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Commercial Bycatch Rates of Blue Shark (*Prionace glauca*) from Longline Fisheries in the Canadian Atlantic

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Abstract

There is no directed fishery for blue sharks (*Prionace glauca*) in Canadian waters, and virtually all blue sharks caught as bycatch in pelagic longline fisheries are discarded at sea. Based on an extensive series of observer measurements, total bycatch by both observed and unobserved vessels was estimated since 1986. Total blue shark bycatch has averaged over 2000 mt annually in recent years; landings and dead discards have averaged about 1000 mt 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.

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.

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 bycatch 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).

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.

Bycatch

Observed Bycatch

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 bycatch 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 bycatch has been by Canadian vessels. Catch locations mapped by quarter over the period 2000-2007 indicate that most of the Canadian bycatch occurred in deep waters off the continental shelves of Nova Scotia and Newfoundland, increasing in quantity through the year (Fig. 1). Significant catches have also been observed in the deep basins of the Scotian Shelf.

Estimation of Unobserved Blue Shark Bycatch

To determine the magnitude of the blue shark bycatch 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 bycatch 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. Bycatch in the foreign fisheries was fully observed, so estimation was used more to calculate bycatch proportion than bycatch 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 bycatch 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 bycatch for each of the bluefin tuna, swordfish, other tuna (mostly bigeye), and porbeagle fisheries. Therefore, each quarter and fishery was characterized by a unique bycatch 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 bycatch proportions represent the minimum actual Canadian bycatch. 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 which reported at least one blue shark. This second set of bycatch proportions assumes that blue sharks were caught in all sets, but reported only in some; thus it sets an upper limit to the bycatch 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 bycatch lies somewhere in the range defined by the minimum and maximum bycatch estimates. For the current analysis, we have assumed that the mean of the minimum and maximum bycatch estimates represents the most probable bycatch for these fisheries, as was assumed by Campana et al. (2004). Minimum bycatch estimates appear to be valid for the Japanese, bluefin tuna and porbeagle fisheries, although bycatch 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 bycatch 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. Bycatch proportions often exceeded 100%. The largest bycatches, around 2000 mt annually in recent years, are taken by the swordfish fishery. Annual bycatch 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.

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; Fig. 2). The proportion of catch mortality contributed by tournament fishing was negligible, averaging 2% of the total catch mortality in recent years.

Commercial and Recreational Catch Rates

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 which fished at least 10 sets in at least 2 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 (Fig. 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 (Fig. 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 (Fig. 5). Females dominated the catch of sexed lengths (170 cm or larger), but sex was typically unreported for sharks under about 160 cm.

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.

References

CAMPANA, S., Gonzalez, P., Joyce, W., and Marks, L. 2002. Catch, bycatch and landings of blue shark (*Prionace glauca*) in the Canadian Atlantic. CSAS Res. Doc. 2002/101. 40 p.

CAMPANA, S. E., Marks, L., Joyce, W., and Kohler, N. 2004. Influence of recreational and

commercial fishing on the blue shark (*Prionace glauca*) population in Atlantic Canadian waters. CSAS Res. Doc. 2004/069. 68 p.

CASEY, J. G. and Kohler, N. E. 1991. Long distance movements of Atlantic sharks from the NFS cooperative shark tagging program. Underwater Naturalist 19:87-91.

CORTES, E. 2000. Life history patterns and correlations in sharks. Reviews Fish. Sci. 8:299-344.

FAO (Food and Agriculture Organization of the United Nations). 1998. International Plan of Action for the Conservation and Management of Sharks. Document FI:CSS/98/3, Rome.

MUSICK, J. A., Burgess, G., Cailliet, G., Camhi, M., and Fordham, S. 2000. Management of sharks and their relatives (Elasmobranchii). Fisheries 25(3):9-13.

TEMPLEMAN, W. 1963. Distribution of sharks in the Canadian Atlantic (with special reference to Newfoundland waters). Bull. Fish. Res. Board Can. 140: 77p.

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

Year	Canada	Faroe Is	Japan	USSR	Other	Total
1978	0		0			0
1979	0		4			4
1980		0	0	13	3	16
1981		0	1		1	2
1982			2			2
1983			1			1
1984			0			0
1985	0		0			0
1986			13	0		13
1987		0	38			38
1988		0	5		1	6
1989	0	0	10			10
1990	1	0	13	0		14
1991	4	6	5	0		15
1992	0	30	30		0	60
1993	1	62	47			110
1994	16		116		0	132
1995	15		73			88
1996	2		173			175
1997	1		36			37
1998	1		17			18
1999	1		11			12
2000	1		0			1
2001	0		0			0
2002	1		0		0	1
2003	0		0			0
2004	0					0
2005	4					4
2006	0					0
2007	0					0

DISCARDS

Year	Canada	Faroe Is	Japan	USSR	Other	Total
1978	1		8			9
1979	10		8			18
1980		3	6	0	3	12
1981		1	12		1	14
1982			52			52
1983			25			25
1984			14			14
1985	1		0			1
1986			31	1		32
1987		2	121			123
1988		16	129		1	146
1989	42	8	164			214
1990	7	22	102	1		132
1991	20	59	129	19		227
1992	2	82	202		1	287
1993	14	19	186			219
1994	48		207		3	258
1995	107		100			207
1996	37		61			98
1997	30		0			30
1998	210		17			227
1999	185		282			467
2000	70		3			73
2001	179		0			179
2002	228		0		4	232
2003	85		0			85
2004	59					59
2005	57					57
2006	140					140
2007	80					80

DISCARD PERCENTAGE

Year	Canada	Faroes	Japan
1978	.	.	100
1979	100	.	22
1980	.	.	100
1981	.	100	73
1982	.	.	100
1983	.	.	96
1984	.	.	96
1985			
1986	.	.	80
1987	.	100	76
1988	.	100	96
1989	100	100	96
1990	100	100	92
1991	98	90	96
1992	.	73	97
1993	100	23	79
1994	78	.	64
1995	88	.	59
1996	89	.	26
1997	98	.	.
1998	100	.	45
1999	100	.	96
2000	100	.	100
2001	100	.	.
2002	100		
2003	100		
2004	100		
2005	93		
2006	100		
2007	100		

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

TABLE 3. BLUE SHARK BYCATCH 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													

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
	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
	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

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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	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	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		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	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: BFTmainspc_TunaSFPORcatch gearselected.sav

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

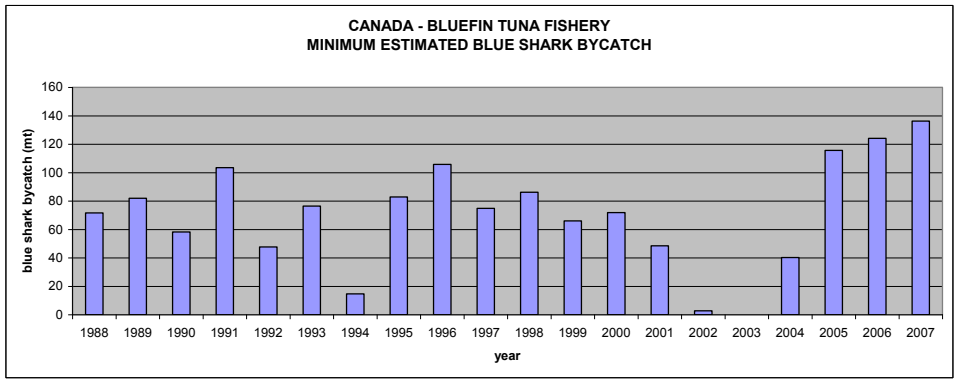

TABLE 4. BLUE SHARK BYCATCH AND PROPORTIONS IN CANADIAN SWORDFISH FISHERY.

CANADA

QUARTILE		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)																						

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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	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	130

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
	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
	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		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	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_TunaSFPORcatch gearselected.sav

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

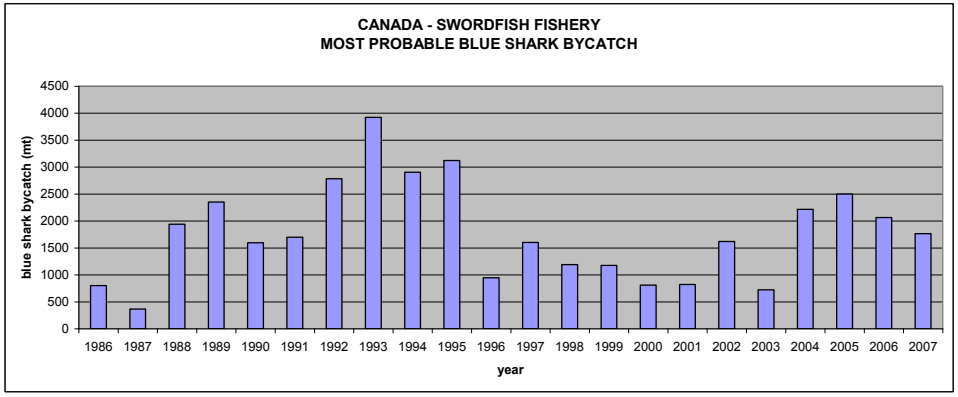

TABLE 5. BLUE SHARK BYCATCH AND PROPORTIONS IN CANADIAN OTHER TUNA FISHERY.

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)																						
QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
	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
	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		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	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 maxinum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

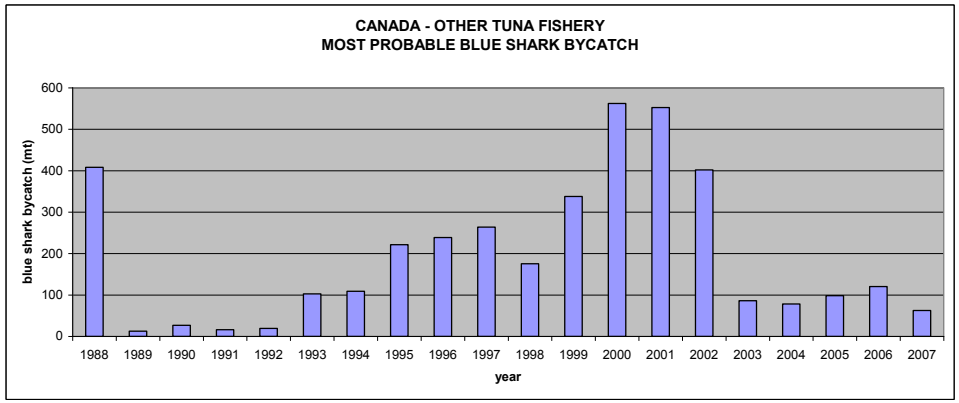

TABLE 6. BLUE SHARK BYCATCH AND PROPORTIONS IN CANADIAN PORBEAGLE SHARK FISHERY.

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	

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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

QUARTILE		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
	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
	blue shark catch (mt) (maximum)						24	23	33	53	40	26	24	14	16	15	0	3		1	1	3	1

TOTAL		YEAR																					
		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
	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 maxinum, represent weighted means from all sets, or only those with blue shark catch, respectively from Campana et al (2002).

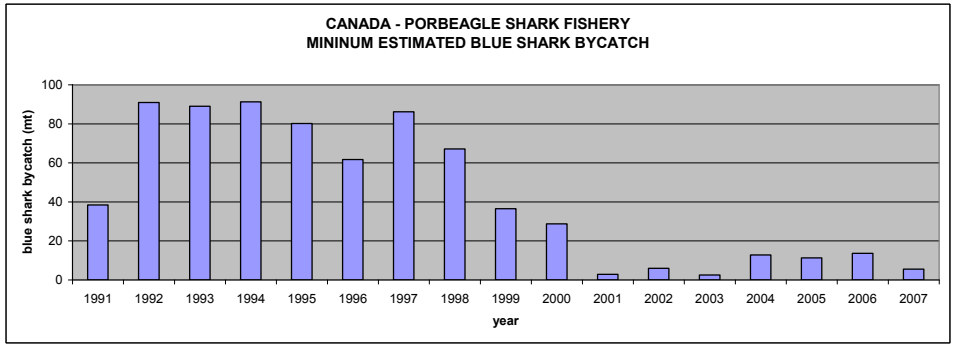

Table 7. Total blue shark catch (mt) in Atlantic Canada by source.

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 (ln-transformed kg/hook) of blue shark in bigeye tuna and swordfish fisheries to fishery, 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 (ln-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

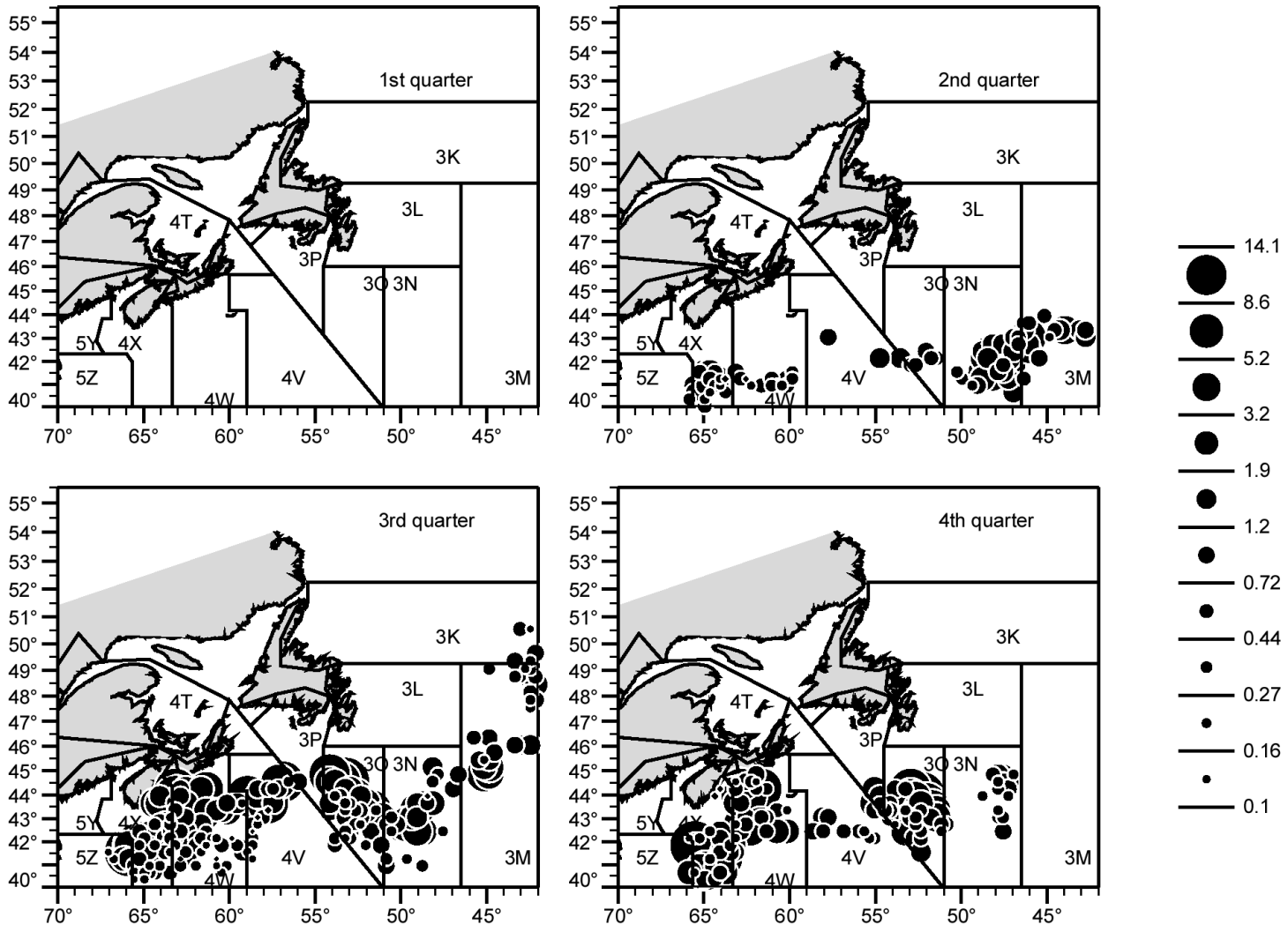

Figure 1. Blue shark catch location by quarter observed by SFOP on Canadian vessels fishing swordfish or tuna between 2000-2007.

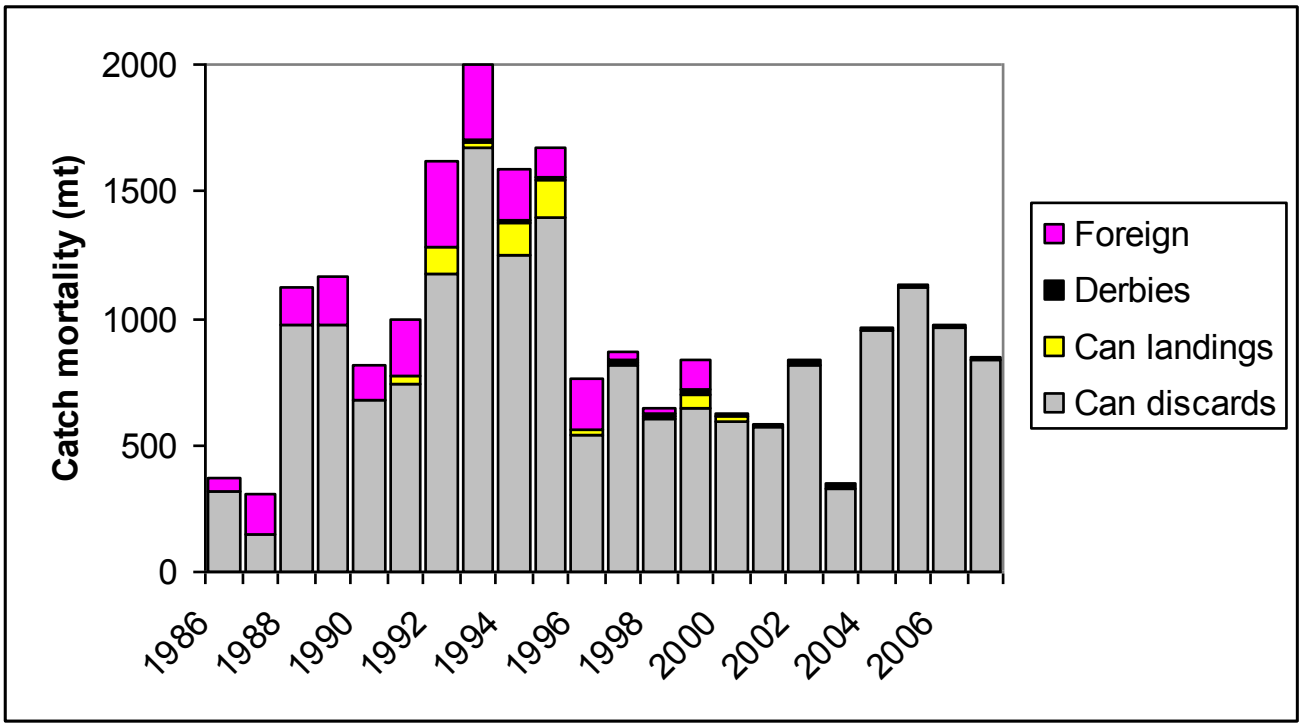

Figure 2. Total catch mortality by source for blue sharks caught in Atlantic Canadian waters.

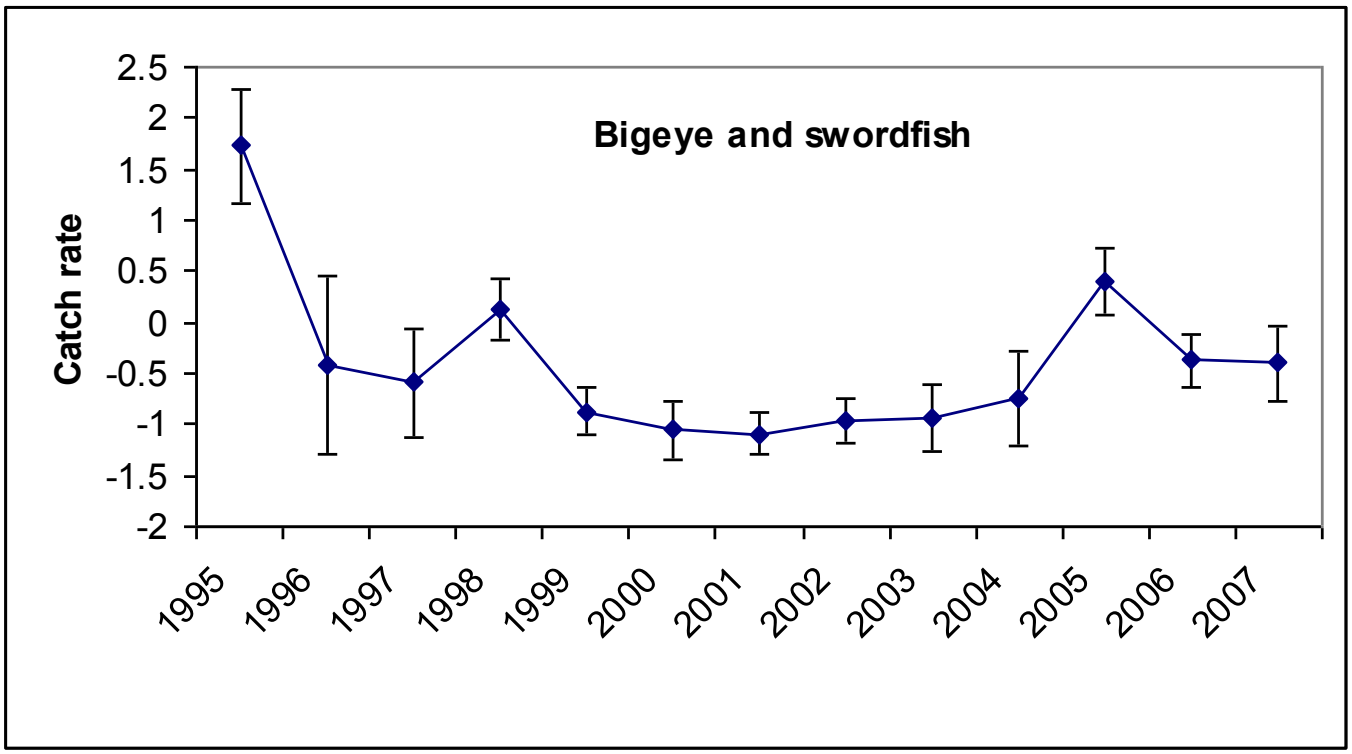

Figure 3. Standardized commercial catch rate (ln-transformed kg/hook ± 1 SE) of blue shark in Canadian and Japanese large pelagic fisheries targeting bigeye tuna and swordfish.

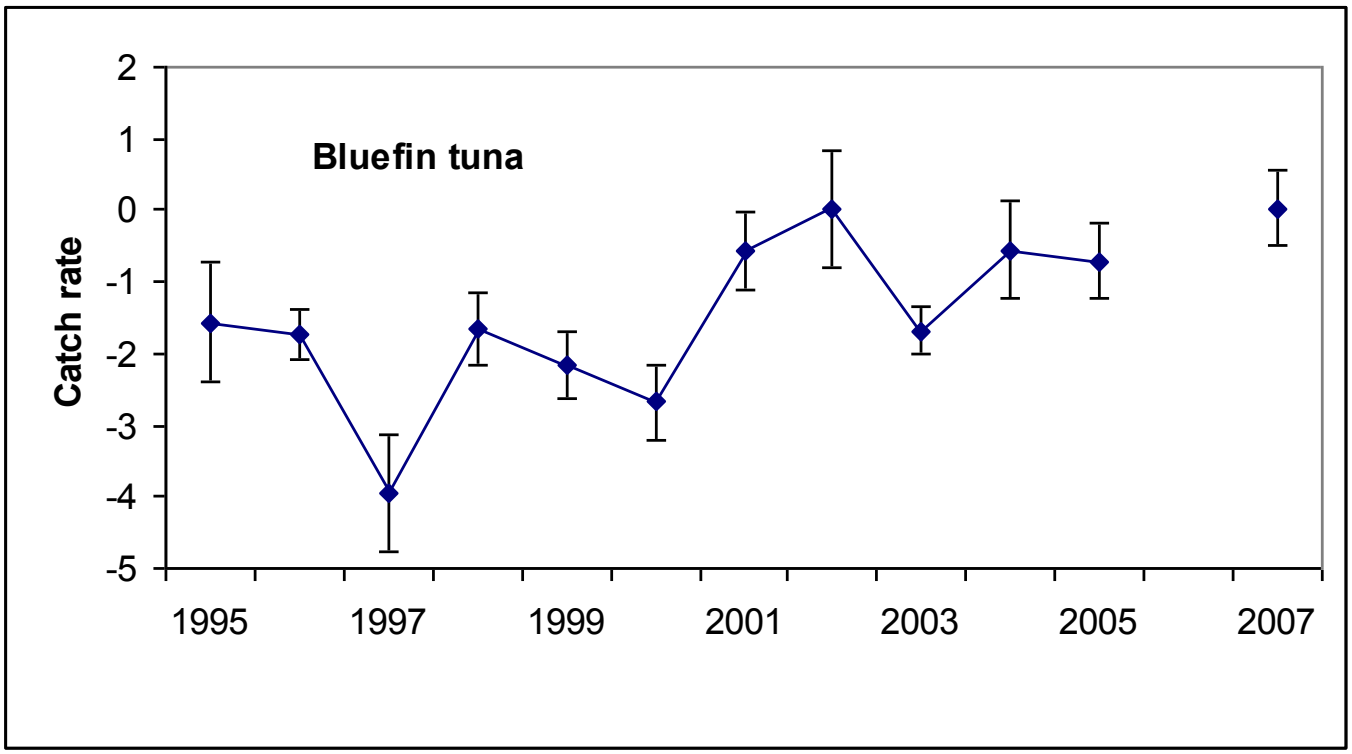

Figure 4. Standardized commercial catch rate (ln-transformed kg/hook ± 1 SE) of blue shark in Canadian and Japanese large pelagic fisheries targeting bluefin tuna.

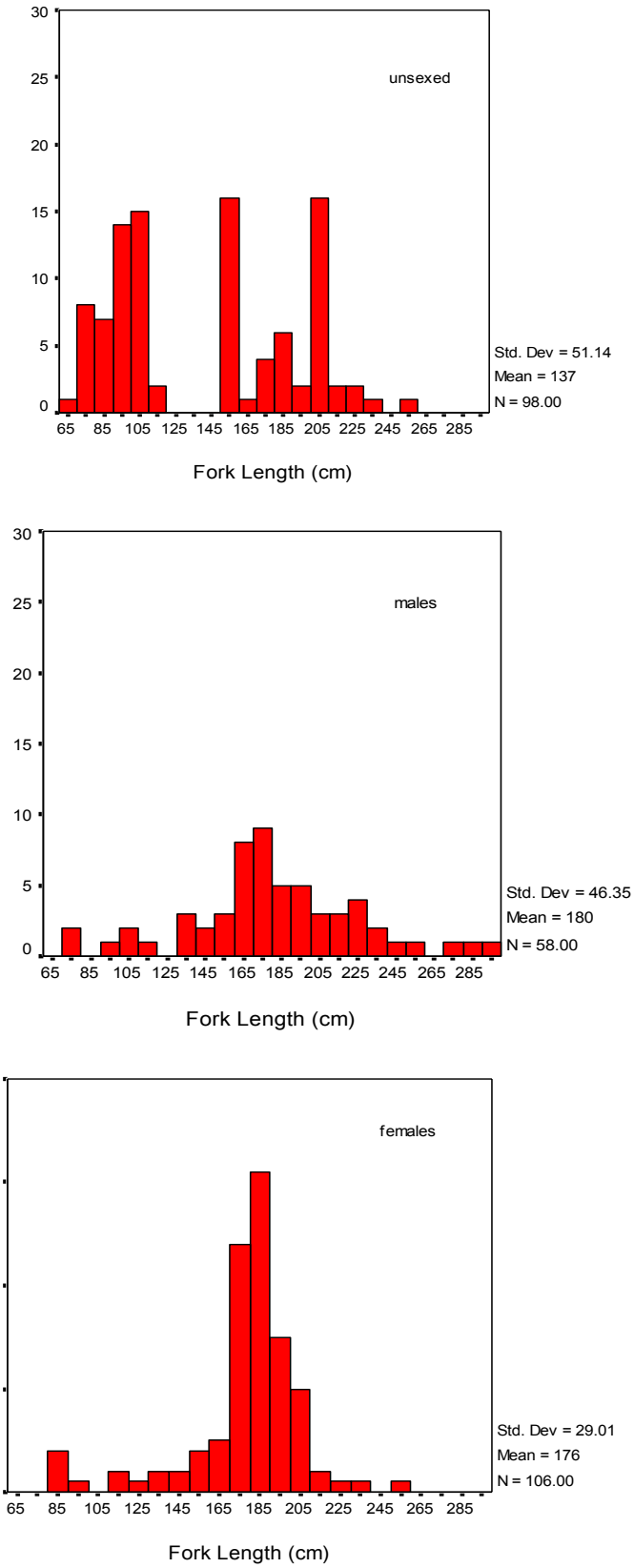

Figure 5. Length frequency histograms of male and female blue shark associated with the Observer data used in the analyses of catch rates.