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Bycatch of Striped Bass, White Hake, Winter Flounder, and Atlantic Tomcod in the Autumn "Open Water" Smelt Fishery of the Miramichi River Estuary

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Bycatch sampling of white hake (*Urophycis tenuis*), winter flounder (*Pleuronectes americanus*), and striped bass (*Morone saxatilis*) was conducted in the Miramichi open water smelt (*Osmerus mordax*) fishery between mid-October and the end of November, 1994 and 1995. The purpose of the study was to: 1) estimate magnitude of the bycatch for these three species in absolute terms and relative to the commercial catch, 2) document size composition of the bycatch and 3) assess the possibility of remedial action to reduce the bycatch. In 1994 and 1995, white hake and winter flounder were intercepted at an average rate of 23 and 3 $kg{\cdot}net^{-1}{\cdot}day^{-1}$ respectively, whereas striped bass were intercepted at an average rate of 312 $fish{\cdot}net^{-1}{\cdot}day^{-1}$. Estimated bycatch magnitude for the open water fishery was on the order of 20 to 40 t for white hake, 3 to 4 t for winter flounder, and 100 to 500 thousand striped bass. Rate of white hake bycatch was comparable to the catch rate of both smelt and the permitted, saleable bycatch of tomcod (*Microgadus tomcod*). Flounder bycatch rate was less than half that of smelt or tomcod. Striped bass were intercepted at a rate of about 30 and 20 fish per landed kilogram of smelt and tomcod respectively. Analysis of timing of bycatch indicates that a delay in the opening date for the fishery could substantially reduce bycatch of striped bass (>50%) and moderately reduce bycatch of white hake (~30%), if coupled with concentration of fishing activity within a 10 to 12 km stretch of the estuary. Culling of winter flounder of market size (>18 cm total length) was shown to be an effective bycatch reduction strategy (>75%). Increased selectivity of fish >20 cm in length, through increased mesh size of nets, could reduce bycatch of white hake and striped bass by about 50% and >95% respectively, but reduced landings of market-sized smelt would undoubtedly occur. Increased mesh size would, however, reduce bycatch of nonmarketable tomcod by about 70% on the basis of fish number without reducing sales of this fish.

RÉSUMÉ

Entre la mi-octobre et la fin de novembre, 1994 et 1995, les prises accessoires de la merluche blanche (*Urophycis tenuis*), la plie rouge (*Pleuronectes americanus*) et le bar rayé (*Morone saxatilis*) ont été échantillonnées de la pêche à l'éperlan (*Osmerus mordax*) dans l'estuaire de la rivière Miramichi. Les buts de l'étude étaient : 1) l'estimation de la grandeur des prises accessoires de ces trois espèces en quantités absolues et relatives aux captures des espèces visées, 2) décrire la composition en terme de longueur des prises accessoires, et 3) évaluer si des mesures correctives pourraient réduire les prises accessoires. Durant 1994 et 1995, les prises accessoires de la merluche et la plie rouge s'élevaient en moyenne à 23 et 3 kg $filet^{-1}$ $jour^{-1}$, respectivement. En moyenne, les filets interceptaient environ 312 individus $filet^{-1}$ $jour^{-1}$ de bar rayé, principalement des juvéniles. La grandeur des prises accessoires dans la pêche d'automne s'élevait à environ 20 à 40 t de merluche, 3 à 4 t de plie rouge et entre 100 milles et 500 milles individus de bar rayé. Le taux de capture de la merluche était comparable à ceux de l'éperlan, l'espèce visée, et le poulamon (*Microgadus tomcod*). Le taux de capture de la plie rouge était la moitié de ceux de l'éperlan et le poulamon. Le bar rayé était capturé à un taux équivalent à 30 et 20 poissons par kg d'éperlan et de poulamon, respectivement. Un délai de l'ouverture de la pêcherie aurait réduit les prises accessoires de bar rayé de plus de 50% et celles de la merluche d'environ 30% si la zone de pêche avait aussi été restreinte à une zone de 10 à 12 km de l'estuaire. Le rejet à l'eau de la plie rouge de taille commerciale (>18 cm longueur totale) est une stratégie de gestion qui réduit de 75%, en terme de biomasse, les mortalités de pêche de cette espèce. Une augmentation du maillage pour éviter la capture des poissons d'une longueur inférieure à 20 cm réduirait les prises accessoires de merluche blanche d'environ 50% et le bar rayé de plus de 95%. Cependant, il y aurait une diminution de captures d'éperlan de taille commerciale. Une plus grande maille aurait aussi l'effet de réduire de 70%, en terme de nombre de poissons, les captures de poulamon inférieures à la taille commerciale sans engendrer des pertes de poulamon de taille commericale.

INTRODUCTION

Overview

The rainbow smelt (*Osmerus mordax*) fishery of the Miramichi River estuary (Fig. 1) is the largest in eastern Canada (LeBlanc and Chaput 1991; Chaput 1995). Landings since 1989 have averaged about 300 t•year^{-1} (LeBlanc and Chaput 1991; Chaput 1995). The fishing season traditionally opens 15 October and continues to about 5 March (extended through variation order). However, fishing is usually interrupted by ice formation by mid-December effectively creating two fishing seasons, commonly referred to as the "open water" (autumn) and "winter" (under the ice) fisheries. The open water fishery typically accounts for about 20% of the smelt landings for the Miramichi River estuary (LeBlanc and Chaput 1991).

The fishing gear is broadly similar for the two fisheries and is classified as fixed gear; box, bag, and square nets are the principal gears as well as gill nets. However, gear set in the open water fishery is fixed to the bottom whereas gear set during winter is suspended from ice cover. Bag and square nets are oriented to fish during a single tidal phase, usually the flood tide with its higher current speeds relative to the ebb. Mesh size of bag and square nets is typically about 2.4 cm (15/16 inch) stretch mesh (Bradford et al 1995b). Consequently, the gear is largely non-selective with respect to fish size and species composition. The Miramichi open water fishery is in fact a two-species fishery. Atlantic tomcod (*Microgadus tomcod*) is a permitted bycatch and is intercepted in smelt gear during the upstream spawning migration (Chaput 1995). Tomcod landings have declined from about 600 t•year^{-1} in the early 1900's to current levels of less than 50 t, due in part to reduced fishing effort (Chaput 1995).

Because fishing gear is non-selective the potential exists for interception of a variety of fish species targeted in recreational, as well as other directed commercial fisheries. Research surveys of the Miramichi estuary fish community during 1991 to 1993 demonstrated that the open water smelt fishery intercepted a broad assemblage of fish species (Hanson and Courtenay 1995). Conservation and resource allocation concerns have recently focused attention on the bycatch of three species in particular: striped bass (*Morone saxatilis*), white hake (*Urophycis tenuis*) and winter flounder (*Pleuronectes americanus*). All three species are of common occurrence during autumn and were a regular component of the bycatch from the open water smelt fishery (Hanson and Courtenay 1995).

The striped bass is a recreational fish currently under conservation management due to low spawner abundance (Chaput and Randall 1990; Bradford et al. 1995b) and low spawner success (Bradford et al 1995a,b). The Miramichi estuary is the principal site of striped bass production in the southern Gulf of St. Lawrence (southern Gulf) (Bradford et al. 1995a). White hake are fished commercially in the southern Gulf (Marine and Anadromous Fish Division 1994), but are at their lowest level of biomass since the introduction of quota mangement in 1982 (Hurlbut et al. 1995). In response to recommendations made by the Fisheries Resource Conservation Council, the Minister of the Department of Fisheries and Oceans closed the white hake fishery in the southern Gulf on 21 December 1994. Winter flounder occur throughout the southern Gulf almost exclusively as a shallow water, inshore species (Marine and Anadromous Fish Division 1994). The present southern Gulf abundance indices are generally considered to be reduced relative to previous years, but abundance in the vicinity of the Miramichi estuary is at a moderate to high level (Marine and

Anadromous Fish Division 1994; R. Morin unpublished data). Until the autumn of 1994, winter flounder bycatch, generally >18 cm total length (R.G. Bradford personal observation) were landed and sold, even though this practice was not explicitily permitted under fishing regulations.

Description of Fishing Practices and Fishing Gear

Bag and square nets account for >95% of all fishing gear deployed during the Miramichi open water smelt fishery, because these gears exploit tidal energy more efficiently than do either box or gill nets. Bag and square nets are effectively of the same design (Fig. 2), with the only difference being the construction of the back portion of the net. Bag nets taper to a cone shape or "bag", whereas square nets remain straight ("square") along the back, with the bunt for removing fish from the net located in one of the lower back corners. Both designs utilize wings (about 10 m in length each side) to lead fish into the mouth of the trap (Fig. 2). Beards, or fykes, are sewn into the mouth of the net in order to funnel the fish into the main compartment of the net and to prevent escapement. Most nets are about 3 m in width by 3 m in height at the front, although this can vary depending on the depth of water available for fishing. Net locations are usually the same from year to year. Extension of the wings forward and outwards from the front of the net increases the fishing width of the gear to about 6 m - 8 m, depending on tidal current speed, and therefore physical strain on the fishing gear, in a particular area.

The nets are fished by raising (and closing) the mouth of the net and hauling the net forward and into the boat. The catch is then dumped into stackable crates (capacity of about 65 kg). Sorting, or culling, of the catch on site has been a condition of fishing since October 1994.

The nets are set in locations where tidal forcing is intensified by bathymetry, (i.e., regions where the width of the estuary is narrow or narrows rapidly over a short distance). Consequently, along the main axis of the Miramichi estuary fishing activity occurs from Sheldrake Island, near Loggievillle, upstream to Chatham (Fig. 1). Similar distributions of fishing activity, relative to bathymetry, are found within the estuaries of the Napan, Black, and Bay du Vin rivers, which exit into the Miramichi River estuary below Sheldrake Island (Fig.1).

Tidal current speed sets the *de facto* upper limit on fishing effort by individual fishers. Nets can not be tended until about 1.5 to 2 h flood tide at which point tidal current speed has increased sufficiently to prevent the net from twisting, or backing under the boat, when raised to the surface. At about 4 h into the flood tide, current speeds are too great to allow for raising and fishing the nets. Consequently, few fishers deploy more than 8 to 10 nets at a time, leaving no more than 10 to 15 minutes to tend each net. Within this pressing time frame, culling of the catch on site is viewed by the fishers as impractical, and a threat to the economic viability of the fishery.

Purpose of Study

Sampling of the bycatch of striped bass, white hake, winter flounder and tomcod in the open water smelt fishery was initiated in 1994 and repeated in 1995. The purpose of the study was:

1. estimate the magnitude of bycatch for these three species in absolute terms and relative to the commercial catch (this study treats both smelt and tomcod as “targeted” species),

2. document the size composition of the bycatch, and
3. assess the possibility of remedial action to reduce bycatch.

MATERIALS AND METHODS

Sampling

During 1994, sampling was conducted weekly from 26 October to 9 November with two fishers from each of the Chatham (upstream) and Loggieville (downstream) regions of the estuary visited once per week. Bag and square nets are the only gears deployed in these regions. On each trip the weight of the total unsorted catch (number of crates: each crate about 65 kg) was estimated, then subsampled (n =3 crates per day) for species composition. When possible, subsamples came from different nets. Subsamples were separated into their bycatch components. The three main bycatch species of interest (striped bass, white hake and winter flounder) were counted, weighed (nearest 0.5 kg), and measured (nearest cm). Occurrence of other fish species was noted but not quantified. The estimated total daily catch for each of the species of interest was obtained by scaling data to the total number of crates of unsorted catch. Number of nets fished, hours fished and landed weight (kg) of both smelt and tomcod were recorded. Total daily effort (nets and hours fished) for the river region was determined through interviews with other fishers.

Sampling proceeded in a similar fashion during 1995 with the exception that only two fishers were visited regularly (one per river region) two times per week from 15 October to 21 November. In addition, individual fish lengths (cm) and weights (g) were obtained for striped bass (fork length, FL), white hake (total length, TL), winter flounder (TL), smelt (FL), and tomcod (TL). These data were then used to characterise the size-distributions of the catch by species in order to identify possible measures leading to reduced bycatch, less discarding of fish and, as a consequence, lessen the time spent sorting the catch. Number of samples, net days represented by sampling, and total net days for the fishery are summarized by year, river region, and fish species in Table 1. In neither year was sampling extended to the end of fishing. However, sampling did cover the period of time during which participation in the fishery and fishing effort (nets per fisher) were highest.

Data Analysis

Subsamples of the daily catch were pooled (i.e., no estimates were made of within-site variability for individual days). Both the landed catch and bycatch were standardized to a catch-per-unit-of-effort (CPUE) of catch•net^{-1}•day^{-1}. CPUEs of white hake and winter flounder were calculated on the basis of both number and weight (kg) of fish. CPUEs were calculated by weight for smelt and tomcod because landings for these species were reported as weight. Striped bass are managed on the basis of fish number and, therefore, bycatch estimates are reported as such. Striped bass ages, as determined from the reading of annuli recorded on external body scales, were assigned as described in Bradford et al. (1995a). Magnitude of the catch per species·year^{-1} was calculated as the sum of the product of the arithmetic mean CPUE multiplied by total net days for each river region.

Two-sample F-tests were used to test for between-year differences in CPUE in terms of both number of fish and kilograms for individual fish species. Two way ANOVA (Wilkinson 1989) was used to test for differences in CPUE (kgs for all species except striped bass) between years and between river regions for individual species.

The within-year change in catch with time for individual species was examined by transforming the daily CPUE to its corresponding proportion of total observed catch per species and then plotted versus time (day of year). Bycatch data collected for striped bass during the 1993 open water smelt fishery, following similar sampling protocols (Bradford et al. 1995b) was also included.

Seasonal length-frequency distributions for white hake and winter flounder were constructed by weighting daily catch per 1 cm length interval by the corresponding proportion of the total observed catch (number of fish) represented by that day of fishing.

$$WSC_L = \sum_{i=1}^{K} n_i \bullet \left(\frac{CPUE_i}{\sum_{i=1}^{K} CPUE_i} \right)$$

where WSC_L = weighted seasonal catch for fish within length interval L

Weighted seasonal catches of striped bass were similarly derived, but age group components were treated separately; daily length-frequency distributions for striped bass were usually constructed on the basis of a subsample of Age-0 fish but the entire bycatch of Age-1 and older fish. Raw length frequencies and conversion factors are listed in Appendix 1 for 1994 and Appendix 2 for 1995.

Reverse cumulative frequency distributions of fish length (cm) were used to identify the largest component of the bycatch (by species) on the basis of body size. They were calculated for species bycaught during the 1995 open water season. These distributions sum the catch from large to small fish and provide an indication of the handling frequency (%) of fish ≥ a given size. Cumulative frequency distributions of fishable biomass (%) were calculated by estimating weight of catch per length increment (cm) using empirically determined weight(g) - length (cm) relationships. Distributions of length, fishable biomass and handling frequency were calculated for both smelt and tomcod. Length frequencies and weight (g) - length (cm) relationships for smelt and tomcod were determined from single samples as opposed to weighted seasonal catches.

RESULTS AND DISCUSSION

Species Composition of the Catch

Thirty-six species of fish were represented in catches sampled from the Miramichi open water smelt fishery (Table 2). Two species had not been reported as a component of bycatch in previous surveys (e.g., Hanson and Courtenay 1995): white perch:striped bass hybrids and alligatorfish.

These data confirm the previous findings (Hanson and Courtenay 1995) that bycatch in the open water smelt fishery regularly consists of a broad assemblage of individual species. However, on a day-to-day basis, few species are of comparable abundance to estimates obtained in this study for white hake, winter flounder, striped bass, smelt and tomcod (see below). The possible exception is smooth flounder (*Pleuronectes putnami*) which is consistently intercepted in numbers comparable to those reported here for winter flounder, particularly in the Chatham (upstream) area of the estuary (R.G. Bradford personal observation).

Average Catch

Mean CPUE (± 1 Standard Deviation (SD)) by weight (kg) for both years combined was generally highest for tomcod (25.7±24.6) followed in decreasing order by white hake (23.4±24.3), smelt (13.3±9.4) and winter flounder (3.1±1.9) (Table 3). Numerically ($CPUE_n$), Age-0 striped bass (311.8±468.5) were the most abundant bycatch component averaged over the two years (white hake; 256.7±235.5, winter flounder; 30.4±27.0) but the order of abundance varied between years (Table 3).

Fish size is an important factor determining the average catch by weight and its variability between years. Reduction by a factor of 2 in white hake $CPUE_{kg}$ (d.f. = 13,19; F =4.59; P <0.01) between years 1994 and 1995 (Table 3) is almost certainly due to the lack of fish larger than 25 cm TL in 1995 (Fig. 3) since $CPUE_n$ did not differ (df =13,19; F =1.36; P =0.25) between years (Table 3). Winter flounder $CPUE_{kg}$ increased by a factor of about 1.6 (df =13,19; F =2.74; P =0.01) even though fish >25 cm TL were less abundant in 1995 than during 1994 (Fig. 4). An increase in $CPUE_n$ by a factor of about 4.5 (df =13,19; F =13.06; P <0.01) appears to be due to greater numbers of fish <15 cm TL during 1995, a feature which tends to explain the moderate increase in $CPUE_{kg}$ (Table 3).

Striped bass bycatch was dominated by Age-0 fish (8-16cm FL; Fig. 5) during both years (Table 3). Age-0 $CPUE_n$ was about 4.8 times higher in 1995 (df=15,20; F =5.12; P <0.01) and was likely due to an increase in relative abundance in 1995. Abundance of spawning females in the Miramichi estuary during May-June 1995 was an order of magnitude greater than during 1994 (Bradford and Chaput 1996). Average $CPUE_n$ for Age-1 striped bass (Table 3) was higher during 1995 than during 1994 (df=15,20; F =775; P <0.01) but no difference in average $CPUE_n$ for Age-2 and older striped bass was observed (df =15,20; F =1.14; P =0.4) (Table 3).

Average smelt $CPUE_{kg}$ did not differ significantly between years (df =13,20; F =1.64; P >0.1) (Table 3). In contrast, tomcod landings were statistically higher (df =13,20; F =3.81; P <0.01) in 1995 than in 1994 even though the minimum market size for tomcod increased from about 15 cm in 1994 to about 18 cm in 1995 (Table 3). Inspection of daily tomcod $CPUE_{kg}$ indicates that similarities of arithmetic means between years is the consequence of a single high value ((125) on 10 November, 1994 (Table 3).

Between-Year: Between-Site Effects

Inclusion of site of sampling (Chatham versus Loggieville) in the analysis does not alter the conclusion that average $CPUE_{kg}$ for white hake was higher during 1995 than during 1994 (Table 4). No site effect was evident for $CPUE_{kg}$ for either winter flounder, or Age- 0 striped bass (Table 4).

However, a significant site effect for smelt (higher average catches in downstream locations) indicates that average smelt catches differ significantly between years in contradiction to the conclusion reached in the previous section (Table 4). Average catches of tomcod do not differ between years when adjusted for site of sampling (Table 4), again in contrast to the conclusion reached in the previous section. In general terms, and for a given year, it appears that average bycatch (white hake, winter flounder, striped bass) rates are similar regardless of fishing location, as is the case for tomcod, but that smelt catch rates are higher downstream.

Relative Catch

Differences between years in size composition of the bycatch influence bycatch abundance relative to landed catches of both tomcod and smelt. Occurrence of larger bodied white hake during 1994 resulted in average catches (kg) of this fish being 8 times and 5 times greater than for smelt and tomcod, respectively (Table 5). In contrast, relative abundance of white hake was closer to one in comparison with smelt (1.2 times) and tomcod (0.8 times) during 1995 (Table 5), even though white hake were more numerous than during 1994 (Table 3). Winter flounder catches (Table 5) never exceeded those of either smelt (0.3-0.4 times) or tomcod (0.2-0.6 times). Age-0 striped bass were intercepted at an average rate of 31 fish and 21 fish per kg of smelt and tomcod respectively over the two years (Table 5). Interception rates for striped bass in older age classess would be considerably less than 1 fish per kilogram of either smelt or tomcod (Table 3).

Magnitude of Bycatch

Magnitude of the catch per species, calculated as the sum of the product of mean $CPUE_{kg}$ and total net days for each site for 1994 indicated total catches of about 40 t and 3 t for hake and flounder, respectively (Table 6). Estimated seasonal landings were about 12 t for smelt and about 30 t for tomcod. Interception of striped bass was estimated to be about 100 thousand Age-0 and <1000 each of Age-1 and Age≥2 fish (Table 6).

Magnitude of the 1995 bycatch of hake declined to ~20 t whereas winter flounder bycatch increased to about 4 t. Striped bass interceptions were estimated to be in the order of 400 thousand Age-0, and ≥1000 Age-1 and Age≥2 fish (Table 6). Estimated 1995 landings of smelt increased to about 20 t whereas those for tomcod (about 30 t) remained comparable to the estimated 1994 landings (Table 6).

Interception of non-targeted fishes is not synonymous with mortality. Catches are partially culled on site (at the net) and a proportion of the bycatch is returned to the water within a few minutes of being boarded. The amount of bycatch returned to the water alive tends to be inversely proportional to the quantity of unsorted catch and can vary from <25% to near 100% among days (R.G. Bradford personal observation). The efficacy of culling live hake is questionable considering that these fish have difficulty descending into the water column after being discarded. Predation by gulls on this species appears to be substantial.

Live-culled fish tend to be the larger bodied members of the bycatch because these are more readily distinguishable. The exception, however, is Age-0 striped bass which are small bodied relative to other bycaught fishes. Bass aggressively work their way to the top of the catch and can be sorted with relative ease. Estimates of bycatch magnitude may be biased upward by the recapture of fish captured previously and released. Furthermore, the exploitation rates for white hake, winter flounder and striped bass in open water smelt fishing gear is not known because the sizes of the populations of these species, at this time, are unknown.

Timing of Occurrence of Catch

Plots of proportion of total catch by species versus day of year (Fig. 6) indicated that bycatch of Age-0 striped bass tended to increase with time in the upstream (Chatham) study area but declined with time in the downstream (Loggieville) study area. This pattern is consistent with the known overwintering behaviour of striped bass (Bradford et al. 1995b; Rulifson and Dadswell 1995). These fish are believed to be intolerant of temperatures below the freezing point of blood (-0.7°C; Fletcher 1981) and therefore they migrate to freshwater/brackish regions of estuaries before the onset of winter conditions (Bradford et al. 1995a,b). Bycatch of bass could be reduced in the Loggieville area through a delay of about two weeks in the opening date for the smelt fishery (Fig. 6). However, this tactic would be ineffective in the Chatham area.

White hake catch tends to decline over time in both sections of the river (Fig. 6) but substantial reduction in bycatch (i.e., by a factor of 2) would not be realized until about mid-November, when fishers in the upstream sector are reducing effort in anticipation of the formation of ice cover. Winter flounder bycatch does not show any obvious trend with time which could be used to fine tune timing of opening of the fishing season: these fish remain within the estuary all winter (Hanson and Courtenay 1996). Plots of proportion of catch versus day of year for smelt and tomcod did not show a consistent pattern over time (Fig. 7).

Size and Weight Profiles of Bycatch

Comparison of length-frequency distributions with cumulative frequency distributions of both fishable biomass and handling frequency show that Age-0 fish dominate the bycatch of striped bass, (i.e., striped bass larger than about 16 cm FL account for an insignificant proportion of the total measured bycatch for this species) (Fig. 8). Therefore, reduction of bass bycatch on the basis of both number of fish and weight of catch will be accomplished only by eliminating or severely reducing the interception of Age-0 fish. High representation of Age-0 striped bass relative to older age groups probably reflects higher relative abundance as opposed to gear selection. Conceivably, the contribution of Age-1 and older striped bass to bycatch in this fishery could increase as the population rebuilds, through conservation management, leading to increased abundance of juveniles of all ages. However, even a ten-fold increase in $CPUE_n$ above current levels for older age classes (Table 3) would only result in catches of about 10 fish·trap^{-1}·day^{-1}, a number which could easily be released live into the water.

Profiles for white hake are not weighted towards a particular size component of the fishable population (Fig. 9). White hake bycatch in 1995 consisted of fish of smaller size than in 1994 (Fig. 3). Given the higher abundance of hake >25 cm TL during 1994 it could be expected that, when present, these fish would dominate bycatch both on the basis of handling frequency and fishable biomass. Miramichi open water smelt fishers were adamant that the high bycatch of white hake >25 cm TL reported for 1994 was an unusual occurrence. Fish of this size were not common during a 1993 survey of this fishery (R.G. Bradford personal observation) and open water fishers who operate in other estuaries throughout the southern Gulf of St. Lawrence have commented on the unusually high number of white hake >25 cm TL in their catches during 1994 (see Summary of Public Consultations; Appendix 3). Perhaps oceanographic conditions in the nearshore were unusual during 1994.

Winter flounder of market size (>18 cm TL; R. Bradford personal observation) account for about 75% of the bycatch on the basis of weight (Fig. 10) but <30% of bycatch on the basis of fish number. Therefore, mandatory release of bycaught flounder of market size (>18 cm TL) is an effective measure to reduce bycatch of this species on the basis of biomass, the principal basis for management and resource allocation for this species.

Plots of fishable biomass (%) versus handling frequency (%) for the three bycaught species (year 1995; Fig. 11) show that:

1. Age-0 fish (<18cm FL) dominate striped bass bycatch,
2. white hake bycatch could be reduced at least 50% in number by eliminating interception of fish <20 cmTL, and
3. winter flounder bycatch is reduced by ~75% under current regulations which require that all fish of market size be released live into the water.

Size and Weight Profiles of Commercial Catch

Procedures to reduce bycatch need to be considered in the context of their potential impact on landings of the commercial catch. For example, increase in mesh size of fishing gear could reduce bycatch of every species examined in this study but would almost certainly reduce catches of smelt and tomcod. Current net configurations (i.e., stretch mesh size =2.4 cm) were developed during the early 1930s with the sole purpose to intercept the greatest possible number of smelt of market size (about 12-13 cm FL and larger). As such, current gear configurations represent a solution to the concurrent problems of fish entanglement of Age-0 (< 10cm FL) smelt in smaller mesh, entanglement of smelt and other species at larger mesh sizes, and maximum retention of smelt of commercial size (Daryl Trevors, Miramichi City, personal communication). Many fishers continue to experiment with net configurations (R. Bradford personal observation).

The 2.4 cm mesh effectively retains commercial-sized smelt while avoiding retention and entanglement of the smaller and more numerous Age-0 smelt (see McKenzie 1964 for details of smelt life-history and distribution in the Miramichi estuary) (Figures 12 and 14). Saleable smelt account for about 90% of smelt by biomass and about 85% of smelt by numbers. Market-sized tomcod were those larger than about 15 cm (6") in 1994 and larger than about 18 cm (7") in 1995. Market-sized tomcod accounted for >70% of fishable biomass but only about 30% of fishable numbers during 1995 (Figures 13 and 14).

SUMMARY AND CONCLUSIONS

Bycatch of non-targeted white hake, winter flounder, and striped bass in the Miramichi open water smelt fishery is shown to be high in both magnitude and relative to catch of smelt and tomcod, particularly for white hake and striped bass. Delaying the opening of the fishing season is not likely to reduce bycatch because either timing of peak abundance differs along the longitudinal axis of the river (e.g., striped bass; Fig. 6) or decline in abundance of bycatch occurs too late in the season to allow for equitable fishing of smelt and tomcod. Current management measures that require the return to the water of all winter flounder of market size reduces bycatch for this species by about 75%.

Numerical reduction of bycatch, by >95% for striped bass and by about 50% for white hake, is possible by eliminating interception of the fish <20 cm in length (Figs. 8 and 9). This goal could be accomplished by increased gear selectivity (increase mesh size), but landings of saleable smelt would undoubtedly be severely reduced. Increasing gear selectivity towards larger bodied fish would also target more effectively market-sized (>18 cm TL) tomcod, a resource which in past years has yielded annual landings in excess of 600 t (Chaput 1995). Any change in emphasis towards targeting tomcod in the open water fishery will require extensive evaluations of mesh selectivity and the cooperation and support of the fishers.

Alternatively, bycatch could be reduced through a combination of concentration of fishing effort in the downstream sector of the estuary and a later opening date. A delay of fishing to 1st November could reduce bycatch of striped bass and white hake in the downstream sector by about 50% and 30%, respectively (Fig. 6). Total seasonal landings per fisher would likely decline as a consequence of reduced effort. On the other hand, fishers relocated downstream would probably realize higher average daily catches per net (Table 3) as well as an extended fishing season since ice cover forms later in the season in the downstream section of the river, assuming that fishing sites are available.

As a general rule, the spatial distribution of fishing activity could be linked to the tidal excursion and the distance water, and by implication fish, are advected by tidal forcing during a single tidal phase (Lafleur et al. 1995). This would reduce the lag in timing of peak catches, particularly for striped bass, along the longitudinal axis of the estuary, thereby allowing for more flexibility and greater precision in determination of the opening date for this fishery. Tidal excursions are typically about 10-12 km in the vicinity of Loggieville (St-Hilaire 1993), which indicates that the upstream limit of fishing would be in the vicinity of Middle Island (Fig. 1). It is of interest to note that the impact of bycatch in Miramichi smelt fisheries on a mid-nineteenth century commercial fishery for striped bass was considered to be greatest above Middle Island (Venning 1885).

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LITERATURE CITED

Bradford, R.G., and G.J. Chaput. 1996. The status of striped bass (*Morone saxatilis*) in the southern Gulf of St. Lawrence in 1995. Department of Fisheries and Oceans Atlantic Fisheries Research Document 96/62. 36p.

Bradford, R.G., G. Chaput, and E. Tremblay 1995a. Status of striped bass (*Morone saxatilis*) in the Gulf of St. Lawrence. Department of Fisheries and Oceans Atlantic Fisheries Research Document 95/119. 43p. Department of Fisheries and Oceans, Dartmouth, N.S.

Bradford, R.G., K.A. Robichaud, and S.C. Courtenay. 1995b. By-catch in commercial fisheries as an indicator and regulator of striped bass (*Morone saxatilis*) abundance in the Miramichi River estuary, p. 249-259. *In* E.M.P. Chadwick [*editor*]. Water, science, and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. 123.

Chaput, G.J. 1995. Temporal distribution, spatial distribution, and abundance of diadromous fish in the Miramichi River watershed, p. 121-139. *In* E.M.P. Chadwick [*editor*]. Water, science, and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. 123.

Chaput, G.J., and R.G. Randall. 1990. Striped bass (*Morone saxatilis*) from the Gulf of St. Lawrewnce. Canadian Atlantic Fisheries Scientific Advisory Committee Research Document 90/71: 29p.Department of Fisheries and Oceans, Dartmouth, N.S.

Fletcher, G.L. 1981. Effects of temperature and photoperiod on the plasma freezing point depression, Cl^- concentration, and protein "antifreeze" in winter flounder. Can. J. Zool. 59: 193-201.

Hanson, J.M., and S.C. Courtenay. 1995. Seasonal abundance and distribution of fishes in the Miramichi Estuary, p.141-160. *In* E.M.P. Chadwick [*editor*]. Water, science, and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. 123.

Hanson, J.M., and S.C. Courtenay. 1996. Seasonal use of estuaries by winter flounder in the southern Gulf of St. Lawrence. Trans. Amer. Fish. Soc., 125: 705-718.

Hurlbut, T, G., Chouinard, G. Nielson, R. Hebert, and D. Gillis. 1995. The status of white hake (*Urophysis tenuis*, Mitchill) in the southern Gulf of St. Lawrence (NAFO Division 4T) in 1994. Department of Fisheries and Oceans Atlantic Fisheries Research Document 95/41. Dartmouth, N.S.

Lafleur, C., B. Pettigrew, A. St-Hilaire, D.A. Booth, and E.M.P. Chadwick. 1995. Seasonal and short-term variations in the estuarine structure of the Miramichi, p. 45-71. *In* E.M.P. Chadwick [*editor*]. Water, science and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. 123.

LeBlanc, C.H., and G.J. Chaput. 1991. Landings of estuarine fishes in the Gulf of St. Lawrence 1917-1988. Can. Data Rept. Fish. Aquat. Sci. 842: 101p.

Marine and Anadromous Fish Division. 1994. 1994 Gulf Region stock status report for groundfish and herring. Can. Manuscr. Rep. Fish. Aquat. Sci. 2244: 130p.

McKenzie, R.A. 1964. Smelt life history and fishery in the Miramichi River and estuary, New Brunswick. Fish. Res. Board Can. Bull. No. 144: 77p.

Rulifson, R.A., and M.J. Dadswell. 1995. Life history and population characteristics of striped bass in Atlantic Canada. Trans. Am. Fish. Soc. 124: 477-507.

Scott, W.B., and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731pp.

St-Hilaire, A. 1993. Étude hydrodynamique de l'Estuaire de la Miramichi durant la saison sans glace - 1991. Master Thesis, Université de Moncton, Moncton, N-B. 153p.

Venning, W.H. 1885. Annual report of the Department of Fisheries, Dominion of Canada for the year 1884. MacLean, Roger & Company, Ottawa, Canada. 301p.

Wilkinson, L. 1989. SYSTAT: The System for Statistics. SYSTAT, Inc. 1989. Evanston, IL. X + 822p.

Table 1. Summary of sampling for white hake, winter flounder, Age-0 striped bass, smelt and tomcod in the upstream (Chatham) and downstream (Loggieville) portions of the Miramichi open water smelt fishery during 1994 and 1995. N = number of daily samples, Net Days (S) = number of net days of fishing represented in samples, Net Days (T) = total number of net days for the sampling period.

Year	Site	Variables	White hake	Winter flounder	Striped bass (Age-0)	Smelt	Tomcod
1994	**Upstream**	**N**	6	6	7	6	6
		Net Days (S)	46	46	32	46	46
		Net Days (T)	462	462	462	462	462
	Downstream	**N**	8	8	9	8	8
		Net Days (S)	71	71	78	71	71
		Net Days (T)	872	872	872	872	872
1995	**Upstream**	**N**	10	10	10	10	10
		Net Days (S)	31	31	31	31	31
		Net Days (T)	258	258	258	258	258
	Downstream	**N**	10	10	11	11	11
		Net Days (S)	90	90	99	99	99
		Net Days (T)	798	798	798	798	798

Table 2. List of fish species identified during sampling of the Miramichi (autumn) open water smelt fishery during 1994 and 1995. Species not reported for the estuary by Hanson and Courtenay (1995) are denoted with a checkmark (✓). Identification of fish species based on Scott and Scott (1988).

Species	Common Name	Species	Common Name
Petromyzontidae		**Gasterosteidae**	
Petromyzon marinus	Sea lamprey	Various species	Stickleback(s)
Anguillidae		**Percichthyidae**	
Anguilla rostrata	American eel	*Morone americana*	White perch
		Morone saxatilis	Striped bass
Clupeidae		*Morone* hybrids	Hybrid perch/bass ✓
Alosa aestivalis	Blueback herring		
Alosa pseudoharengus	Alewife	**Labridae**	
Alosa sapidissima	American shad	*Tautogolabrus adspersus*	Cunner
Clupea harengus	Atlantic herring		
		Pholidae	
Salmonidae		*Pholis gunnelis*	Rock gunnel
Salmo salar	Atlantic salmon		
Salvelinus fontinalis	Brook char	**Ammodytidae**	
		Ammodytes americanus	American sand lance
Osmeridae			
Osmerus mordax	Rainbow smelt	**Scombridae**	
		Scomber scombrus	Atlantic mackerel
Gadidae			
Enchelyopus cimbrius	Fourbeard rockling	**Stromateidae**	
Gadus morhua	Atlantic cod	*Peprilus tricanthus*	Butterfish
Gadus ogac	Greenland cod		
Microgadus tomcod	Atlantic tomcod	**Cottidae**	
Urophycis tenuis	White hake	*Hemitripterus americanus*	Sea raven
		Myoxocephalus octodecemspinosus	Longhorn sculpin
Zoarcidae		*Myoxocephalus scorpius*	Shorthorn sculpin
Macrozoarces americanus	Ocean pout		
		Agonidae	
Cyprinidontidae		*Aspidophoroides monopterygius*	Alligatorfish ✓
Fundulus diaphanus	Banded killifish		
Fundulus heteroclitus	Mummichog	**Bothidae**	
		Scopthalmus aquosus	Windowpane
Atherinidae			
Menidia menidia	Atlantic silverside	**Pleuronectidae**	
		Hippoglossoides platessoides	American plaice
		Pleuronectes americanus	Winter flounder
		Pleuronectes ferrugineus	Yellowtail flounder
		Pleuronectes putnami	Smooth flounder

Table 3. Catch per unit effort (number (n) or weight (kg) of fish•net^{-1}•day^{-1}), and net days per sample of white hake, winter flounder, smelt, tomcod, and striped bass (Age-0, Age-1, Age-2 and older), for each day of sampling in 1994 and 1995. Sample size (N), mean catch ± 1SD for each year. Site upstream = Chatham, Site downstream = Loggieville. Blanks represent no data available.

			White hake		Winter flounder		Smelt	Tomcod	Striped bass		
		Net							Age-0	Age-1	Age-2+
Date	Site	Days	N	Kg	N	Kg	Kg	Kg	N	N	N
1994											
18-Oct	Upstream	4							11.5	0.3	0
25-Oct	Upstream	1.5							20.7	0	0
26-Oct	Upstream	8	743.8	108.1	5.3	1.4	3.8	16.9	9.4	0	0
31-Oct	Upstream	12	75.8	12.8	8.7	2.5	5	10			
03-Nov	Upstream	8	188.5	31.3	8.1	2	3.8	22.5	8.6	0	0
04-Nov	Upstream	6		70	0	0	5	15	48.8	0.2	0.7
07-Nov	Upstream	8	563.1	79.1	8.8	1.8	1.9	60.6			
10-Nov	Upstream	4	267	31	28.8	3.5	3.8	125			
21-Nov	Upstream	2							525	0	0
24-Nov	Upstream	2							865	0	0
16-Oct	Downstream	6	64	9.8	2.5	0.3	28.3	0	17.2	0	0
24-Oct	Downstream	8	255.4	32.6	16.1	4.4	20	0	23.4	0	0
25-Oct	Downstream	6	311.5	47.3	15.7	3.7	10	47.5	13	0	0
27-Oct	Downstream	9	34	1.7	7.2	1.1	11.1	1.7	2.7	0	0
01-Nov	Downstream	3	25.3	5.3	11.7	1.7	5	15	1	0	0
02-Nov	Downstream	14	63.1	7.1	14.3	3.4	3.6	4.3	3.9	0	0.3
04-Nov	Downstream	16	104.9	14.7	0	3	7.5	1.9	15.9	0	0.1
09-Nov	Downstream	9	127.8	13.6	11.3	2.1	8.3	35			
22-Nov	Downstream	8							2.3	0	0
23-Nov	Downstream	8							3.4	0	0
N			13	14	14	14	14	14	16	16	16
Mean			217.2	33.2	9.9	2.2	8.4	25.4	98.2	0	0.1
SD			209.2	31	7.3	1.2	7.1	32.9	233.7	0.1	0.2
1995											
18-Oct	Upstream	2	232.5	13.5	30	2.5	13.9	15.6	151.3	2	0
20-Oct	Upstream	2	66	3.7	6	0.6	27.8	31.2	274.3	0.2	0
24-Oct	Upstream	3	298.1	17.4	22.8	1.9	13.9	31.2	181.5	6.8	0.8
30-Oct	Upstream	5	279	16.3	14.9	1.3	7.6	21.8	265	2.6	0.2
01-Nov	Upstream	4	225	13.1	46	3.8	9.3	15.6	756.6	7.8	0.3
06-Nov	Upstream	6	101.7	5.8	41.7	3.4	6.2	18.2	1319.1	0	0
08-Nov	Upstream	3	415.3	24.3	35.8	3	11.1	31.2	2479.6	1.3	0
13-Nov	Upstream	3	224	13	109.7	8.7	7.4	6.2	527.3	0.7	0
16-Nov	Upstream	2	12.5	0.6	29.3	2.5	1.4	5.5	52	0.3	0
20-Nov	Upstream	1	27	1.4	36	3	5.6	12.5	348	0	0
17-Oct	Downstream	9					18.6	6.9	881	0.3	0
19-Oct	Downstream	9	186.7	10.8	53.7	4.4	12.4	20.8	145.3	0.1	0
23-Oct	Downstream	9	188.5	11	99.5	7.9	21.7	69.3	235.5	2	0
25-Oct	Downstream	6	228	13.3	32	2.7	25	66.7	273.6	1.2	0
29-Oct	Downstream	7	889.2	52.3	35.8	3	24.3	46.4	412.5	0.4	0
31-Oct	Downstream	9	700.8	41.2	41.7	3.4	18.6	27.7	461.7	0.1	0
05-Nov	Downstream	16	617.1	36.2	41.7	3.4	10.9	8.8	354.9	0	0
07-Nov	Downstream	9	699.6	41.1	77.6	6.2	24.7	34.6	249.2	0	0
12-Nov	Downstream	7	182.9	10.6	82.9	6.6	31.8	26.7	222.9	0	0
14-Nov	Downstream	9	63.8	3.6	25.4	2.2	37.1	20.8	255.1	0.1	0
21-Nov	Downstream	9	8.7	0.3	34	2.8	18.6	27.7	118.7	0	0
N			20	20	20	20	21	21	21	21	21
Mean			282.3	16.5	44.8	3.7	16.6	26	474.5	1.2	0.1
SD			247.8	14.6	26.5	2.1	9.2	17.1	532.9	2.1	0.2
1994 and 1995											
N			33	34	34	34	35	35	37	37	37
Mean			256.7	23.4	30.4	3.1	13.3	25.7	311.8	0.7	0.1
SD			235.5	24.3	27	1.9	9.4	24.6	468.5	1.7	0.2

Table 4. Two way ANOVA of $CPUE_{kg\ or\ N}$ of white hake, winter flounder, smelt, tomcod, and Age-0 striped bass by site (upstream or downstream) and year (1994 or 1995) of sampling. df =degrees of freedom, F =F-ratio, P = probability.

	Year			Site			Year x Site		
Species	**df**	**F**	**P**	**df**	**F**	**P**	**df**	**F**	**P**
White hake	1,30	7.8	0.01	1,30	3.9	0.06	1,30	12.8	<0.01
Winter flounder	1,30	5.6	0.03	1,30	2.0	0.17	1,30	0.2	0.64
Smelt	1,31	11.9	<0.01	1,31	15.8	<0.01	1,31	0.6	0.44
Tomcod	1,31	0.1	0.83	1,31	0.8	0.37	1,31	6.5	0.02
Striped bass	1,33	6.6	0.02	1,33	3.1	0.09	1,33	0.1	0.72

Table 5. Bycatch ($CPUE_{Kg}$) of white hake, winter flounder, and Age-0 striped bass ($CPUE_N$) relative to $CPUE_{kg}$ of smelt and tomcod. Sample size = N, relative CPUE expressed as mean ± 1 SD for each year and years combined. Upstream = Chatham, downstream = Loggieville. Blanks represent no data.

		White hake		Flounder		Age-0 Striped bass	
Date	Site	Smelt	Tomcod	Smelt	Tomcod	Smelt	Tomcod
1994							
26-Oct	Upstream	28.83	6.41	0.37	0.08	2.5	0.6
31-Oct	Upstream	2.55	1.28	0.5	0.25		
03-Nov	Upstream	8.33	1.39	0.53	0.09	2.3	0.4
04-Nov	Upstream	14	4.67	0	0	9.8	3.3
07-Nov	Upstream	42.2	1.31	0.93	0.03		
10-Nov	Upstream	8.27	0.25	0.93	0.03		
16-Oct	Downstream	0.35	9.8	0.01	0.3	0.6	17.2
24-Oct	Downstream	1.63	32.6	0.22	4.4	1.2	23.4
25-Oct	Downstream	4.73	1	0.37	0.08	1.3	0.3
27-Oct	Downstream	0.15	1	0.1	0.67	0.2	1.6
01-Nov	Downstream	1.07	0.36	0.33	0.11	0.2	0.1
02-Nov	Downstream	1.98	1.65	0.94	0.78	1.1	0.9
04-Nov	Downstream	1.96	7.83	0.4	1.6	2.1	8.5
09-Nov	Downstream	1.63	0.39	0.25	0.06		
N		14	14	14	14	10	10
Mean		8.41	5	0.42	0.61	2.1	5.6
SD		11.95	8.22	0.31	1.13	2.7	7.8
1995							
18-Oct	Upstream	0.97	0.87	0.18	0.16	10.9	9.7
20-Oct	Upstream	0.13	0.12	0.02	0.02	9.9	8.8
24-Oct	Upstream	1.25	0.56	0.14	0.06	13	5.8
30-Oct	Upstream	2.15	0.75	0.18	0.06	35	12.1
01-Nov	Upstream	1.41	0.84	0.4	0.24	81.1	48.5
06-Nov	Upstream	0.94	0.32	0.55	0.19	213.6	72.5
08-Nov	Upstream	2.19	0.78	0.27	0.09	222.7	79.5
13-Nov	Upstream	1.76	2.09	1.18	1.4	71	84.6
16-Nov	Upstream	0.41	0.1	1.76	0.45	37.4	9.5
20-Nov	Upstream	0.26	0.11	0.54	0.24	62.5	27.9
17-Oct	Downstream					47.5	127.1
19-Oct	Downstream	0.88	0.52	0.35	0.21	11.7	7
23-Oct	Downstream	0.51	0.16	0.37	0.11	10.9	3.4
25-Oct	Downstream	0.53	0.2	0.11	0.04	10.9	4.1
29-Oct	Downstream	2.15	1.13	0.12	0.06	17	8.9
31-Oct	Downstream	2.22	1.49	0.18	0.12	24.9	16.7
05-Nov	Downstream	3.34	4.13	0.32	0.39	32.7	40.5
07-Nov	Downstream	1.66	1.19	0.25	0.18	10.1	7.2
12-Nov	Downstream	0.33	0.4	0.21	0.25	7	8.3
14-Nov	Downstream	0.1	0.17	0.06	0.1	6.9	12.3
21-Nov	Downstream	0.02	0.01	0.15	0.1	6.4	4.3
N		20	20	20	20	21	21
Mean		1.16	0.8	0.37	0.22	44.9	28.5
SD		0.9	0.93	0.4	0.29	60.2	33.6
1994 and 1995							
N		34	34	34	34	31	31
Mean		4.14	2.53	0.39	0.38	31.1	21.1
SD		8.49	5.71	0.37	0.78	53.5	30

Table 6. Mean catch per day (upper table) and magnitude of seasonal catch (lower table) of white hake, winter flounder, smelt, tomcod, and striped bass by year and site in the open water smelt fishery of the Miramichi estuary. Upstream = Chatham, downstream = Loggieville.

			CPUE (kg per net per day)				CPUE (fish per net per day)				
			White	Winter			White	Winter	Striped bass		
Year	Site		hake	flounder	Smelt	Tomcod	hake	flounder	Age-0	Age-1	Age-2+
1994	Upstream	Mean	55	2	4	42	368	10	213	0	0
		SD	33.0	1.1	1.0	40.8	247.8	9.0	318.5	0.1	0.2
	Downstream	Mean	17	3	12	13	123	10	9	0	0
		SD	14.6	1.3	7.8	17.1	98.7	5.7	7.8	0.0	0.1
1995	Upstream	Mean	11	3	10	19	188	37	636	2	0
		SD	7.4	2.1	6.9	9.3	124.8	26.7	708.9	2.7	0.2
	Downstream	Mean	22	4	22	32	377	52	328	0	0
		SD	17.6	1.9	7.4	19.8	299.1	24.0	200.6	0.6	0.0

		Total Catch Weight (t)				Total Catch Number (thousands of fish)				
		White	Winter			White	Winter	Striped bass		
Year	Site	hake	flounder	Smelt	Tomcod	hake	flounder	Age-0	Age-1	Age-2+
1994	Upstream	26	1	2	19	170	5	98	0	0
	Downstream	14	2	10	12	108	9	8	0	0
	Both	40	3	12	30	277	13	106	<1	<1
1995	Upstream	3	1	3	5	49	10	164	1	0
	Downstream	18	3	18	26	300	42	262	0	0
	Both	20	4	20	30	350	50	425	1	<1

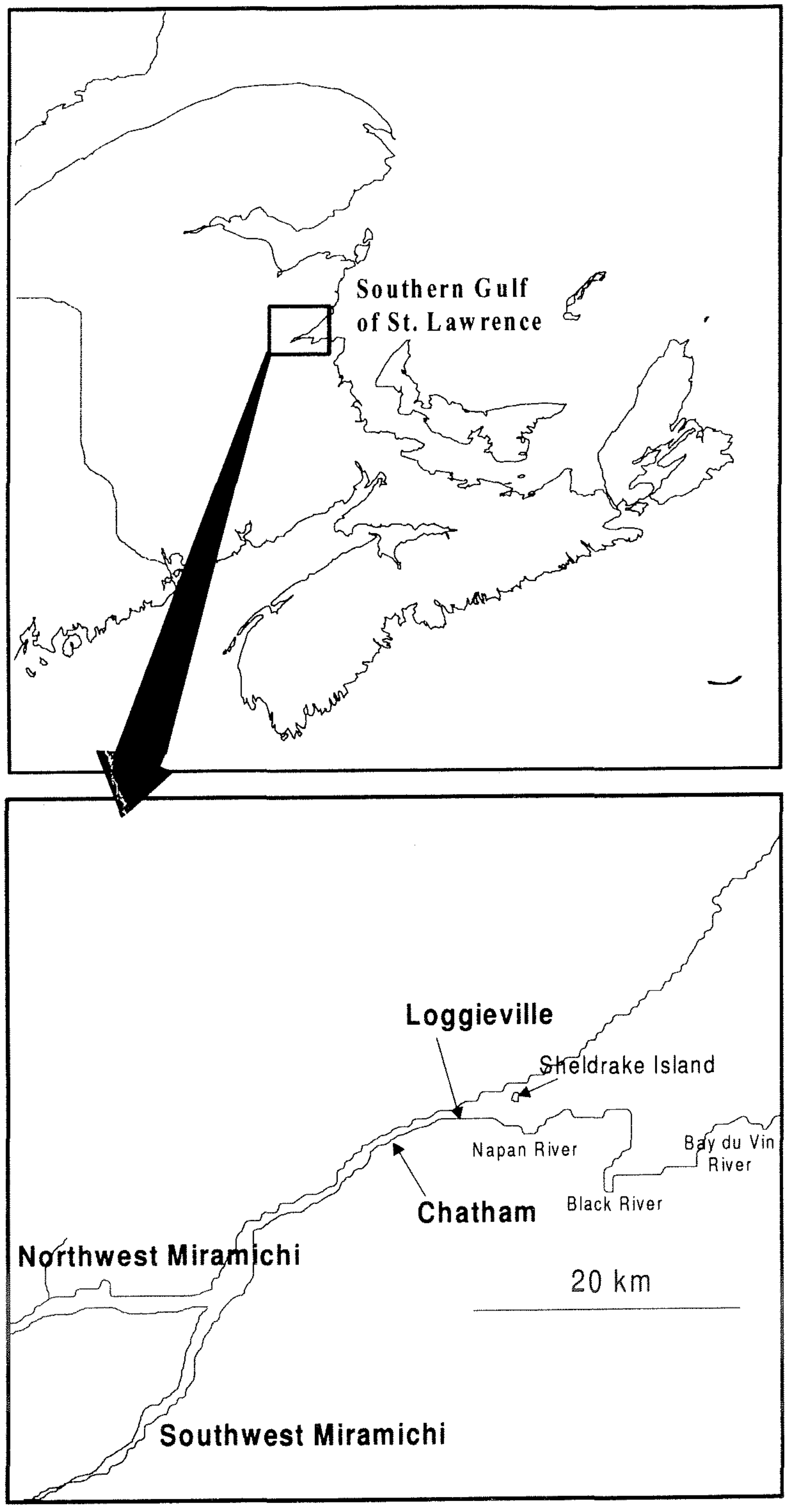


Figure 1. Miramichi estuary and bay indicating place names referred to in the text.

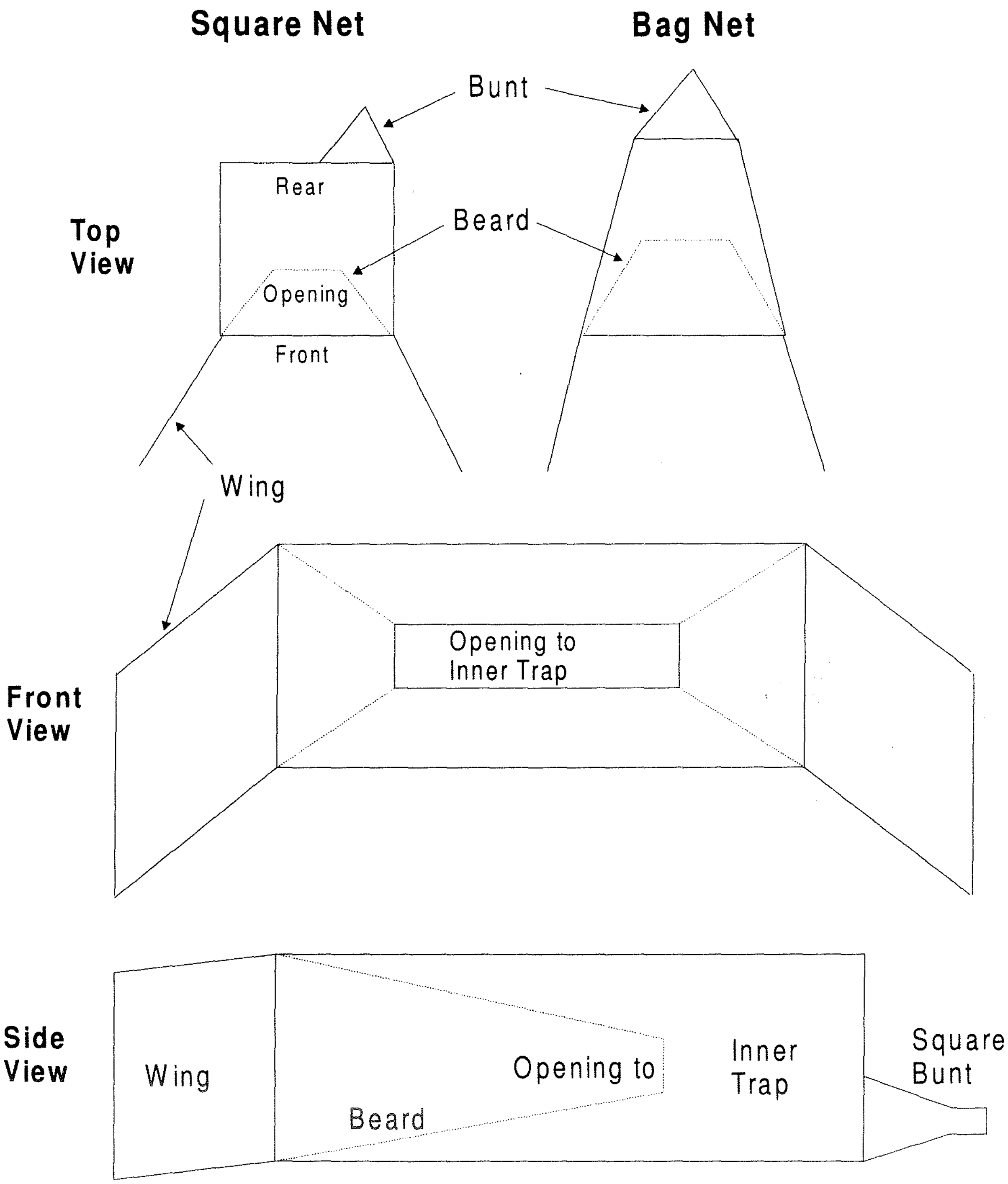


Figure 2. Top and front views of smelt square and bag nets, and side view of a square net. General dimensions are: height at mouth = 3m, width at mouth = 6m, overall length = 6 to 10m.

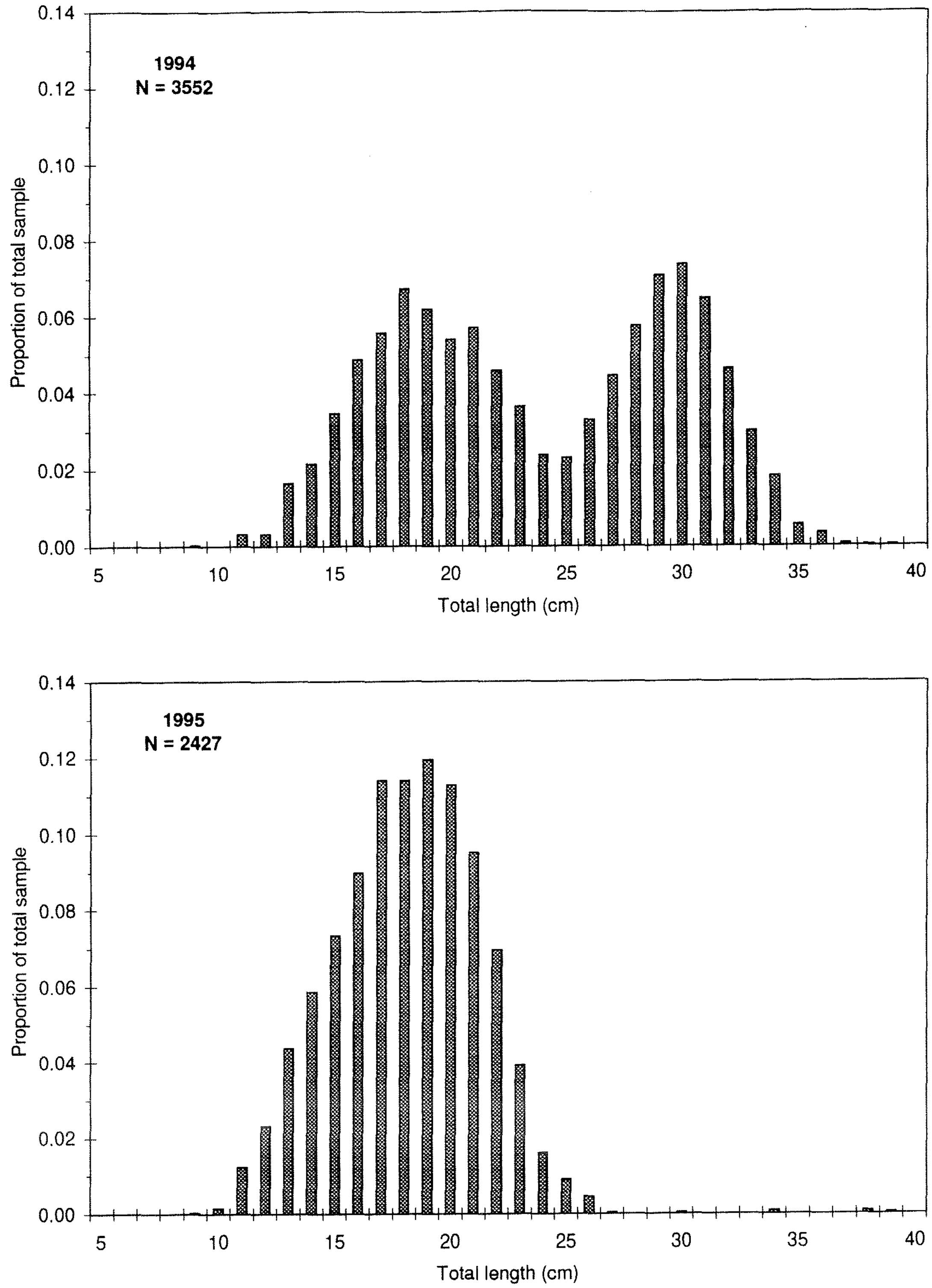


Figure 3. Length-frequency distributions for white hake bycatch for the years 1994 (upper) and 1995 (lower). N = sample size.

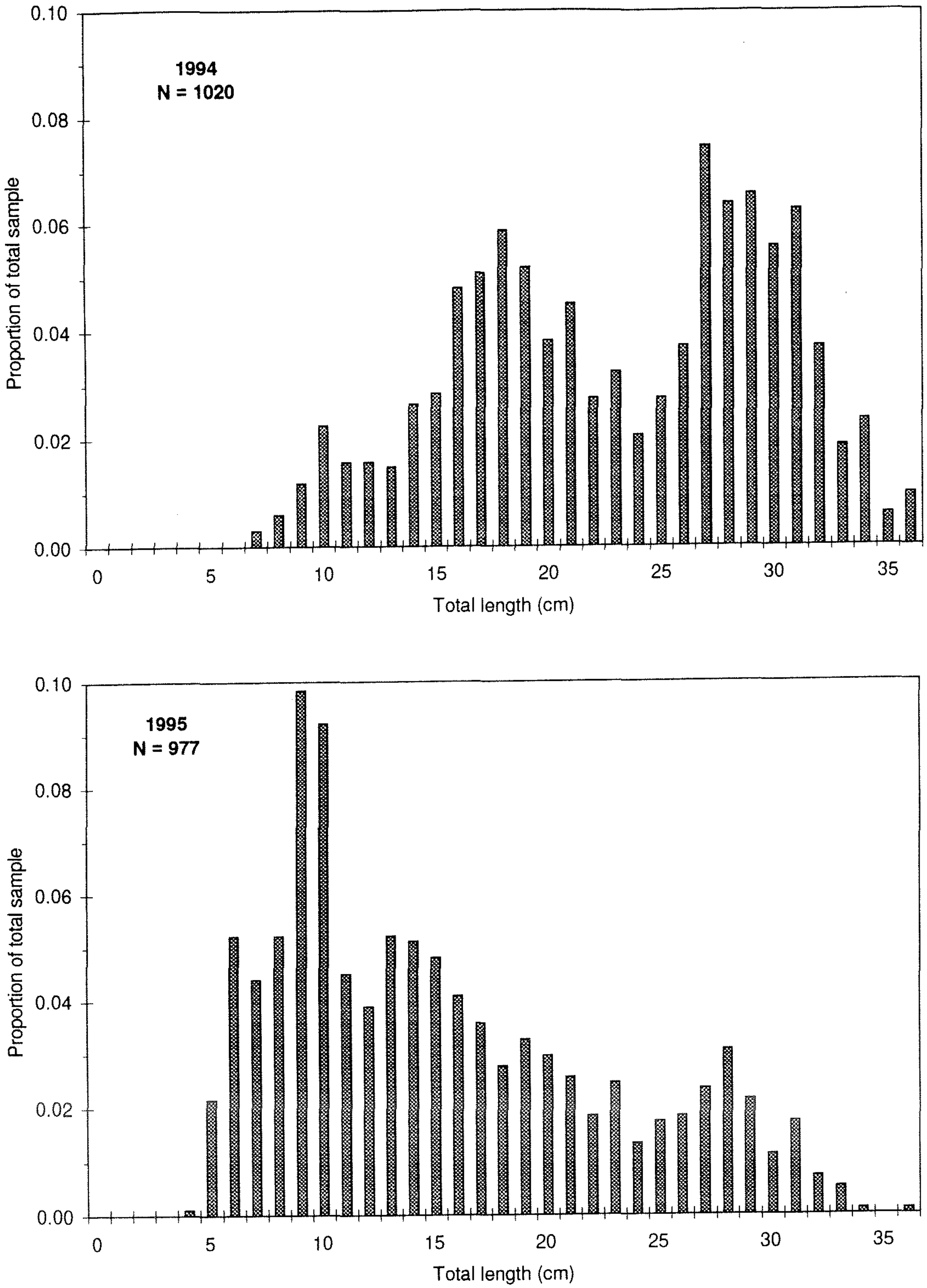
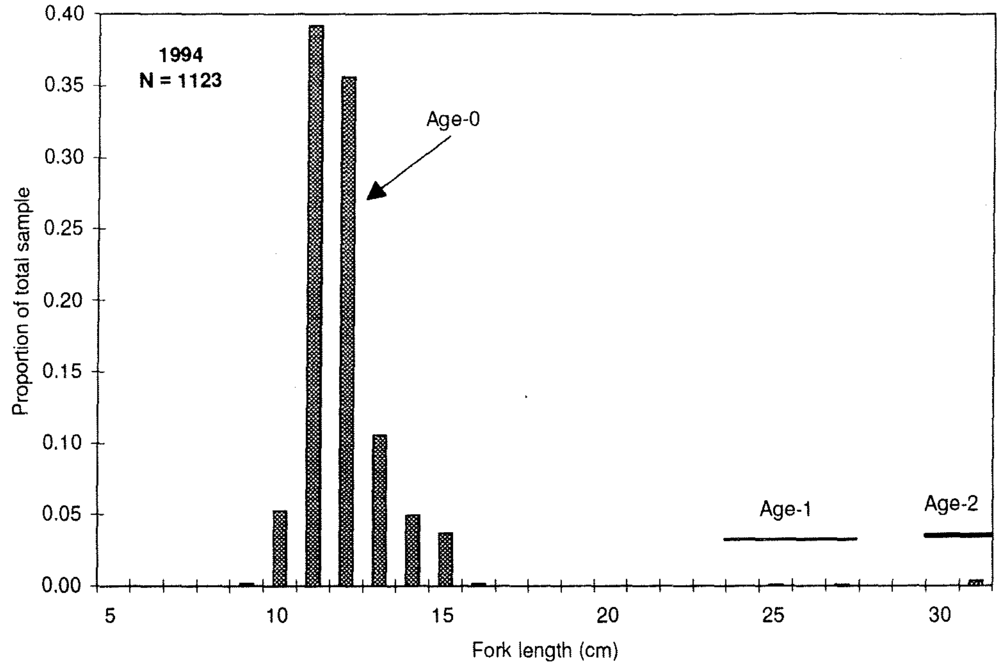


Figure 4. Length-frequency distributions for winter flounder bycatch for the years 1994 (upper) and 1995 (lower). N = sample size.



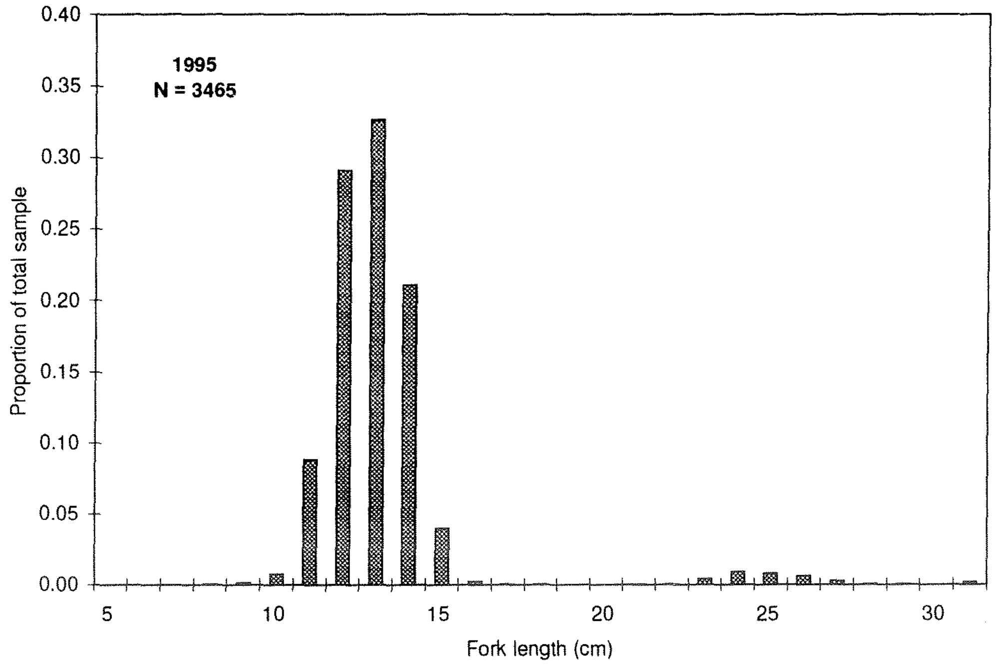


Figure 5. Length frequency distributions for striped bass bycatch for the years 1994 (upper) and 1995 (lower). N = sample size, Age-0, Age-1, and Age-2 refers to length range of age groups of bass in the bycatch.

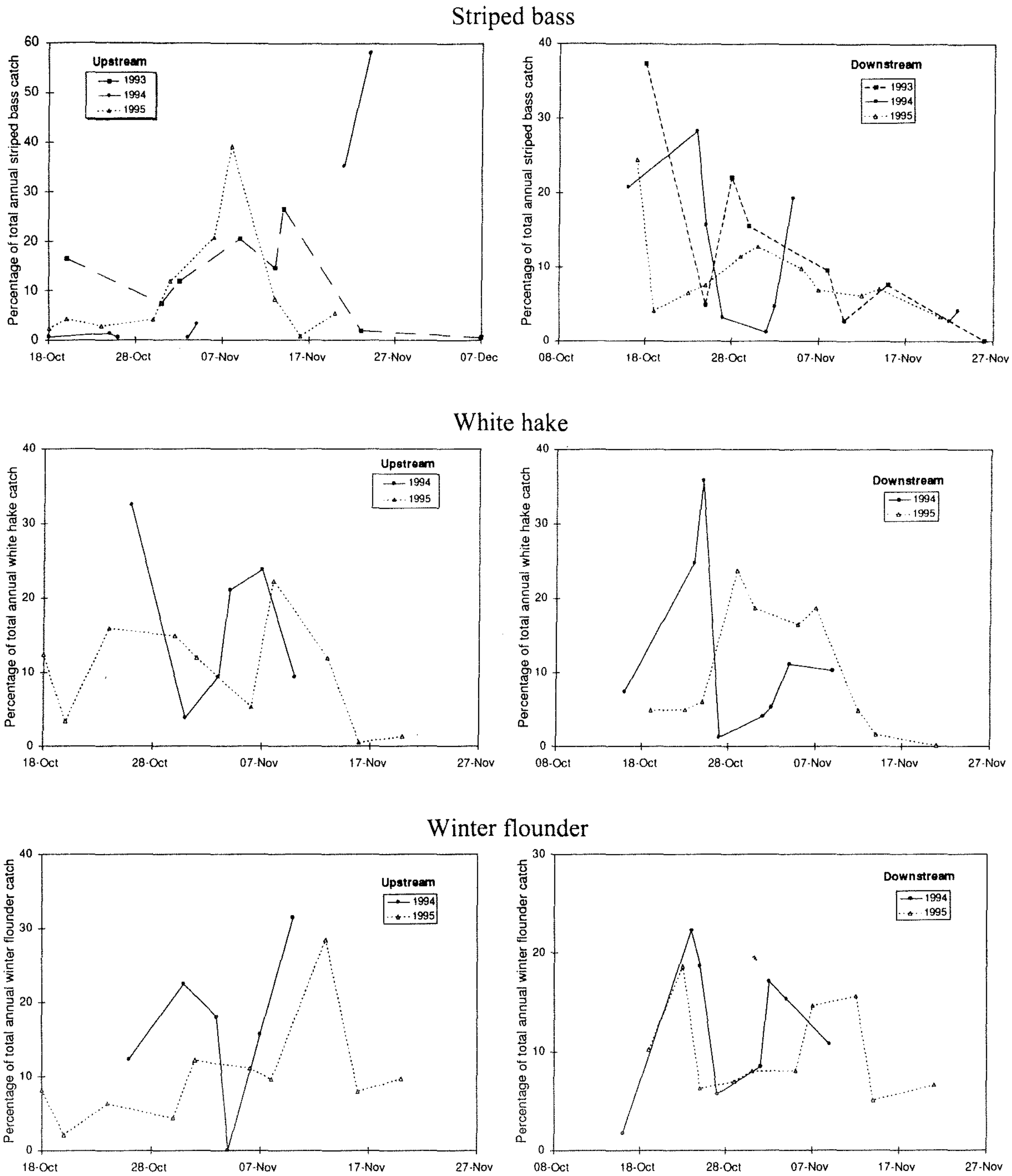


Figure 6. Proportion of total observed bycatch per species relative to the season for striped bass (upper), white hake (middle), and winter flounder (lower) in the upstream (left) and downstream (right) locations of the Miramichi estuary.

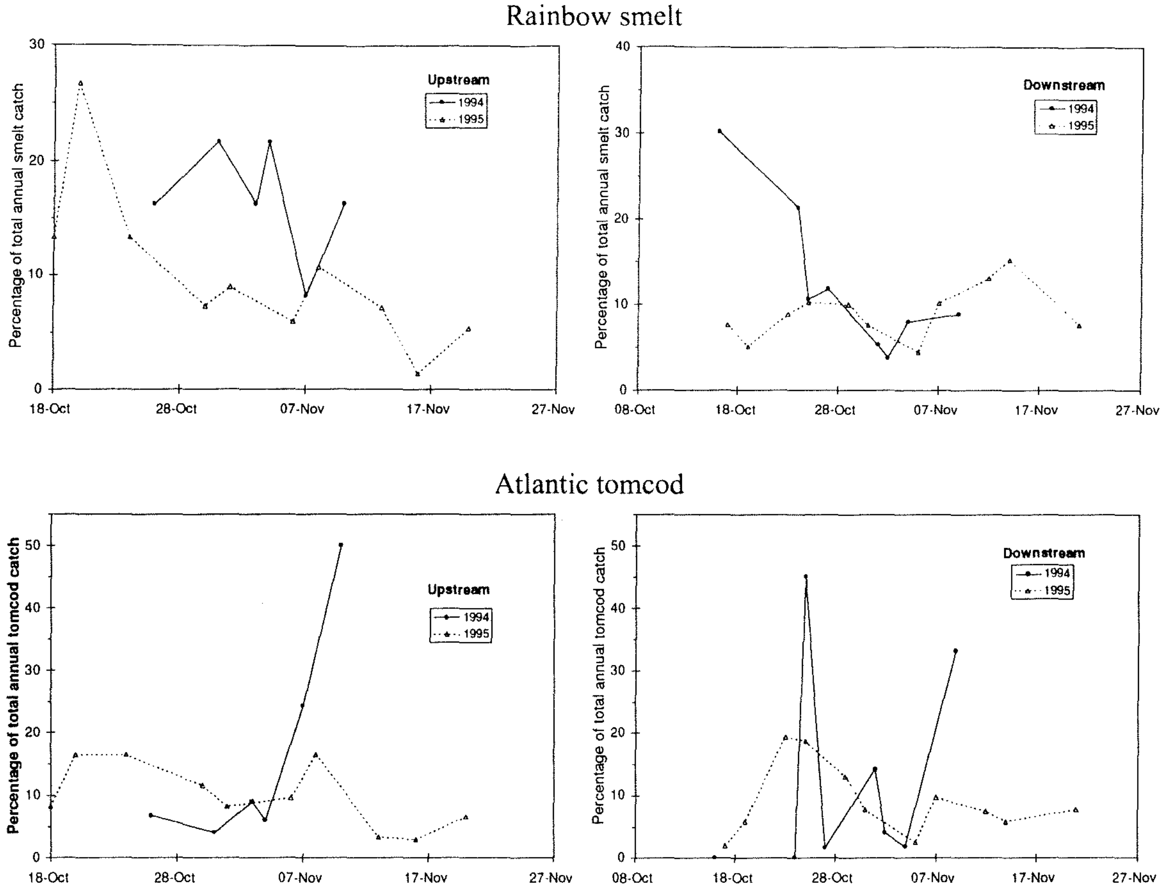


Figure 7. Proportion of total observed catch of rainbow smelt (upper) and Atlantic tomcod (lower) relative to the season in the upstream (left) and downstream (right) locations of the Miramichi estuary.

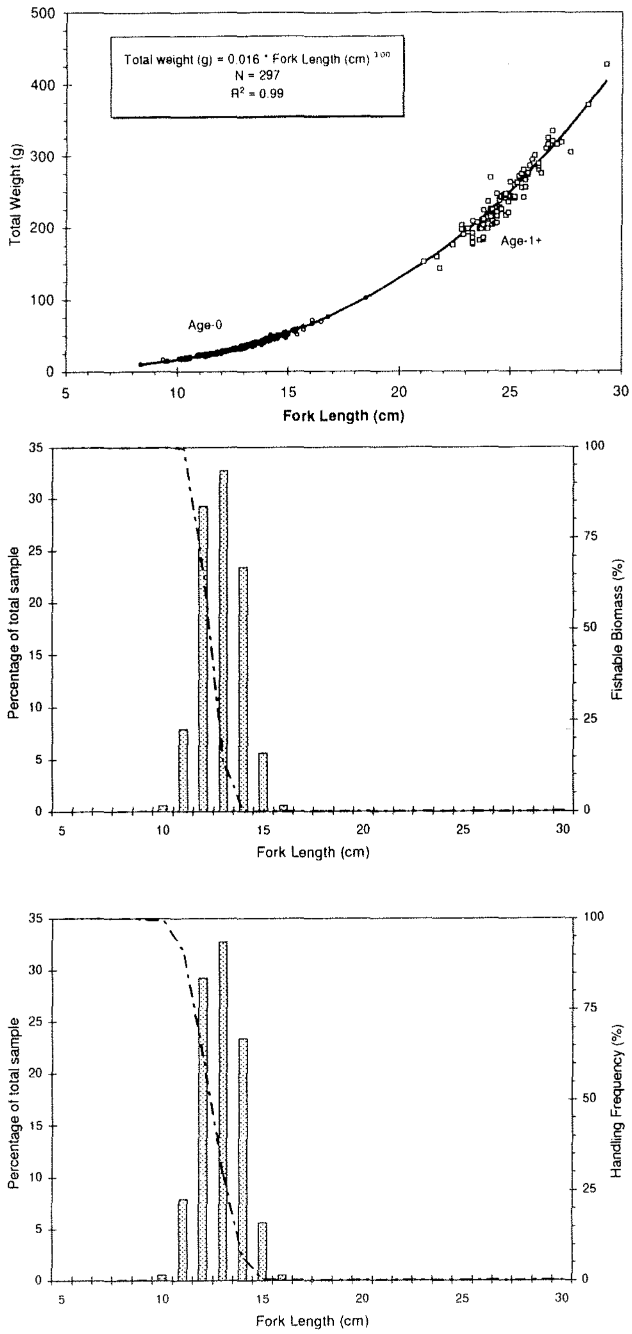


Figure 8. Weight-length relationship (upper), length frequency distribution and cumulative fishable biomass relative to fork length (middle), and cumulative handling frequency relative to fork length (lower) for striped bass during 1995.

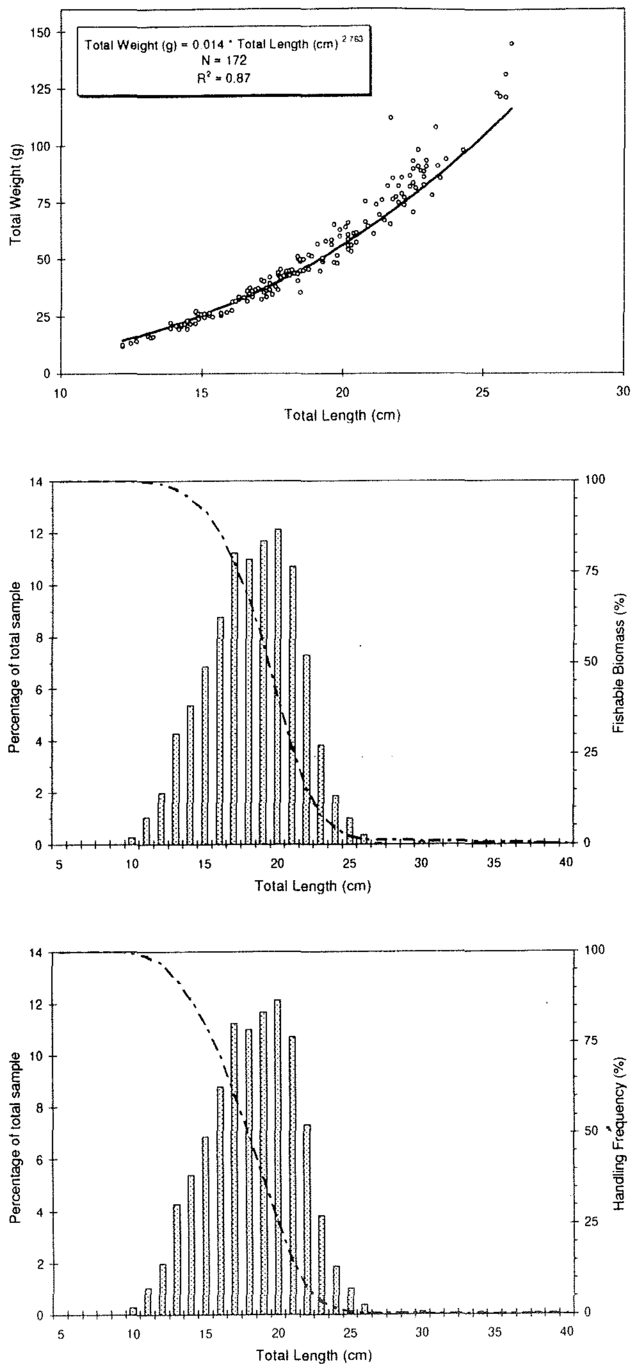


Figure 9. Weight-length relationship (upper), length frequency distribution and cumulative fishable biomass relative to fork length (middle), and cumulative handling frequency relative to fork length (lower) for white hake during 1995.

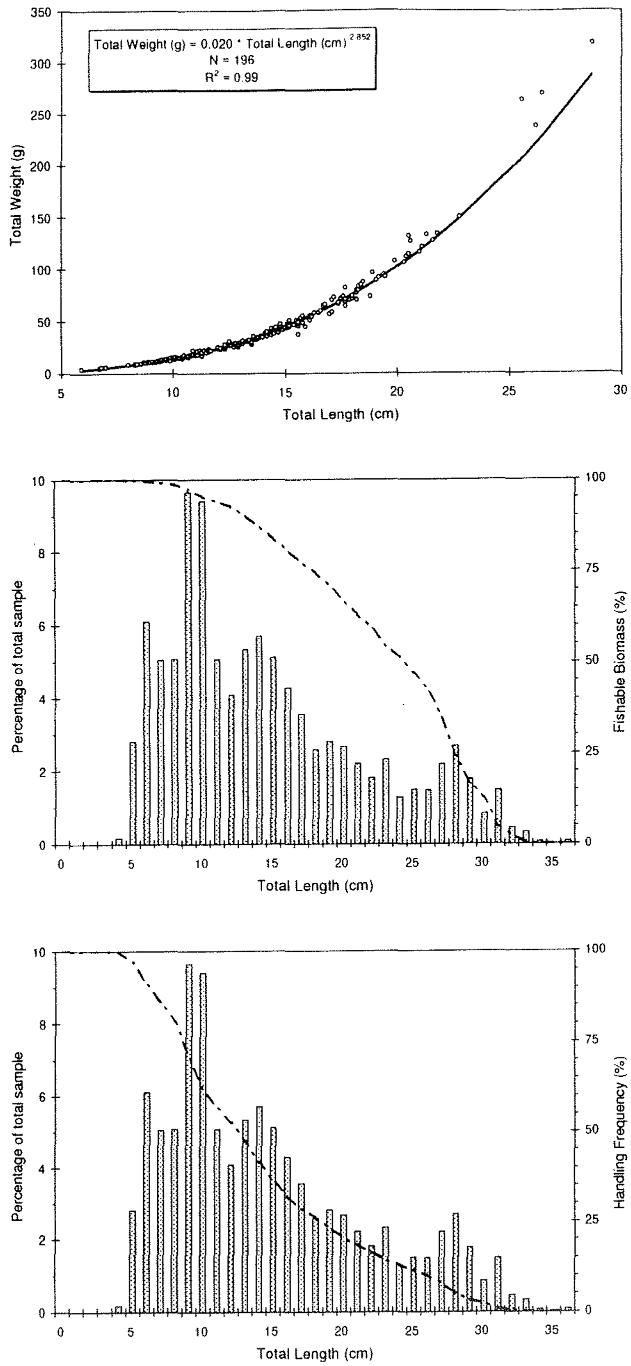


Figure 10. Weight-length relationship (upper), length frequency distribution and cumulative fishable biomass relative to fork length (middle), and cumulative handling frequency relative to fork length (lower) for winter flounder during 1995.

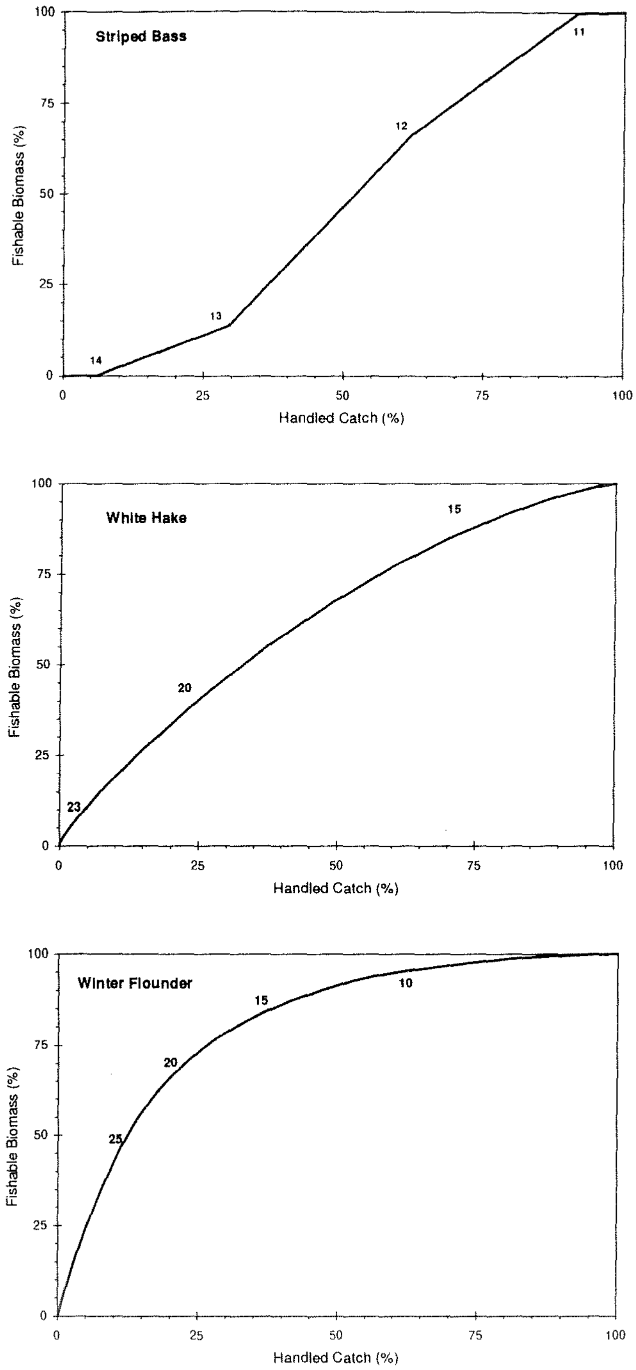


Figure 11. Fishable biomass (%) versus handled catch (%) for striped bass (upper), white hake (middle) and winter flounder (lower). Numbers on each figure represent fish length (fork length for striped bass, total length for others).

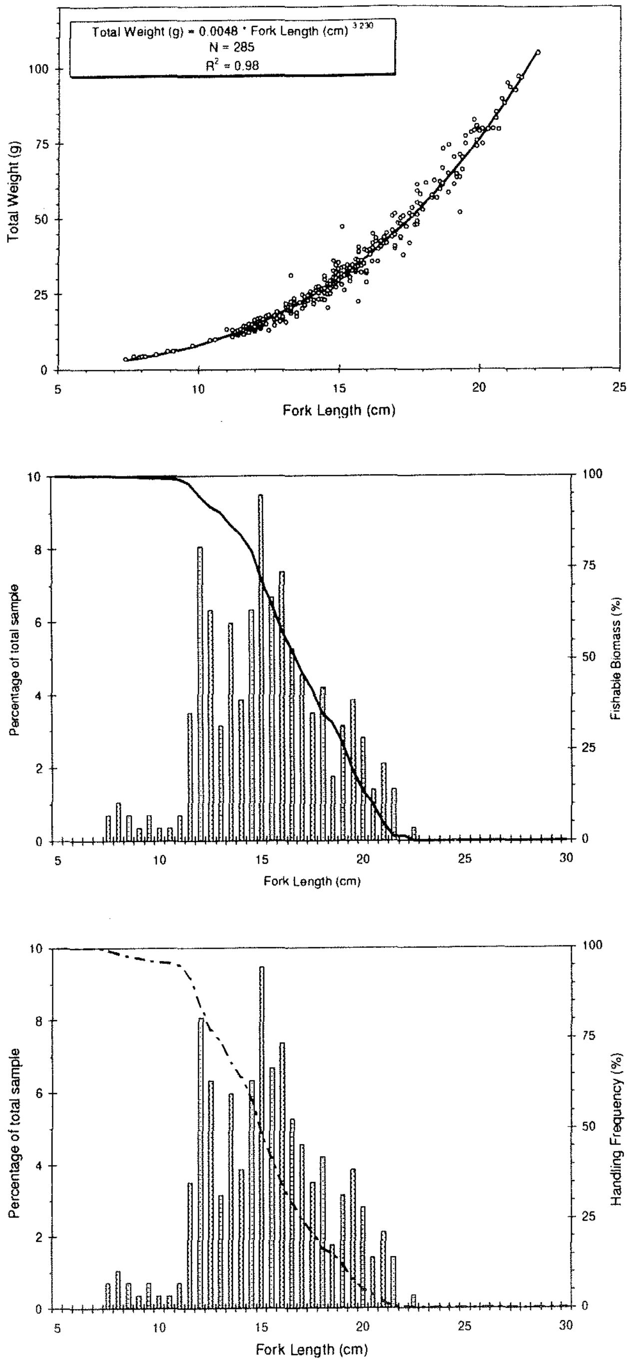


Figure 12. Weight-length relationship (upper), length frequency distribution and cumulative fishable biomass relative to fork length (middle), and cumulative handling frequency relative to fork length (lower) for rainbow smelt during 1995.

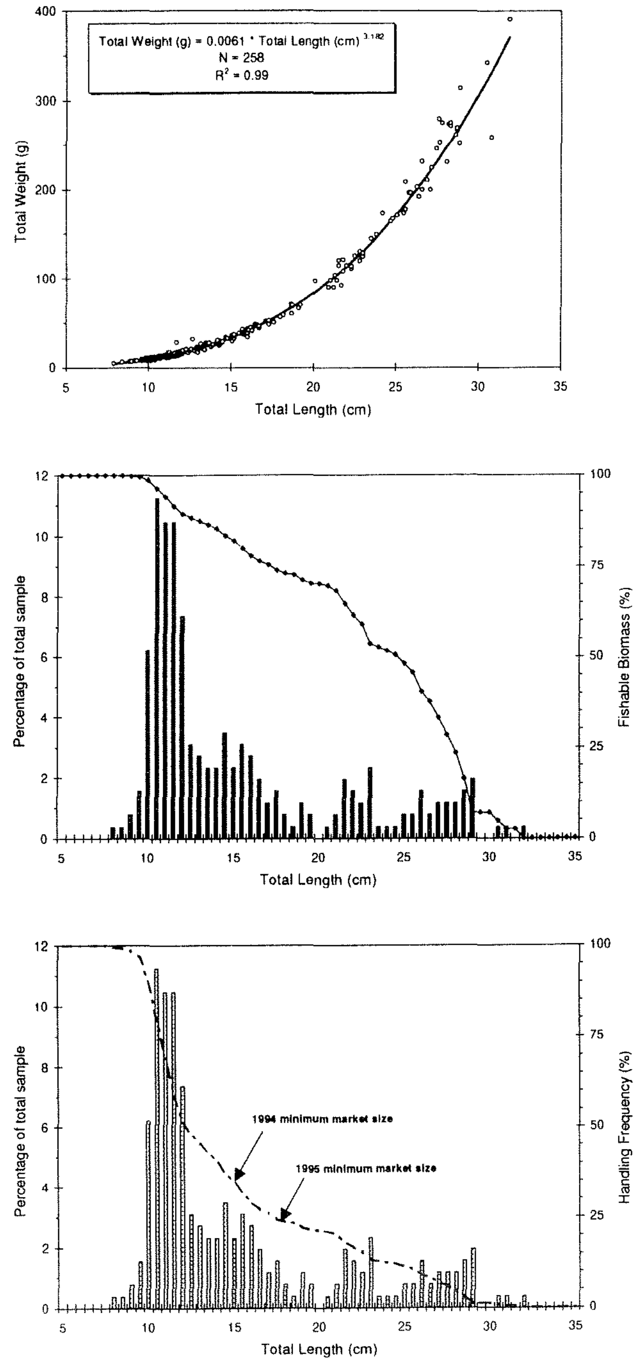
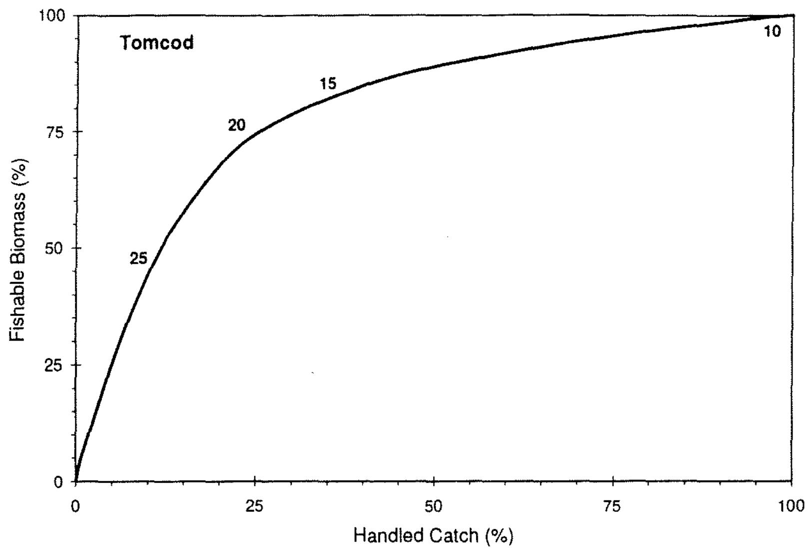


Figure 13. Weight-length relationship (upper), length frequency distribution and cumulative fishable biomass relative to fork length (middle), and cumulative handling frequency relative to fork length (lower) for Atlantic tomcod during 1995.



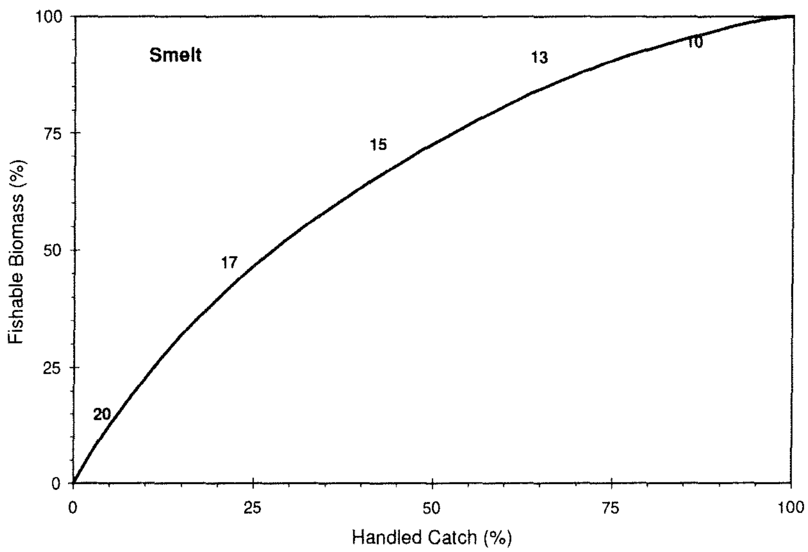


Figure 14. Fishable biomass (%) versus handled catch (%) for tomcod (upper), smelt (lower). Numbers on each figure represent fish length (fork length for smelt, total length for tomcod).

APPENDICES

Appendix 1. Raw daily length frequency distributions for striped bass, winter flounder, and white hake sampled during 1994 (CPUE =fish·net^{-1}·day^{-1} ; P(CPUE)= proportion of cumulative CPUE per species for the fishing season; 0 =Age-0; 1 =Age-1; 2 =Age-2 and older).

Appendix 2. Raw daily length frequency distributions for striped bass, winter flounder, and white hake sampled during 1995 (CPUE =$fish \cdot net^{-1} \cdot day^{-1}$; P(CPUE)= proportion of cumulative CPUE per species for the fishing season; 0 =Age-0; 1 =Age-1; 2 =Age-2 and older).

Appendix 3. Summary report for public consultation regarding timing, magnitude and mitigation of bycatch in open water smelt fishery (Held 19 January, 1996, Wharf Inn, Miramichi City, N.B.)

Miramichi Bay Fall Smelt Fishery Science Workshop
January 19, 1996
Wharf Inn, Miramichi

Participants

Normand Allain	Fisher, Richibucto Village
Arthur Arsenault	Fisher, Tracadie-Sheila
Rod Bradford	Consultant, Mt. Uniack, NS
Guy Caissie	Fisher, Grande-Digue
Ken Clark	Fisher, Douglastown
Reginald Comeau	M.F.U.
Edmond Drysdale	M.F.U. Shédiac
Omer Duplessis	Fisher, Bouctouche
Jean Louis Gallant	Cap Pélé
Sterling King	Fisher, Douglastown
Shane Heartz	Biologist, NBCC Miramichi
Edouard Landry	Fisher, Pokemouche
William MacEachern	Fisher, Tabusintac
Jean-Guy Maillet	Pècheries, Cap-Lumière
Althenard Paulin	Fisher, Shippaggan
Gilles T. Power	Fisher, Pokemouche
Harold Somerville	Burnt Church First Nation
Georges L. St. Coeur	Fisher, Lower Néguac
Alvin Scott	Fisher, Miramichi
Arthur Taylor	Fisher, New Mills
Daryl G. Trevors	Fisher, Chatham
Harry Williston	Fisher, Bay du Vin
Raymond Michaud	NBAPC, Fredericton
François Mondo	MPA, Caraquet
Claude Williams	MPA (NB), Bouctouche
Florence Albert	DFO, Tracadie-Sheila
Robert Allain	DFO, Tracadie-Sheila
Rhéal Boucher	DFO, Tracadie-Sheila
Gérald Chaput	DFO Science, Moncton
Rodrique Morin	DFO, Science, Moncton

The workshop commenced at 930 and was chaired by Gérald Chaput. After introduction of all the participants, the agenda and objectives of the workshop were described.

1 - describe the open-water smelt fishery
  - species of fish caught
  - relative abundance of different species
  - variation among locations in the estuary
  - variation over time during the open-water season
  - variation between years (1994, 1995)
2 - describe size composition of species caught
3 - are there concerns about the species caught
  - what are the conditions of the fish stocks (healthy, poor, ...)
  - what are the impacts of the catches
  - can we suggest changes to the fishery to:
    - improve the efficiency (selectivity) on the directed species
    - reduce impacts on by-catch species
4 - what was wrong with this study? what information are we missing?

Several groundfish fisheries in the Gulf of St. Lawrence are under moratoria and the few remaining fisheries must adhere to strict conservation harvesting plans. The open-water smelt fishery has been rumored to have significant by-catch of groundfish species, namely white hake and winter founder. Without accurate information, this fishery could be unjustly targeted. DFO Science, under contract to Dr. Rod Bradford, undertook the study in 1995 as a follow-up to the 1994 initiative with the objective of providing quantitative data on the open-water smelt fishery in Miramichi Bay in terms of composition and level of by-catch.

Several participants from outside the Miramichi area had concerns that the meeting was to address only the Miramichi fishery and wondered why they had been notified of this meeting. They expected to discuss other points relevant to the smelt fishery of which the most important was the low price being offered this year. Participants were reminded that in the letter announcing the meeting, it was specifically stated that it was a science workshop which would provide information on the results of the open-water monitoring study of Miramichi Bay. Rhéal Boucher reminded everyone that their participation was important because although only the Miramichi Bay fishery had been monitored, DFO wanted to know if the situation observed in the Miramichi in 1994 and 1995 was unique to the Miramichi or more of a southern Gulf of St. Lawrence situation.

Rod Bradford was the main presenter, Gérald Chaput provided the French translation.

Why study the Miramichi smelt fishery?

It is the single largest fishery in eastern Canada representing 30% to 40% of the total landings from the southern Gulf of St. Lawrence. The fall fishery represents 20% to 25% of the annual landings. By-catch species of concern include white hake, winter flounder and striped bass.

Methods

Rod Bradford undertook direct sampling of the catches. The fishery was sampled in two zones: lower bay at Loggieville and upper bay at Chatham. Individual fishers were accompanied on the fishing trips. The catch was sorted by species, weighed, counted, and samples for length were obtained.

Results

In 1995, the average catch per net per day of fishing was:

White hake	- 16.5 kg per net per day,	282 fish per net per day
Tomcod	- 26.0 kg per net per day,	
Smelt	- 16.6 kg per net per day,	
Winter flounder	- 3.7 kg per net per day,	
Striped bass	- not weighed,	475 fish per net per day.

The bycatch of other species relative to smelt was lower in 1995 compared to 1994. In 1994, the following catch rates were observed:

White hake	- 33.2 kg per net per day,	217 fish per net per day,
Tomcod	- 25.4 kg per net per day,	
Smelt	- 8.4 kg per net per day,	
Winter flounder	- 2.2 kg per net per day,	
Striped bass	- not weighed,	98 fish per net per day.

Using these catch rate estimates, the catch by species for the open-water season in the Loggieville and Chatham area were:

	1994	1995
Smelt	12 tons	17 tons
Tomcod	34 tons	27 tons
White hake	44 tons	17 tons
Winter flounder	3 tons	4 tons

Striped bass bycatch is mostly young-of-the-year and are estimated as numbers caught

131000 fish 501000 fish

These quantities are fish caught, not necessarily harvested. White hake, winter flounder, and striped bass are returned to the water but the survival rates of these discarded fish are unknown.

The only species for which there was a noticeable decline in catches over the season was for striped bass at the Loggieville site. Catches of young-of-the-year striped bass were highest at the start of the season, Oct. 15, and declined to negligible values by the end.

Winter flounder and tomcod had the widest size range in the catches. For winter flounder and tomcod, 50% of the biomass caught was comprised of fish less than 25 cm total length but these small fish made up more than 85% of the catch in terms of numbers. For white hake, fish less than 20 cm made up 50% of the biomass but almost 70% of the catch in terms of numbers. More than 90% of the biomass and numbers of striped bass were less than 15 cm fork length (these were young-of-the-year). Smelt had the most even distribution, 50% of the biomass consisted of smelt greater than 16 cm and in terms of numbers, 50% of the catch was made up of smelt greater than 15 cm.

The minimum size for tomcod increased from 6 inches to 7 inches resulting in about a 10% marketable biomass in 1995 relative to 1994.

The conclusions were:

- in 1995, the extent of bycatch in terms of weight was less than in 1994. The white hake catch was half the level in 1994, winter flounder and tomcod catch levels were similar but smelt catch was higher in 1995.

Several fishers from the Miramichi area provided some important insights.

1 - Mr. Alvin Scott indicated that two years of observations are insufficient to conclude anything on the bycatch in the openwater fishery. Hake occurs periodically in the Miramichi, not every year. In the late 1950s, there were no hake in the Miramichi. There is large variation in the abundance of hake in smelt nets over a 10-year period. This point was supported by Mr. Daryl Trevors experience regarding hake catches. It was also indicated that bass of all sizes are flushed out by freshets and appear in traps following an increase in flow.

2 - Mr. Ken Clark indicated that the location of the nets is also an important factor. Where he fishes, he seldom sees hake, his nets have high catches of tomcod.

3 - Mr. Alvin Scott asked if weather conditions had been factored into the analysis because these affect catches immensely. These data could be considered but had not been to date.

An informal survey of conditions in other areas of the Gulf was conducted by asking fishers to provide an indication of whether the bycatches observed in the Miramichi are similar to those in their areas.

Baie des Chaleurs (New Mills)

No open-water smelt fishery. Results are not comparable.

Shippagan

One fisher that operates a gillnet fishery for smelt claimed that there was little bycatch in the smelt fishery, other than some tomcod. Smelt catches have declined over the past 3-4 years.

Pokemouche

Bycatches were not as severe, some striped bass and tomcod, occasionally hake. Many fishers use gillnets rather than bagnets. Smelt fishery is strong and about 90% of the catch is smelt.

Baie de Tracadie

One fisher stated that he abandonned the open-water fishery because of excessive bycatch and the need to sort the catch. The smelt fishery has affected the fish communities. He maintains that gillnets are more selective for large smelt, whereas box nets take several species.

Tabusintac

Juvenile bass and some trout are caught in the fall smelt fishery. Very few winter flounder are caught. Bycatches are dependent on freshets.

Néguac

Smelt fishery is roughly half smelt and half bycatch. Tomcod and juvenile herring contribute most of the bycatch.

Richibucto

Fall fisheries catch all species, probably same extent as in Miramichi.

Cocagne

Not much winter flounder in the bycatch and winter flounder tend to be large (>10 inches).

Not much tomcod. The smelt fishery is conducted mostly in the autumn because there is not enougth water in the winter to conduct a smelt fishery.

Several individuals indicated that they had switched to gillnets because of the high bycatch in bagnets and they felt that this gear should not be allowed. This opinion was obviously not shared by everyone.

Rodrique Morin, DFO Science, provided an overview of the status of the winter flounder and white hake stocks of the southern Gulf of St. Lawrence.

For winter flounder, the important points were:

- there is uncertainty about landing statistics for winter flounder. Landings were decreasing since 1991 but the reduction was comparable to the previously observed annual variation.
- species is not under quota management
- it is a coastal species, considered to be composed of multiple stocks,
- the yearly DFO groundfish survey does not cover inshore habitat where winter flounder are found.. Ooverall, the status is considered to be at moderate to low level but it varies regionally. In the Miramichi region, winter flounder is at an intermediate level of abundance compared to the past 25 years.

For white hake, the important points were:

- the fisheries for this species are under moratoria in 1995 (closed)
- annual research surveys indicate a shift in overall distribution in the Gulf. In the past, white hake were found throughout the Gulf, the distribution is now mostly east of PEI and in St. George's Bay. The stock is considered to be at a low level and is particularly scarce in the western parts of the southern Gulf.

In summary, the status of the winter flounder stock of the Miramichi area is considered to be average relative to the long term trend. The status of the white hake is considered to have declined and is at a low level relative to the long term trend.

There was a brief discussion on possible changes to the gear which would reduce the level of bycatch and/or focus on the marketable product. Generally, changes in mesh size were not well received - increases in mesh size would mean decreased smelt catches (the species of interest) and would lead to meshing of fish in the gear which would defeat the purpose. This question was deferred to the regular consultation meetings after fishers and fisheries management had considered the information presented during the science workshop.

The meeting was closed by reminding participants that the everyone was now working from the same information base. The challenge facing the industry and fisheries management was to determine if the present fishery is sustainable for all species or if changes are required. If the fishery needs to be modified, what would industry suggest.

The meeting adjourned at 1215.