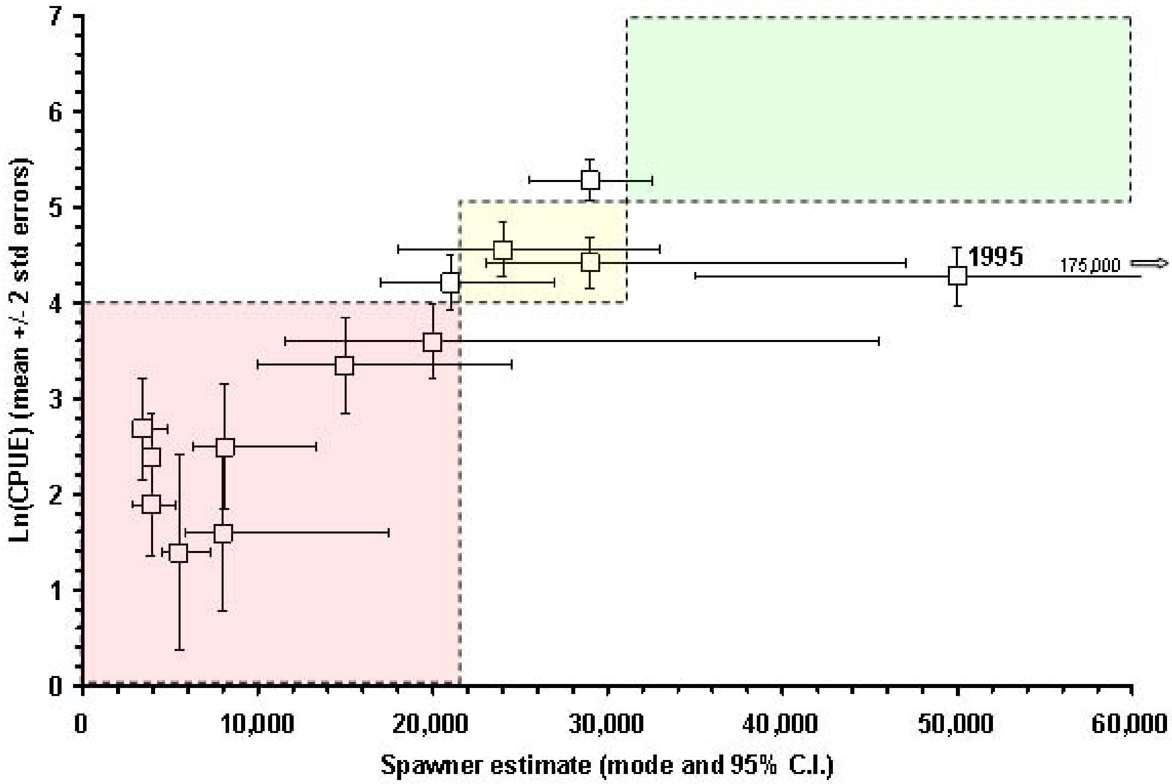


Figure 2.5. Association between spawner estimates from CPUE and mark-recapture experiments for the same year in the gaspereau fishery of the NW Miramichi. The CPUE estimate is based on catches during the mark-recapture experiment. The rectangles describe the corresponding red, yellow and green zones for defining the limit and target recovery objectives.

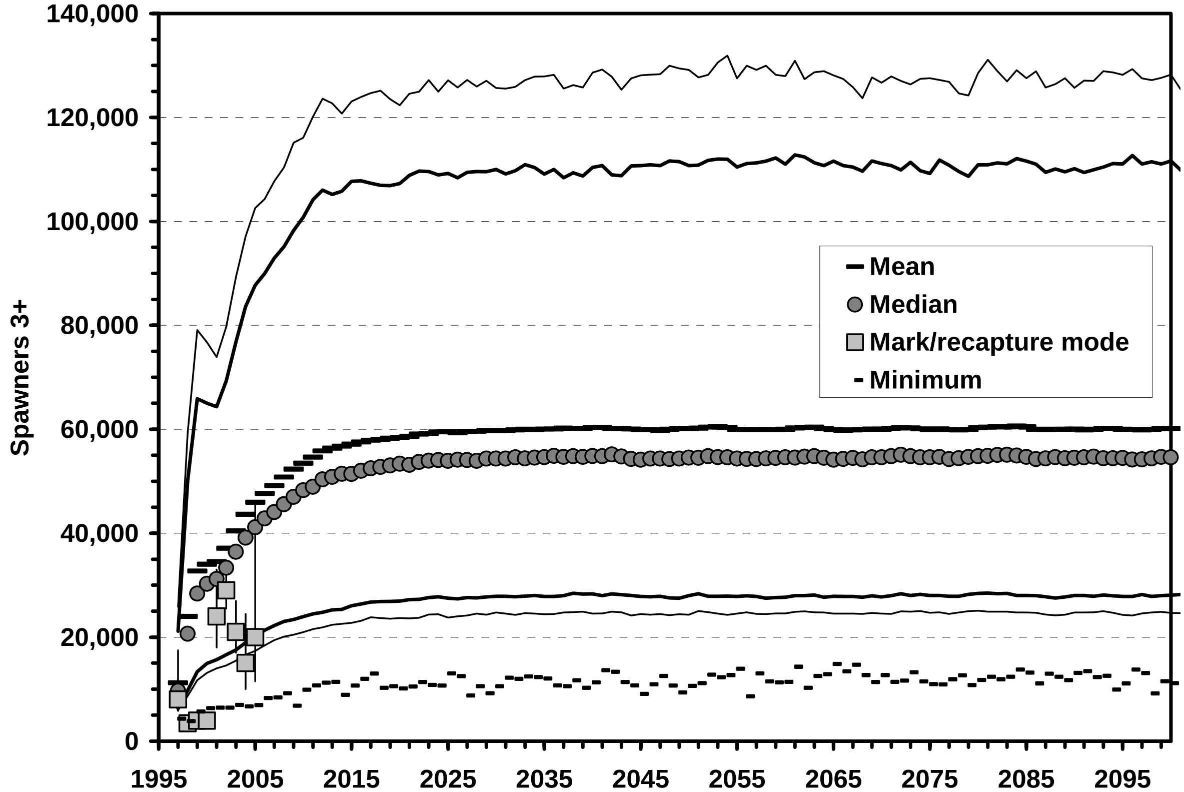


Figure 2.6. Trajectories of modeled spawner abundance of striped bass from the southern Gulf resulting from stochastic variation in survival in the absence of directed fisheries. Upper and lower lines represent 97.5 and 95th percentiles, 5 and 2.5th percentiles, respectively. Error bars around the mark and recapture modes are 95% confidence interval range for the spawner estimates, 1997 to 2005.

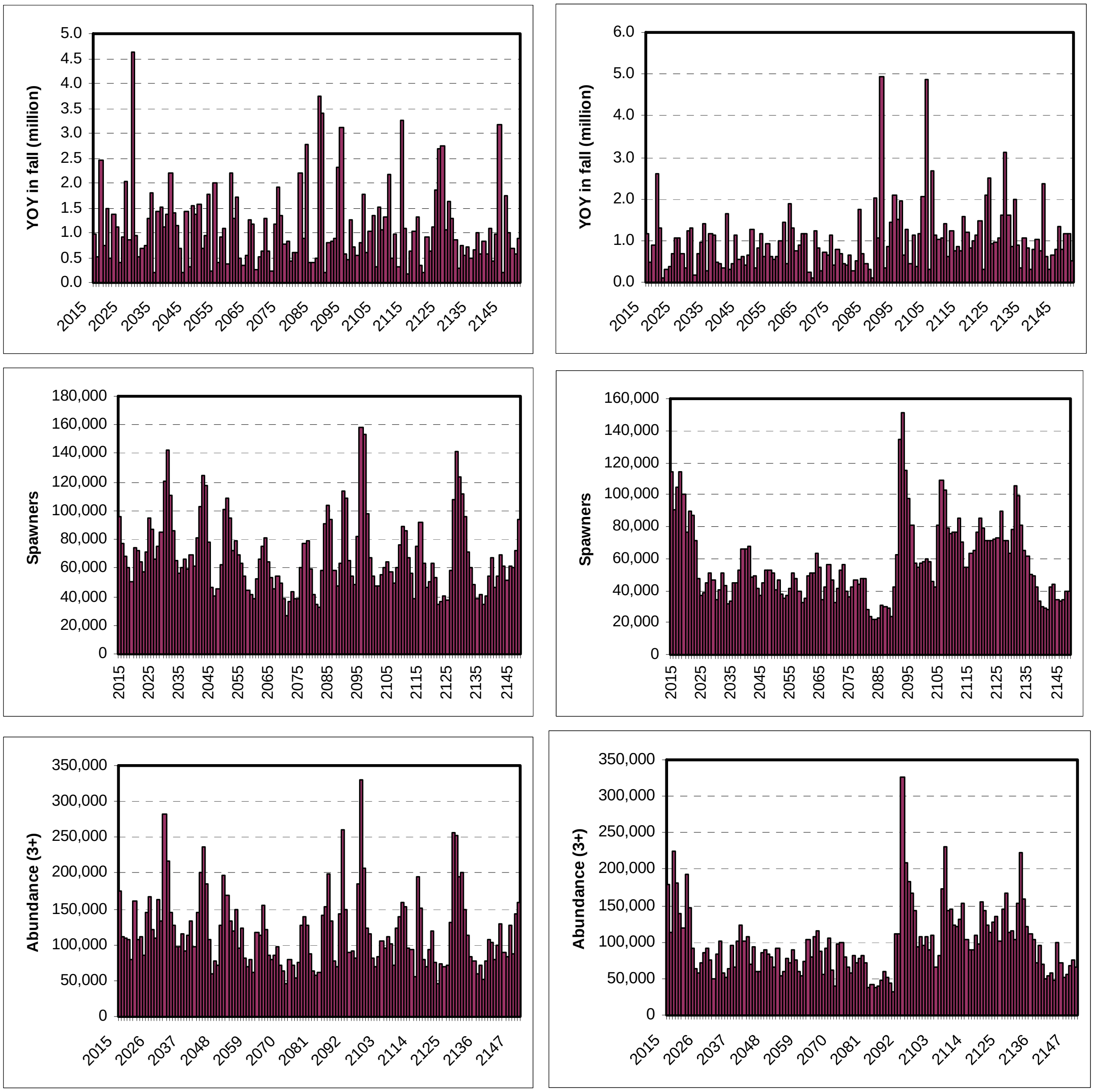


Figure 2.7. Examples of individual trajectories (left, right panels) of YOY abundance, spawner abundance and total adult abundance generated by the life history model with stochasticity in the absence of directed fisheries.

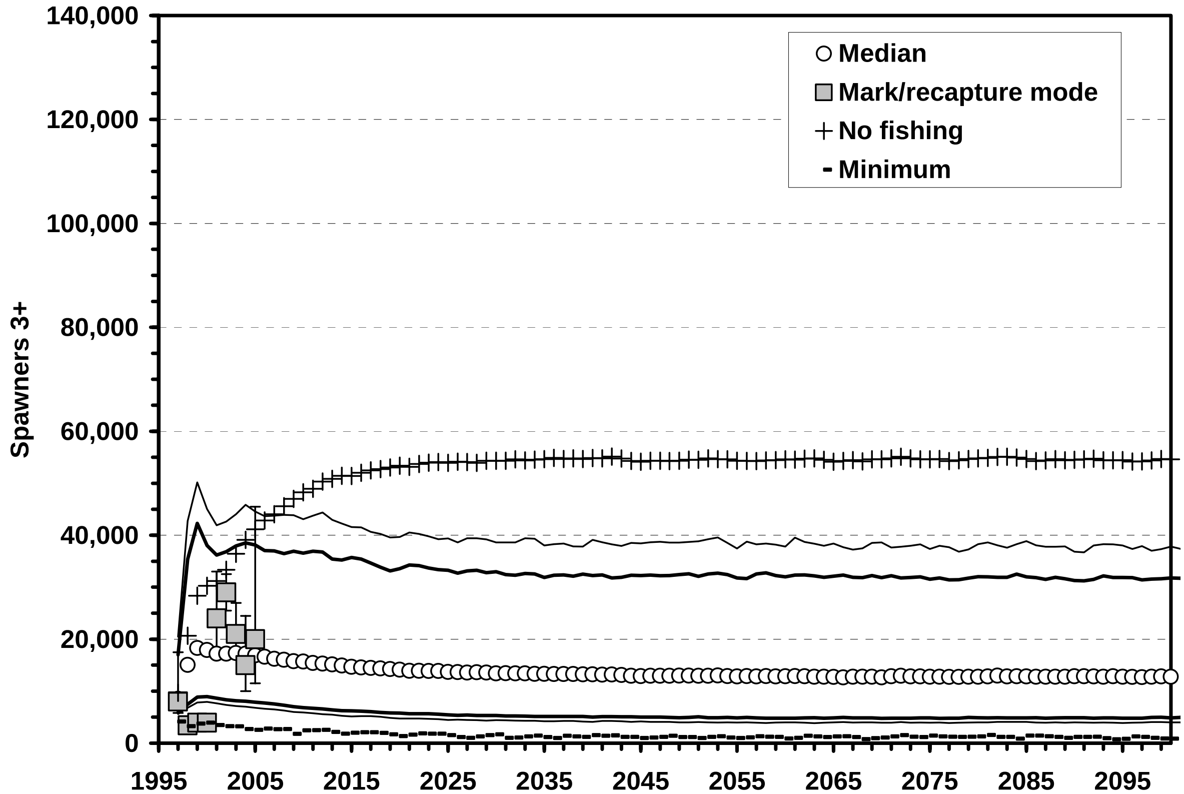


Figure 2.8. Trajectories of modeled spawner abundance of striped bass from the southern Gulf resulting from stochastic variation in survival with bycatch of young-of-the-year at a rate of F = 0.1 and fishing on adults age 2 years and older of F = 0.2. Upper and lower lines represent 97.5 and 95th percentiles, 5 and 2.5th percentiles, respectively. Error bars around the mark and recapture modes are 95% confidence interval range for the spawner estimates, 1997 to 2005.

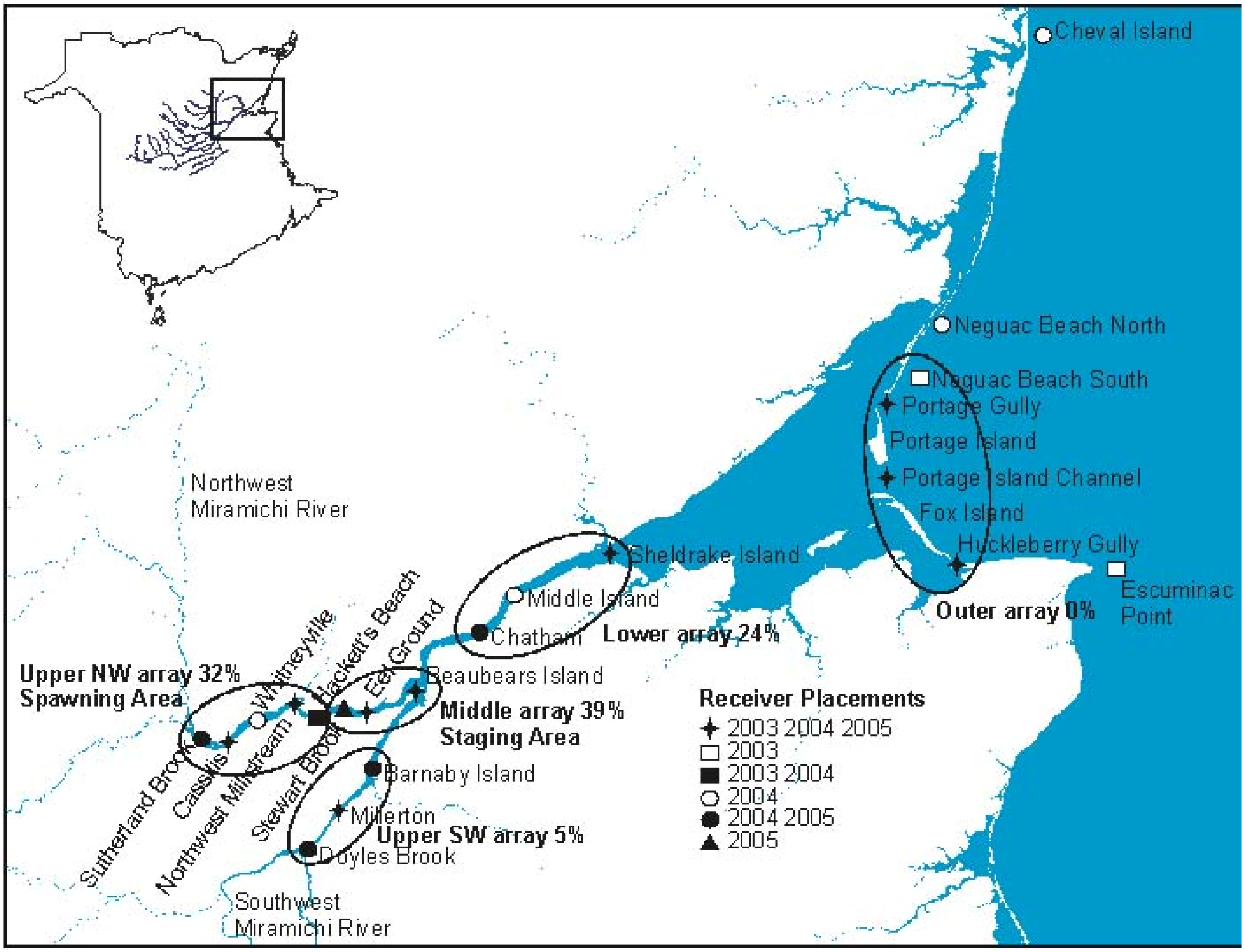


Figure 2.9. Preliminary analysis of the proportion of time (bolded text) occupied by implanted striped bass in the Miramichi system in 2004-05.

Appendix A. Remit for striped bass RPA held in Moncton on November 30-December 2, 2005.

Recovery Potential Assessment
Striped Bass Populations of Miramichi, Bay of Fundy and St. Lawrence Estuary

Meeting of the Gulf Regional Advisory Process

Gulf Fisheries Centre,
Miramichi Boardroom (6th floor)
Moncton, New Brunswick

November 30 – December 2, 2005

REMIT

Background

In November 2004, three designatable units of Striped Bass were considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Miramichi and Bay of Fundy DUs were both designated as Threatened (TH) while that of the St. Lawrence Estuary was designated as Extirpated (EX). These DUs are being considered for listing in Schedule 1 of the Canada's Species at Risk Act (SARA). For DUs designated and listed under SARA as EN or TH, activities that would harm the species would be prohibited and a recovery plan would be required. Until such a plan is available, section 73 (2) of SARA authorizes competent Ministers to permit otherwise prohibited activities affecting a listed wildlife species, any part of its critical habitat, or the residences of its individuals. These activities can only be authorized, 1) if the activity is scientific research relating to the conservation of the species and conducted by qualified persons, 2) or benefits the species 3) or is required to enhance its chances of survival in the wild, 4) or affecting the species is incidental to the carrying out of the activity.

Decisions made on permitting of incidental harm and in support of recovery planning need to be informed by the impact of human activities on the species, alternatives and mitigation measures to these and the potential for recovery. An evaluation framework, consisting of three phases (species status, scope for human induced harm and mitigation) has been established by DFO to allow determination of whether or not SARA incidental harm permits can be issued.

To inform decisions relating to listing of the Miramichi and Bay of Fundy Striped Bass DUs and their recovery planning, the meeting participants will review analyses prepared to meet the objectives stated below.

Objectives

For each Designable Unit (DU):

Phase I: Species Status

1. Evaluate present species trajectory
2. Evaluate present species status
3. Evaluate expected order of magnitude / target for recovery
4. Evaluate expected general time frame for recovery to the target
5. Evaluate Residence-Habitat Requirements

Phase II: Scope for Human – Induced Mortality

Évaluation du Potentiel de Rétablissement
Populations du bar rayé de la Miramichi, baie de Fundy et de l'estuaire du Saint Laurent

Processus Consultatif Régional de la région du Golfe

Centre des pêches du Golfe,
Salle Miramichi (6ième étage)
Moncton, Nouveau Brunswick

Du 30 novembre au 2 décembre 2005

MANDAT

Contexte

En novembre 2004, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a considéré trois populations (unité désignable : UD) de bar rayé. Les populations de la Miramichi et de la Baie de Fundy ont été toutes deux désignées comme menacées (M) tandis que celle de l'estuaire du Saint Laurent a été désignée comme disparue du Canada (DC) par COSEPAC. Ces populations sont présentement considérées pour être ajoutées à la l'annexe 1 de la loi sur les espèces en péril (LEP) du Canada. Pour les populations désignées et inscrites sous la LEP comme menacées (M) ou en voie de disparition (VD), les activités qui nuiraient à l'espèce seraient interdites et un plan de rétablissement serait exigé. Jusqu'à ce qu'un tel plan ne soit disponible, la section 73 (2) de la LEP autorise des Ministres assignés de permettre des activités normalement interdites affectant une espèce inscrite, son habitat critique, ou les résidences de ses individus. Ces activités ne peuvent être autorisées que si les activités; 1) sont des travaux scientifiques visant à la conservation de l'espèce et sont conduites par des personnes qualifiées, 2) ou bénéficieront l'espèce 3) ou son nécessaires pour augmenter ses chances de survie en milieu naturel, 4) ou l'impact sur l'espèce est accidentel et le résultat d'activités fortuites.

La décision de permettre des dommages fortuits et du besoin d'un plan de rétablissement, doivent prendre en considération les impacts des activités humaines sur l'espèce, les alternatives et les mesures permettant d'atténuer ces impacts, ainsi que le potentiel de rétablissement. Une structure d'évaluation, consistant de trois phases (le statut d'espèce, la portée des activités humaines et impacts incités, ainsi que les mesures d'atténuation) ont été établis par DFO pour permettre de déterminer si vraiment des permissions de dommages fortuits peuvent peut être émis

Pour informer des décisions touchant à l'inscription du bar rayé de l'unité désignable de la Miramichi et de la Baie de Fundy et leur planification de rétablissement, les participants à la réunion passeront en revue des analyses préparées pour rencontrer les objectifs exposés ci-dessous.

Objectifs

Pour chaque unité désignable (UD)

Phase 1 : Statut de l'espèce

1. Évaluer la trajectoire de l'espèce (population).
2. Évaluer le statut de l'espèce.
3. Évaluer l'ampleur / la cible attendu pour le rétablissement.
4. Évaluer des délais généraux attendus pour le rétablissement à la cible.
5. Évaluer les exigences liées à la résidence de l'espèce.

Phase II Portée des activités humaines - Mortalité incitée

Appendix A continued. Remit for striped bass RPA held in Moncton on November 30-December 2, 2005.

6. Evaluate maximum human-induced mortality which the species can sustain and not jeopardize survival or recovery of the species
7. Document major potential sources of mortality/harm
8. For those factors NOT dismissed, quantify to the extent possible the amount of mortality or harm caused by each activity.
9. Aggregate total mortality / harm attributable to all human causes and contrast with that determined in task 5

*Phase III**: Mitigation and Alternatives***

To the extent possible,

10. Develop an inventory of all reasonable alternatives to the activities in task 7, but with potential for less impact. (e.g. different gear)
11. Develop an inventory of all feasible measures to minimize the impacts of activities in task 7
12. Document the expected harm after implementing mitigation measures as described and determine whether survival or recovery is in jeopardy after considering cumulative sources of impacts

Products

- For each DU, Canadian Science Advisory Secretariat (CSAS) Research Documents and a Recovery Assessment Report to address all objectives
- CSAS Proceedings of meeting
- For each DU, CSAS Research Document

List of requested and tentative participation

- National Headquater (NHQ) and Zonal DFO Science (requested)
- NHQ and Zonal DFO Fisheries Management (requested)
- First Nations
- Provinces NS, NB and Quebec (requested)
- NS, NB and Quebec harvesters
- Non Governmental Organizations

1. Évaluer le maximum de mortalité incitée par les activités humaines que l'espèce peut supporter tout en ne mettant pas en danger la survie ou le rétablissement de l'espèce.
2. Documenter les sources potentielles principales de mortalité et dommages.
3. Pour les sources ayant un impact, évaluez dans la mesure du possible l'impact et l'étendu de la mortalité ou du dommage causé par chaque activité.
4. Agréger la mortalité et les dommages attribuables aux activités humaines et les mettre dans le contexte des exigences identifiées à l'item 5.

Phase III : ***Réduction et alternatives***

Dans la mesure du possible,

5. Développer un inventaire de toutes les alternatives raisonnables aux activités dans l'item 7, mais avec le potentiel de minimiser l'impact. (Ex : différents engins de pêche).
6. Développer un inventaire de toutes les mesures réalisables permettant de réduire au minimum l'impact des activités dans l'item 7.
7. Documenter les dommages attendus après l'exécution de mesures de réduction/alternatives décrites. Déterminer si la survie ou le rétablissement sont menacés après considération du cumule des sources ayant des impacts.

Produits

- Pour chaque unité désignable, un document de recherche et un rapport d'évaluation du rétablissement seront produits afin d'adresser tous les objectifs identifiés. Ces documents seront publiés dans la série du secrétariat canadien de consultation scientifique (SCCS).
- Un compte rendu de la réunion
- Si possible, des documents de recherche du SCCS pour chaque unité désignable.

Participation requise et tentative

- Bureau National et les Sciences du MPO de différentes régions de l'atlantique (requis)
- Bureau National et Gestion de Pêche du MPO de différentes régions de l'atlantique (requis)
- Premières Nations
- Provinces de la N-É, du N-B et du Québec (requis)
- Industrie des pêches de la N-É, du N-B et du Québec
- Organisations non gouvernementales

Appendix B. Environmental conditions in the Miramichi.

INTRODUCTION

Hydrological events are important factors which can influence not only water resource availability but many fishery resources and their management. In particular, water availability and streamflow variability can affect stream biota at different life stages during the year. Striped bass is no exception, and environmental conditions can play an important role in its overall survival and growth. As a result and in order to increase our understanding of the influence of hydrometeorological events on striped bass habitat and population dynamics, an analysis was conducted within the Miramichi River basin to show historical environmental conditions.

The objective was to carry out hydrometeorological analyses within the Miramichi River basin and specifically to: a) investigate peak flow conditions in autumn and during winter, as well as annual flood events, b) determine overwintering conditions (e.g., duration of ice condition), c) determine average air temperature conditions during the summer as growth potential, and d) investigate hydrological conditions during spawning periods in the spring.

STUDY AREA

This study was conducted within the Miramichi river basin and two rivers were used for the analysis, the Southwest Miramichi River and the Northwest Miramichi River. The Southwest Miramichi River (station 01BO001) was used because it is the largest gauge basin within the Miramichi River and provides generalized hydrological information. The Northwest Miramichi River was used because striped bass are known to spawn there and therefore streamflow conditions within this river will better represent specific events of interest. Therefore, data from the Southwest Miramichi River was used for historical analysis and to analyze general environmental conditions while the Northwest Miramichi River data was used for specific event analysis related to spawning in the spring. The drainage basin of the Southwest Miramichi River at the hydrometric station is 5050 km^2 while the drainage basin area for the Northwest Miramichi River is 948 km^2 at the hydrometric station. Hydrometric data from 1962 to 2003 were obtained from the HYDAT CD-ROM version 2003 and more recent data 2004 and 2005 were obtained from Environment Canada.

METHODS

The analysis was carried out using historical hydrometric and weather data from the study area. Daily discharge data were also used to calculate annual floods and daily high flow events. Ice conditions in the Miramichi River were also obtained from hydrometric gauged data. Data on air temperature and precipitation were obtained from the Miramichi Airport.

For the study of flood data, each annual maximum daily discharge is established in relation to its cumulative frequency (*f*) using the Weibull plotting position formula (Chow et al. 1988):

[1] $$f = \frac{m}{n+1}$$

where *m* refers to the rank of the annual maximum daily discharge in increasing order, and *n* is the number of years of record. For instance, the highest flood in 35 years of data has a value of *m* = 35 and *n* = 35. Therefore the frequency of such event is *f* = 35/36 = 0.972. Given the frequency (*f*) of an event it can be potted on a flood frequency paper where the position on the *x* axis is determined using the Gumbel reduced variable *y'*:

[2] $$y' = -\ln(-\ln(f))$$

where *f* is the cumulative frequency calculated by [1]. In the above case with 35 years of data (i.e. *f* = 0.972), the highest flood value has a *y'* value of 3.56 using [2]. This type of transformation was used for plotting annual floods due to the logarithmic nature of these events. Such a plotting transformation is referred to as a Gumbel paper frequency plot.

For the ice study, a *B* symbol indicator is included with the discharge data to identify that the discharge value had been corrected for periods when the hydrometric station was influenced by ice conditions. The presence of the *B* symbol was used as an index of ice conditions or ice cover. This ice condition index was observed within the Miramichi River using two approaches. The first approach estimated the duration of ice conditions in days and was obtained by the summation of all *B* indicators during the winter season. In the second approach, we identified both the beginning (first date with *B*) and end (last date with *B*) of ice condition in the river. If open water conditions are present in winter, the duration will be less than the difference between the beginning and the end of ice condition. Within the present study, only the ice duration was presented.

RESULTS

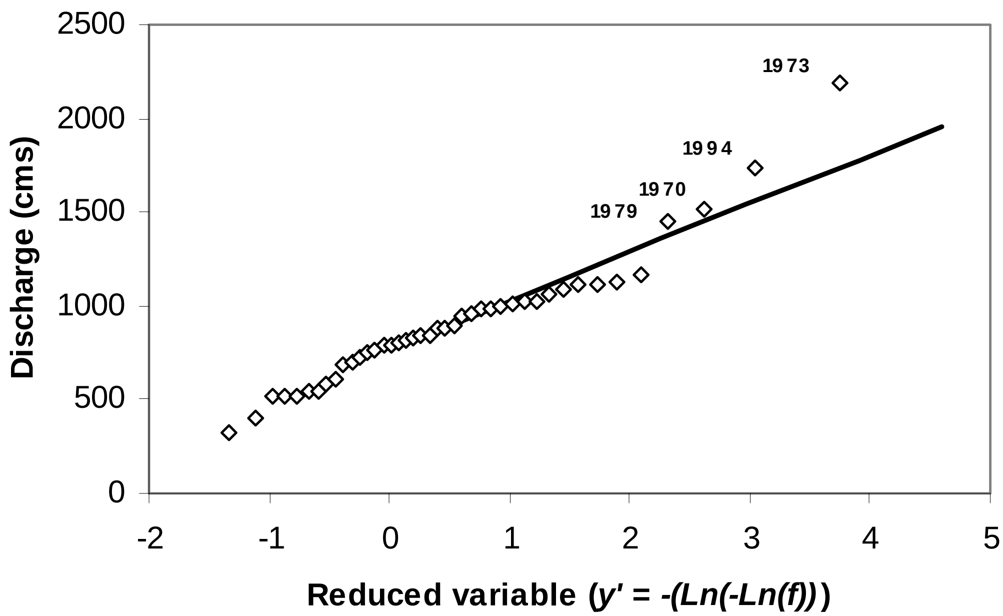
Flood events

The fitting of annual flood data for the Miramichi River was carried out using the 3 parameter lognormal distribution function to determine the frequency of events over the past 40 years (1962-2003). For this analysis data from the Southwest Miramichi River were used. Results showed good agreement between predicted frequencies and observed flood discharge, with the exception of very high flood events which exceeded calculated frequencies (Figure B-1). In fact, the four highest floods, which occurred in 1973, 1994, 1970 and 1979, all exceeded the predicted frequencies estimated using the 3 parameter lognormal distribution. It was also noted that among these four events, three occurred in the 1970s including the highest flood at 2190 m^3/s (1973) while the second highest and most recent high flood event occurred in 1994 at 1730 m^3/s.

Discharges as a function of recurrence interval are presented in Table B-1 for the Southwest Miramichi River. This table shows that the 2-year flood was estimated at 852 m^3/s (*y'* = 0.37 on Figure B-1) while the 50-year and 100-year flood events were estimated at 1780 m^3/s and 1957 m^3/s respectively (*y'* = 3.9 for 50-year and *y'* = 4.6 for 100-year flood; Figure B-1). It is clear from the fitted distribution function that the highest observed flood in the Miramichi River (i.e., at 2190 m^3/s in 1973), would exceed the recurrence interval of a 100 years. In fact, this event is more representative of a 1 in 240 year event based on the fitted distribution. The most recent high flood event was in 1994 at 1730 m^3/s and the recurrence interval of this event was estimated at 1 in 40 year based on data from Figure B-1.

Appendix Table B-1. Flood frequency analysis for the Miramichi River (using the Southwest Miramichi River data).

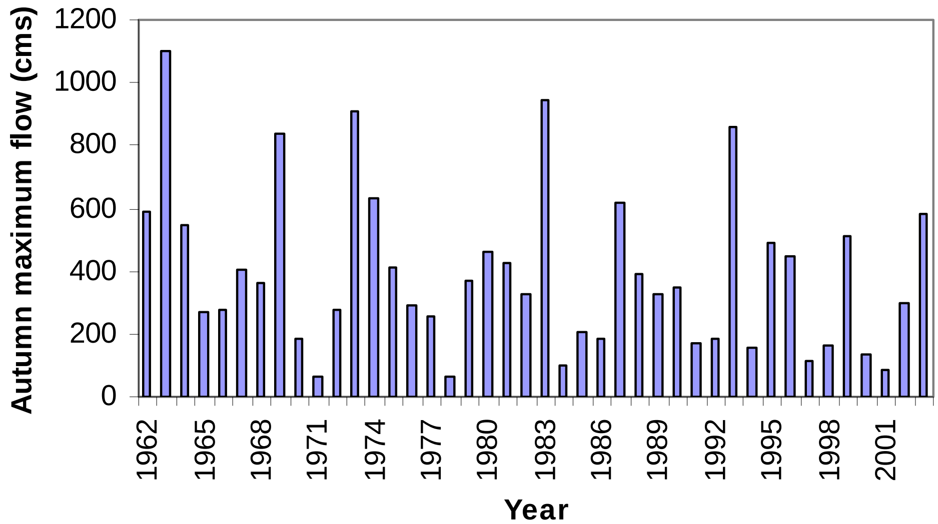
Recurrence interval (year)	Reduced variable (y')	Discharge (m^3/s)
2	0.37	852
5	1.50	1158
10	2.25	1355
20	2.97	1541
50	3.90	1780
100	4.60	1957



Appendix Figure B-1. Flood frequency analysis for the Miramichi River showing annual flood events between 1962 and 2003.

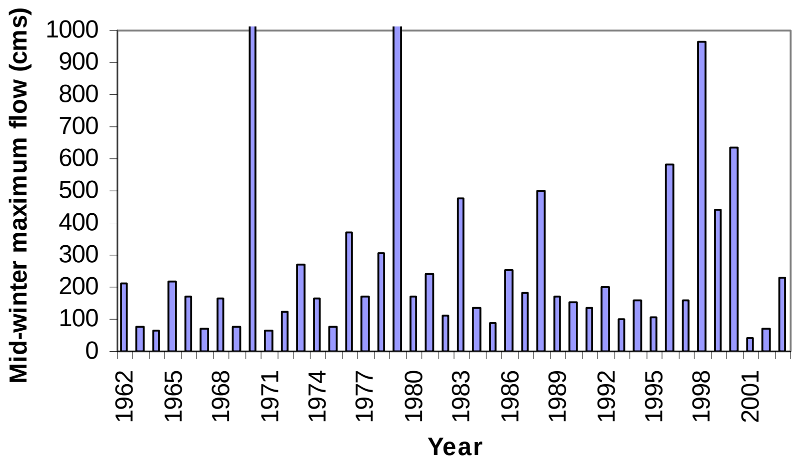
Autumn - winter peak flows

The second analysis consisted of looking at winter peak flows within the Miramichi River which may impact on overwintering survival conditions of striped bass. Data from the Southwest Miramichi River were used to better represent the basin wide condition within the Miramichi River. For this analysis, two separate periods were considered; autumn peak flows and mid-winter peak flows. For autumn peak flow, the month of November and December were selected while mid-winter peak flow consisted of analysing peak flows between January and March.



Appendix Figure B-2. Autumn peak flows (Nov-Dec) within the Miramichi River (using the Southwest Miramichi R. data) from 1962 to 2003.

Peak flows in autumn showed historical values ranging from 65 m^3/s (1978) to a high value of 1100 m^3/s (1963) with a mean value of 390 m^3/s, which represented an average flow of approximately half of a 2-year flood (Table B-1). Recent years showed lower than average values with the exception of 1999 and 2003 which showed autumn peak flows of 514 m^3/s and 583 m^3/s respectively (Figure B-2). The second analysis of winter peak flow consisted of analysing mid-winter conditions for the period of January to the end of March. It should be pointed out that mid-winter conditions generally excludes the spring maximum discharge for the Miramichi River because the peak spring flow almost always occurs in April and May. Therefore, this period of mid-winter conditions will be reflective of mid-winter thaw period resulting from higher air temperature and rainfall events which may contribute to ice break-up and occasionally ice jams. From this time series, two peak flow values were observed to exceed 1000 m^3/s during mid-winter (Figure B-3). The highest value was observed in 1970 (Feb 5) at 1520 m^3/s and the second highest was observed in 1979 (1440 m^3/s; Mar 27). In recent years both high and low peak flows were observed. For instance, the lowest mid-winter peak flow value of the time series was observed in 2001 at 42 m^3/s. Conversely, a number of significant mid-winter peak flows were observed in the late 1990s and the maximum value was observed in 1998 at 964 m^3/s.

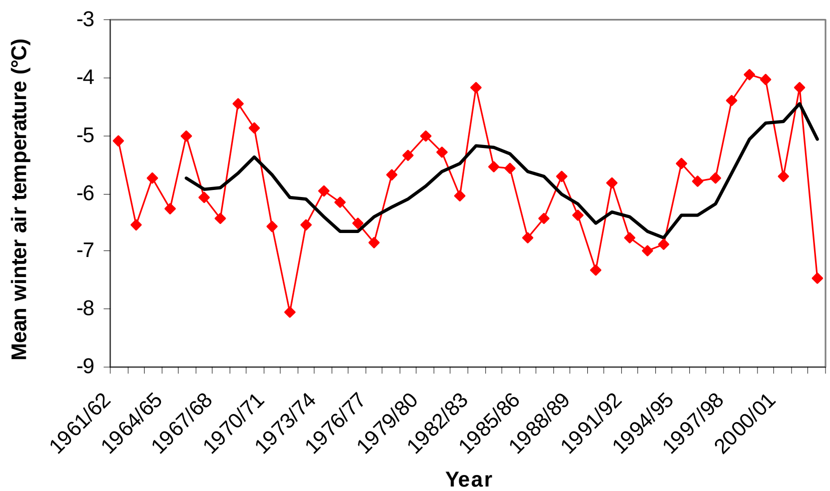


Appendix Figure B-3. Mid-winter peak flows (Jan-Mar) within the Miramichi River (using the Southwest Miramichi R. data) from 1962 to 2003.

Winter air temperatures

Following the analysis of peak flows on both an annual basis and during the winter period, mean winter air temperatures (from November to March) were investigated to help explain factors that could influence the overwintering survival of striped bass. Results of mean winter temperatures are shown in Figure B-4. Results show a significant level of variability in mean winter air temperature ranging from -8.1°C (1971-72) to -4.0°C (1998-99). The average mean winter temperature for the whole time series (between 1961 and 2003) was calculated at -5.8°C.

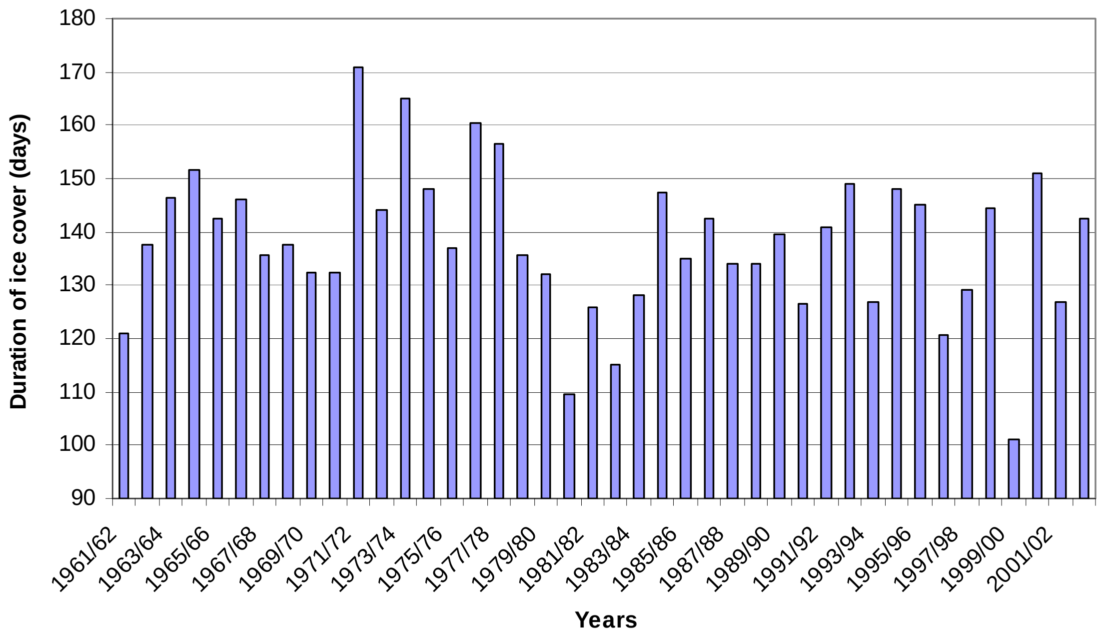
The long-term signal, represented by the 5 year running mean, was also shown in Figure B-4 and results show consecutive periods of warm and cold winter temperatures. For instance, a warm period was observed in mid-1980s while the warmest period of the time series was observed in 2001-02 mainly as a result of 4 warm winters starting in 1997-98 and extending into 2001-02 season.



Appendix Figure B-4. Mean winter air temperature (Nov – March) within the Miramichi River (using the Miramichi Airport data) from 1962 to 2003 (square symbols). Solid line represents 5 year running mean.

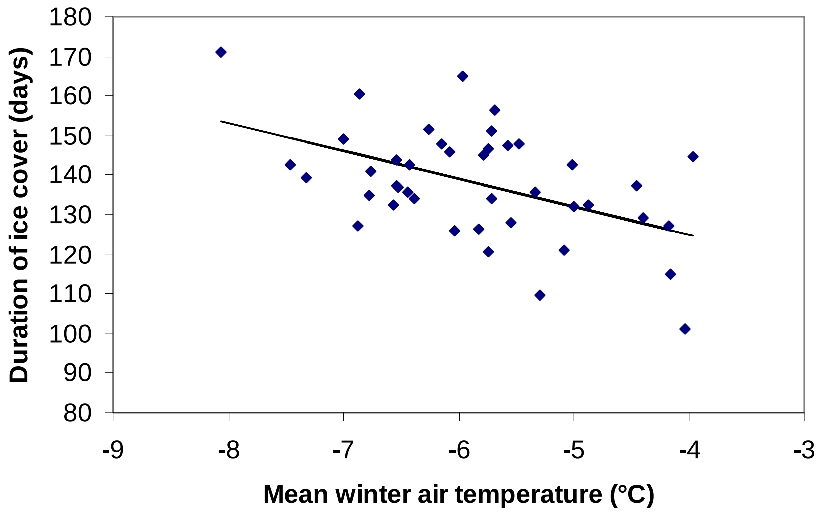
Winter severity
Winter conditions can be studied using peak flows and mean air temperature as indices; however, the ice conditions or the duration of ice cover can also be an important indicator of the severity of winter within the Miramichi River system. As such, ice condition within the Miramichi River was studied using hydrometric gauged data (using data from both the Southwest Miramichi and Northwest Miramichi rivers) based on the *B* indicator, which is used by Environment Canada when a station's water level is influenced by ice. Therefore, in this study ice influence will be assumed to be the same as ice cover. The two rivers were analyzed and average conditions among them were used to reflect ice conditions for the whole system. Data on the duration of ice cover are a good indicator of the severity of winters over the years and should provide valuable information on historical trends.

The duration of ice cover in the Miramichi River ranged from 101 days during the winter of 1999/00 to 171 days during the winter of 1971/72 (Figure B-5). The mean number of ice covered days in the river was calculated at 138 days (±14 days; std). Data indicate that the duration of ice cover in 1960s and 1970s were somewhat higher than in recent years. For instance, only one season experienced less than 130 days of ice cover in the 1960s while no seasons were observed with less than 130 days during 1970s. During the 1980s, four consecutive seasons experienced duration of ice cover less than 130 days (winters 1980-84). Similarly, during the 1990s, a total of five winter seasons experienced duration less than 130 days: 1990-91, 1993-94, 1996-97, 1997-98 and 1999-00. After the year 2000, the winter season of 2001-02 was observed to have less than 130 days of ice cover.



Appendix Figure B-5. Duration of ice cover within the Miramichi River from 1961 to 2003.

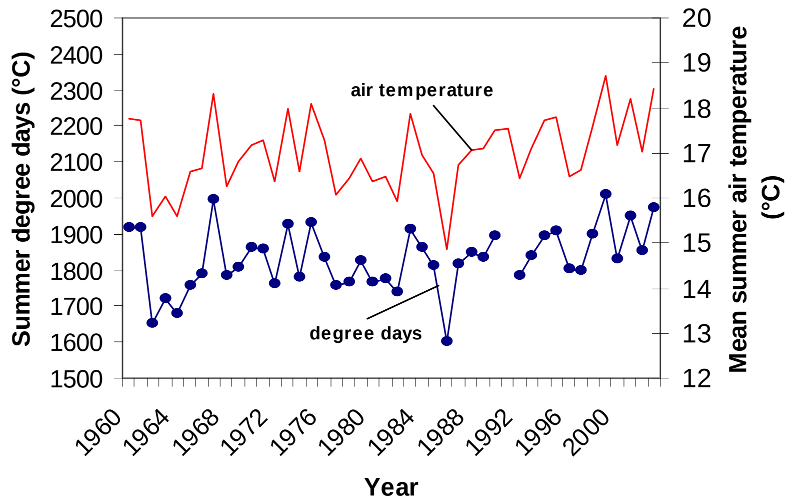
The severity of winter in terms of mean air temperature was significantly correlated with the duration of ice cover (R^2 = 0.24, p<0.0001; Figure B-6). Although the relationship shows some variability, it was observed to be significant and the regression shows that an increase in mean winter air temperature of 1°C will reduce the duration of ice cover by 7 days.



Appendix Figure B-6. Duration of ice cover related to the mean winter air temperature (°C) within the Miramichi River from 1961 to 2003.

Summer air temperature

Environmental conditions during the summer can also be important for the growth potential of striped bass. As such, we have investigated the mean summer air temperature from June to September as well as the total degree days during that period (Figure B-7). The mean summer temperature was calculated at 17.0°C; however, summer air temperature can vary between 14.9°C (1986) to a high value of 18.7 (1999). The years 2001 and 2003 experienced high summer temperatures at 18.2°C and 18.4°C respectively. When investigating trends within this time series a weak trend was detected for the whole period ($p < 0.05$) with an increase in temperature of approximately 0.19°C / decade; however recent years have shown higher increases in air temperature. For instance, the last 15 years (1989-2003) have shown a much more marked trend of 0.57°C / decade, although not significant ($p = 0.16$) due the variability.

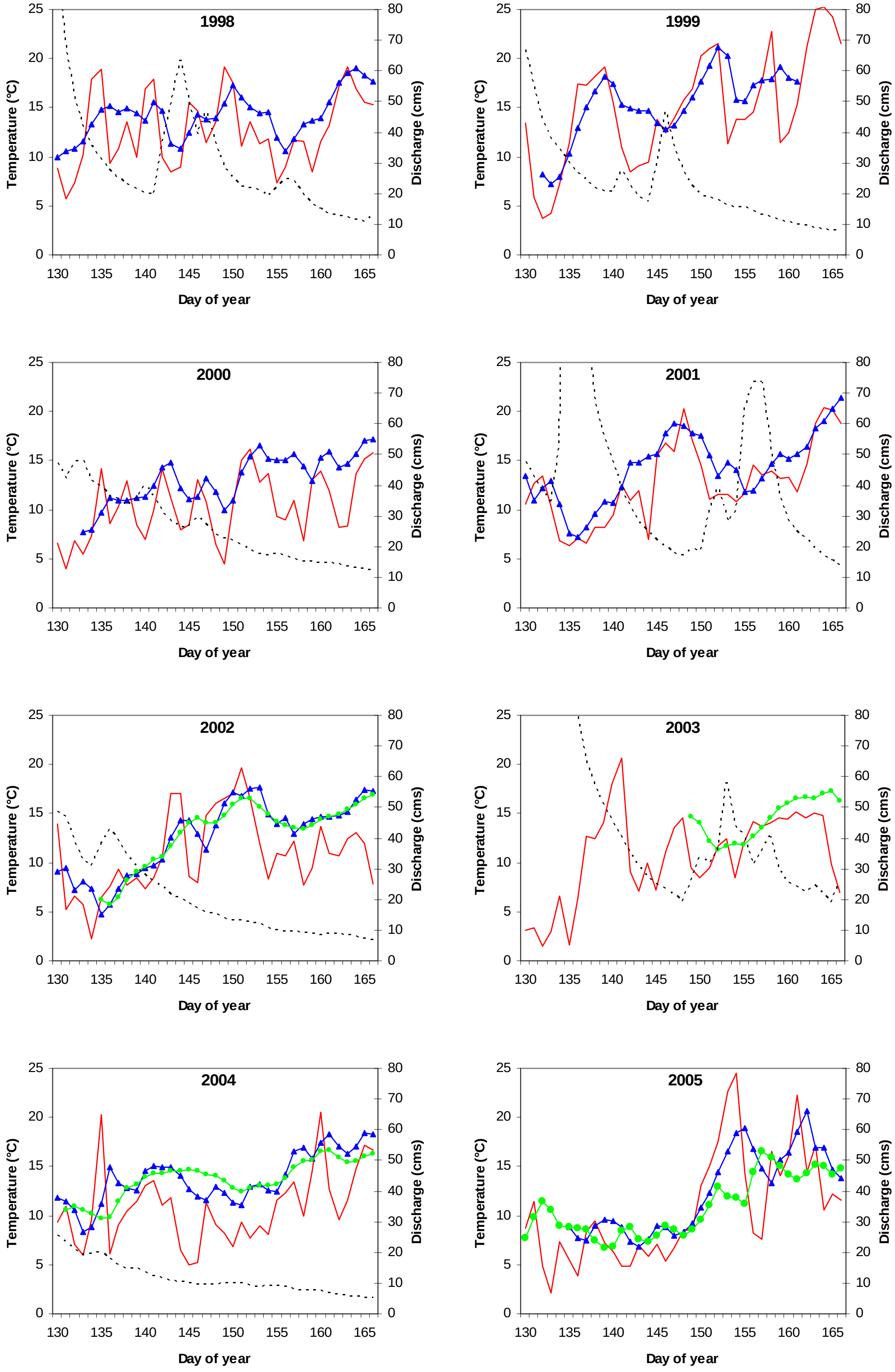


Appendix Figure B-7. Mean summer air temperature (June to September) and total degree days for the same period for the Miramichi River (Miramichi Airport data; 1960 to 2003).

Spring spawning conditions

The next analysis was conducted to provide a description of hydrological conditions during the striped bass spawning and hatching conditions (i.e., early spring conditions) as these activities could be impacted by river discharge, air and water temperature, and other abiotic factors. Figure B-8 shows the results of this analysis with parameters such as river discharge (Northwest Miramichi River), air temperature at the Miramichi Airport as well as water temperature data from the Cassilis Trap located on the Northwest Miramichi River.

Results show that discharge from the Northwest Miramichi generally decline from May 10 (day 130) to June 15 (day 166) whereas a few years have shown significant peak flows in May. In fact, a peak flow of 189 m^3/s was observed on May 15, 2001 (not shown on Figure B-8 because the discharge axis is limited to 80 m^3/s). Peak flows exceeding 80 m^3/s were also observed in mid-May 2003 and extending from May 10 (day 130) to May 15 (day 135) with a corresponding peak discharge of 97 m^3/s during that period. Discharge data were not shown in 2004 and 2005 because the data were not yet available. Other years showed relatively lower flows during the spring and this was observed in 2000 and 2002 where flows were below 20 m^3/s in late May and early June. The most complete water temperature time series was available from the Cassilis Trap and data were available from 1998 to 2005, with the exception of 2003. During the mid-May to early June period the water temperature is somewhat linked to air temperature; however water temperature shows much less variability with a significant lag effect. Also, when comparing Cassilis Trap water temperature data to those collected within the spawning ground of the Northwest Miramichi River, it can be observed that the Northwest Miramichi data are less variable than at Cassilis. Nonetheless, the two time series are showing relatively similar results.



Appendix Figure B-8. Spring environmental conditions on the Northwest Miramichi River including discharge (dashed line), water temperature (circles), Cassilis water temperature (triangles), and Miramichi Airport air temperature (solid line).

Appendix C. COSEWIC's quantitative criteria A to D for the designations of "Endangered" and "Threatened". Features which resulted in the proposed "Threatened" designation for southern Gulf striped bass are boxed and bolded.

	Endangered	Threatened
A. Declining Total Population Reduction in population size based on any of the following 4 options and specifying a-e as appropriate:		
	≥ 70 %	≥ 50 %
(1) population size reduction that is observed, estimated, inferred, or suspected in the past 10 years or 3 generations, whichever is longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) one or more of a-e below.		
	≥ 50 %	≥ 30 %
(2) population size reduction that is observed, estimated, inferred or suspected over the last 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) one or more of of a-e below.		
(3) population size reduction that is projected or suspected to be met within in the next 10 years or 3 generations, whichever is longer (up to a maximum of 100 years), based on (and specifying) one or more of b-e below.		
(4) population size reduction that is observed, estimated, inferred, projected or suspected over any 10 year or 3 generation period, whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) one or more of a-e below.		
a. direct observation b. an index of abundance appropriate for the taxon c. a decline in area of occupancy, extent of occurrence and/or quality of habitat d. actual or potential levels of exploitation e. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites		
B. Small Distribution, and Decline or Fluctuation		
1. Extent of occurrence	< 5,000 km^2	< 20,000 km^2
Or		
2. Area of occupancy	< 500 km^2	< 2,000 km^2
For either of the above, specify at least two of a-c:		
(a) either severely fragmented or known to exist at # locations	≤ 5	**≤ 10**
(b) continuing decline observed, inferred or projected in one or more of the following: i. extent of occurrence ii. area of occupancy iii. area, extent and/or quality of habitat iv. number of locations or populations v. number of mature individuals		
(c) extreme fluctuations in one or more of the following:	> 1 order of magnitude	**> 1 order of magnitude**
i. extent of occurrence ii. area of occupancy iii. number of locations or populations **iv. number of mature individuals**		

Appendix C continued. COSEWIC's quantitative criteria for the designations of "Endangered" and "Threatened". Features which resulted in the proposed "Threatened" designation for southern Gulf striped bass are boxed and bolded.

	Endangered	Threatened
C. Small Total Population Size and Decline Number of mature individuals and 1 of the following 2:	< 2,500	< 10,000
(1) an estimated continuing decline rate of at least:	20% in 5 years or 2 generations (up to a maximum of 100 years in the future)	10% in 10 years or 3 generations (up to a maximum of 100 years in the future)
(2) continuing decline, observed, projected, or inferred, in numbers of mature individuals and at least one of the following (a-b):		
(a) fragmentation-- population structure in the form of one of the following:	(i) no population estimated to contain >250 mature individuals	(i) no population estimated to contain >1,000 mature individuals
	(ii) at least 95 % of mature individuals in one population	(ii) all mature individuals are in one population
(b) extreme fluctuations in the number of mature individuals		
D. Very Small Population or Restricted Distribution (1) Number of mature individuals	< 250	< 1,000
Or		
(2) Applies only to threatened: Population with a very restricted area of occupancy (area of occupancy typically < 20 km^2) or number of locations (typically 5 or fewer) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus is capable of becoming highly endangered or even extinct in a very short time period.		

Appendix D. Southern Gulf of St. Lawrence striped bass life history model.

The recovery objectives, potential, and time frame for recovery were examined using a discrete life history model (Table D-1). Mortality, fecundity, and stock and recruitment dynamics were modeled using general life history information of the species and observed or assumed values specific to the southern Gulf striped bass. The choice of parameter values in the model were governed by observations on characteristics of the population and balancing of life stage abundances. The characteristics of the southern Gulf population of particular interest included:

- relative age structure of the spawners
- sex ratio of spawners

Specific assumptions and functional relationships (Table D-1) are described below.

Egg production

A general fecundity relationship as summarized in Goodyear (1985) was used. Average weight at age data were taken from observations of bass from the southern Gulf (Fig. D-1). Total egg production was the product of the average weight at age, fecundity at weight relationship and number of female spawners at age.

There is no southern Gulf specific fecundity to weight relationship. Data presented in Paramore (1998) indicated that fecundity of Shubenacadie bass varied from 41,000 to 2.1 million eggs for bass ranging in length from 44.9 to 91.0 cm fork length. Goodyear (1985) presented fecundity at weight data for striped bass which translates to about 83,000 eggs per kg (Fig. D-2). Based on the observed mean length at age of bass from the Miramichi and the weight to length relationship, fecundity of an age 4 female bass averaged 83,000 eggs whereas fecundity of age 10 years and older (average weight 6 kg) averaged 600,000 eggs.

Egg to YOY functional relationship

The combination of high fecundity and iteroparity of striped bass are indicative of a species for which mortality in the early stages is high. Year-class variability in striped bass has been observed to be high and largely determined during the egg and larval stages and influenced by environmental factors (see references within Richards and Rago 1999). Increased juvenile production is not guaranteed by increased spawning stock but the chances of producing a strong year class are improved at high spawner abundances. We assumed that there is a density dependent compensatory function between eggs spawned and production of young-of-the-year (YOY) in the first summer (Goodyear 1985). We modeled this dynamic as a Beverton-Holt function (Hilborn and Walters 1992; Myers et al. 1995) and set the parameters based on survival values in the early stages reported in the literature and on reasonable abundance levels of young-of-the-year bass in the fall of the year.

Instantaneous daily rates of mortality ($M\ d^{-1}$) between the egg and the 8 mm larval stage have been estimated to vary between 0.11 and 0.34 with survival after 20 days varying between 0.03% and 11% (Rutherford et al. 1997). We chose a conservative rate of 0.1% for this population at the northern limit of the species distribution. Although there are no measures of absolute abundance of YOY in the fall, the abundance is assumed to be in the order of a few million fish on average with several million individuals possible for strong year classes. Estimates of bycatch in the fall open water smelt fishery of the Miramichi have been over half a million fish in an exceptional year (Bradford et al. 1997b).

Overwinter mortality of YOY

We assumed an instantaneous M of 1.5 (survival = 0.22) for YOY in the first winter (6 months). Overwinter mortality is expected to be high for this northern population. Like adults, juveniles do not feed in the winter and no food items have been found in stomachs of juvenile bass sampled from the open water smelt fishery in November at low water temperatures (pers. obs.). The period of fasting likely extends from late October to late April in most years (see Natural Mortality section above). There is empirical evidence that small bodied striped bass have a lower fitness than large bodied juveniles during the first winter. Some juvenile bass have been found frozen in surface ice in the Miramichi. Variations in quantity of optimal habitat in the winter has been suggested as a possible factor contributing to variations in recruitment of the Hudson River striped bass population (Hurst and Conover 1998).

Survival of age 1 and older bass

We assumed similar proportional survival for male and female bass, although the sex ratio at age data suggest that there may be differential survivals for males and females (age 8 and older fish are predominantly female). Mortality rate of age 1 bass is not known but assumed to be less than that of YOY but higher than age 2 and older bass. Instantaneous mortality rates for age 2 and older were assumed to be 0.6, an average value below the Z values estimated for spawners in the southern Gulf for 1994 to 2005 which are still subjected to some losses from fishing (see Phase I). The high mortality rate for the southern Gulf is consistent with the relative rarity of striped bass older than 10 years of age in the southern Gulf. For the eastern U.S. stocks, M is usually assumed to be 0.15 to 0.2 but these stocks have many fish older than 10 years and they do not undergo the same fasting and overwintering conditions of the southern Gulf fish (Richards and Rago 1999).

Maturity schedules

We assumed different maturity schedules for male and female bass, with male bass maturing at younger ages than female bass (Fig. D-1). To account for the observed sex ratios on the spawning grounds (biased towards males), we modeled female recruitment to the spawning grounds to a maximum of 75% of mature fish for age 5 and older.

Stochasticity

The annual variability in the abundance at age was incorporated as variation around the mean survival of the form $e^{\left(R\sigma-0.5\sigma^2\right)}$, where R is a random normal deviate and σ is the standard deviation of the natural log transformed deviations of year class survival. For the egg to YOY survival, we borrowed the standard deviation of Goodyear (1985) representing the variation in year class strength of the Maryland stock (σ = 0.72). For overwinter survival of YOY, we assumed σ = 0.2 and for all other age groups, σ = 0.1. The resultant survivals are log normal and had a range of 0.09 to 6.69 of the mean for egg to YOY, 0.5 to 1.8 of the mean for age 1, and 0.7 to 1.3 of the mean for age 2 and older fish. Variation in mortality was assumed to be similar for bass age one and older but the value varied annually. Variability in fork length at age was modeled assuming a triangular distribution bounded by the minimum and maximum observed length at age with the peak at the average length (Fig. D-1). The draws were independent across age but similar for all years in each run.

Initial values for the simulations

The model was initiated using the abundance of male and female spawners at age three and older for the years 1994 to 1996. The point estimates of the mode of the spawner estimates at age for the years 1994 to 2005 were retained. The number of eggs produced, YOY in the summer, abundance of spawners and total abundance of age 3 and older bass were simulated for the years 2005 to 2149.

Simulations were run using CrystalBall@, an add-in for Excel.

Appendix Table D-1. Life history model and functions.

$$Eggs_j = \sum_{i=3}^{20} 83177 * Weight_i * Spawners_{i,f,j}$$

where Eggs$_j$ = total eggs spawned in year j
Weight$_i$= length(cm)$_i$ $^{2.993}$ * 0.0000137 for age i
Length$_i$ = length at age i, triangular distribution, range minimum and maximum, peak at mean length
Spawners$_{i,f,j}$ = abundance of female spawners of age i in May year j

$$YOYFall_j = \frac{\alpha * Eggs_j * \gamma}{1 + \frac{\alpha * Eggs_j * \gamma}{YOY_{cap}}} * e^{\left(R_j \sigma - 0.5 * \sigma^2\right)}$$

where YOYFall$_j$ = abundance of young-of-the-year bass in the fall in year j
α = mean density independent mortality, 0.1%
YOY$_{cap}$ = mean asymptotic abundance of YOY in the fall
γ = 1 for unexceptional event with probability A, uniform (0,1), 0.5 otherwise
R$_j$ = normal random deviate for year j
σ = inter year class variability

$$N_{1\,j+1} = \exp^{-(M+F_0)} YOYFall_j * e^{\left(R_j \sigma - 0.5\sigma^2\right)}$$

where N$_{1j+1}$ = abundance of one year old in May, year j+1
M = overwinter mortality, (M = 1.5)
F$_0$ = instantaneous fishing rate on YOY in fall and winter fisheries

$$N_{2,s,j+2} = \exp^{-(M+F_1)} N_{1,j+1} * 0.5 * e^{\left(R_j \sigma - 0.5\sigma^2\right)}$$

where N$_{2,s,j+2}$ = abundance of two year old bass at s (male, female) in May, year j+2
M = instantaneous mortality in year k (j+1 to j+2) (M = 1)
F$_1$ = instantaneous fishing rate on one year old bass during j+1 to j+2

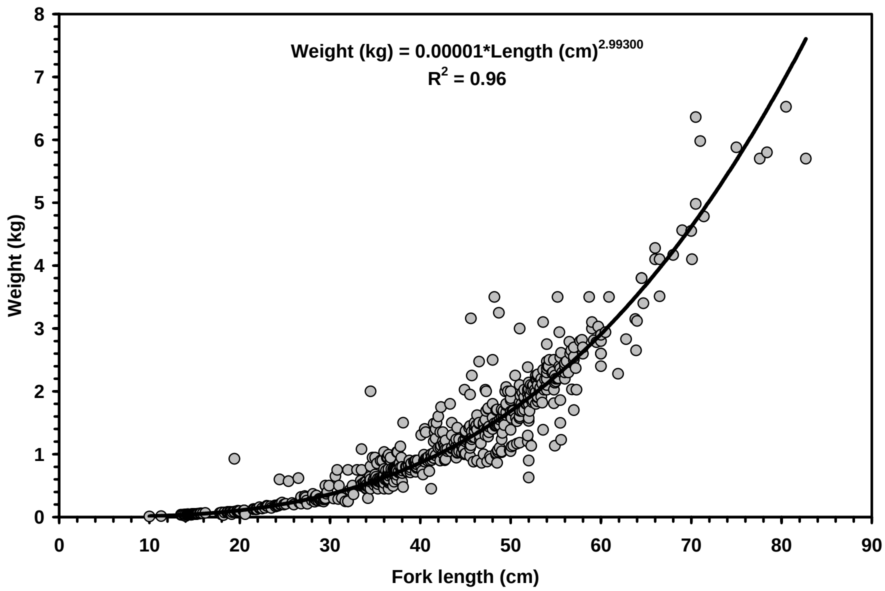
$$N_{i,s,j+i} = \exp^{-(M+F_{si})} N_{i-1,s,j+i-1} * e^{\left(R_j \sigma - 0.5\sigma^2\right)}$$

where N$_{i,s,j+i}$ = abundance of bass age i (i = 3 to 20) and sex s in May, year j+i
s = male, female
M = instantaneous mortality of sex s in year k (j+i-1 to j+i), (M = 0.5)
F$_i$ = instantaneous fishing rate on bass age i during j+i-1 to j+i

$$Spawner_{i,s,j} = N_{i,s,j} * Mat_{i,s}$$

where Spawner$_{i,s,j}$ = abundance on the spawning ground of age i, sex s, in May, year j
Mat$_{i,s}$ = proportion of bass age i and sex s on the spawning grounds

Appendix Figure D-1. Life history characteristics used in the striped bass in the life history model.



Fork length of striped bass from the Miramichi (1994 to 2005)

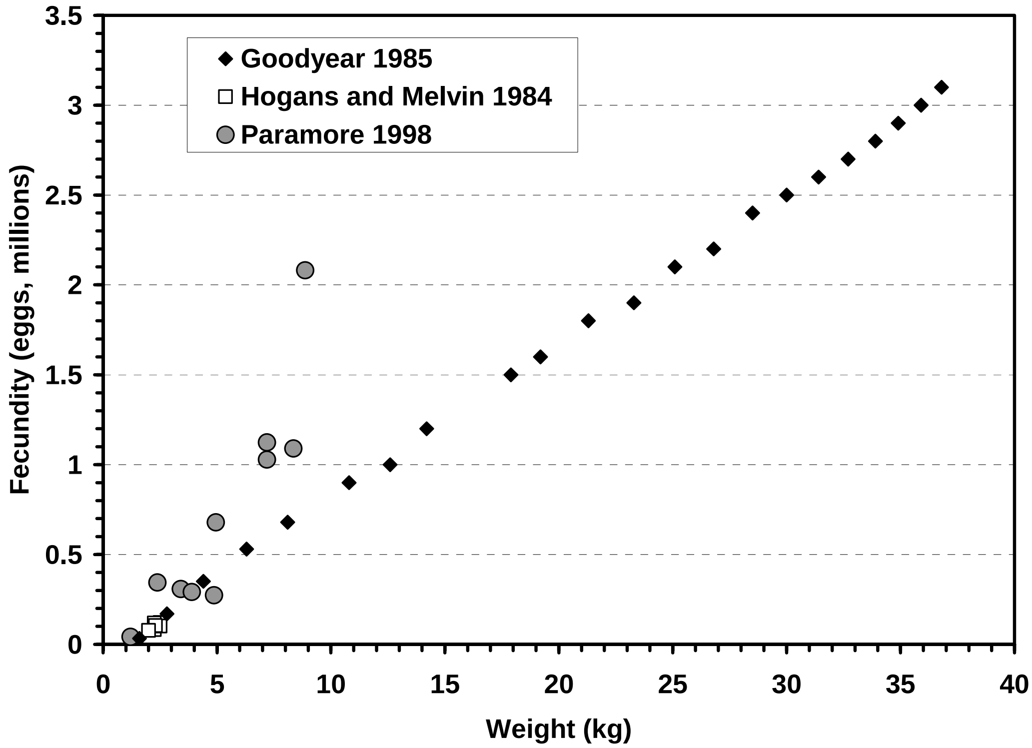
Age (years)	3	4	5	6	7	8	9	10	11	12	13
Mean	40.3	46.7	52.8	58.5	63.7	68.0	74.2	76.4	78.8	85.5	80.9
Min	27.0	29.0	35.7	44.8	52.3	51.5	63.2	72.4	70.2	81.7	80.9
Max	51.2	57.5	65.8	72.6	72.4	82.0	80.5	82.9	86.1	88.5	80.9
N	2812	2338	1073	300	76	37	18	4	6	4	1

In the population model, the mean, minimum and maximum lengths for ages 12 and older were assumed to be the average (81.4), minimum (70.2) and maximum (88.5) lengths observed for age 11 to 13 years.

Maturity schedule (proportion of age group on the spawning grounds)

Age (years)	3	4	5	6 and older
Male	0.5	0.95	1	1
Female	0.1	0.5	0.75	0.75

Appendix Figure D-2. Fecundity (eggs per female) versus weight (kg) of striped bass as reported by Goodyear (1985), Hogans and Melvin (1984) and Paramore (1998).



Fecundity (eggs per female fish) = weight (kg) * 83177 eggs per kg

Appendix E. Potential fishing effort and gear for gaspereau in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000a; DFO 2001a; DFO 2002a).

Location	Fishers	Trapnets	Gillnets (fathoms)
Eastern New Brunswick			
Caraquet Bay	2	4	
Waterways and bays of Lamèque and Miscou Islands	1		150
Saint-Simon Bay	1	4	
Pokemouche River above the railway bridge at Inkerman	6	60	
Big Tracadie River	9	40	
Little Trcadie River	1	1	
Tabusintac River	1	2	
Napan River	4	5	
Miramichi River	13	17	
Northwest Miramichi River	6	12	
Black River	8	14	
Eel River	9	13	
Bay du Vin River	9	11	
French River	1	1	
Portage River	1	1	
Miramichi Bay	4	4	
Richibucto River	20	50	
Richibucto River	1		450
St. Charles (Aldouane) River	3	8	
Kouchibouguac River within the National Park	8	11	
Kouchibouguac River outside the National Park	5	15	
Buctouche River	5	15	
Little Buctouche River	5	10	
Cocagne River and Bay	1	2	
Shediac River	8	20	
Aboujagane River	2	5	
Scoudouc River	2	7	
No licence condition	2	2	
Eastern NB Total	**138**	**334**	**600**
Prince Edward Island			
*anywhere in the province - commercial license	23		
**anywhere in the province - bait license	923		
PEI Total	946		

* gear includes: dipnets, gillnets, and trapnets, or any combination of the three
** gear includes: dipnets, gillnets, and trapnets

Gulf Nova Scotia Statistical District (Fishing area)	Commercial				Bait
	Inland	Coastal / estuary		*Mackerel	Coastal
	Weirs	Trapnets	Gillnets	Trapnets	Gillnets
01 Bay St. Lawrence					42
02 Pleasant Bay - Broad Cove Marsh	50				40
03 Inverness – Creignish					19
13 Aulds Cove – Arisaig	6		20	12	54
12 Lismore - Pictou Landing	4	4		1	18
11 Pictou Harbour - Logans Point	2	3	3		20
10 Barrachois		1			4
46 Malagash – Wallace		2	6		8
45 Pugwash – Linden		5	1		11
Total	**62**	**15**	**30**	**13**	**216**

*Only includes those commercial coastal mackerel trap nets that have allowances for gaspereau retention in-season

Appendix F. Potential fishing effort and gear for rainbow smelt in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000b; DFO 2001b; DFO 2002b).

Location	Fishers	Box nets	Bag nets	Gillnets (fathoms)
Restigouche River above the Van Horne Bridge at Campbellton	18	69	5	
Chaleur Bay	17	49		750
Chaleur Bay, east of the ferry wharf at Dalhousie	1			75
Bathurst Harbour	7	41		225
Caraquet Bay	47	198		405
Saint-Simon Bay	65	265		555
Pokesudie Island	47	198		405
Pokemouche River between the Inkerman bridge and Route 113 bridge	3	14		300
Pokemouche River above the Landry office bridge	12	34		150
Shippagan Bay	18	120		300
Petite Lamèque Bay	17	118		300
Lamèque Bay	17	118		300
Miscou Bay	5	26		
Miscou Harbour	12	85		
Gloucester County	112	3		25,955
Tracadie Bay	12	123	1	
Big Tracadie River	24	163		150
Little Tracadie River	21	19	1	150
Tabusintac Bay, Tabusintac River	33	125	4	420
Neguac Bay	38	317	2	375
Miramichi Bay	130	1,321		315
Miramichi River	25	164		150
Napan River	1	31		
Bay du Vin River	2	17		
Black River	5	25		
Kouchibouguacis River, in Kouchibouguac National Park	12	47		1,095
Kouchibouguac Bay, in Kouchibouguac National Park	5	32		
Kouchibouguac River, in Kouchibouguac National Park	11	53	1	
Kouchibouguac River, outside of Kouchibouguac National Park	8	20	2	15
St. Louis Bay	2	15		
Richibouctou River	44	227	2	3,415
Richibouctou Harbour	2	12		330
Baie du Village, Richibouctou	4	6		500
Bouctouche River	5	10	2	
Bouctouche Bay	19	130		675
Cocagne River	13	26	1	1,747
Cocagne Bay	11	47		2,060
St. Charles River (Aldouane)	4	12		450
Shediac Bay	14	73		1,575
Shediac River	3	19		675
Aboujagane River	4	27		680
Shemogue	24	76	34	
Northumberland Strait, adjacent to Kent County	51	170		2,515
Northumberland Strait, adjacent to Westmorland County	29	93	9	1,125
Murray Corner Wharf	1	1		
Cape Spear	1	2		
Gaspereau River	3	2	5	
Baie Verte	1	2		
No fishing area indicated	2	7		
Eastern NB Total	**962**	**4,752**	**69**	**48,137**
Prince Edward Island				
*anywhere in the province - commercial license	359			
**anywhere in the province - recreational license	100			
***anywhere in the province - Lennox Island First Nation license	1			
PEI Total	**460**			

* gear includes: gillnets, trapnets, and bag nets or any combination of the three
** gear includes: gillnet only
*** gear includes: 10 gillnets and 2 trapnets

Appendix F continued. Potential fishing effort and gear for rainbow smelt in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000b; DFO 2001b; DFO 2002b).

Gulf NS Statistical District	Recreational	Commercial		
(Fishing area)	Gillnets	Gillnets	Bag Nets	Box / Trap Nets
01 Bay St. Lawrence				
02 Pleasant Bay - Broad Cove Marsh	3	22		
03 Inverness - Creignish	4	8		
14 Aulds Cove		3		
13 Aulds Cove - Arisaig	23	33		6
12 Lismore - Pictou Landing	12	14	1	3
11 Pictou Harbour - Logans Point	9	50	6	11
10 Barrachois				4
46 Malagash – Wallace	4	5	2	9
45 Pugwash – Linden		5	15	13
Total	**55**	**136**	**24**	**46**

Note: Some recreational gillnet licenses overlap more than one statistical area and some are valid for all tidal waters of Nova Scotia that border on the Northumberland Strait, however they have been grouped according to the statistical districts that they are mostly fished in.

Appendix G. Potential fishing effort and gear for American eel in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000c; DFO 2001c; DFO 2002c).

Location	Licenses	Trapnets	Fyke nets	Hooks	Weirs	Box nets
Eel River	1	2				
Pokesudie Island	1	1				
Waters off Pokesudie Island	1		2			
Pokesudie Island, east coast	1	1				
Pokesudie Island, small channel	1	2				
Saint-Simon Bay, below the wharf	1	14				
Pokemouche River, above the Landry Office River Bridge	8	5	382			
Pokemouche River, above the railway bridge at Inkerman to the bridge over the Pokemouche River at Landry Office	1		12			
Miscou Island Bay	4		22			
Miscou Island Bay	2	7				
Miscou Island Bay, excluding Miscou Harbour	1	2				
Lamèque Island Bay	1		2			
Shippagan Harbour	1		1			
Lamèque Island Bay, excluding Miscou Harbour	1	18				
Little Tracadie River	2		21			
Big Tracadie River	14	383	20	100		
Little and Big Tracadie River	1	75				
Little Tracadie River, including Tracadie Bay	1	5				
Tabusintac Bay and River	3	126				
Tbusintac River	4	123				
Tabusintac Bay	5	29				
Tabusintac Bay and Portage River	2	20				
Portage River	1	2				
Neguac Bay	26	151				
Neguac and Miramichi bays	2	7	2			
Miramichi Bay	8	50				
Miramichi River	5		68			
Miramichi Bay and River	3	48				
Miramichi Napan, Northwest and Southwest Miramichi rivers	1		80			
Black River and Napan Bay	1		20			
Miramichi Bay and Black River	1	13				
Miramichi Bay and Eel River	1	20				
Bay du Vin River	3	17				
French River	2	11				
Black River	1	21				
Kouchibouguac River, within the park boundaries	4			1,100		
Kouchibouguac River, within the park boundaries	6	38				

Appendix G continued. Potential fishing effort and gear for American eel in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000c; DFO 2001c; DFO 2002c).

Location	Licenses	Trapnets	Fyke nets	Hooks	Weirs	Box nets
Kouchibouguac River and Kouchibouguac Bay, within the park boundaries	2	24				
Northumberland Strait, off Kent County	2	3				
Northumberland Strait, off Kent County	1				4	
Kouchibouguacis River, Kent County, inside and outside the park boundaries, to bridge on route 134	1			400		
Kouchibouguacis River, Kent County, inside and outside the park boundaries	1	2		300		
Kouchibouguacis River outside the park boundaries	1	2				
Kouchibouguac River	1	1				
Richibuctou Bay and River	1			500		
Richibuctou River	9	79				
Richibuctou River	1		7			
Richibuctou River	2			1,100		
Richibuctou Harbour, outside the park boundaries	1			850		
Richibuctou River outside the park boundaries	4			2,875		
Richibuctou and St. Charles rivers, outside the park boundaries	1			700		
Buctouche Bay	2		18			
Buctouche Bay	1	1				
Buctouche Bay	1				2	
Buctouche River	2	9				
Buctouche River, above the bridge on Route 11	1	20				
Buctouche and Cocagne Bays	1				3	
Buctouche and Cocagne Bays	1				7	
Northumberland Strait, Kent County, including Buctouche Bay	1				4	
Cocagne River	1				4	
Cocagne River	1	24				
Cocagne River, above the Route 11 bridge	2	6				
Cocagne Bay	3				11	
Cocagne Bay	1		5			
Cocagne Bay	3	7				
Cocagne Bay	1					2
Saint-Charles River (Aldouane River)	1	2				
Shediac Bay and River	1	31	4			
Shediac Bay	4	22				
Aboujagane River	1	4				
Shemogue Harbour	2	2				
Little Shemogue Harbour	1	2				
Northumberland Strait, along Westmorland County	2	3				
No conditions	1	8				
No conditions	1		4			
Eastern NB Total	**186**	**1,443**	**670**	**7,925**	**35**	**2**
Prince Edward Island						
anywhere in the province - commercial spear license	508					
anywhere in the province - commercial trapnet/fyke net license	127					
anywhere in the province - commercial spear and trapnet/fyke net license	120					
anywhere in the province - Lennox Island First Nation communal commercial s	50					
anywhere in the province - Abegweit First Nation communal commercial spear	23					
anywhere in the province - Native Council of PEI communal commercial spear	20					
*anywhere in the province - Lennox Island First Nation communal 25,000 lbs.						
PEI Total	**848**					

* gear includes: spears and 10 trapnets/fyke nets

Appendix G continued. Potential fishing effort and gear for American eel in eastern NB and PEI (upper panel) and Gulf NS (lower panel) (DFO 2000c; DFO 2001c; DFO 2002c).

Gulf NS Statistical district (Fishing area)	Commercial			Recreational	
	Trapnets	Pots	Spears	Pots	Fykes
01 Bay St. Lawrence		1			
02 Pleasant Bay – Broad Cove Marsh	25	5			
03 Inverness – Creignish	3	3			
14 Aulds Cove		3		1	
13 Aulds Cove – Arisaig	24	8	24	4	
12 Lismore - Pictou Landing	6	3	9		
11 Pictou Harbour – Logans Point	3	20	4	1	
10 Barrachois		3	3		
46 Malagash – Wallace	1	8		1	
45 Pugwash – Linden	6	12			
Total	**68**	**66**	**40**	**6**	**0**

Note: Some fishers have more than one fishing gear on their eel licence.
The total number of commercial eel fishers in the GNS area is 116.