# COMMERCIAL BY-CATCH RATES OF SHORTFIN MAKO (*ISURUS OXYRINCHUS*) FROM LONGLINE FISHERIES IN THE CANADIAN ATLANTIC

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*SUMMARY*

*Shortfin makos* (Isurus oxyrinchus) *are a high-value by-catch of pelagic longline fisheries off the eastern coast of Canada. Annual catches in Canadian waters average 60-80 mt per year. Therefore, Canadian catches represent but a small part of that for the North Atlantic population as a whole. A standardized catch rate series was developed based on observed foreign tuna fleets fishing within Canadian waters and the Canadian swordfish fleet. There was no consistent trend in abundance since 1996 based on the standardized catch rate analysis.*

*RÉSUMÉ*

*Le requin taupe bleue* (Isurus oxyrinchus) *est une espèce accessoire de grande valeur au sein de la pêcherie palangrière pélagique qui opère au large de la côte Est du Canada. Les prises annuelles réalisées dans les eaux canadiennes s'élèvent en moyenne à 60-80 t par an. Par conséquent, les prises canadiennes ne représentent qu'une faible part de cela pour l'ensemble de la population nord-atlantique. Une série standardisée de taux de capture a été élaborée sur la base des flottilles thonières étrangères ayant une couverture d'observateur et pêchant dans les eaux canadiennes et de la flottille canadienne ciblant l'espadon. Depuis 1996, l'abondance n'a pas dégagé de tendance cohérente, sur la base de l'analyse du taux de capture standardisé.*

*RESUMEN*

*El marrajo dientuso (*Isurus oxyrinchus*) es una captura fortuita de gran valor de la pesquería de palangre pelágico en aguas de la costa oriental de Canadá. Las capturas anuales en aguas canadienses alcanzan una media de 60-80 t por año. Por lo tanto, las capturas canadienses representan sólo una pequeña parte de las capturas de la población del Atlántico norte en su conjunto. Se desarrolló una serie de tasas de captura estandarizadas basándose en las flotas atuneras extranjeras observadas que pescan en aguas canadienses y en la flota canadiense dirigida al pez espada. Basándose en el análisis de la tasa de captura estandarizada no existía una tendencia coherente en la abundancia desde 1996.*

*KEYWORDS*

*Shortfin mako, by-catch, catch rates*

## 1. Introduction

The shortfin mako shark (*Isurus oxyrinchus)* is a large temperate and tropical pelagic shark species of the family Lamnidae that occurs in the Atlantic, Pacific and Indian oceans. In Canadian waters the shortfin mako shark is most closely associated with warm waters such as in and around the Gulf Stream. It has been recorded from Georges and Browns Bank, along the continental shelf of Nova Scotia, the Grand Banks and even into the Gulf of St. Lawrence (Templeman 1963). In Canadian waters these sharks are not abundant, due to their preference for warm waters, but neither are they uncommon. The species is highly migratory, with tagging results suggesting that there is a single well-mixed population in the North Atlantic (Casey and Kohler 1992). Atlantic

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Canada represents the northern extension of their range, and most of their population is believed to reside in more temperate waters.

O'Boyle *et al.*, 1996 provided an early summary of catches, but the status of the mako shark population has only recently been assessed in Canadian waters (Campana *et al.*, 2004a, 2006). The results of the recent analysis were somewhat uncertain due to limited statistical power, but suggested that abundance had been relatively stable since 1988. Based on an analysis of U.S. pelagic longline logbooks fishing outside of Canadian waters, Baum *et al.*, 2003 suggested that the North Atlantic population had declined since 1986. An initial attempt to prepare a North Atlantic-wide stock assessment of shortfin makos also suggested that the population may have declined, but the assessment was hampered by poor data quality, and the conclusion was considered to be very provisional (ICCAT 2004).

Non-restrictive catch guidelines of 250t have been in place for mako since 1995, but these guidelines were not based on any scientific advice. A recent recovery potential assessment suggested that Canadian catches be limited to 100t annually, and that live catches be returned alive to the water (Campana *et al.*, 2006).

The objective of the current analysis is to provide an updated and improved standardized catch rate analysis as an index of abundance of shortfin mako in the Canadian Atlantic.

## 2.Landings

Mako shark landings and/or nominal catch in the Canadian Atlantic (NAFO Areas 2-5) are recorded for all Canadian vessels landing their catch, as well as for foreign vessels, which operate under 100% observer coverage within the EEZ. Reported landings peaked at around 160 mt in 1994 (**Table 1**). Since 1998 landings have varied between about 60 and 100 mt. It is possible that part of the mako catch reported prior to 1996 was actually porbeagle. Only Canadian, Japanese and Faroese vessels are known to have caught significant quantities of mako shark in Canadian waters. In the northwest Atlantic as a whole (north of Florida), mean reported catches are somewhat larger, averaging 400-800 mt in the 1990s. North Atlantic nominal catches are substantially larger, averaging about 2300 mt since 1998. It is likely that a significant portion of the mako catch in international waters goes unreported.

There is no directed fishery for mako, with most of it being bycatch in pelagic longline fisheries (**Table 2**). The swordfish fishery is the main source of mako catches. Bycatch in the groundfish gillnet fishery is also significant. Recreational catches are minor, accounting for only a few sharks landed each year (Campana *et al.*, 2004b). A breakdown of the Canadian catch by region and gear type indicates that most of the catch is taken by longline in the Scotia-Fundy region (**Table 3**).

The Scotia-Fundy Observer Program (SFOP) has maintained 100% coverage of foreign fisheries in the Canadian zone since 1987, thus allowing accurate determinations of both nominal catch and bycatch. SFOP coverage of domestic longline vessels has been considerably less, probably on the order of 5%. Nevertheless, SFOP observations confirm that most of the mako caught by both foreign and domestic vessels is retained, and not discarded (Campana *et al.*, 2004a). Observed catch between 1990-1999 averaged about 20 mt annually, with most of that coming from Japanese vessels. Since 1999, virtually all observed catch has been by Canadian vessels. Catch locations mapped by quarter over the period 2000-2007 indicate that most of the Canadian mako catch occurred in deep waters off the continental shelves of Nova Scotia and Newfoundland in the summer and fall (**Figure 1**). Significant catches have also been observed in the deep basins of the Scotian Shelf.

An analysis of SFOP-observed sets between 1990-2003 indicates that makos typically comprise less than 2-3% of the catch (Campana *et al.*, 2004a). The fisheries for swordfish and yellowfin tuna contain the highest proportions of makos, consistent with their being warm-water fisheries.

The length composition of the commercial catch as observed by SFOP for 1987-2007 indicates that mature females and young-of-the-year are rarely caught in Canadian waters (**Figure 2**).

## 3. Commercial catch rates

Calculations of mako catch rate (kg/hook) were based on directed longline catches for large pelagic species, which account for most of the mako sharks caught in Canada. All foreign data came from the Scotia-Fundy Observer Program (SFOP) and are thus considered accurate. All Canadian data came from pelagic longline

logbook data cross-matched to landings; for the period examined (1996+), these data are also considered to be relatively accurate. Initial examination of the catch rate data indicated that the major data sources could be categorized by country (Japan, Canada, Faroes), vessel identity (CFV), area fished (around Newfoundland; eastern Scotian Shelf (NAFO Division 4VW); and the southern region (NAFO Division 4X, 5Z)), season (quarter), and species sought (bigeye tuna, swordfish, bluefin tuna, yellowfin tuna, porbeagle). The distribution of the set by set data was highly skewed, with many zero sets. Since previous analyses of blue shark had demonstrated that the reporting rate prior to 1994 was inconsistent due to finning (Campana *et al.*, 2002), it was likely that some of the zero sets were actually unreported sets. Accordingly, the data were first analyzed at a trip level; all trips that reported at least one mako shark were assumed to have been accurately reported, and thus all sets of that trip (including zero sets) were used in the analysis. Trips with no makos reported were not used. The catch rate of makos in porbeagle-directed trips was very low, so this category of data was not used.

A succession of generalized linear models (GLMs) were tried in previous analyses of mako catch rates (Campana *et al.*, 2004a). The data were first analyzed at the set by set level using a GLM with a negative binomial error distribution, with year, region, season, species sought and vessel (CFV) as factors. However, the frequency of zero sets and missing cells for combinations of factor levels confounded the analysis. Therefore, the data were aggregated to the trip level, and then restricted to the factor levels with the most data. In the case of the Japanese fishery, the trips included were those targeting bigeye tuna in the 4$^{th}$ quarter on the Scotian Shelf between 1987-1999. Canadian data were restricted to trips targeting swordfish between July and September on the Scotian Shelf between 1996-2003. For both countries, only vessels which fished more than one year were included in the model. The same data selection criteria were used in the model reported here, with the inclusion of the more recent years.

The final (and accepted) catch rate model was a trip-level GLM with a gamma error distribution using year and CFV as factors. Models with CFV tended to outperform models using country (but not CFV) as a factor. Model results indicated that both year and CFV were significant factors. Since not all vessels fished all years, an interaction term could not be tested. This model has been maintained for subsequent updates of mako shark catch rate series (Campana *et al.*, 2006; the current analysis). There was no evidence of a trend in the standardized catch rate since 1996 (**Figure 3**). However the model could only explain 26% of the deviance in the data. The higher catch rates of the earlier years are exclusive to the Japanese fishery, which cannot be properly standardized to the later Canadian fishery. The corresponding decline in associated standard errors of estimates between earlier and later years is due to the much smaller number of trips available to the time series for the Japanese component of the data (never more than 2 trips for a vessel in a given year), and fewer years per vessel (rarely more than the 2 years minimum for inclusion). Data for years since 1996 by Canadian vessels were characterized by several trips per vessel per year, and 20 of these vessels fished 6 or more years of the time period.

## 4. Discussion

Catches of shortfin mako in the Canadian Atlantic have averaged less than 100 mt annually, and are bycatch of pelagic longline fisheries for swordfish and tuna. There was no evidence of a trend in abundance based on a standardized catch rate series.

## 5. References


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**Table 1.** Reported mako shark landings (mt) by country.

**Canadian Atlantic (NAFO Areas 2 - 5)**

| Year | Canada | Faroe Is | Japan | Other | Total |
|---|---|---|---|---|---|
| 1979 | | | 0 | | 0 |
| 1980 | | 2 | 0 | | 2 |
| 1981 | | | 1 | | 1 |
| 1982 | | | 0 | | 0 |
| 1983 | | | 5 | | 5 |
| 1984 | | | 1 | | 1 |
| 1985 | | | | | |
| 1986 | | | 2 | | 2 |
| 1987 | | | 10 | | 10 |
| 1988 | | 0 | 17 | | 18 |
| 1989 | | 1 | 13 | | 14 |
| 1990 | | 5 | 8 | | 13 |
| 1991 | | 2 | 14 | | 16 |
| 1992 | | 2 | 29 | | 31 |
| 1993 | 4 | 0 | 16 | | 20 |
| 1994 | 142 | | 21 | | 164 |
| 1995 | 111 | | 4 | | 115 |
| 1996 | 67 | | 5 | | 72 |
| 1997 | 110 | | 2 | | 112 |
| 1998 | 71 | | 1 | 0 | 72 |
| 1999 | 70 | | 2 | | 72 |
| 2000 | 79 | | | | 79 |
| 2001 | 70 | | | | 70 |
| 2002 | 79 | | | 1 | 79 |
| 2003 | 74 | | | | 74 |
| 2004 | 81 | | | | 81 |
| 2005 | 96 | | | | 96 |
| 2006 | 72 | | | | 72 |
| 2007 | 69 | | | | 69 |

Notes: Canada 1991-2002 is from DFO Zonal Statistics File.
Canada 2003-2005 Scotia-Fundy is from MARFIS, other regions by ad hoc request.
Canada 2006-2007 is Scotia-Fundy only, from MARFIS.
Japan, Faroes, other countries in Canadian Atlantic are from Scotia-Fundy & NF IOP (excludes discards)

**Table 2.** Canadian mako shark landings (mt) by fishery.

| Year | Porbeagle fishery | Swordfish fishery | Tuna fishery | Unspecified pelagic fishery | Groundfish bycatch | Fishery not recorded | Mako Total |
|---|---|---|---|---|---|---|---|
| 1991 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| 1994 | 0 | 63 | 5 | 49 | 14 | 11 | 141 |
| 1995 | 0 | 56 | 9 | 23 | 20 | 3 | 112 |
| 1996 | 1 | 33 | 7 | 13 | 10 | 3 | 67 |
| 1997 | 2 | 53 | 14 | 21 | 15 | 4 | 109 |
| 1998 | 0 | 40 | 5 | 7 | 18 | 0 | 70 |
| 1999 | 1 | 34 | 7 | 8 | 21 | 0 | 71 |
| 2000 | 0 | 30 | 15 | 10 | 24 | 0 | 79 |
| 2001 | 0 | 33 | 15 | 7 | 15 | 0 | 70 |
| 2002 | 0 | 32 | 13 | 11 | 22 | 0 | 78 |
| 2003 | 0 | 49 | 8 | 2 | 15 | 0 | 74 |
| 2004 | 1 | 45 | 18 | 0 | 18 | 0 | 81 |
| 2005 | 0 | 56 | 13 | 1 | 25 | 0 | 96 |
| 2006 | 0 | 34 | 2 | 6 | 26 | 4 | 72 |
| 2007 | 0 | 30 | 1 | 2 | 36 | 3 | 72 |

Notes: Canada 1991-2002 is from DFO Zonal Statistics File.
Canada 2003-2005 Scotia-Fundy is from MARFIS, other regions by ad hoc request.
Canada 2006-2007 is Scotia-Fundy only, from MARFIS.

**Table 3.** Canadian landings (mt) of mako shark by fishing gear, area and year.

| Year | Region | Longline | Handline | Gillnet | Otter trawl | Other | Derby | Subarea total | Annual total |
|---|---|---|---|---|---|---|---|---|---|
| 1993 | Scotia-Fundy | | | 0.3 | | | | 0 | 4 |
| | NF | 1.1 | | 2.3 | | 0.1 | | 4 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | | | | | | | 0 | |
| 1994 | Scotia-Fundy | 117.6 | 2.3 | 9.5 | 1.7 | 0.1 | | 131 | 142 |
| | NF | 6.5 | | 4.5 | | | | 11 | |
| | Quebec | | 0.2 | | | | | 0 | |
| | Gulf | | | | | | | 0 | |
| 1995 | Scotia-Fundy | 88.0 | 0.2 | 13.4 | 0.7 | 0.5 | | 103 | 111 |
| | NF | 5.9 | | 2.4 | | | | 8 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | 0.1 | | | | | | 0 | |
| 1996 | Scotia-Fundy | 50.5 | 0.3 | 7.8 | 1.0 | | 0.0 | 60 | 68 |
| | NF | 5.6 | | 2.3 | | | | 8 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | | | | | | | 0 | |
| 1997 | Scotia-Fundy | 90.2 | 0.2 | 9.3 | 1.5 | | | 101 | 110 |
| | NF | 4.0 | | 4.0 | 0.1 | | | 8 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | 0.2 | | | | | | 0 | |
| 1998 | Scotia-Fundy | 46.2 | 0.2 | 8.0 | 2.2 | 0.6 | | 57 | 71 |
| | NF | 9.5 | | 4.0 | | | | 14 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | 0.2 | | | | | | 0 | |
| 1999 | Scotia-Fundy | 45.8 | | 4.8 | 1.8 | 0.7 | | 53 | 70 |
| | NF | 7.8 | 0.1 | 9.2 | 0.1 | | | 17 | |
| | Quebec | 0.0 | | | | | | 0 | |
| | Gulf | 0.1 | | | | | | 0 | |
| 2000 | Scotia-Fundy | 48.2 | 0.1 | 5.3 | 0.4 | 0.8 | 0.5 | 55 | 80 |
| | NF | 10.7 | | 12.9 | 0.1 | 0.5 | | 24 | |
| | Quebec | 0.0 | | | | | | 0 | |
| | Gulf | 0.1 | | | | | | 0 | |
| 2001 | Scotia-Fundy | 51.2 | 0.2 | 5.2 | 0.2 | 0.4 | | 57 | 70 |
| | NF | 8.6 | | 3.6 | 0.1 | | | 12 | |
| | Quebec | 0.0 | 0.1 | 0.2 | | 0.0 | | 0 | |
| | Gulf | 0.0 | | | | 0.1 | | 0 | |
| 2002 | Scotia-Fundy | 54.3 | 0.3 | 9.8 | 0.8 | 1.3 | 0.7 | 67 | 79 |
| | NF | 6.4 | 0.1 | 4.5 | | | | 11 | |
| | Quebec | | | 0.1 | | | | 0 | |
| | Gulf | 0.8 | | 0.2 | | 0.1 | | 1 | |
| 2003 | Scotia-Fundy | 57.6 | 0.2 | 6.8 | 0.5 | 1.4 | 0.4 | 67 | 74 |
| | NF | 6.0 | | 1.4 | | 0.1 | | 8 | |
| | Quebec | 0.0 | | | | | | 0 | |
| | Gulf | | | | | | | 0 | |
| 2004 | Scotia-Fundy | 62.1 | 0.2 | 6.8 | 0.1 | 1.0 | 1.0 | 71 | 82 |
| | NF | 8.0 | | 3.0 | | | | 11 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | 0.2 | | | | | | 0 | |
| 2005 | Scotia-Fundy | 71.3 | 0.5 | 11.9 | 0.9 | 0.9 | 0.4 | 86 | 96 |
| | NF | 5.3 | | 4.4 | 0.1 | | | 10 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | 0.4 | | | | | | 0 | |
| 2006 | Scotia-Fundy | 61.5 | 0.1 | 5.0 | 0.3 | 0.5 | 0.4 | 68 | 72 |
| | NF | | | | | 4.0 | | 4 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | | | | | | | 0 | |
| 2007 | Scotia-Fundy | 61.2 | | 6.0 | 0.8 | 0.6 | 0.2 | 69 | 72 |
| | NF | | | | | 3.0 | | 3 | |
| | Quebec | | | | | | | 0 | |
| | Gulf | | | | | | | 0 | |

Notes: 1991-2002 is from DFO Zonal Statistics File.
2003-2005 Scotia-Fundy is from MARFIS, other regions by ad hoc request.
2006-2007 is Scotia-Fundy only, from MARFIS.

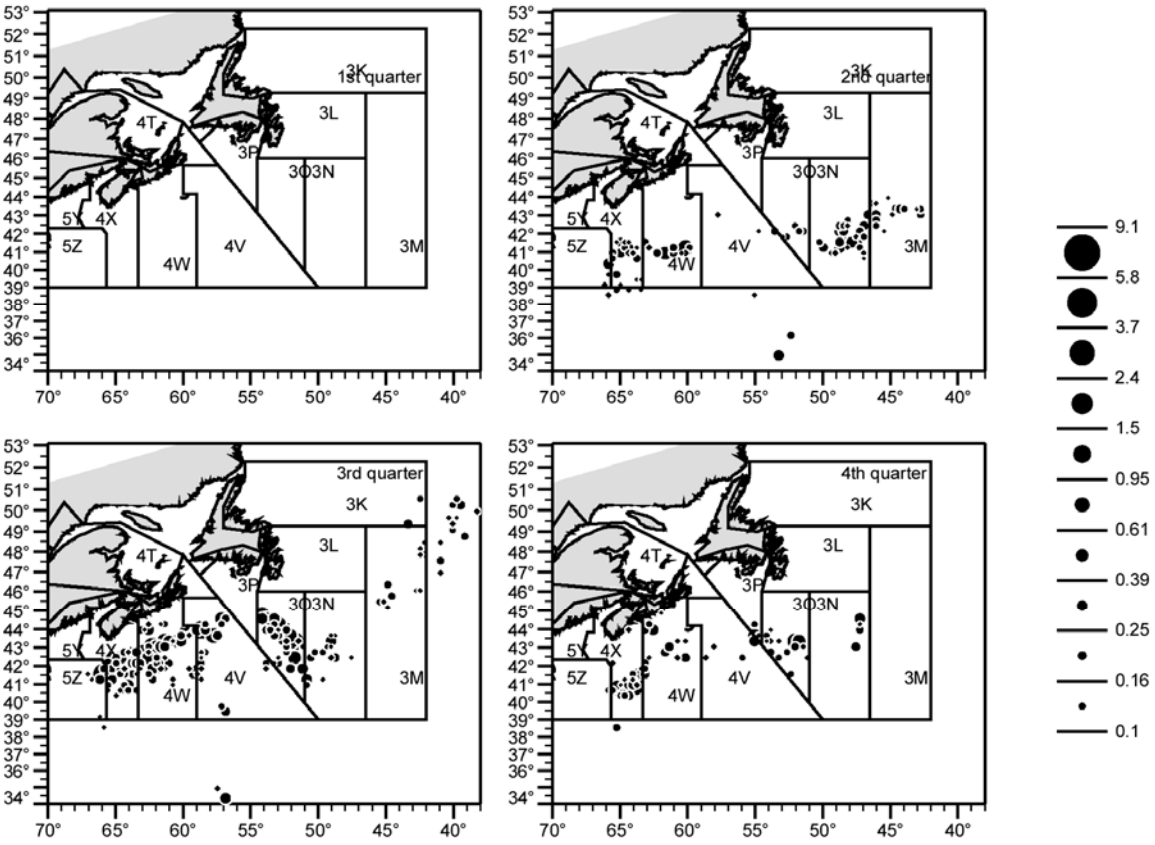


**Figure 1.** Shortfin mako catch location by quarter observed by SFOP on Canadian vessels fishing for large pelagics between 2000-2007.

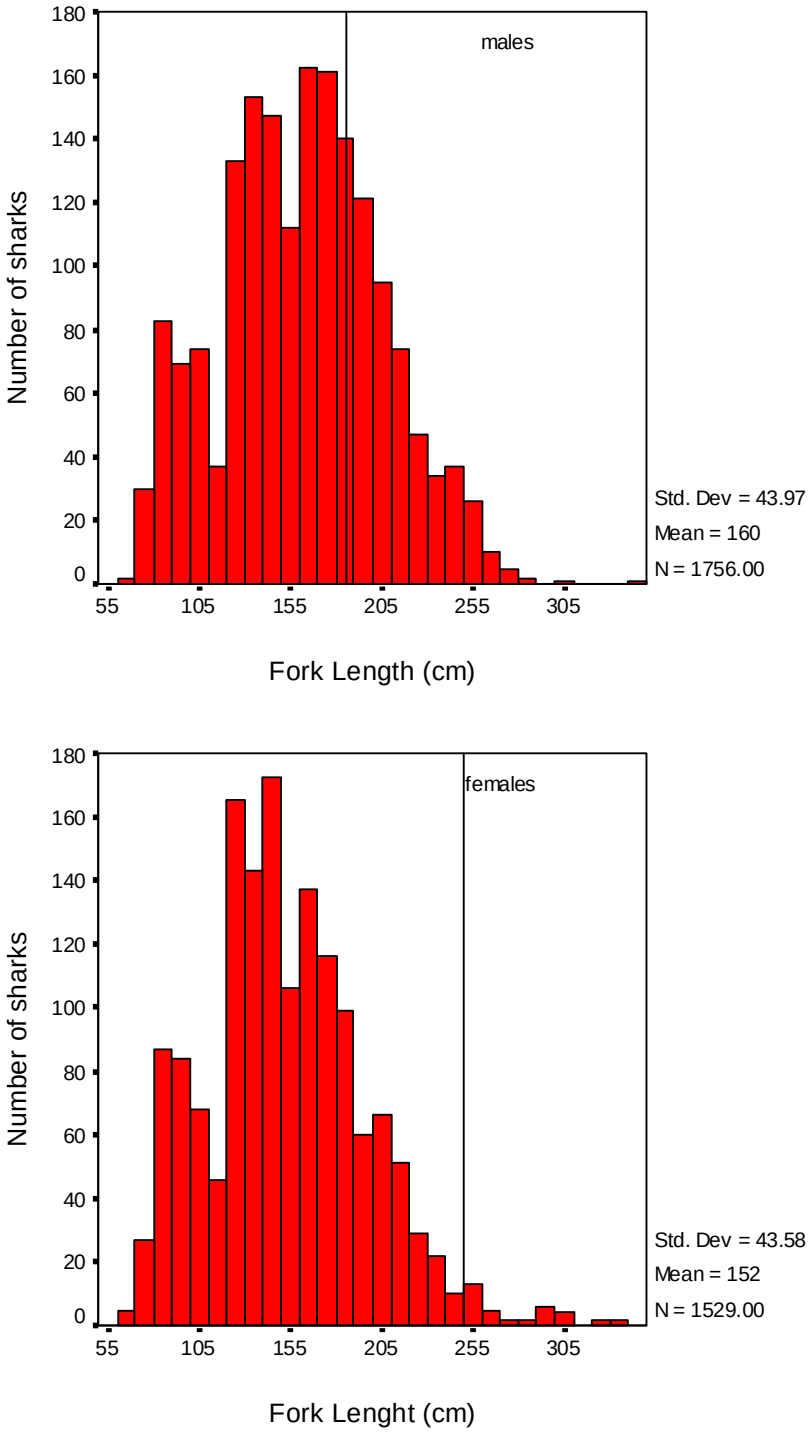


**Figure 2.** Length frequency histograms of male and female shortfin mako sharks (year, area and season combined) from Observer data collected from 1987-2007 from the waters around Newfoundland, the Scotian Shelf, and off southern Nova Scotia. Length at maturity (fork length) for females is between 250-280 cm and males 185-205 cm. Reference lines represent minimum length at maturity.

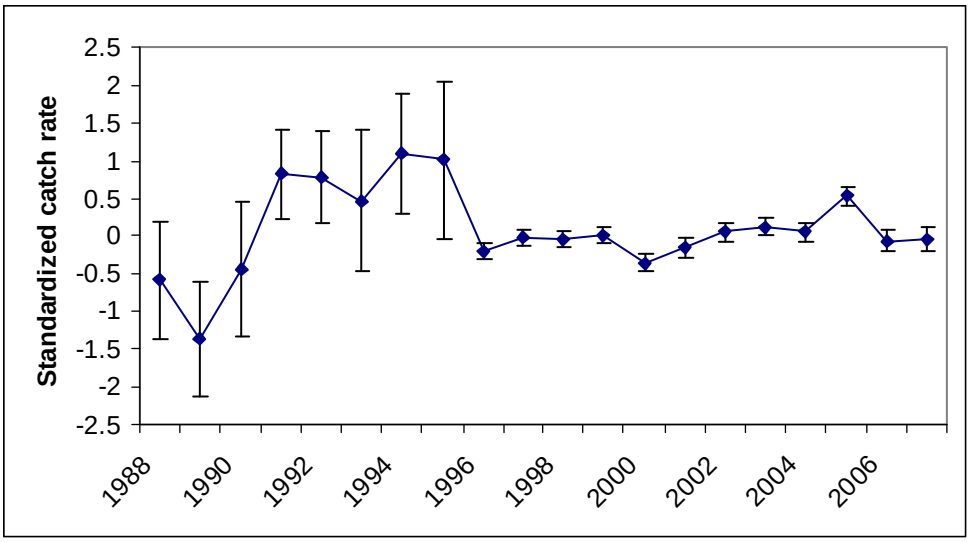


**Figure 3.** Standardized trip-level catch rate (ln kg/hook) of shortfin mako sharks caught by pelagic longliners on the Scotian Shelf between 1988 and 2007. Data were restricted to Japanese longliners targeting bigeye tuna between Oct-Dec of 1987-1999 and Canadian longliners targeting swordfish between July-Sept of 1996-2007. The GLM model was fit to non-zero trips using a gamma error distribution with the factors Year and Vessel as main effects. Error bars represent 1 SE around the mean.