Fisheries and Oceans Canada Pêches et Océans Canada

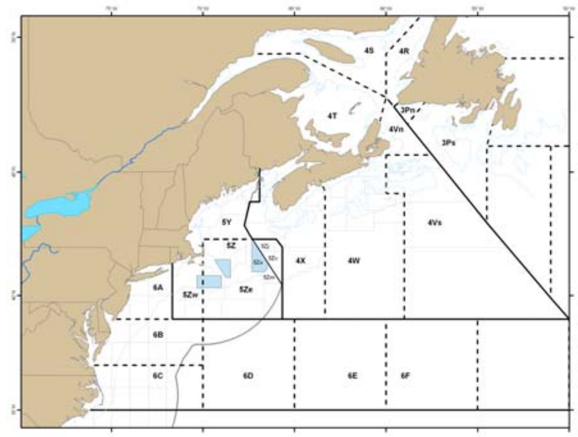
NOAA FISHERIES
NATIONAL MARINE FISHERIES SERVICE

Transboundary Resources Assessment Committee

Status Report 2010/02

NORTHWEST ATLANIC

SPINY DOGFISH



Summary

- A consensus transboundary stock assessment was not developed at this benchmark TRAC. Nevertheless, the TRAC agreed that the model used in the Northeast Regional Stock Assessment Workshop (SAW) 43 spiny dogfish assessment in 2006, with data updated through the 2009 Northeast Fisheries Science Center (NEFSC) spring survey, was appropriate to determine stock status for US management purposes. The status of spiny dogfish and management advice in Canada will be deferred until a TRAC benchmark assessment is developed in the future.

- Combined Canada and USA landings in 2007 and 2008 were 5,887 mt and 5,681 mt, respectively.

- Female spawning stock biomass (SSB) ($\geq$ 80 cm fish) declined from 234,000 mt in 1991 to 52,000 mt in 1999, and remained below 65,000 mt through 2005. Biomass then increased reaching 195,000 mt in 2008 but declined slightly to 163,000 mt in 2009.

- Recruitment between 1968-1996 was highly variable. During 1997-2003, pup production was a record low, but subsequently has improved. Recruitment in 2009 was the fifth highest in the 42-year NEFSC spring survey time series.

- Fishing mortality (F = female catch/female exploitable biomass) peaked in 1994 at 0.47 and remained high until 2001. Subsequently, fishing mortality has been very much lower, with the exception of 2004, and ranged between 0.11 and 0.13 during 2005-2008.

Catch Biomass (mt); calendar year

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average[1]	Min.[1]	Max.[1]
US landings	14,855	9,257	2,294	2,199	1,170	982	1,147	2,249	3,503	4,108		5,709	69	27,136
CA landings	2,091	2,741	3,820	3,584	1,302	2,362	2,270	2,439	2,384	1,572		921	1	3,820
Other landings	554	402	677	474	643	330	330	0	0	0		3,904	0	24,513
Total Landings	17,500	12,400	6,791	6,257	3,115	3,674	3,747	4,688	5,887	5,681		10,064	235	27,803
US Discards	9,690	7,412	12,123	10,537	9,266	12,330	10,853	11,142	13,248	10,208		17,343	7,233	40,304
US Dead Discards	4,444	2,769	4,621	4,269	3,550	5,359	4,759	4,897	5,597	4,131		7,661	2,769	18,940
CA Discards[2]	1,192	3,248	1,155	931	1,758	1,419	1,582	1,818	3,643	1,303		2,579	585	9,920
CA Dead Discards[2]	283	801	269	215	420	351	391	400	883	317		545	146	2,322
Rec Landings	53	5	28	205	40	105	45	94	84	232		177	5	1,493
Rec Discards	532	685	2,099	1,673	2,987	3,490	3,509	3,840	4,300	3,115		1,475	296	4,300
Rec Dead Discards	133	171	525	418	747	873	877	960	1,075	779		369	74	1,075
Female Catch[3]	18,230	14,336	11,117	10,805	6,622	8,775	7,378	8,536	10,829	9,669		17,535	6,622	32,461
Biomass (mt)														
Exploitable Female	77,142	66,023	96,233	107,026	63,794	39,745	17,432	54,587	90,651	123,742	89,151	104,706	17,432	339,405
Exploitable Male	107,825	100,960	189,725	184,169	213,989	201,452	219,604	271,991	142,511	299,031	271,390	213,984	100,960	299,031
Total Exploitable	185,468	167,483	286,458	291,695	278,283	241,697	237,536	327,077	233,662	423,273	361,040	319,190	167,483	570,113
Total Biomass	406,287	358,185	343,602	337,686	371,200	347,176	338,170	453,881	524,205	586,413	505,116	468,845	337,686	664,850
Female SSB	51,821	52,562	61,552	64,844	58,376	53,625	47,719	106,180	141,351	194,616	163,256	124,493	47,719	269,624
Pups	50	157	75	123	274	1,562	691	268	556	1,052	6,715	2,200	50	9,824
Fishing Mortality														
Females[4]	0.29	0.15	0.11	0.17	0.17	0.47	0.13	0.09	0.09	0.11		0.22	0.08	0.47

[1] 1962-2008 for landings, 1989-2008 for US discards, 1984-2008 CA discards, 1981-2008 for recreational, 1991-2009 for biomass & female catch & Fishing mortality, 1968-2009 for Pups

[2] fishing year (may 1- apr 30)

[3] US & CA landings + US discards+ US recreational ;sex ratios of US landings & discards applied to CA landings

[4] Female Catch /female exploitable biomass

Stock Distribution and Identification

Spiny dogfish in the Northwest Atlantic are distributed between Labrador and Florida. The species is most abundant between Nova Scotia and Cape Hatteras, and the stock comprises both resident and migratory components. Dogfish in US and Canadian waters (Northwest Atlantic Fisheries Organization Subareas 2-6) are not genetically distinct, but spatial structuring of the population is evident. Available evidence supports a conceptual model with resident components in the northern part of the range, overlaid by a migratory, transboundary component (Fig.1). Seasonal migrations are pronounced throughout the range; these movements are primarily north-south in US waters and inshore-offshore in Canadian waters. The seasonal north-south migration extends into portions of Canadian waters each spring/summer, with return movements during autumn/winter. Most of the population biomass occurs in US waters.

Analyses of raw recapture rates from USA and Canadian tagging studies suggest limited movements of dogfish outside of the country of release. Less than 20% of recaptures have been outside of the country of release, although overall recovery rates have been very low (less then 1%). Although the tagging data are informative, they are insufficient to accurately quantify migration rates. More detailed examination of time-at-large and the general patterns of fishing effort in the area of release are necessary before the tag recaptures data can be used to quantify movement flux among release areas. As well, the influence of fishing effort and reporting rates on recapture probabilities needs to be addressed. A more comprehensive, integrated modeling approach is also required to resolve uncertainties in movement rates.

Fishery

Total landings of dogfish during 1962-1965 were almost exclusively from the US commercial fishery. During 1966 to 1977, distant water fleet landings predominated, peaking in 1974 at about 25,000 mt (Fig. 2). Since 1978, distant water fleet landings have been minimal. US commercial landings dominated the catch from 1979 to 2000, peaking in 1996 at about 28,000 mt (about five times greater than the 1980-1989 average). In 2001, US landings sharply declined due to management measures. During 2001-2006, total landings ranged between 3,100 mt (2003) and 6,800 mt (2001), with Canadian landings accounting for more than 50 per cent of the total harvest. Total combined Canada and USA landings in 2007 and 2008 were 5,900 mt and 5,700 mt, respectively.

US Catches. US landings averaged about 400 mt annually during 1962-1979, but averaged 4,300 mt during 1980-1989. With the advent of the USA directed fishery in 1990, landings averaged 17,900 mt from 1990-2000, but averaged only 2,200 mt during 2001-2008 due to quota restrictions. **Recreational landings** have always been very low (averaging 200 mt from 1981-2008), although recreational discards have been much higher (averaging 1,500 mt from 1981-2008). Quantitative estimates of **discards** are available for US fisheries from 1989 onwards (Fig. 3). Discards during 1964-1988 were imputed using the ratio of dogfish discards to total landings of all species. Estimated discard mortalities range from 2,900 mt to 22,800 mt assuming gear-specific mortality rates. In recent years, US discards have been much lower than before the mid-1990s.

Canadian Catches. Canadian landings averaged about 400 mt from 1962-1997, but averaged 2,300 mt during 1998-2008. Quantitative discard estimates for Canadian fisheries are available from 1984 onwards, tabulated by the annual period May 1 – April 30 (Fig. 4). Estimated discard mortalities range from 150 mt to 550 mt assuming gear-specific mortality rates. Canadian discards in recent years are lower than those before 1995.

Harvest Strategy and Biological Reference Point

There is no co-management of spiny dogfish by Canada and the US. In Canada, a precautionary total allowable catch (TAC) is set based upon historical catches pending development of a transboundary stock assessment and establishment of a harvest strategy with associated reference points.

The US harvest strategy must comply with the provisions of the Magnuson–Stevens Fishery Conservation and Management Act. As such, the spiny dogfish stock must be rebuilt because the stock was declared overfished in 1998. Accordingly, management must maintain exploitation below $F_{REBUILD}$ to achieve the B_{MSY} proxy within the 10-year rebuilding horizon.

In the US Spiny Dogfish Fishery Management Plan (prepared jointly by the Mid-Atlantic and New England Fishery Management Councils and implemented in 1999), the reference points established for Federal waters include a B_{TARGET} of 180,000 mt and a $B_{THRESHOLD}$ of 100,000 mt, (both expressed in terms of adult (>= 80 cm) female biomass), and an $F_{THRESHOLD}$ of F=0.11 and an F_{TARGET} of F=0.08. The threshold and target fishing mortality rates represent the full F corresponding to a knife edge fishery selectivity pattern with a minimum size of 70 cm. The B_{TARGET} reference point was subsequently disapproved by NMFS because it did not correspond to the biomass associated with maximum recruitment (approximately 200,000 mt) in a Ricker stock-recruitment function. At the US Stock Assessment Research Committee (SARC) 43 in 2006, biomass reference points were re-estimated using the Ricker model using survey data updated through 2006. These results gave an unrealistically high estimate of SSB_{MAX} which was rejected by the SARC. Ricker model results suggest that the recent stanza of lower than expected recruitment could be associated with changes in maternal size, and possibly also with the ratio of mature males to females.

The biomass target for spiny dogfish in state waters is set by the Atlantic States Marine Fishery Commission (ASMFC). The biomass target in the ASMFC Fisheries Management Plan (ASMFC 2002) was determined by applying a Ricker model to the swept area estimates of SSB and recruits in the NEFSC spring trawl survey for the period 1968-1996. Based on a nominal trawl footprint of 0.012, SSB_{MAX} in the ASMFC plan was estimated to be 167,000 mt.

Updated fishery selectivity through 2005 resulted in a shift toward harvesting larger dogfish and a subsequent increase in the fishing mortality threshold to F=0.39 and in F_{TARGET} to 0.284 (Rago and Sosebee 2009). The overfishing threshold depends strongly on the size selectivity of the fishery and the assumed constancy of the life history parameters associated with maturation, fecundity, and first year survival of dogfish.

The TRAC reviewed various models of the stock-recruitment relationship, in which the potential effects of mature female size, pup size, and male/female sex ratio on pup mortality were included. The TRAC recommended further exploration of these models, and indicated that additional diagnostics be provided to facilitate model selection. The TRAC agreed to review, via email, the revised stock-recruitment models along with estimates of fishery selectivity and, if a model was accepted, the resulting biomass reference point would be made available for use in US management.

State of Resource

A consensus transboundary stock assessment was not developed at this benchmark TRAC. The status of spiny dogfish and management advice in Canada will be deferred until an accepted TRAC benchmark assessment is available. However, given that US management advice was required for fishing year 2010, the TRAC agreed to accept the 2006 NEFSC assessment model (NEFSC 2006, Section 7.3) with data updated through the 2009 NEFSC spring survey, to determine stock status.

The TRAC examined two different forward projecting benchmark models. The first model considered the dogfish stock as composed of two (US and Canada) spatially interacting components, by age, length, and sex. The model included a resident northern subpopulation and a southern subpopulation having both resident and migratory components. The model included a constant migration rate between stock components for all years by half-year time steps. Selectivity estimated for each fishing fleet was constant throughout the time series, and multiple NMFS and DFO surveys were used to provide indices of abundance.

The second model, implemented in Stock Synthesis 3 (SS3), considered the population as a single unit stock of female dogfish without spatial structure and with an annual time step. Fishery selectivity of two fleets, defined as US landings and US discards aggregated over all gear types, was allowed to vary over time using a random walk. Fishery selectivity for each of the two Canadian fleets (landings and discards aggregated over all gears), was assumed to be constant over time.

The two models also differed in the parameters applied for growth and natural mortality, and the first model lacked algorithms for determining biological reference points and for conducting catch and stock projections.

While the two models represented progress from the approach used in the NEFSC 2006 assessment, comparing the performance of the two models was difficult because of differences in the data used in model fitting and to the widely divergent assumptions in each model. Neither model produced satisfactory fits to times series of relative abundance estimates from the research surveys. Model fits to survey length frequencies were generally better than for abundance, in part due to the large number of observations available for fitting. The results of both models appeared to be strongly influenced by initial starting conditions. Neither model was accepted by the TRAC due to unacceptable levels of uncertainty in the model outputs. Further model explorations were encouraged in both cases.

In the NEFSC 2006 assessment model, updated to 2009 for US stock status determination, estimates of biomass and fishing mortality are derived from a stochastic length-based, survey swept-area method using data from the commercial and recreational fisheries and the NEFSC spring trawl survey. Information about the footprint of the trawl is used to impute survey catchability for dogfish. The swept area model incorporates uncertainty in survey indices, the footprint of the trawl, discards, and recreational landings plus discards. Natural mortality (M) is assumed to be 0.092 based on a life span of 50 years. Selectivity patterns for exploited female and male dogfish were developed for landings plus discards. A size- and sex-structured equilibrium life history model, incorporating known biological parameters, is used to estimate yield per recruit and female pups per recruit corresponding to various levels of F and the minimum size at entry to the fishery. Biological data on the relationship between maternal size, and numbers and size of pups are also incorporated. A stochastic, length-based projection model is used to predict yield, population sizes, and rebuilding times under alternative management scenarios.

Female spawning stock biomass (SSB) (>= 80 cm fish) declined from 234,000 mt in 1991 to 52,000 mt in 1999, and remained below 65,000 mt through 2005 (Fig.5). Biomass then increased, reaching 195,000 mt in 2008 but declined slightly to 163,000 mt in 2009.

Recruitment (total male and female pups) biomass is directly related to the number and size of spawning females. Spiny dogfish fecundity is low with 2-9 pups per litter every two years. During 1997-2004, pup production was a record low, but subsequently improved. Recruitment in 2009 was the fifth highest in the 42-year NEFSC spring survey time series (Fig. 6).

Fishing mortality (F = female catch/female exploitable biomass) peaked in 1994 at 0.47 and remained high until 2001. Subsequently, fishing mortality has been very much lower, with the exception of 2004, and ranged between 0.11 and 0.13 during 2005-2008 (Fig.7).

Productivity

The **low abundance of pups** during 1997-2003 will result in reduced spawning biomass when these weak cohorts reach maturity. Declines in the abundance of dogfish less than 60 cm suggest that the estimates of low pup production are not artifacts of reduced availability to the survey gear. **Population size structure**, as reflected in both US commercial and survey length frequency data, indicate that a pronounced, consistent decline in the average length of mature females occurred from 1992 through the early 2000s. **Average pup size** in the surveys has also declined, consistent with the observed relationship between maternal size and average pup length. Short term increases in stock size will continue for several more years until the effects of reduced recruitment reduce SSB. The **sex ratio** of mature males (>60 cm) to females (>80 cm) increased in 1993, rose nearly 3-fold by 2000, but has declined from 2004 onwards. The skewed sex ratio may have implications for decreased reproductive output, but direct evidence for this effect in *Squalus acanthias* is lacking. **Spatial distributions** since 1995 indicate that male spiny dogfish are distributed closer to shore than during 1980-1995, while the distribution of females has not changed. These spatial patterns increase the potential overlap of the two sexes; however, the effect of this increased co-occurrence on productivity is speculative (e.g., increased cannibalism of pups; interference of typical mating behaviors).

Outlook

Short term forecasts of spiny dogfish biomass are strongly influenced by the size structure of the current population. Under the status quo F (F=0.11), the biomass of mature females is expected to continue to increase through 2011 as fish < 80 cm grow and mature. Long term projections, not presented here, indicate that SSB will decline between 2011 and 2017 as the low number of 1997-2003 recruits mature. If recruitment then returns to levels consistent with the expected size-specific reproduction, the mature female biomass will increase again. These oscillations are expected to occur irrespective of the intensity of fishing.

Scenario	F	Year	Total Landings (mt)	Female SSB (mean, mt)
Status Quo	0.11	2009	5,015	163,304
		2010	5,692	193,679
		2011	6,201	202,540
		2012	6,537	199,843

Special Considerations

The overall population biomass of spiny dogfish (male, females, and juveniles) is currently high, greater than 500,000 mt. About 60% of the total biomass is male dogfish, which are less marketable. The current size composition of the female biomass is predominately between 70-95 cm, whereas a broader size range (40-105 cm) was evident prior to 1988.

The magnitude of total discard and estimated mortality of discarded fish is highly uncertain and influences the estimation of (a) selectivity; (b) fishing mortality and exploitable biomass; and (c) fishing mortality reference points.

Spiny dogfish consumption is a function of stock abundance, sexual dimorphism, seasonality, and stock size composition. Annual total estimated consumption averaged 230,000 mt over the time series (1981-2007) which, when apportioned to specific prey species (primarily small pelagic fishes and invertebrates), represents a significant removal of biomass. Annual average consumption of squid, herring, and ctenophores was estimated to be 16,000, 32,000 and 36,000 mt, respectively.

A large scale contemporary tagging program consisting of conventional external tags, data storage tags, and satellite pop-up tags could help clarify movement patterns and migration rates. Once reliable data on movements are available, this information could be used in spatially structured models. However, additional spatial and temporal analyses of fishing effort and reporting rates would also be necessary for proper interpretation of the tagging results.

Source Documents

Atlantic States Marine Fisheries Commission. 2002. Interstate Fishery Management Plan for Spiny Dogfish. Fishery Management Report No. 40. Washington D.C. 128 p.

Campana, S.E., A.J.F. Gibson, L. Marks, W. Joyce, R. Rulifson, and M. Dadswell. 2007. Stock Structure, Life History, Fishery and Abundance Indices for Spiny Dogfish (*Squalus acanthias*) in Atlantic Canada. DFO Canadian Science Advisory Secretariat Research Document 2007/089.

Haist, V., M. Fowler, and S. Campana. 2010. A Length-Based, Spatially Explicit Population Model for Spiny Dogfish (*Squalus acanthias*) in the Northwest Atlantic. TRAC Reference Document 2010/02.

Northeast Fisheries Science Center. 2006. 43rd Northeast Regional Stock Assessment Workshop (43rd SAW): 43rd SAW Assessment Report. US Dep. Commer., Northeast Fisheries Science Centre Reference Document 06-25; 400 p.

Rago, P. and K. Sosebee. 2010. Biomass Reference Points for Spiny Dogfish. NEFSC Reference Document 2010/*in prep*.

Sosebee, K.A., L. Jacobson, P. Rago, and M. Traver. 2010. Description of Data and Exploratory Stock Assessments of Spiny Dogfish, *Squalus acanthias*, using Stock Synthesis. TRAC Reference Document 2010/03.

Correct Citation

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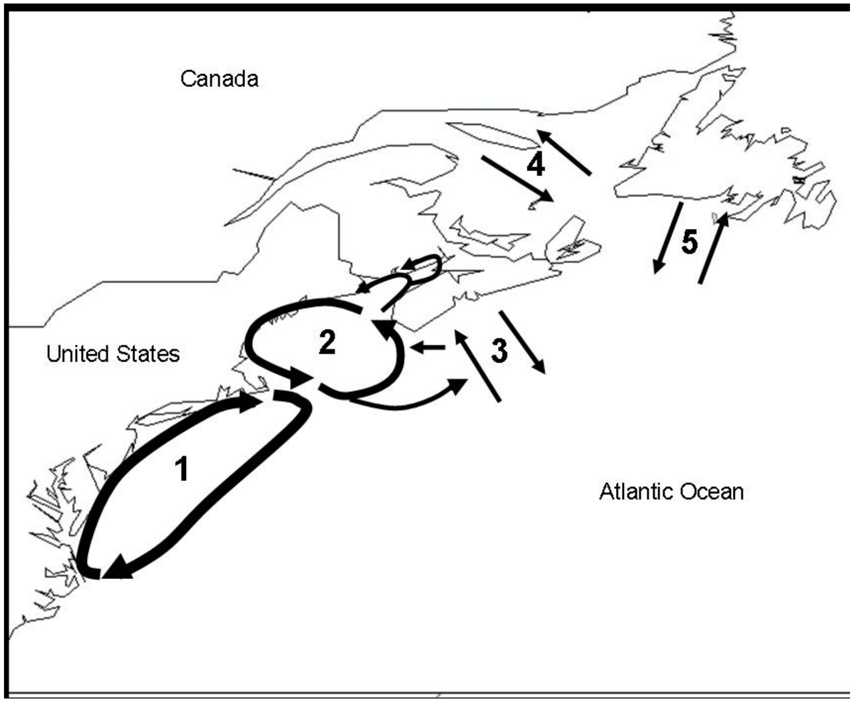

Figure 1. Spiny dogfish movements in the western North Atlantic based on preliminary tagging results.

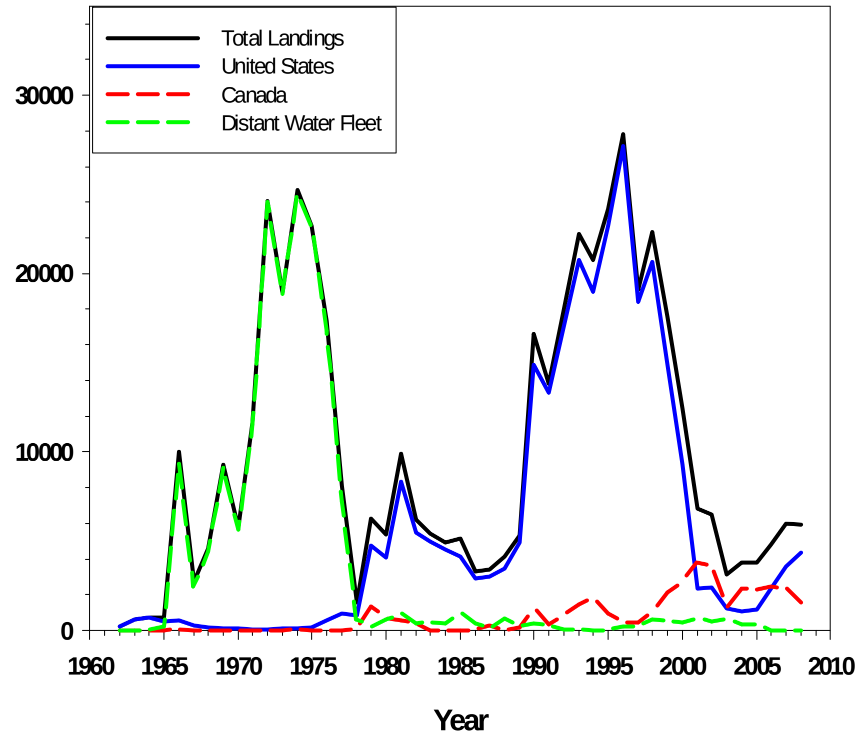

Figure 2. Total landings of spiny dogfish from US, Canada, and the distant-water fleet.

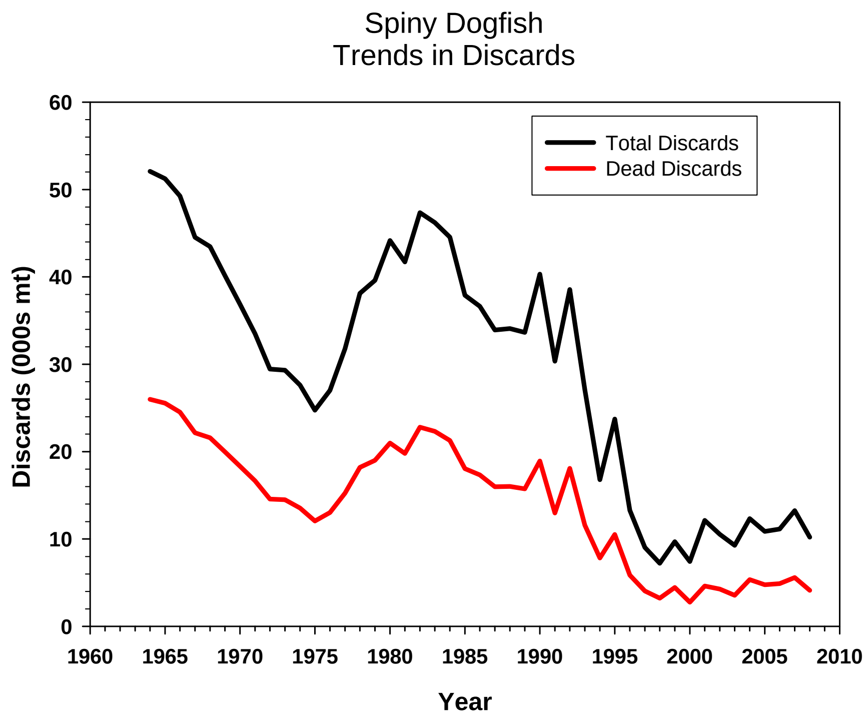

Figure 3. Estimated US total and dead discards during 1964-2008.

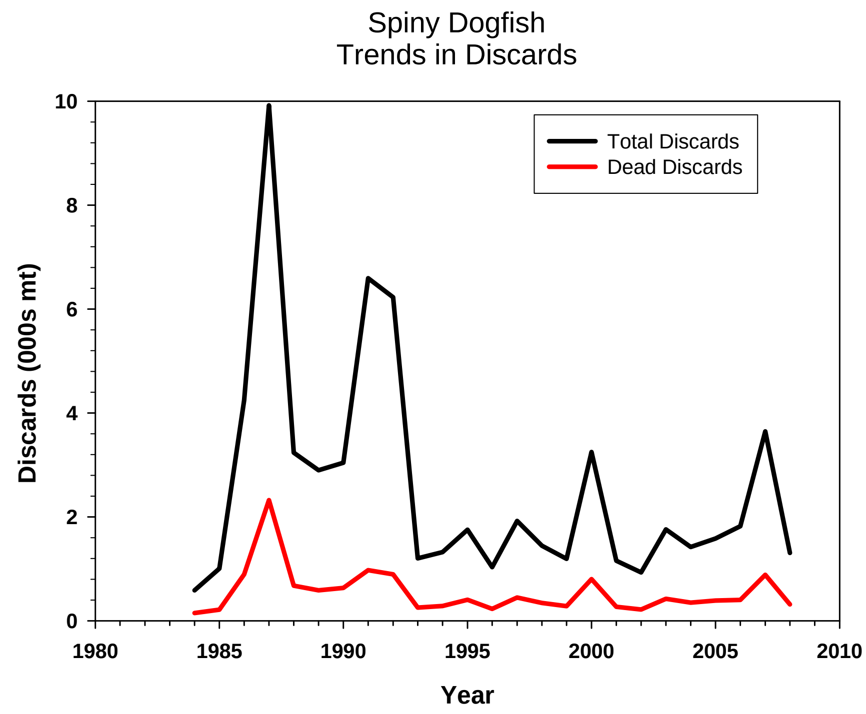

Figure 4. Estimated Canadian total and dead discards during 1984-2008.

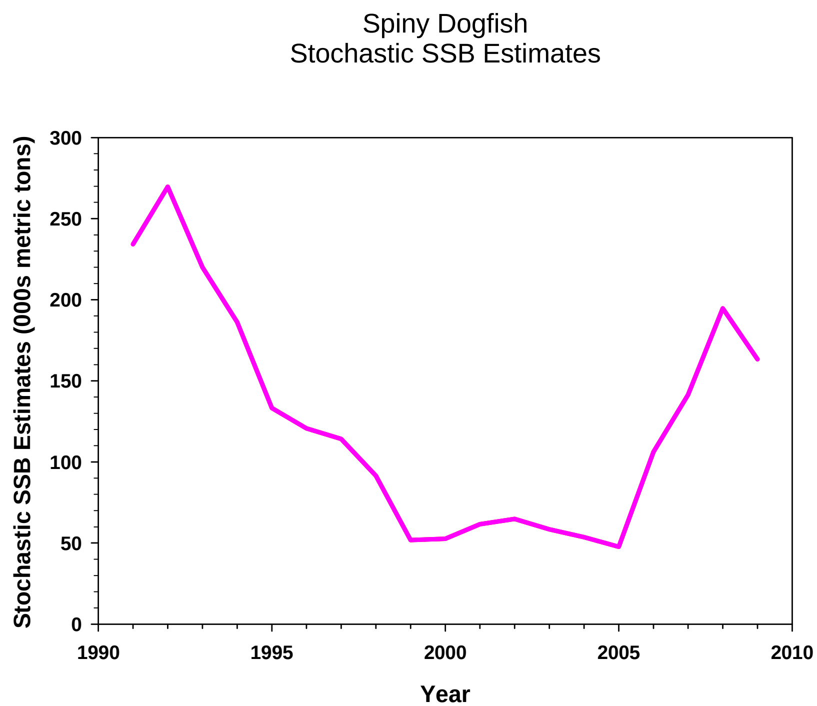

Figure 5. Stochastic estimates of female (>= 80 cm) SSB during 1991-2009.

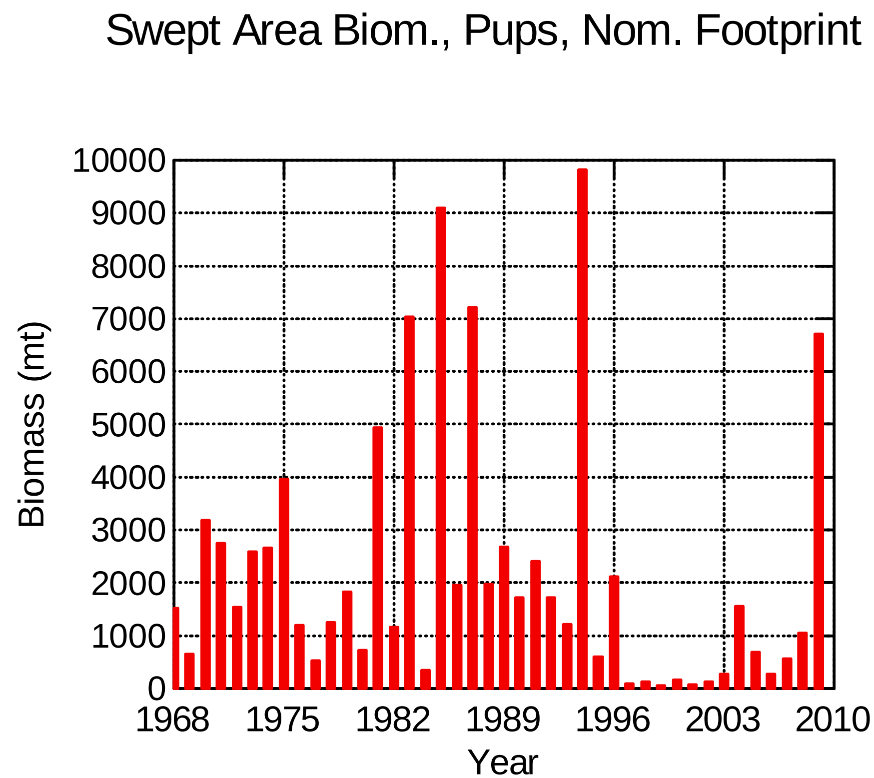

Figure 6. Biomass of spiny dogfish pups (<= 25 cm) from the US spring survey from 1968-2009.

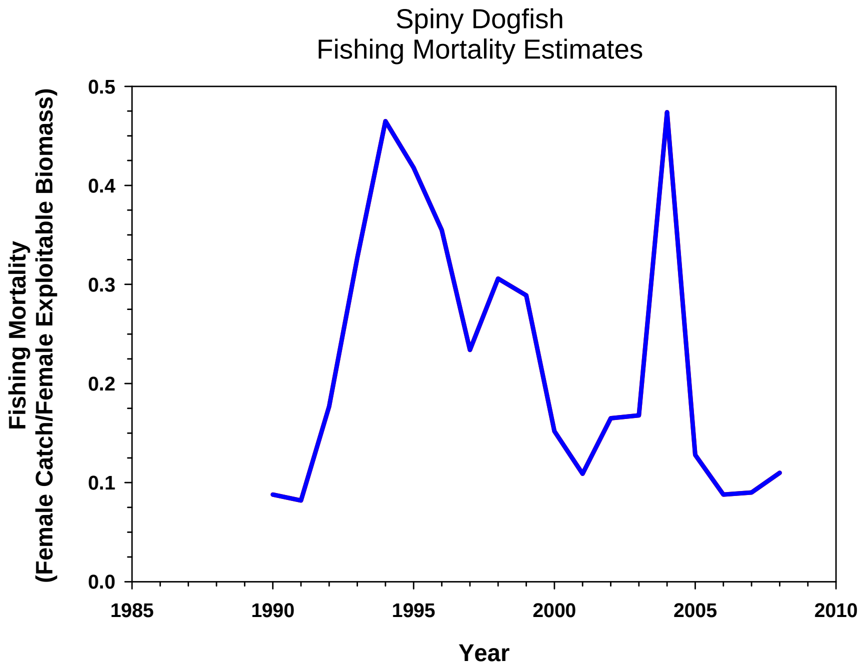

Figure 7. Spiny dogfish fishing mortality (female catch/exploitable female biomass) during 1990-2008.