

COMMERCIAL BY-CATCH RATES OF BLUE SHARK (*PRIONACE GLAUCA*) FROM LONGLINE FISHERIES IN THE CANADIAN ATLANTIC

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SUMMARY

There is no directed fishery for blue sharks (Prionace glauca) in Canadian waters, and virtually all blue sharks caught as by-catch in pelagic longline fisheries are discarded at sea. Based on an extensive series of observer measurements, total by-catch by both observed and unobserved vessels was estimated since 1986. Total blue shark by-catch has averaged over 2000 t annually in recent years; landings and dead discards have averaged about 1000 t annually since 2002. Two indices of abundance were developed from standardized blue shark catch rates in tuna and swordfish longline fisheries. Although the two abundance indices were not completely consistent with each other, neither one showed a decline in net abundance since 1996. The models demonstrated both strong interaction and aliasing between the factors year and vessel, a combination that has the potential to confound a catch rate series. Nevertheless, there was no evidence that blue shark abundance has declined in Atlantic Canadian waters in recent years.

RÉSUMÉ

Il n'y a pas de pêche dirigée sur le requin peau bleue (Prionace glauca) dans les eaux canadiennes et pratiquement tous les requins peaux bleues qui sont capturés comme prise accessoire par les pêcheries palangrières pélagiques sont rejetés en mer. Sur la base d'une grande série de mensurations effectuées par des observateurs, on a estimé depuis 1986 la prise accessoire totale réalisée à la fois par les navires faisant l'objet d'une couverture d'observation et ceux dépourvus de couverture. Ces dernières années, le total des prises accessoires de requin peau bleue s'est élevé, en moyenne, à plus de 2.000 t annuellement. Depuis 2002, les débarquements et les rejets morts se sont élevés en moyenne à environ 1.000 t annuellement. Deux indices d'abondance ont été élaborés à partir des taux de capture standardisés du requin peau bleue au sein des pêcheries palangrières de thonidés et d'espadon. Même si les deux indices d'abondance n'étaient pas complètement cohérents entre eux, aucun des deux n'a indiqué de baisse de l'abondance nette depuis 1996. Les modèles ont dégagé à la fois une forte interaction et un chevauchement (aliasing) entre les facteurs année et navire, combinaison qui a le potentiel de confondre une série de taux de capture. Néanmoins, aucun élément n'a permis d'affirmer que l'abondance du requin peau bleue avait chuté dans les eaux canadiennes de l'Atlantique au cours de ces dernières années.

RESUMEN

No existe una pesquería dirigida a la tintorera (Prionace glauca) en aguas canadienses, y prácticamente todas las tintoreras capturadas como captura fortuita son descartadas en el mar. Basándose en una amplia serie de mediciones de observadores, se estimó la captura fortuita total desde 1986 tanto de los buques observados como de los no observados. La captura fortuita total de tintorera ha alcanzado una media de 2000 t anuales en años recientes; los desembarques y los descartes muertos han alcanzado una media de 1000 t anualmente desde 2002. Se desarrollaron dos índices de abundancia a partir de las tasas de captura estandarizadas de la tintorera en las pesquerías de palangre dirigidas a los túnidos y al pez espada. Aunque los dos índices de abundancia no eran completamente coherentes entre sí, ninguno mostraba un descenso en la abundancia neta desde 1996. Los modelos demostraron una fuerte interacción y solapamiento (aliasing) entre los factores año y buque, una

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combinación que tiene el potencial de confundir las series de tasas de captura. No obstante, no había pruebas de que la abundancia de la tintorera haya descendido en aguas canadienses atlánticas en años recientes.

KEYWORDS

Blue shark, by-catch, catch rates

1. Introduction

The blue shark (*Prionace glauca*) is a large temperate and tropical pelagic shark species of the family Carcharhinidae that occurs in the Atlantic, Pacific and Indian oceans. The species is highly migratory, with tagging results suggesting that there is a single well-mixed population in the North Atlantic (Casey and Kohler 1991, Campana *et al.*, 2004). In Canadian waters the blue shark has been recorded off southeastern Newfoundland, the Grand Banks, the Gulf of St. Lawrence, the Scotian Shelf and in the Bay of Fundy. At certain times of the year, it is probably the most abundant large shark species in eastern Canadian waters (Templeman 1963).

The inherent vulnerability of sharks and other elasmobranchs to overfishing and stock collapse is well documented. FAO's *International Plan of Action for the Conservation and Management of Sharks* (FAO 1998) concluded that many of the world's shark species are severely depleted. The issue was also highlighted in an American Fisheries Society policy statement, which noted that most elasmobranch populations decline more rapidly and recover less quickly than do other fish populations (Musick *et al.*, 2000). Indeed, numerous authors have noted the low productivity of elasmobranchs compared with teleosts, which is largely a result of their low fecundity and late age at sexual maturation. The blue shark is among the more productive of pelagic shark species (Cortés 2000), with a sustainable fishing mortality (F_{msy}) in the range of 0.18 (Campana *et al.*, 2004). However estimation of mortality rates may be confounded by discarding and reporting practices. Campana *et al.*, (2002) concluded that unreported bycatch was about 20 times larger than reported catch in Canadian waters. The objective of the current analysis is to provide improved and updated bycatch estimates of blue sharks in the Canadian Atlantic, as well as standardized catch rate estimates as indices of population abundance.

2. Fisheries management

Since 1995, fisheries management plans for blue sharks in Atlantic Canada have maintained non-restrictive catch guidelines of 250 mt annually for blue sharks in the directed shark fishery. The non-restrictive catch guidelines approximated the reported landings of these species in Atlantic Canada in 1992 and were not based upon estimates of stock abundance. Fishing gears to be used in the directed fishery were limited to longline, handline or rod and reel gear for commercial licenses, and to rod and reel only for recreational licenses. The recreational fishery is restricted to hook and release only except during authorized shark derbies. No catch restrictions were put on shark caught as by-catch in large pelagic fisheries. A ban on "finning" sharks (the removal of the fins and at-sea disposal of the finless carcass) was implemented in June 1994. Full details of the Canadian shark management plan are presented in Campana *et al.*, 2002.

3. Commercial landings

Blue shark landings and/or nominal catch in the Canadian Atlantic (NAFO Areas 2-5) are known only for Canadian vessels landing their catch, or for foreign vessels operating under 100% observer coverage within the EEZ. Landings peaked at around 250 mt in 1994, declining thereafter to only 9 mt in 2007 (**Table 1**). Only Canadian, Japanese and Faroese vessels are known to have caught significant quantities of blue shark in Canadian waters.

Blue shark landings by Canadian vessels are very small, averaging 52 mt per year since 1990. Most of this catch is restricted to the Scotian Shelf in the first half of the year, extending northwards into the Gulf of St. Lawrence and the Newfoundland shelf between July and December (Campana *et al.*, 2004). Most landings are from longlines, although recreational shark fishing derbies averaging 10-20 mt annually have accounted for a growing proportion of the landings in recent years. Minor differences between the Canadian catch reported in **Table 1** and DFO Zonal Statistics are due to the more accurate derby landings reported here.

4. By-catch

4.1 Observed by-catch

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 indicate that Canadian, Japanese and (in earlier years) Faroese longliners caught substantially larger numbers of blue sharks (**Table 2**) than would otherwise be known from nominal catch statistics (**Table 1**). Blue shark bycatch in fisheries other than that for large pelagics was much smaller, although the 1-2 mt observed on 4X groundfish longlines could add up to 20-60 mt annually when pro-rated across non-observed trips.

Observed catch and by-catch between 1990-1999 averaged about 215 mt annually, with most of that coming from Japanese vessels. In most years, virtually all of the blue shark catch was discarded (**Table 2**). Since 1999, essentially all observed catch and by-catch has been by Canadian vessels. Catch locations mapped by quarter over the period 2000-2007 indicate that most of the Canadian by-catch occurred in deep waters off the continental shelves of Nova Scotia and Newfoundland, increasing in quantity through the year (**Figure 1**). Significant catches have also been observed in the deep basins of the Scotian Shelf.

4.2 Estimation of unobserved blue shark by-catch

To determine the magnitude of the blue shark by-catch in the various large pelagic fisheries, bycatch was estimated by country, fishery, quarter and year from Scotia-Fundy Observer Program (SFOP) observations made between 1986-2000, with by-catch defined as the summed weight of the kept and discarded blue sharks relative to the summed large pelagic catch (tuna, swordfish and porbeagle). The summed large pelagic catch accounted for virtually all of the catch, and its use in the estimation avoided problems associated with the species sought being unknown. The analysis was restricted to Canadian, Japanese and Faroese vessels, since they accounted for more than 99% of the blue shark catch. By-catch in the foreign fisheries was fully observed, so estimation was used more to calculate by-catch proportion than by-catch weight. Total pelagic catch for each cell was determined from ZIF for Canadian vessels and from SFOP for foreign vessels. Full details on the estimation protocol are presented in Campana *et al.*, 2004.

Campana *et al.*, 2004 concluded there were no consistent trends in blue shark by-catch proportions across years for any of the major large pelagic fisheries (Canadian or Japanese), so the weighted mean proportion (weighted by number of observed sets) across years 1986-2003 was used to estimate the Canadian by-catch for each of the bluefin tuna, swordfish, other tuna (mostly bigeye), and porbeagle fisheries. Therefore, each quarter and fishery was characterized by a unique by-catch proportion, but this proportion was maintained for all years. This method of calculation is considered to be less susceptible to sampling variability than was the year by year method of Campana *et al.*, 2002. In addition, the sum of the large pelagic catches was updated and revised from those of Campana *et al.*, 2002, 2004.

Anecdotal reports on observer catch estimation methods highlight the difficulty of estimating, or even recording, the component of the catch which is not brought onto deck before discarding. Since some Canadian vessels routinely remove blue sharks (or cut off the leader) before they reach the deck, it is likely that the estimated by-catch proportions represent the minimum actual Canadian by-catch. In order to estimate the extent of any such underreporting, Campana *et al.*, 2004 prepared a second set of analyses based only on those sets that reported at least one blue shark. This second set of by-catch proportions assumes that blue sharks were caught in all sets, but reported only in some; thus it sets an upper limit to the by-catch estimate, termed the maximum estimate. Campana *et al.*, 2002 concluded that blue shark bycatch on Canadian vessels fishing swordfish or other tunas was underreported by some observers, and that actual by-catch lies somewhere in the range defined by the minimum and maximum by-catch estimates. For the current analysis, we have assumed that the mean of the minimum and maximum by-catch estimates represents the most probable by-catch for these fisheries, as was assumed by Campana *et al.*, 2004. Minimum by-catch estimates appear to be valid for the Japanese, bluefin tuna and porbeagle fisheries, although by-catch for both domestic and foreign fleets may have been higher than that shown for the period prior to 1994, due to the prevalence of finning at the time. Minimum, maximum and most probable estimates for each fishery are all shown in **Tables 3-6**.

Blue shark by-catch and proportions for each year and quarter in the Canadian bluefin tuna, swordfish, and other tuna (albacore, yellowfin, and bigeye) fisheries are presented in **Tables 3-6**. By-catch proportions often exceeded 100%. The largest by-catches, around 2000 mt annually in recent years, are taken by the swordfish fishery.

Annual by-catch estimates averaged 71 mt for the bluefin tuna fishery over the time series, but rose in 2005 and have exceeded 100 mt since that time. For fisheries on tunas other than bluefin, bycatch averaged 195 mt over the time series, but have not exceeded 120 mt since 2003. Blue shark bycatch in the porbeagle fishery tended to be small in both the Canadian and Faroese longline fisheries, averaging 43 mt, and never exceeding 14 mt since 2001.

4.3 Total catch mortality

Campana *et al.*, 2004, in a study of hooking mortality, determined that 60% of the discarded sharks would be expected to survive capture in commercial longline fisheries. Survival in the recreational fishery would be expected to be higher at 81%. Commercial discards in some fisheries were finned prior to June 1994; these discards were assumed to be 100% dead.

Total estimated annual blue shark catches and discards in Canadian waters are shown in **Table 7**. Discards from the Canadian large pelagic fisheries were responsible for the largest proportion of blue sharks caught in Canadian waters since 1986. Total estimated catch mortalities, based on the discard rates and hooking mortalities, averaged around 1000 mt per year over the time series (**Table 7; Figure 2**). The proportion of catch mortality contributed by tournament fishing was negligible, averaging 2% of the total catch mortality in recent years.

5. Commercial and recreational catch rates

5.1 Commercial catch rate

Calculations of commercial catch rate (ln-transformed kg/hook) were based on directed longline catches for large pelagic species, which account for most of the blue sharks caught in Canada. All data came from the Scotia-Fundy Observer Program (SFOP) and are considered accurate since 1995 (Campana *et al.*, 2004). Previous analyses of catch rate data by Campana *et al.*, 2004 indicated that the major data sources could be categorized by country (Japan, Canada), area fished (Newfoundland, eastern Scotian Shelf (NAFO Division 4VWX), and the southern region (NAFO Division 4X, Georges Bank), season (fall and winter), and species sought (bigeye tuna, swordfish and bluefin tuna). Catch rate trends in the southern region tended to be quite different (and based on a much smaller sample size) than those off Newfoundland and the Scotian Shelf, so only the latter two regions were used. Trends for swordfish and bigeye tuna were similar, so were left together in the same analysis; the different trend for bluefin tuna necessitated a separate analysis. Models with vessel (CFV) as a factor tended to outperform models using country (but not CFV) as a factor, but vessels fishing only a single year could not be included in the model. Therefore, only vessels that fished at least 10 sets in at least two years were included.

Consistent with the approach in Campana *et al.*, 2004, the overall trend in blue shark catch rate for the period after 1994 was analyzed using a generalized linear model (GLM) with year, region (Newfoundland, Scotian Shelf), season (fall, winter), species sought (bluefin tuna, swordfish/bigeye tuna) and CFV as factors. The GLM of blue shark catch rate based on the bigeye tuna and swordfish data indicated that all factors were significant (**Table 8**). Predicted catch rates from this model declined from 1995 through 2001, but catch rates have increased since 2001 (**Figure 3**). The GLM based on bluefin tuna fisheries was significant with respect to all factors except season (**Table 9**). Similar to the swordfish/bigeye tuna fisheries, blue shark catch rates in bluefin tuna fisheries since 2001 have been higher than in earlier years (**Figure 4**).

An examination of the length composition of the blue sharks in the data used to derive catch rates indicates that most of the sharks caught fell within a fork length range of 90 - 210 cm (**Figure 5**). Females dominated the catch of sexed lengths (170 cm or larger), but sex was typically unreported for sharks under about 160 cm.

6. Discussion

Catch mortality of blue sharks in Atlantic Canadian waters has remained roughly constant at about 1000t per year since 1997. Virtually all of this catch mortality has been due to discarding from commercial pelagic longline fisheries.

Two indices of blue shark abundance were developed from standardized blue shark catch rates in tuna and swordfish longline fisheries. Although the two abundance indices were not completely consistent with each other, neither one showed a decline in net abundance since 1996. The models demonstrated both strong interaction and aliasing between the factors year and vessel, a combination that has the potential to confound a catch rate series. Nevertheless, there was no evidence that blue shark abundance has declined in Atlantic Canadian waters in recent years.

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Table 1. Reported blue shark landings (mt) by country.

| Canadian Atlantic (NAFO Areas 2 - 5) | | | | | |
|---|---------------|-----------------|--------------|--------------|--------------|
| Year | Canada | Faroe Is | Japan | Other | Total |
| 1979 | | | 4 | | 4 |
| 1980 | | | | 13 | 13 |
| 1981 | | | 1 | | 1 |
| 1982 | | | 2 | | 2 |
| 1983 | | | 1 | | 1 |
| 1984 | | | | | 0 |
| 1985 | | | | | 0 |
| 1986 | | | 13 | | 13 |
| 1987 | | | 38 | | 38 |
| 1988 | | | 5 | | 5 |
| 1989 | | | 10 | | 10 |
| 1990 | 8 | | 13 | | 21 |
| 1991 | 31 | 16 | 5 | | 52 |
| 1992 | 101 | 30 | 30 | | 161 |
| 1993 | 24 | 44 | 47 | | 115 |
| 1994 | 138 | | 116 | | 254 |
| 1995 | 152 | | 73 | | 225 |
| 1996 | 23 | | 173 | | 196 |
| 1997 | 19 | | 36 | | 55 |
| 1998 | 14 | | 17 | | 31 |
| 1999 | 67 | | 11 | | 78 |
| 2000 | 34 | | | | 34 |
| 2001 | 8 | | | | 8 |
| 2002 | 25 | | | | 25 |
| 2003 | 19 | | | | 19 |
| 2004 | 11 | | | | 11 |
| 2005 | 7 | | | | 7 |
| 2006 | 10 | | | | 10 |
| 2007 | 9 | | | | 9 |

Notes: Canada is from DFO Zonal Statistics File and shark derby statistics
 Japan, Faroes, other countries in Canadian Atlantic are from Scotia-Fundy & NF Observer programs (excludes discards)

Table 2. Blue shark catches and discards (mt) by country in Canadian waters as observed by the Scotia-Fundy and Newfoundland Observer programs. The percentage of the catch that was discarded is also shown.

| CATCH | | | | | | DISCARDS | | | | | | DISCARD PERCENTAGE | | | | | |
|-------|--------|----------|-------|------|-------|----------|------|--------|----------|-------|------|--------------------|-------|------|--------|--------|-------|
| Year | Canada | Faroe Is | Japan | USSR | Other | Total | Year | Canada | Faroe Is | Japan | USSR | Other | Total | Year | Canada | Faroes | Japan |
| 1978 | 0 | | 0 | | | 0 | 1978 | 1 | | 8 | | | 9 | 1978 | . | . | 100 |
| 1979 | 0 | | 4 | | | 4 | 1979 | 10 | | 8 | | | 18 | 1979 | 100 | . | 22 |
| 1980 | | 0 | 0 | 13 | 3 | 16 | 1980 | | 3 | 6 | 0 | 3 | 12 | 1980 | . | . | 100 |
| 1981 | | 0 | 1 | | 1 | 2 | 1981 | | 1 | 12 | | 1 | 14 | 1981 | . | 100 | 73 |
| 1982 | | | 2 | | | 2 | 1982 | | | 52 | | | 52 | 1982 | . | . | 100 |
| 1983 | | | 1 | | | 1 | 1983 | | | 25 | | | 25 | 1983 | . | . | 96 |
| 1984 | | | 0 | | | 0 | 1984 | | | 14 | | | 14 | 1984 | . | . | 96 |
| 1985 | 0 | | 0 | | | 0 | 1985 | 1 | | 0 | | | 1 | 1985 | . | . | |
| 1986 | | | 13 | 0 | | 13 | 1986 | | | 31 | 1 | | 32 | 1986 | . | . | 80 |
| 1987 | | 0 | 38 | | | 38 | 1987 | | 2 | 121 | | | 123 | 1987 | . | 100 | 76 |
| 1988 | | 0 | 5 | | 1 | 6 | 1988 | | 16 | 129 | | 1 | 146 | 1988 | . | 100 | 96 |
| 1989 | 0 | 0 | 10 | | | 10 | 1989 | 42 | 8 | 164 | | | 214 | 1989 | 100 | 100 | 96 |
| 1990 | 1 | 0 | 13 | 0 | | 14 | 1990 | 7 | 22 | 102 | 1 | | 132 | 1990 | 100 | 100 | 92 |
| 1991 | 4 | 6 | 5 | 0 | | 15 | 1991 | 20 | 59 | 129 | 19 | | 227 | 1991 | 98 | 90 | 96 |
| 1992 | 0 | 30 | 30 | | 0 | 60 | 1992 | 2 | 82 | 202 | | 1 | 287 | 1992 | . | 73 | 97 |
| 1993 | 1 | 62 | 47 | | | 110 | 1993 | 14 | 19 | 186 | | | 219 | 1993 | 100 | 23 | 79 |
| 1994 | 16 | | 116 | | 0 | 132 | 1994 | 48 | | 207 | | 3 | 258 | 1994 | 78 | . | 64 |
| 1995 | 15 | | 73 | | | 88 | 1995 | 107 | | 100 | | | 207 | 1995 | 88 | . | 59 |
| 1996 | 2 | | 173 | | | 175 | 1996 | 37 | | 61 | | | 98 | 1996 | 89 | . | 26 |
| 1997 | 1 | | 36 | | | 37 | 1997 | 30 | | 0 | | | 30 | 1997 | 98 | . | |
| 1998 | 1 | | 17 | | | 18 | 1998 | 210 | | 17 | | | 227 | 1998 | 100 | . | 45 |
| 1999 | 1 | | 11 | | | 12 | 1999 | 185 | | 282 | | | 467 | 1999 | 100 | . | 96 |
| 2000 | 1 | | 0 | | | 1 | 2000 | 70 | | 3 | | | 73 | 2000 | 100 | . | 100 |
| 2001 | 0 | | 0 | | | 0 | 2001 | 179 | | 0 | | | 179 | 2001 | 100 | . | |
| 2002 | 1 | | 0 | | 0 | 1 | 2002 | 228 | | 0 | | 4 | 232 | 2002 | 100 | . | |
| 2003 | 0 | | 0 | | | 0 | 2003 | 85 | | 0 | | | 85 | 2003 | 100 | . | |
| 2004 | 0 | | | | | 0 | 2004 | 59 | | | | | 59 | 2004 | 100 | . | |
| 2005 | 4 | | | | | 4 | 2005 | 57 | | | | | 57 | 2005 | 93 | . | |
| 2006 | 0 | | | | | 0 | 2006 | 140 | | | | | 140 | 2006 | 100 | . | |
| 2007 | 0 | | | | | 0 | 2007 | 80 | | | | | 80 | 2007 | 100 | . | |

Notes: Based on data from Scotia-Fundy (1978-2007) and Newfoundland Observer programs (1980-1995)

Table 3. Blue shark by-catch and proportions in Canadian bluefin tuna fishery.

CANADA

| QUARTILE | | YEAR | | | | | | | | | | | | | | | | | | | | | | |
|----------|----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | |
| I | bluefin tuna catch (mt) | | | 35 | 77 | 8 | | 8 | | 27 | | | | | | | | | | | | | | |
| | blue shark proportion (minimum) | | | 0.48 | 0.48 | 0.48 | | 0.48 | | 0.48 | | | | | | | | | | | | | | |
| | blue shark catch (mt) (minimum) | | | 17 | 37 | 4 | | 4 | | 13 | | | | | | | | | | | | | | |
| | blue shark proportion (maximum) | | | 0.48 | 0.48 | 0.48 | | 0.48 | | 0.48 | | | | | | | | | | | | | | |
| | blue shark catch (mt) (maximum) | | | 17 | 37 | 4 | | 4 | | 13 | | | | | | | | | | | | | | |
| II | bluefin tuna catch (mt) | | | | | 3 | 0 | 0 | | | | 2 | | | 6 | | | | | | 10 | 10 | 11 | |
| | blue shark proportion (minimum) | | | | | 4.85 | 4.85 | 4.85 | | | | 4.85 | | | 4.85 | | | | | | 4.85 | 4.85 | 4.85 | |
| | blue shark catch (mt) (minimum) | | | | | 14 | 1 | 2 | | | | 9 | | | 31 | | | | | | 49 | 49 | 53 | |
| | blue shark proportion (maximum) | | | | | 4.85 | 4.85 | 4.85 | | | | 4.85 | | | 4.85 | | | | | | 4.85 | 4.85 | 4.85 | |
| | blue shark catch (mt) (maximum) | | | | | 14 | 1 | 2 | | | | 9 | | | 31 | | | | | | 49 | 49 | 53 | |
| III | bluefin tuna catch (mt) | | | 275 | 381 | 350 | 273 | 319 | 247 | 263 | 326 | 317 | 265 | 357 | 280 | 155 | 265 | 351 | 234 | 189 | 186 | 252 | 102 | |
| | blue shark proportion (minimum) | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| | blue shark catch (mt) (minimum) | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | blue shark proportion (maximum) | | | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| | blue shark catch (mt) (maximum) | | | 49 | 69 | 63 | 49 | 57 | 44 | 47 | 59 | 57 | 48 | 64 | 50 | 28 | 48 | 63 | 42 | 34 | 33 | 45 | 18 | |
| IV | bluefin tuna catch (mt) | | | 90 | 74 | 66 | 168 | 69 | 125 | 3 | 136 | 159 | 123 | 141 | 57 | 118 | 79 | 4 | | 66 | 110 | 124 | 136 | |
| | blue shark proportion (minimum) | | | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | | | 0.61 | 0.61 | 0.61 | |
| | blue shark catch (mt) (minimum) | | | 55 | 45 | 40 | 102 | 42 | 76 | 2 | 83 | 97 | 75 | 86 | 35 | 72 | 48 | 3 | | 40 | 67 | 76 | 83 | |
| | blue shark proportion (maximum) | | | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | | | 1.14 | 1.14 | 1.14 | |
| | blue shark catch (mt) (maximum) | | | 103 | 84 | 75 | 191 | 79 | 143 | 4 | 155 | 181 | 140 | 161 | 65 | 134 | 91 | 5 | | 75 | 125 | 141 | 155 | |
| TOTAL | | | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) (minimum)* | | | 72 | 82 | 58 | 104 | 48 | 76 | 15 | 83 | 106 | 75 | 86 | 66 | 72 | 48 | 3 | 0 | 40 | 116 | 124 | 136 | |
| | blue shark catch (mt) (maximum) | | | 169 | 190 | 156 | 242 | 142 | 187 | 64 | 214 | 247 | 188 | 225 | 146 | 162 | 138 | 68 | 42 | 109 | 207 | 235 | 227 | |

* most probable catch

Tuna, swordfish, and porbeagle shark catch from ZIF for LL, troller lines, rod & reel, handline

DATABASE FOR CATCH: BFTmainipc_TunaSFPOrcatch gearselected.sav

Blue shark proportions, minimum and maximum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

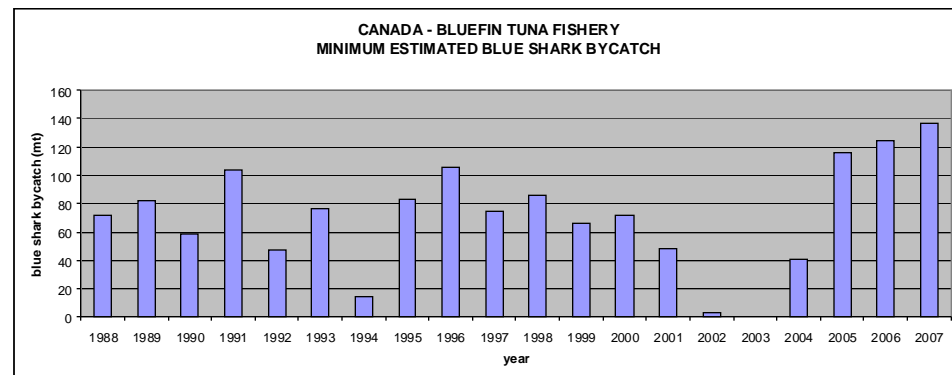


Table 4. Blue shark by-catch and proportions in Canadian swordfish fishery.

CANADA

| QUARTILE | | YEAR | | | | | | | | | | | | | | | | | | | | | |
|----------|--|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| I | swordfish catch (mt) | | | | | | 1 | | | 29 | | | | | | | | | | | | | |
| | blue shark proportion | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) | | | | | | | | | | | | | | | | | | | | | | |
| II | swordfish catch (mt) | | | 2 | | 1 | 48 | 87 | 74 | 42 | 32 | 8 | 29 | 26 | 139 | 62 | 25 | 41 | 22 | 23 | 63 | 43 | 35 |
| | blue shark proportion (minimum) | | | 0.55 | | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| | blue shark catch (mt) (minimum) | | | 1 | | 1 | 26 | 48 | 41 | 23 | 18 | 5 | 16 | 14 | 77 | 34 | 14 | 23 | 12 | 13 | 35 | 24 | 19 |
| | blue shark proportion (maximum) | | | 3.70 | | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 | 3.70 |
| | blue shark catch (mt) (maximum) | | | 6 | | 0 | 4 | 177 | 323 | 275 | 154 | 119 | 31 | 107 | 97 | 515 | 230 | 94 | 152 | 82 | 85 | 233 | 159 |
| III | swordfish catch (mt) | 321 | 193 | 665 | 800 | 635 | 764 | 1103 | 1666 | 1167 | 1015 | 540 | 831 | 802 | 1029 | 790 | 915 | 820 | 804 | 751 | 1001 | 922 | 792 |
| | blue shark proportion (minimum) | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |
| | blue shark catch (mt) (minimum) | 173 | 104 | 359 | 432 | 343 | 413 | 596 | 900 | 630 | 548 | 291 | 449 | 433 | 556 | 426 | 494 | 443 | 434 | 406 | 541 | 498 | 428 |
| | blue shark proportion (maximum) | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 | 1.14 |
| | blue shark catch (mt) (maximum) | 366 | 220 | 758 | 912 | 724 | 871 | 1257 | 1899 | 1331 | 1157 | 615 | 947 | 915 | 1173 | 900 | 1043 | 935 | 917 | 856 | 1141 | 1051 | 903 |
| IV | swordfish catch (mt) | 95 | 37 | 246 | 300 | 189 | 171 | 298 | 422 | 328 | 393 | 85 | 150 | 82 | 3 | 2 | 0 | 150 | | 274 | 272 | 214 | 183 |
| | blue shark proportion (minimum) | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 | 4.63 |
| | blue shark catch (mt) (minimum) | 440 | 169 | 1141 | 1388 | 876 | 790 | 1381 | 1955 | 1517 | 1819 | 393 | 696 | 380 | 13 | 11 | 0 | 697 | | 1269 | 1259 | 991 | 847 |
| | blue shark proportion (maximum) | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 | 6.57 |
| | blue shark catch (mt) (maximum) | 624 | 240 | 1618 | 1970 | 1244 | 1120 | 1959 | 2774 | 2152 | 2581 | 557 | 988 | 539 | 19 | 16 | 0 | 989 | | 1800 | 1787 | 1406 | 1202 |
| TOTAL | swordfish catch (mt) | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) (minimum) | 613 | 273 | 1500 | 1820 | 1220 | 1229 | 2024 | 2896 | 2170 | 2384 | 689 | 1161 | 828 | 645 | 472 | 508 | 1162 | 446 | 1687 | 1835 | 1512 | 1294 |
| | blue shark catch (mt) (maximum) | 990 | 460 | 2382 | 2882 | 1971 | 2169 | 3540 | 4948 | 3637 | 3857 | 1203 | 2042 | 1551 | 1707 | 1146 | 1137 | 2075 | 998 | 2741 | 3161 | 2616 | 2235 |
| | blue shark catch (mt) (most probable)* | 801 | 367 | 1941 | 2351 | 1595 | 1699 | 2782 | 3922 | 2903 | 3120 | 946 | 1601 | 1189 | 1176 | 809 | 823 | 1619 | 722 | 2214 | 2498 | 2064 | 1764 |

* most probable catch calculated as mean of minimum and maximum
 Tuna, swordfish, and porbeagle shark catch from ZIF for LL, troller lines, rod & reel, handline
 DATABASE FOR CATCH: Sfmainspc_TunaSFFORcatch gearselected.sav
 Blue shark proportions, minimum and maximum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

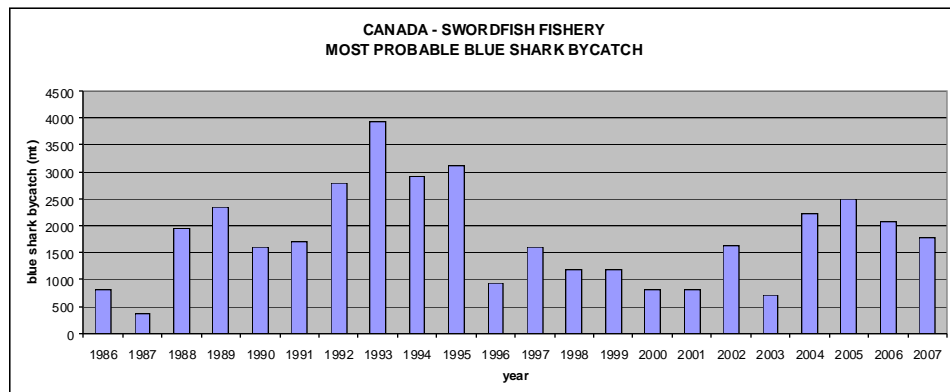


Table 5. Blue shark by-catch and proportions in Canadian other tuna fishery.

CANADA

| QUARTILE | | YEAR | | | | | | | | | | | | | | | | | | | | | |
|----------|--|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| I | other tunas catch (mt) | | | 8 | 113 | 7 | 2 | 0 | | 2 | | | | | | | | | | | | | |
| | blue shark proportion | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) | | | | | | | | | | | | | | | | | | | | | | |
| II | other tunas catch (mt) | | | | | 3 | 1 | | 13 | 27 | 41 | 51 | 47 | 43 | 82 | 180 | 232 | 23 | 27 | 7 | 24 | 24 | 5 |
| | blue shark proportion (minimum) | | | | | 1.42 | 1.42 | | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 | 1.42 |
| | blue shark catch (mt) (minimum) | | | | | 5 | 1 | | 18 | 38 | 58 | 73 | 66 | 60 | 116 | 255 | 329 | 33 | 38 | 10 | 34 | 34 | 7 |
| | blue shark proportion (maximum) | | | | | 1.41 | 1.41 | | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 |
| | blue shark catch (mt) (maximum) | | | | | 5 | 1 | | 18 | 38 | 58 | 72 | 66 | 60 | 115 | 253 | 327 | 33 | 38 | 10 | 34 | 34 | 7 |
| III | other tunas catch (mt) | | | 0 | 1 | 4 | 26 | 31 | 89 | 97 | 269 | 273 | 184 | 93 | 97 | 336 | 152 | 283 | 86 | 47 | 92 | 91 | 59 |
| | blue shark proportion (minimum) | | | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| | blue shark catch (mt) (minimum) | | | 0 | 0 | 2 | 9 | 11 | 31 | 34 | 94 | 96 | 64 | 33 | 34 | 118 | 53 | 99 | 30 | 16 | 32 | 32 | 21 |
| | blue shark proportion (maximum) | | | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 | 0.77 |
| | blue shark catch (mt) (maximum) | | | 0 | 1 | 3 | 20 | 24 | 68 | 75 | 207 | 210 | 142 | 72 | 75 | 259 | 117 | 218 | 66 | 36 | 71 | 70 | 45 |
| IV | other tunas catch (mt) | | | 127 | 4 | 6 | 0 | 1 | 11 | 5 | 4 | 4 | 29 | 20 | 52 | 37 | 43 | 65 | | 13 | 4 | 11 | 7 |
| | blue shark proportion (minimum) | | | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 | 2.48 |
| | blue shark catch (mt) (minimum) | | | 314 | 9 | 15 | 1 | 1 | 27 | 12 | 10 | 10 | 73 | 48 | 129 | 92 | 107 | 162 | | 32 | 10 | 27 | 17 |
| | blue shark proportion (maximum) | | | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 |
| | blue shark catch (mt) (maximum) | | | 502 | 15 | 24 | 1 | 2 | 43 | 20 | 16 | 16 | 117 | 77 | 206 | 147 | 171 | 259 | | 51 | 16 | 44 | 28 |
| TOTAL | other tunas catch (mt) | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) (minimum) | | | 314 | 10 | 21 | 11 | 12 | 76 | 85 | 162 | 178 | 204 | 141 | 279 | 465 | 490 | 294 | 68 | 59 | 76 | 93 | 45 |
| | blue shark catch (mt) (maximum) | | | 502 | 16 | 32 | 22 | 26 | 129 | 133 | 281 | 299 | 324 | 209 | 396 | 659 | 615 | 509 | 104 | 98 | 121 | 147 | 80 |
| | blue shark catch (mt) (most probable)* | | | 408 | 13 | 27 | 16 | 19 | 103 | 109 | 222 | 238 | 264 | 175 | 338 | 562 | 552 | 402 | 86 | 78 | 98 | 120 | 63 |

* most probable catch calculated as mean of minimum and maximum

Tuna, swordfish, and porbeagle shark catch from ZIF for LL, troller lines, rod & reel, handline

DATABASE FOR CATCH: OtherTunamainspc_TunaSFPOrcatch gearselected.sav

Blue shark proportions, minimum and maximum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

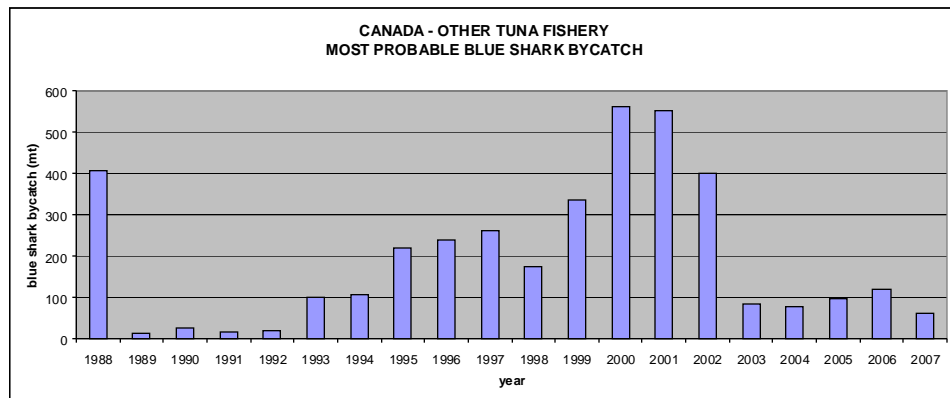


Table 6. Blue shark by-catch and proportions in Canadian porbeagle shark fishery.

CANADA

| QUARTILE | | YEAR | | | | | | | | | | | | | | | | | | | | | |
|----------|----------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
| I | porbeagle catch (mt) | | | | | | | 75 | | 49 | 89 | 184 | 237 | 143 | 253 | 168 | 20 | 0.41 | | 17 | | 18 | |
| | blue shark proportion (minimum) | | | | | | | 0.07 | | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | | 0.07 | | 0.07 | |
| | blue shark catch (mt) (minimum) | | | | | | | 5 | | 3 | 6 | 13 | 17 | 10 | 18 | 12 | 1 | 0 | | 1 | | 1 | |
| | blue shark proportion (maximum) | | | | | | | 0.14 | | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | | 0.14 | | 0.14 | |
| | blue shark catch (mt) (maximum) | | | | | | | 11 | | 7 | 13 | 26 | 33 | 20 | 35 | 23 | 3 | 0 | | 2 | | 3 | |
| II | porbeagle catch (mt) | | | | | | | 233 | 319 | 766 | 525 | 379 | 565 | 554 | 520 | 558 | 457 | 146 | 86 | 139 | 139 | 92 | 47 |
| | blue shark proportion (minimum) | | | | | | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | blue shark catch (mt) (minimum) | | | | | | | 5 | 6 | 15 | 11 | 8 | 11 | 11 | 10 | 11 | | | 3 | 3 | 2 | 1 | |
| | blue shark proportion (maximum) | | | | | | | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| | blue shark catch (mt) (maximum) | | | | | | | 14 | 19 | 46 | 32 | 23 | 34 | 33 | 31 | 33 | 27 | 9 | 5 | 8 | 8 | 6 | 3 |
| III | porbeagle catch (mt) | | | | | | 126 | 306 | 298 | 228 | 208 | 135 | 210 | 172 | 13 | 3 | 6 | 20 | 11 | 35 | 34 | 40 | 18 |
| | blue shark proportion (minimum) | | | | | | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| | blue shark catch (mt) (minimum) | | | | | | 30 | 73 | 72 | 55 | 50 | 32 | 50 | 41 | 3 | 1 | 1 | 5 | 3 | 8 | 8 | 10 | 4 |
| | blue shark proportion (maximum) | | | | | | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| | blue shark catch (mt) (maximum) | | | | | | 35 | 86 | 84 | 64 | 58 | 38 | 59 | 48 | 4 | 1 | 2 | 6 | 3 | 10 | 10 | 11 | 5 |
| IV | porbeagle catch (mt) | | | | | | 202 | 190 | 276 | 445 | 335 | 221 | 197 | 118 | 133 | 128 | 0 | 28 | | 10 | 8 | 23 | 7 |
| | blue shark proportion (minimum) | | | | | | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| | blue shark catch (mt) (minimum) | | | | | | 8 | 8 | 11 | 18 | 13 | 9 | 8 | 5 | 5 | 5 | 0 | 1 | | 0 | 0 | 1 | 0 |
| | blue shark proportion (maximum) | | | | | | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| | blue shark catch (mt) (maximum) | | | | | | 24 | 23 | 33 | 53 | 40 | 26 | 24 | 14 | 16 | 15 | 0 | 3 | | 1 | 1 | 3 | 1 |
| TOTAL | | | | | | | | | | | | | | | | | | | | | | | |
| | blue shark catch (mt) (minimum)* | | | | | | 38 | 91 | 89 | 91 | 80 | 62 | 86 | 67 | 37 | 29 | 3 | 6 | 3 | 13 | 11 | 14 | 6 |
| | blue shark catch (mt) (maximum) | | | | | | 60 | 133 | 136 | 170 | 143 | 113 | 149 | 116 | 86 | 73 | 32 | 18 | 8 | 22 | 19 | 22 | 9 |

* most probable catch

Tuna, swordfish, and porbeagle shark catch from ZIF for LL, troller lines, rod & reel, handline
 DATABASE FOR CATCH: Porbeagle catch selected.sav

Blue shark proportions, minimum and maximum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

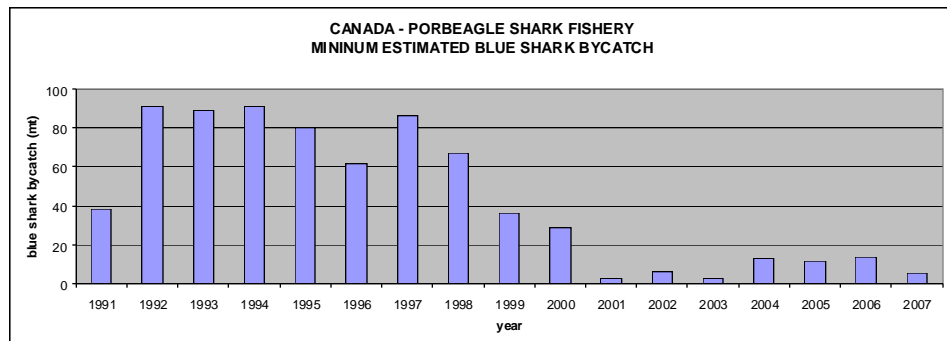


Table 7. Total blue shark catch (mt) in Atlantic Canada by source.

| Year | Derbies | Recreational ¹ | Landed commercial ² | Observed foreign catch ³ | Observed foreign discards [‡] | Observed Canadian discards [†] | Estimated catch and discards from Canadian fishery* | TOTAL ESTIMATED CATCH MORTALITY** |
|------|---------|---------------------------|--------------------------------|-------------------------------------|--|---|---|-----------------------------------|
| 1986 | | | | 13 | 32 | | 801 | 365 |
| 1987 | | | | 38 | 123 | | 367 | 308 |
| 1988 | | | | 6 | 146 | | 2421 | 1120 |
| 1989 | | | | 10 | 172 | 42 | 2446 | 1160 |
| 1990 | | | 8 | 13 | 125 | 7 | 1680 | 818 |
| 1991 | | | 31 | 11 | 207 | 20 | 1857 | 992 |
| 1992 | | | 101 | 60 | 285 | 2 | 2940 | 1622 |
| 1993 | 4 | 3 | 21 | 91 | 205 | 14 | 4190 | 1998 |
| 1994 | 5 | 3 | 133 | 116 | 210 | 53 | 3118 | 1586 |
| 1995 | 6 | 4 | 145 | 73 | 100 | 106 | 3505 | 1667 |
| 1996 | 5 | 3 | 18 | 173 | 61 | 37 | 1352 | 762 |
| 1997 | 10 | 7 | 9 | 36 | 0 | 28 | 2026 | 867 |
| 1998 | 10 | 7 | 4 | 17 | 17 | 210 | 1518 | 646 |
| 1999 | 15 | 10 | 53 | 11 | 282 | 185 | 1616 | 840 |
| 2000 | 16 | 11 | 19 | 0 | 3 | 70 | 1471 | 627 |
| 2001 | 8 | 13 | 0.4 | 0 | 0 | 179 | 1426 | 581 |
| 2002 | 19 | 13 | 5 | 0 | 4 | 228 | 2029 | 840 |
| 2003 | 19 | 13 | 0.1 | 0 | 0 | 85 | 811 | 346 |
| 2004 | 10 | 7 | 0.3 | 0 | 0 | 59 | 2383 | 965 |
| 2005 | 6 | 4 | 0.5 | 0 | 0 | 57 | 2817 | 1134 |
| 2006 | 10 | 7 | 0.4 | 0 | 0 | 140 | 2414 | 977 |
| 2007 | 8 | 5 | 0.1 | 0 | 0 | 80 | 2086 | 843 |

¹ catch and release fishery, excluding derbies; 2001-2003 estimated from rec logs and phone survey; other years assumed to be 0.66 of derby catches based on tag recaptures and 2002-2003 ratios

² Canadian landings only

³ Scotia-Fundy Observer Program measurements of all foreign kept catch

[‡] Scotia-Fundy Observer Program measurements of all foreign discarded catch

[†] Scotia-Fundy Observer Program measurements of Canadian discards; coverage was about 5% of fleet

* from Tables 3-6; sum of most probable bycatches from porbeagle, bluefin tuna, swordfish and other tuna fisheries

** Sum of landed catches, plus hooking mortality probabilities (Campana et al, 2004) applied to recreational, foreign discards and estimated catch from Canadian fishery; foreign discards prior to 1994 assumed to be dead due to finning

Table 8. Results of the catch rate standardization model relating the catch rate (In-transformed kg/hook) of blue shark in bigeye tuna and swordfish fisheries to region, season, CFV and year.

Dependent Variable: LNCPUE

| Source | Deviance | df | Resid. Dev | Resid. Df | F | Sig. |
|---------------|----------|----|---------------|--------------|--------|-------|
| NULL | | | 720.4 | 497 | | |
| YR | 96.492 | 12 | 623.9 | 485 | 10.775 | 0.000 |
| CFV | 77.663 | 12 | 546.2 | 473 | 8.672 | 0.000 |
| REGION | 12.486 | 1 | 533.7 | 472 | 16.731 | 0.000 |
| SPECS | 3.506 | 1 | 530.2 | 471 | 4.698 | 0.031 |
| SEASON | 5.271 | 1 | 525.0 | 470 | 7.063 | 0.008 |
| YR:CFV | 118.064 | 19 | 406.9 | 451 | 8.326 | 0.000 |
| YR:REGION | 38.904 | 5 | 368.0 | 446 | 10.426 | 0.000 |
| YR:SPECS | 8.491 | 5 | 359.5 | 441 | 2.275 | 0.046 |
| YR:SEASON | 3.384 | 3 | 356.1 | 438 | 1.512 | 0.211 |
| CFV:REGION | 26.816 | 5 | 329.3 | 433 | 7.187 | 0.000 |
| CFV:SPECS | 0.069 | 2 | 329.2 | 431 | 0.046 | 0.955 |
| CFV:SEASON | 1.818 | 2 | 327.4 | 429 | 1.218 | 0.297 |
| REGION:SPECS | 8.246 | 1 | 319.2 | 428 | 11.050 | 0.001 |
| REGION:SEASON | 0.513 | 1 | 318.7 | 427 | 0.688 | 0.407 |
| SPECS:SEASON | 0.000 | 0 | 318.7 | 427 | | |

55.8% of Deviance Explained

Table 9. Results of the catch rate standardization model relating the catch rate (In-transformed kg/hook) of blue shark in bluefin tuna fisheries to region, season, CFV and year.

Dependent Variable: LNCPUE

| Source | Deviance | df | Resid. Dev | Resid. Df | F | Sig. |
|---------------|----------|----|------------|-----------|--------|-------|
| NULL | | | 324.3 | 138 | | |
| CFV | 83.487 | 6 | 240.8 | 132 | 10.007 | 0.000 |
| YR | 31.431 | 10 | 209.4 | 122 | 2.261 | 0.019 |
| REGION | 14.772 | 1 | 194.6 | 121 | 10.624 | 0.001 |
| SEASON | 3.395 | 1 | 191.2 | 120 | 2.442 | 0.121 |
| CFV:YR | 0.000 | 0 | 191.2 | 120 | | |
| CFV:REGION | 11.671 | 3 | 179.5 | 117 | 2.798 | 0.043 |
| CFV:SEASON | 2.668 | 2 | 176.9 | 115 | 0.960 | 0.386 |
| YR:REGION | 19.733 | 2 | 157.1 | 113 | 7.096 | 0.001 |
| YR:SEASON | 0.000 | 0 | 157.1 | 113 | | |
| REGION:SEASON | 0.000 | 0 | 157.1 | 113 | | |

51.6% of Deviance Explained

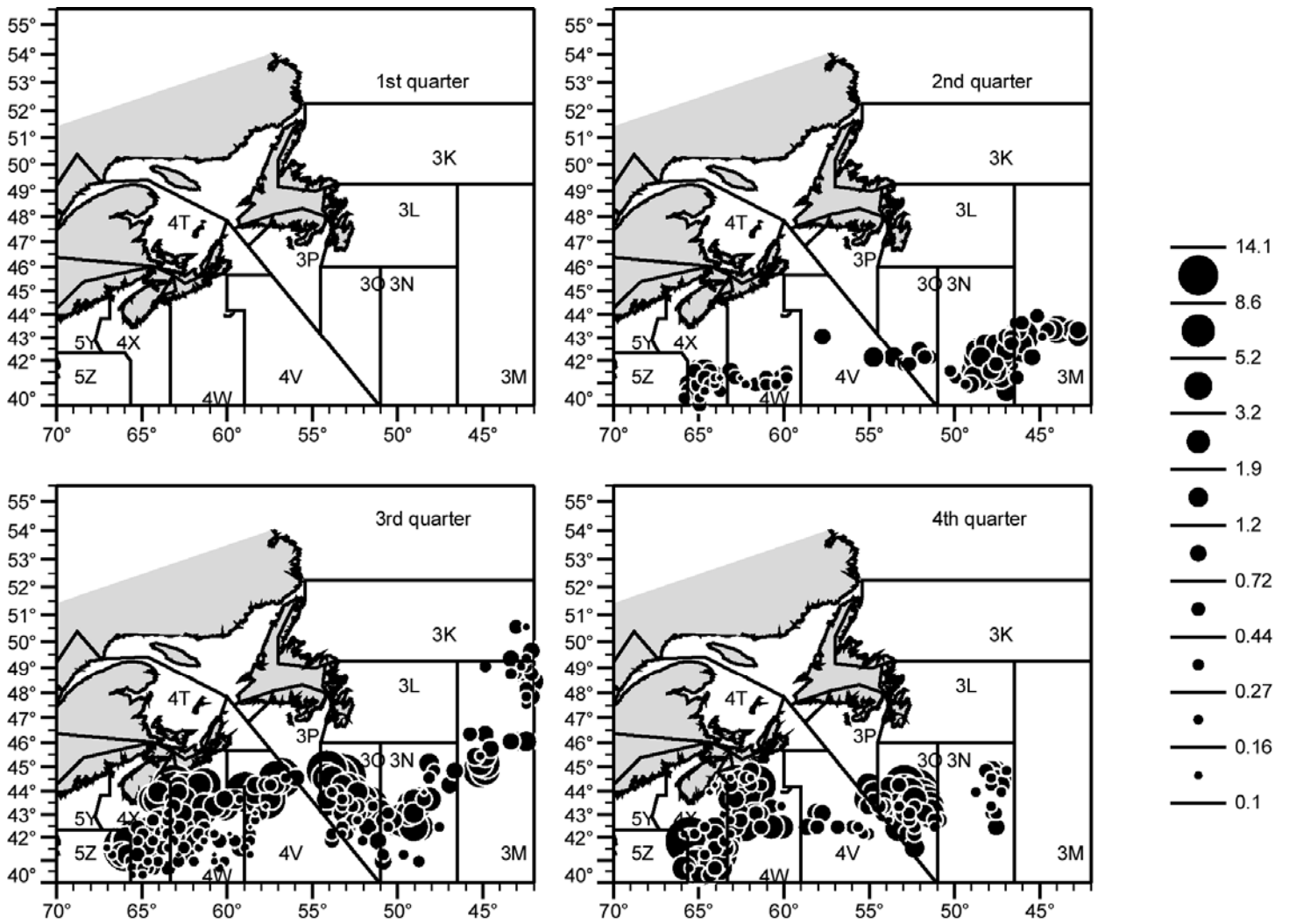


Figure 1. Blue shark catch location by quarter observed by SFOP on Canadian vessels fishing swordfish or tuna between 2000-2007.

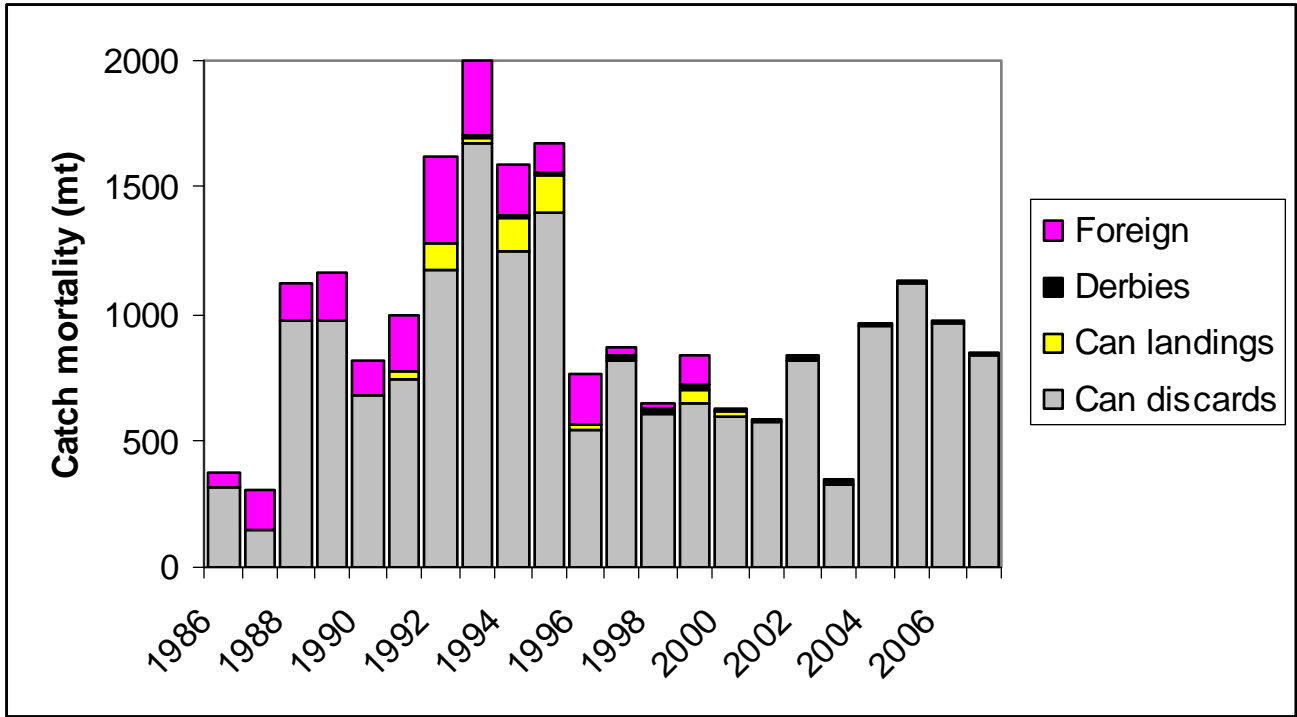


Figure 2. Total catch mortality by source for blue sharks caught in Atlantic Canadian waters.

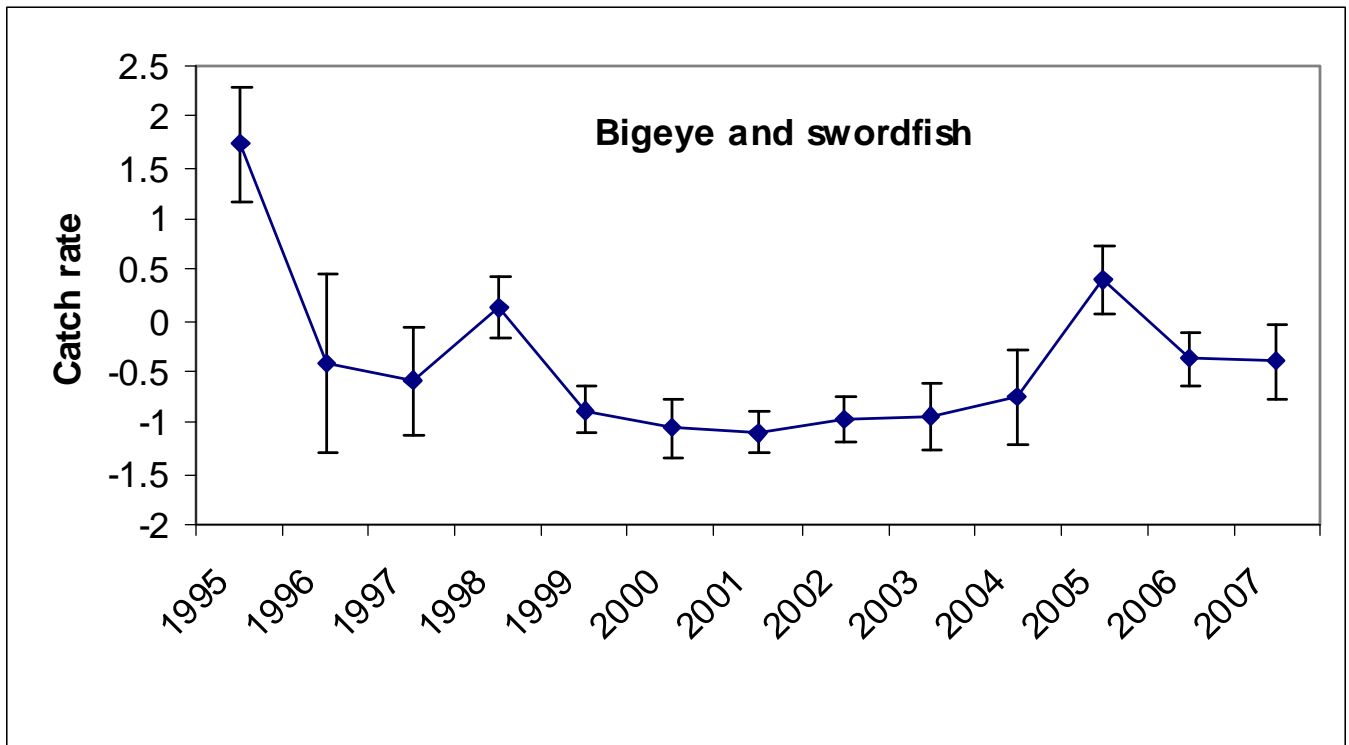


Figure 3. Standardized commercial catch rate (ln-transformed kg/hook \pm 1 SE) of blue shark in Canadian and Japanese large pelagic fisheries targeting bigeye tuna and swordfish.

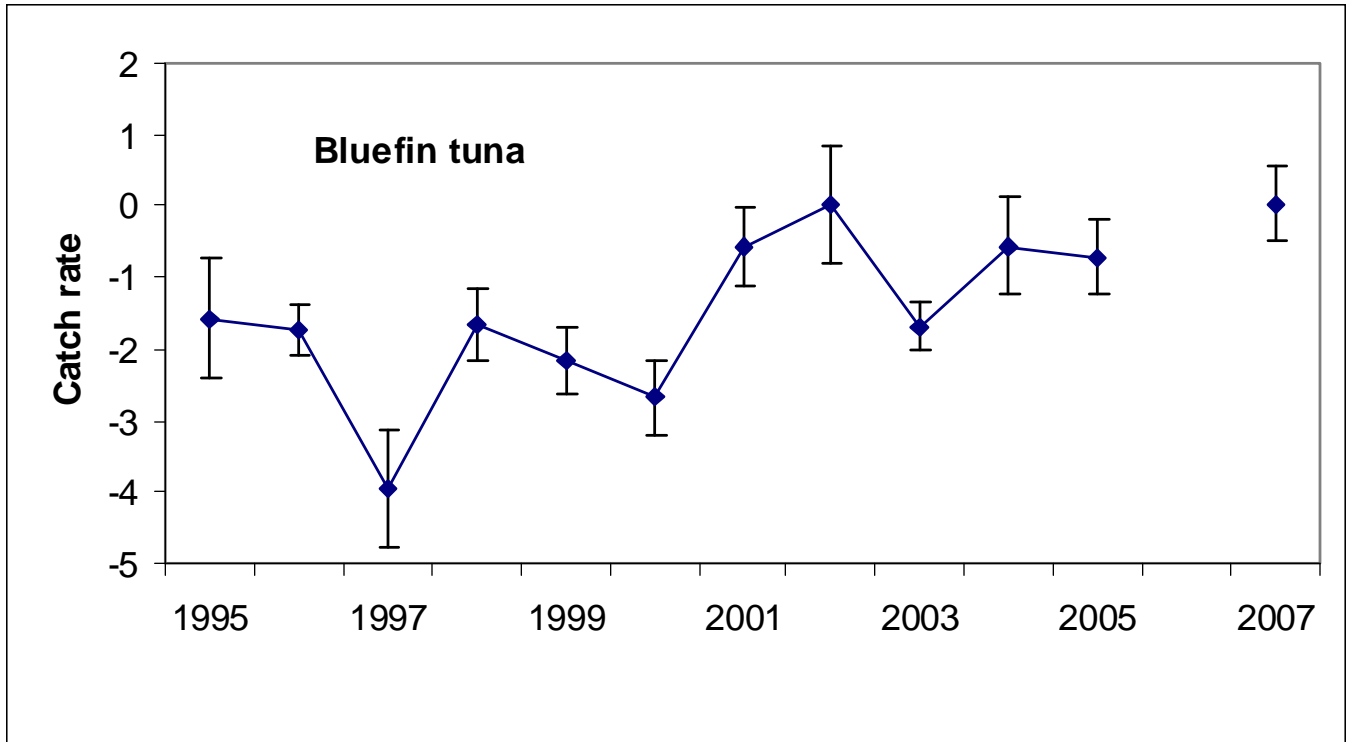


Figure 4. Standardized commercial catch rate (ln-transformed kg/hook \pm 1 SE) of blue shark in Canadian and Japanese large pelagic fisheries targeting bluefin tuna.

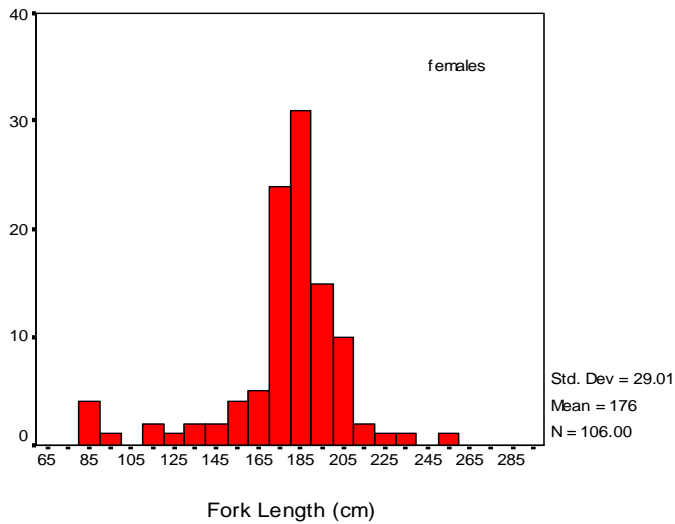
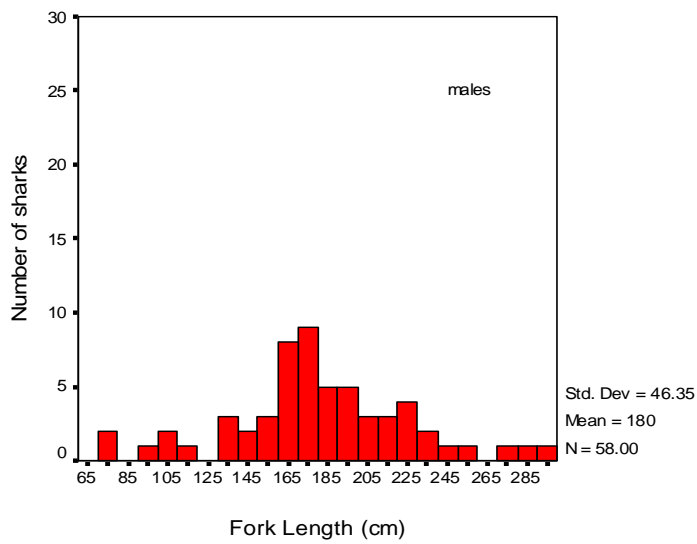
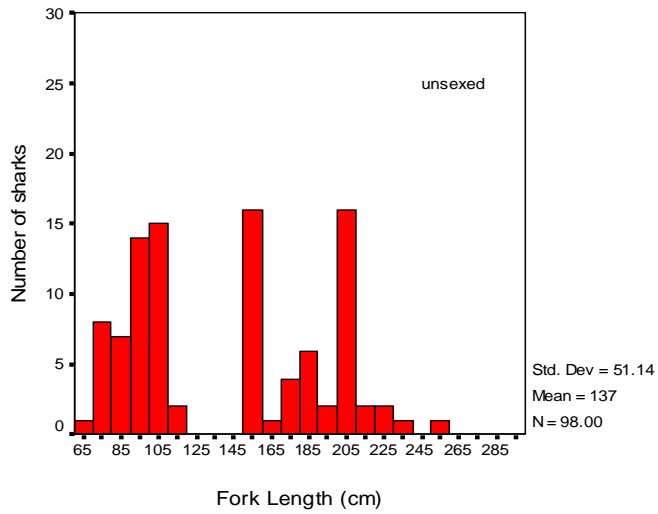


Figure 5. Length frequency histograms of male and female blue shark associated with the Observer data used in the analyses of catch rates.