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Update on the Status of Spiny Dogfish in 2011 and Initial Evaluation of Alternative Harvest Strategies

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Executive Summary

The purpose of this report is to summarize the most recent information on the status of spiny dogfish (*Squalus acanthias*) in 2011. Information on the NEFSC spring bottom trawl survey trends and total removals are provided along with an analysis of estimated stock size, fishing mortality rates, and projections of stock size under varying fishing mortality rates.

This report draws heavily on the results of the last peer-reviewed stock assessment vetted at SARC 43 in 2006, assessment model described in Rago and Sosebee (2009), and a revision of the biological reference points for spiny dogfish described in Rago and Sosebee (2010). The revised biomass reference points were peer-reviewed by the Transboundary Resource Assessment Committee in April 2010. The revised biological reference points required an update of the size and sex-based selectivity estimates of the fishery. Previous biomass reference points for spiny dogfish were based on a Ricker stock-recruitment model derived from Northeast Fishery Science Center trawl survey data. SSBmax, the biomass that results in the maximum projected recruitment, is the proxy for BMSY. The revised biomass reference point incorporates additional information on the average size of the recruits as an important explanatory variable. A hierarchical AIC-based model building approach is used to identify the best model. Comparisons of maximum likelihood and robust nonlinear least squares regression models suggested that the robust estimator had the lowest AIC and highest precision for the estimate of SSBmax.

The revised target reference point, expressed in terms of average weight (kg) per tow of female spiny dogfish greater than 80 cm, is estimated as 30.343 kg/tow. Conversion of this metric to swept area biomass depends on the average swept area per tow, i.e., the trawl footprint. The nominal footprint of the R/V Albatross is 0.01 nm^2. Using this value, the swept area estimate of SSB_{max} is 189,553 mt. Using an alternative footprint more consistent with recent gear mensuration suggests that a footprint of 0.0119 nm^2 is more appropriate. The revised swept area biomass target (SSB_{max}) corresponding to this footprint is 159,288 mt. Applying the convention defined in the current control rule in the Spiny Dogfish Fishery

Management Plan, the threshold biomass is one half of the target or 79,644 mt. Based on the revised biomass reference point and using the trawl footprint of 0.0119 nm^2, the US spiny dogfish resource was rebuilt in 2008 when the swept area female spawning stock biomass was 194,616 mt. Biomass estimates in 2009 (163,256 mt), 2010 (164,066 mt) and 2011 (169,415 mt) also exceeded the biomass reference point. Therefore, the stock is not overfished and is rebuilt. Stochastic model estimates of female spawning stock biomass suggest a greater than 50% chance of exceeding the biomass target.

Changes in the estimated selectivity of the fishery also led to revised estimates of fishing morality reference points. The updated target and threshold fishing mortality rates of 0.207 and 0.325, respectively were based on a life history model described in Rago et al. 2008. During the Meeting of the MAFMC SSC on September 21, 2010 the committee noted that the longterm projections were inconsistent with these reference points. The SSC recommended that the fishing mortality reference points be reexamined. Additional analyses were conducted with the projection model to identify fishing mortality rates that would lead to a stable population structure and a finite rate of increase of 1. A revised fishing mortality rate of 0.2439 was estimated (Rago 2011). These analyses and results were reviewed and approved on August 19 by the SSC.

Estimated fishing mortality rates in 2009 and 2010 were 0.113 and 0.093 respectively. Sampling distributions for both F estimates suggested almost no chance that the fishing mortality threshold rate was exceeded. In the mid 1990's F on fully recruited spiny dogfish was about 2 to 4 times greater than contemporary rates. Moreover, a greater fraction of the mature female population was vulnerable to fishing mortality in the earlier period. The reduced rate of fishing mortality and shift in selectivity led to major reductions in the overall force of mortality on the population. Fishing mortality rates on male dogfish are negligible (<0.01).

Two alternative harvest scenarios were evaluated. These included catch projections based on fishing mortality rates at the Fmsy proxy (0.2439) and at 75% of this value (i.e., F=0.1829). As discards, Canadian landings and US recreational catch constitute a sizable fraction of the overall catch, the translation of US commercial landings to total dogfish catch requires a sequence of assumptions. For management purposes it is important to recognize that projections rely on static relationships between landings and discards, and continuation of current fishery selectivity patterns in the future. Changes in management regulations or economic value of spiny dogfish would reduce the tenability of these assumptions.

Projections for each of these scenarios can be compared with respect to their projected landings, probabilities of overfishing and probabilities of falling below SSB targets and thresholds. A common feature of all projections is the oscillation in future stock sizes induced by the stanza of low recruitment between 1997 and 2003. Higher rates of fishing mortality tend to induce greater declines in abundance and a greater chance that the population will fall to levels requiring rebuilding measures. These future oscillations have important implications for selection of contemporary harvest policies, especially with respect to variability of landings streams and the risk of introducing measures to reduce overfishing or rebuild the stock.

The median of the Overfishing Limit (OFL) for 2012 is 25,131 mt. The 90% confidence interval for the OFL is 18,534 to 31,723 mt. Assuming the same ratio of landings to total catch as in recent years, the corresponding confidence interval on landings would be 10,138 mt to 18,890 mt.

A. Catch Trends

1. This document summarizes the most recent information on spiny dogfish stock status using survey data from the spring 2011 NEFSC bottom trawl survey and catch data from 2010. Catch data include landings from US and Canadian commercial fisheries, and US recreational landings. Discard information includes discards from US commercial fisheries and US recreational fisheries. Estimates of dead discards are obtained by multiplying the total discards by the gear-specific discard mortality rates.
2. Total landings estimates are summarized in Table 1. US landing increased by 31% from 4108 in 2008 to 5377 in 2009. US landings in 2010 of 5,440 mt were nearly equivalent to 2009. Canadian landings declined from by 93% to 113 mt in 2009; landings in 2010 were only 6 mt (Stephen Campana, pers comm.)
3. Total discards in US otter trawl fleet in 2010 were about equal to estimates in 2009 of about 5600 mt. Sink gill net discards of 2,385 mt dropped to the lowest value since 1999. (Table 2). Discard mortality rates vary by gear type and are used to adjust predicted total removals downward. The estimated total discards (Table 3) declined by 33% in 2010; total dead discards fell by a comparable amount (31%) compared to 2009. The combination of low Canadian landings and reduced discards resulted in a 16% decline in overall catch between 2009 and 2010.
4. Biological samples collected by port agents are used to estimate size composition and sex ratios for spiny dogfish in landings (Table 4). Overall Landings are dominated by females, a trend that has persisted since the US EEZ fishery began. Most fishing takes place near shore where females are more abundant.
5. The sex ratios of discarded fish are similarly dominated by females, but the smaller males are more frequent in the landings (Table 4). Nearshore fishing patterns are thought to be responsible for the high female to male ratios.
6. A report on 15 port samples from gill net fishermen and 1 report from a longline trip were analyzed by Steven Correia of the Massachusetts DMF. In 2010 all of the trips were between Jul 1 and August 10. In 2011 trips were recorded between July 8 and Aug 25. The trips revealed the expected pattern of greater female numbers than males but the ratio in 2010 was 57:43. In contrast the ratio for female to males in NMFS port samples was 86:14. Female to male landings have increased in recent years since the resumption of the directed fishery but the lowest observed ratio of females to males was 74:26 in 2005. NMFS port samples tend to be distributed overall four quarters. There was insufficient time to compare the results of the two sampling programs. However, an increase in the fraction of the males in the catch would allow for increased overall quotas.
7. Discard rates are high. By weight, dead discards constitute nearly 75% of the captured male dogfish and 35% of the females catch. Notably, the fraction of female catch discarded dropped from 46% in 2009 to 35% in 2010 (Table 4 and 5)

B. Survey Indices

1. Beginning in 2009 the NEFSC spring bottom trawl surveys were conducted by the FSV Bigelow instead of the R/V Albatross IV. The Bigelow is a larger, acoustically-quiet vessel. It tows a larger net and has different sampling protocols. A large-scale side-by-side calibration experiment was conducted in 2008 to compare catches between the two vessels. A peer-review committee met in August 2009 to review the

results of the experiment and to provide additional guidance on methodology for estimating the magnitude of the gear-vessel-protocol differences.

2. The calibration factor for spiny dogfish was estimated using a beta-binomial estimator. Overall the Bigelow caught 1.1468 times as many spiny dogfish per tow as the Albatross. The standard error of the estimate was 0.0441 and the 95% confidence interval was 1.0636 to 1.2365. The 2011 Bigelow-based estimates of relative abundance were converted to predicted Albatross equivalents by dividing each estimate by 1.1468.
3. The use of a calibration coefficient increases the variance of the estimated Albatross equivalent because this prediction includes the sampling errors of the original Bigelow survey value and the calibration coefficient. A Taylor series expansion method was used to estimate the variance as
   a. $$Var\left[\frac{I_{Bigelow}}{\gamma}\right] = \frac{Var\left[I_{Bigelow}\right]}{\gamma^2} + \frac{I_{Bigelow}^2 Var[\gamma]}{\gamma^4}$$
   b. Application of this formula to 2010 Bigelow survey increased the CV by less than 5%. See computational details in Appendix 1.
4. Swept area biomass estimates, using a nominal trawl survey footprint of 0.010 nm^2 suggested almost no change in the abundance of dogfish between 2009 and 2011. (Table 6). This table is included to facilitate comparisons with previous summaries of this information. Improved stochastic estimates of swept area biomass are given in Table 7.
5. Size frequency plots for males and females were not plotted at the time this report was prepared.

C. Stochastic Estimates of Biomass and Fishing Mortality

1. The simple arithmetic average of stock size does not incorporate sampling variations in the underlying survey data or uncertainty in the size of the footprint of the average trawl tow. A stochastic estimator of spawning stock biomass for female dogfish is described in SARC 43. Results of this estimator are depicted in Table 7 and Fig. 1. Computational details on this estimator may be found in Rago and Sosebee (2009). The stochastic estimator incorporates uncertainty in the sampling observation (ie. the variance of the relative abundance index) of a 3 yr average and variation in the survey footprint. Average biomass estimates are summarized in Table 7 while Figure 1 is depicts the variability in biomass estimates.
2. The estimator for fishing mortality is based on the ratio of total catch and swept area biomass. Ostensibly this assumes that the trawl is 100% efficient in capturing dogfish between the wings. Alternatively, it implies that the trawl is about 50% efficient in capturing dogfish between the doors. An external mass balance model was first applied at SARC 43 and has been recently updated for a chapter in a forthcoming book on spiny dogfish (Rago and Sosebee 2009). The mass balance model supports the biomass estimates based on simple swept area concepts. However, it is acknowledged that this is a source of uncertainty in the assessment and subject to change at a future benchmark assessment.
3. Female spawning stock biomass in 2011 increased by about 3% from 2010 estimates (Table 7). The probability that female spiny dogfish SSB exceeds the biomass reference point is greater than 50% (Fig. 1). Dogfish continue to exceed the rebuilding target biomass.
4. Fishing mortality estimates incorporate uncertainty in the biomass as well as landings and discards. Variance estimates of discards by gear type and sex are computed for trawls, gillnets and recreational catch.

Results of the fishing mortality estimates are summarized in Table 8 and Figure 2. Fishing mortality rates for female spiny dogfish are less than 1/2 of the F msy proxy.

D. Harvest Scenarios

Stock projections are based on a stochastic model that incorporates uncertainty in initial population size. Uncertainty in population size is derived by consideration of sampling variability of a 3 year average abundance, and uncertainty in the average area swept per tow. The effects of harvest policies are estimated using length-based sex-specific projection model that has been used for catch and status projections since 2003. (See Rago and Sosebee, 2009 for a summary and example. Other examples in NEFSC 2003, and 2006).

In addition to specifying target fishing mortality rates and/or quotas, it is necessary to specify a number of key assumptions about future fisheries. The key assumptions include:

- All life history parameters, especially those related to reproduction are effectively constant
- Selectivity patterns in the fishery remain the same over time.
- Discard patterns and proportions of total catch remain constant over time
- Recent recruitment trends will continue and that the low recruitment period from earlier will not return
- The relationship between male and female fishing mortality rates scales directly with the magnitude of female fishing mortality. When Fs are increased to the Fmsy proxy (0.2439) and 75% Fmsy proxy (0.1829) it is assumed that the F on males would increase proportionally to 0.013 (Table 10) and 0.009 (Table 12), respectively.
- In all of the scenarios it is assumed that the catch in 2011 is the same as observed in 2010. See Table 10 and 12.

Changes in discard patterns could become extremely important. Discard mortality presently constitutes 75% of fishing mortality by weight on male dogfish and 35% by weight on females. The male population is at or near historic highs, but its low marketability and offshore distribution reduce the chances of male dogfish contributing significantly to future landings. All of the projections described herein assume that there will not be major increases in male dogfish landings.

D.1 Scenarios

All of the scenarios assumed that the 2011 fishery had the same selectivity and fishing mortality properties as the 2010 fishery and was equal in magnitude. The implications of this assumption are illustrated in Table 9, which demonstrates that the there almost no chance that the fishing mortality rate would exceed the Fmsy proxy in 2011. Morever there is at least a 60% chance that the population would exceed the Bmsy proxy of 159 kt. The scenario planning horizon was 30 years (2010-2039). The longer term projections should be viewed as informative of potential trends, but the absolute values are less reliable. Longer term trends are useful for comparing the likely state of the resource after a sustained harvest period. Two alternative F-Based scenarios were considered.

F= Fmsy proxy =0.2439

F=75% Fmsy proxy =0.75 * 0.2439 = 0.1829

The F-based harvest scenarios create a sampling distribution of catch (Fig. 4-5 Panel A), total landings (Fig. 4-5 Panel C) and a sampling distribution of female SSB (Panel B) and fraction of the SSB target (Panel D).

D.2 Results

The constant F harvest policies lead to a static population when F=Fmsy proxy (Fig. 3) and a population that grows at about 1.5% per year when F=75% Fmsy proxy (Fig. 3). For both scenarios the short term response is dominated by oscillations that are primarily a function of the contemporary size structure of the population. All of the projections suggest that the population will oscillate as the low recruitments from 1997-2003 enter into the spawning stock.

Box plots are used to convey the predicted uncertainty in catch, landings, and female SSB (Fig. 4-5); numerical details are provided in Tables 10 to 13. Tables 11 and 13 provide detailed information on the percentiles of catch, landings, discards and female SSB for 2012 to 2014. The 40%-ile of catch under F=0.2439 averages 24,034 mt for 2012 to 2014 with no meaningful variation between years. Table 11 can be viewed as an approximation of the sampling distribution of the Overfishing Level (i.e., a function of the Fmsy proxy and the uncertainty in the population size). The 90% confidence interval for the OFL in 2012 is 18,534 mt to 31,723 mt. Goodness of fit tests for predicted total yield in 2012 are summarized in Appendix 2. Neither the normal nor log normal distributions are supported by the the Chi-square test statistic , but visual inspection suggests that either approach is reasonable biologically. A simple kernel smoother fit (Appendix 2 Fig. 1) did seem to fit better, but no parametric model was found that was better than the normal or log normal distribution.

Figures 4 and 5 illustrate the expected increases in uncertainty over time and among scenarios. The expectations for SSB (panels B and D) are particularly instructive for selection of harvest policies. The last four columns of Tables 10 and 12 include important information for the comparison of alternative harvest scenarios. Estimates of the probability of falling below the target and below the threshold biomass targets can be used to evaluate the risk of initiating a rebuilding program in future years or other management measures. The last two columns provide estimates of the probabilities of F exceeding the overfishing limit and the target F. These considerations are relevant only for quota based policies.

E. Sources of Uncertainty

1. The long term dynamics of spiny dogfish are an important guide for structuring harvest scenarios. The current size structure and sex ratio of the population have important implications for stock dynamics over the next decade. However, it should also be noted that long-term forecasts are inherently uncertain. The history of this resource during periods of high exploitation is informative about the magnitudes of likely fishing mortality rates. Changes in average size in both the surveys and landings suggest that the magnitude of population biomass from the swept area computations is approximately correct.

2. Scientific advice on catch levels for spiny dogfish needs to be carefully crafted. A longer term perspective is necessary to ensure that the transient effects of the current population size and sex structure are considered

over a period of several decades. At the same time, such longer term projections become increasingly uncertain and are driven by the assumptions used to model the stock dynamics. It is imprudent to look at short term changes in harvest levels without considering the longer-term implications.

3. Recent changes in survey based abundance suggest that changes in availability play an important role in abundance indices. As the male population is largely unexploited, it may offer additional insights into changes in availability to the survey since inter-annual changes in the male component of the stock should be less variable.
4. Other important source of uncertainty include
    a. Potential changes in fishery selectivity
    b. Implications of changing selectivity on estimation of biological reference points
    c. Potential inconsistency between the life history based estimates of fishing mortality rates and the biomass reference points derived from the Ricker stock recruitment curve.
    d. Total discard estimates AND estimated mortality of discarded dogfish.
    e. The revised estimate of biomass reference point is uncertain with an asymptotic CV of about 30%.

F. Potential Indicators of Stock Status during Multi-year fishery management Quotas

- a. Discard rates, especially rapid increases within gear types
- b. Survey abundance Trends
    - i. Size composition
    - ii. Sex ratio
    - iii. Pup size
- c. Average size and sex ratio in Commercial catch
- d. Agreement between observed and predicted landings and survey forecasts
- e. Changes in Canadian landings

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Table 1. Total spiny dogfish landings (mt, live) in NAFO Areas 2 to 6, 1962-2010.

	United States				
Year	Commercial	Recreational	Canada	Distant Water Fleets	Total
1962	235		0	0	235
1963	610		0	1	611
1964	730		0	16	746
1965	488		9	198	695
1966	578		39	9,389	10,006
1967	278		0	2,436	2,714
1968	158		0	4,404	4,562
1969	113		0	9,190	9,303
1970	106		19	5,640	5,765
1971	73		4	11,566	11,643
1972	69		3	23,991	24,063
1973	89		20	18,793	18,902
1974	127		36	24,513	24,676
1975	147		1	22,523	22,671
1976	550		3	16,788	17,341
1977	931		1	7,199	8,131
1978	828		84	622	1,534
1979	4,753		1,331	187	6,271
1980	4,085		660	599	5,344
1981	6,865	1,493	564	974	9,896
1982	5,411	70	389	364	6,234
1983	4,897	67		464	5,428
1984	4,450	91	2	391	4,935
1985	4,028	89	13	1,012	5,142
1986	2,748	182	20	368	3,318
1987	2,703	306	281	139	3,429
1988	3,105	359	1	647	4,112
1989	4,492	418	167	256	5,333
1990	14,731	179	1,309	393	16,611
1991	13,177	131	307	234	13,848
1992	16,858	215	868	67	18,008
1993	20,643	120	1,435	27	22,225
1994	18,798	155	1,820	2	20,774
1995	22,578	68	956	14	23,615
1996	27,136	25	431	236	27,827
1997	18,351	66	446	214	19,078
1998	20,628	39	1,055	607	22,329
1999	14,855	53	2,091	554	17,552
2000	9,257	5	2,741	402	12,405
2001	2,294	28	3,820	677	6,819
2002	2,199	205	3,584	474	6,462
2003	1,170	40	1,302	643	3,155
2004	982	105	2,362	330	3,778
2005	1,147	45	2,270	330	3,792
2006	2,249	94	2,439	10	4,792
2007	3,503	84	2,384	31	6,002
2008	4,108	214	1,572	131	6,025
2009	5,377	34	113	82	5,606
2010	5,440	21	6	127	5,594

Table 2. Estimated total discards of spiny dogfish (mt) from commercial and recreational US fisheries.
The values for otter trawl and gill net from 1981-1989 are hindcast estimates (see SARC 43)

	Total Discards					Assumed Discard Mortality Rate				
						0.50	0.30	0.75	0.10	0.20
						Dead Discards				
Year	Otter Trawl	Sink Gill Net	Scallop Dredge	Line gear	Recreational	Otter Trawl	Sink Gill Net	Scallop Dredge	Line gear	Recreational
1981	36,360	5,360	na	na	296	18,180	1,608	na	na	59
1982	42,910	4,454	na	na	349	21,455	1,336	na	na	70
1983	42,188	4,042	na	na	540	21,094	1,213	na	na	108
1984	39,625	4,918	na	na	424	19,813	1,475	na	na	85
1985	33,354	4,539	na	na	964	16,677	1,362	na	na	193
1986	31,745	4,883	na	na	1,187	15,873	1,465	na	na	237
1987	29,050	4,864	na	na	1,056	14,525	1,459	na	na	211
1988	28,951	5,132	na	na	876	14,476	1,540	na	na	175
1989	28,286	5,360	na	na	1,344	14,143	1,608	na	na	269
1990	34,242	6,062	na	na	1,170	17,121	1,819	na	na	234
1991	19,322	11,030	32	97	1,350	9,661	3,309	24	10	270
1992	32,617	5,953	827	650	1,019	16,309	1,786	620	65	204
1993	17,284	9,814	209	44	1,110	8,642	2,944	157	4	222
1994	13,908	2,887	723	na	968	6,954	866	542	na	194
1995	16,997	6,731	378	na	654	8,499	2,019	284	na	131
1996	9,402	3,890	121	na	329	4,701	1,167	91	na	66
1997	6,704	2,326	198	na	837	3,352	698	149	na	167
1998	5,268	1,965	120	na	610	2,634	590	90	na	122
1999	7,685	2,005	41	na	532	3,843	602	31	na	106
2000	2,728	4,684	14	na	685	1,364	1,405	11	na	137
2001	4,919	7,204	30	na	2,099	2,460	2,161	23	na	420
2002	5,540	4,997	58	4,015	1,673	2,770	1,499	44	402	335
2003	3,853	5,413	103	2	2,987	1,927	1,624	77	0	597
2004	8,299	4,031	53	497	3,490	4,150	1,209	40	50	698
2005	7,515	3,338	15	1,175	3,509	3,758	1,001	11	118	702
2006	7,773	3,369	14	131	3,840	3,886	1,011	10	13	768
2007	8,115	5,133	61	73	4,300	4,058	1,540	45	7	860
2008	5,604	4,864	237	260	3,115	2,802	1,459	178	26	623
2009	7,010	4,874	364	835	2,869	3,505	1,462	273	84	574
2010	5,564	2,385	196	509	1,930	2,782	716	147	51	386

Table 3. Total catch for spiny dogfish, 1989-2010

Year	Total Discard	Total Dead Discards (mt)	Total Landings (mt)	Dead Disc/Landings	Total Discard / Landings	Total Catch (mt)
1989	34,990	16,020	5,333	3.00	6.56	21,353
1990	41,474	19,174	16,611	1.15	2.50	35,785
1991	31,831	13,274	13,848	0.96	2.30	27,122
1992	41,066	18,983	18,008	1.05	2.28	36,991
1993	28,461	11,969	22,225	0.54	1.28	34,194
1994	18,486	8,556	20,774	0.41	0.89	29,330
1995	24,760	10,932	23,615	0.46	1.05	34,547
1996	13,742	6,025	27,827	0.22	0.49	33,852
1997	10,065	4,366	19,078	0.23	0.53	23,443
1998	7,963	3,435	22,329	0.15	0.36	25,764
1999	10,263	4,581	17,552	0.26	0.58	22,134
2000	8,111	2,917	12,405	0.24	0.65	15,321
2001	14,252	5,063	6,819	0.74	2.09	11,882
2002	16,283	5,049	6,462	0.78	2.52	11,510
2003	12,358	4,225	3,155	1.34	3.92	7,380
2004	16,370	6,146	3,778	1.63	4.33	9,925
2005	15,552	5,589	3,792	1.47	4.10	9,382
2006	15,126	5,688	4,792	1.19	3.16	10,480
2007	17,681	6,510	6,002	1.08	2.95	12,512
2008	14,080	5,088	6,025	0.84	2.34	11,113
2009	15,952	5,897	5,606	1.05	2.85	11,503
2010	10,584	4,081	5,594	0.73	1.89	9,675

Table 4 . Summary of estimated landings of US, Canadian and foreign fisheries by sex. US recreational landings included. Estimated total weights based on summation of estimated weights from sampled length frequency distributions. Estimated weights computed from length-weight regressions. Female W = exp(-15.025)*L^3.606935. Male W = exp(-13.002)*L^3.097787 with weight in kg and length in cm. "Samples" = number of measured dogfish.

	NMFS Biological Samples from Ports								Prorated Landings by Sex				
Year	Total Samples Males	Est Total Wt (kg) Males	Average Wt (kg) Males	Total Samples Females	Est Total Wt (kg) Females	Average Wt (kg) Females	Fraction Females by Weight	Total Landings (mt)	Est Landings (mt) of Males	Est Landings (mt) of Females	Number of Males Landed (000)	Number of Females Landed (000)	Total Numbers Landed (000)
1982	24	52.0	2.167	680	3015.7	4.435	0.9830	6234	106	6128	49	1382	1431
1983				610	2513.9	4.121	1.0000	5428	0	5428		1317	1317
1984	9	15.8	1.760	1499	6626.0	4.420	0.9976	4935	12	4923	7	1114	1120
1985	21	35.2	1.678	1657	6799.2	4.103	0.9948	5142	27	5116	16	1247	1263
1986	64	104.1	1.626	1165	4669.0	4.008	0.9782	3318	72	3246	44	810	854
1987	31	52.7	1.700	2000	7550.1	3.775	0.9931	3429	24	3406	14	902	916
1988	7	14.8	2.114	1764	7560.7	4.286	0.9980	4112	8	4104	4	957	961
1989	35	67.5	1.927	1375	5528.0	4.020	0.9879	5333	64	5269	33	1311	1344
1990	19	33.7	1.772	2230	8916.6	3.998	0.9962	16611	63	16549	35	4139	4174
1991	161	379.2	2.356	1518	5923.9	3.902	0.9398	13848	833	13015	354	3335	3689
1992	12	22.3	1.861	3187	12180.6	3.822	0.9982	18008	33	17975	18	4703	4721
1993	42	78.4	1.866	2773	9927.5	3.580	0.9922	22225	174	22051	93	6159	6253
1994	47	86.6	1.843	2092	6639.9	3.174	0.9871	20774	267	20507	145	6461	6606
1995	25	38.9	1.555	2266	6676.6	2.946	0.9942	23615	137	23479	88	7969	8056
1996	569	886.7	1.558	1662	4397.6	2.646	0.8322	27827	4669	23158	2996	8752	11749
1997	303	449.1	1.482	382	780.9	2.044	0.6349	19078	6966	12112	4700	5925	10625
1998	68	85.4	1.257	683	1434.5	2.100	0.9438	22329	1255	21073	999	10034	11033
1999	93	130.3	1.401	311	625.5	2.011	0.8276	17552	3026	14527	2160	7223	9382
2000	345	473.1	1.371	1921	3921.2	2.041	0.8923	12405	1335	11069	974	5423	6397
2001	12	17.1	1.422	215	456.5	2.123	0.9640	6819	246	6573	173	3096	3269
2002	1	1.3	1.279	278	752.5	2.707	0.9983	6462	11	6451	9	2383	2392
2003	34	48.3	1.421	966	2338.4	2.421	0.9798	3155	64	3091	45	1277	1322
2004	15	23.9	1.593	1180	3296.9	2.794	0.9928	3778	27	3751	17	1343	1360
2005	745	1018.7	1.367	2065	5196.0	2.516	0.8361	3792	622	3171	455	1260	1715
2006	646	924.4	1.431	4211	10382.9	2.466	0.9182	4792	392	4400	274	1785	2058
2007	507	720.7	1.421	2865	7514.8	2.623	0.9125	6002	525	5477	370	2088	2458
2008	236	342.0	1.449	2925	7973.8	2.726	0.9589	6025	248	5777	171	2119	2290
2009	472	696.6	1.476	3378	9161.6	2.712	0.9293	5606	396	5210	268	1921	2189
2010	821	1213.375	1.477924	4963	14217.35	2.864669	0.921366	5594	440	5154	298	1799	2097

Table 5 . Summary of estimated discards of combined US fleets by sex. Estimated total weights based ib summation of estimated weights from sampled length frequency distributions. Estimated weights computed from length-weight regressions.

Female W = exp(-15.025)^L^3.606935. Male W = exp(-13.002)*L^3.097787 with weight in kg and length in cm.

"Samples" = number of measured dogfish that were discarded. 2010 estimates based on fishing year rather than calendar year.

	NMFS Biological Samples of Discards from Observers								Prorated Discards by Sex				
Year	Total Samples Males	Est Total Wt (kg) Males	Average Wt (kg) Males	Total Samples Females	Est Total Wt (kg) Females	Average Wt (kg) Females	Fraction Females by Weight	Total Dead Discards (mt)	Est Discards (mt) of Males	Est Discards (mt) of Females	Number of Males Discarded (000)	Number of Females Discarded (000)	Total Numbers Discarded (000)
1991	376	463	1.231	894	2350	2.628	0.8355	13274	2184	11090	1775	4219	5994
1992	449	504	1.123	632	1090	1.724	0.6836	18983	6007	12976	5347	7526	12873
1993	57	62	1.087	130	414	3.184	0.8697	11969	1559	10410	1434	3270	4704
1994	207	207	1.001	747	1397	1.870	0.8708	8556	1105	7451	1104	3985	5090
1995	2191	2342	1.069	2384	3064	1.285	0.5668	10932	4735	6197	4431	4821	9251
1996	1643	1833	1.115	1370	2013	1.469	0.5234	6025	2871	3153	2574	2147	4721
1997	1359	1391	1.024	1427	2070	1.451	0.5980	4366	1755	2611	1714	1800	3514
1998	1289	1320	1.024	1463	1939	1.326	0.5951	3435	1391	2044	1359	1542	2901
1999	447	440	0.984	870	1808	2.078	0.8044	4581	896	3685	911	1773	2684
2000	423	568	1.343	1498	3207	2.141	0.8495	2917	439	2478	327	1157	1484
2001	650	842	1.295	2987	7377	2.470	0.8976	5063	518	4545	400	1840	2241
2002	1293	1819	1.407	5880	13899	2.364	0.8843	5049	584	4464	415	1889	2304
2003	4711	5367	1.139	12826	27210	2.121	0.8353	4225	696	3529	611	1664	2275
2004	10878	14480	1.331	28583	64771	2.266	0.8173	6146	1123	5023	844	2217	3060
2005	7470	9450	1.265	13024	28593	2.195	0.7516	5589	1388	4201	1098	1914	3011
2006	4512	5449	1.208	7041	14559	2.068	0.7277	5688	1549	4139	1283	2002	3284
2007	3955	5183	1.310	9830	24621	2.505	0.8261	6510	1132	5378	864	2147	3011
2008	3096	3969	1.282	6140	14857	2.420	0.7892	5088	1073	4015	837	1659	2496
2009	1719	2088	1.215	3083	6849	2.221	0.7664	5897	1378	4519	1134	2034	3169
2010	1634	2190	1.340	2086	4994	2.394	0.6952	4081	1244	2837	928	1185	2113
formula	*A*	*B*	*C=B/A*	*D*	*E*	*F=E/D*	*G=E/(E+B)*	*H*	*I=(1-G)*H*	*J=G*H*	*K=I/C*	*L=J/F*	*M=K+L*

Table 6. Biomass estimates for spiny dogfish (thousands of metric tons) based on area swept by NEFSC trawl during spring surveys, 1968-2011.

Year	Lengths >= 80 cm			Lengths 36 to 79 cm			Length <= 35 cm			All Lengths	3-pt Average Female SSB
	Females	Males	Total	Females	Males	Total	Females	Males	Total		
1968			41.4			110.4			1.52	153.3	
1969			27.4			69.3			0.66	97.3	
1970			36.7			33.0			3.19	72.9	
1971			103.8			27.6			2.76	134.2	
1972			126.6			145.9			1.55	274.1	
1973			178.7			165.3			2.58	346.5	
1974			221.9			179.6			2.66	404.1	
1975			105.1			125.0			3.97	234.0	
1976			96.3			120.8			1.20	218.3	
1977			77.3			68.0			0.53	145.9	
1978			87.4			131.2			1.24	219.8	
1979			52.3			18.6			1.82	72.7	
1980	104.7	15.3	168.1	16.8	72.2	123.5	0.32	0.39	0.84	292.4	
1981	266.5	24.4	293.8	25.5	75.1	100.6	2.14	2.80	5.06	399.5	
1982	454.0	34.6	488.6	61.6	143.3	204.9	0.48	0.69	1.17	694.6	275.1
1983	77.7	30.1	107.8	36.7	98.5	135.3	3.09	3.95	7.03	250.1	266.1
1984	115.6	27.5	143.1	33.4	88.0	121.4	0.14	0.21	0.35	264.9	215.8
1985	317.0	125.5	442.6	102.5	502.5	605.0	4.01	5.10	9.10	1056.7	170.1
1986	191.3	3.5	194.8	51.9	29.6	81.5	0.84	1.11	1.96	278.2	208.0
1987	219.1	90.5	309.6	61.5	171.7	233.1	2.46	4.76	7.22	550.0	242.5
1988	433.1	26.2	459.4	93.3	153.6	247.0	0.89	1.09	1.98	708.4	281.2
1989	162.1	40.5	202.6	100.4	158.2	258.6	1.14	1.54	2.68	463.9	271.5
1990	400.3	70.7	471.0	163.5	303.1	466.6	0.68	1.03	1.71	939.3	331.8
1991	220.4	30.0	250.3	108.4	186.3	294.7	0.98	1.43	2.41	547.4	260.9
1992	280.5	41.9	322.4	179.9	231.9	411.8	0.73	1.00	1.73	735.9	300.4
1993	234.6	27.8	262.5	104.1	198.5	302.6	0.55	0.65	1.21	566.3	245.2
1994	105.3	37.1	142.4	108.3	254.2	362.5	4.28	5.54	9.82	514.8	206.8
1995	102.4	29.5	131.9	154.0	174.5	328.5	0.25	0.35	0.59	460.9	147.5
1996	196.5	33.4	229.9	201.7	334.8	536.4	0.98	1.14	2.12	768.5	134.7
1997	83.7	17.5	101.2	205.2	209.1	414.3	0.05	0.05	0.10	515.5	127.5
1998	26.7	22.9	49.7	69.0	236.4	305.4	0.05	0.08	0.13	355.2	102.3
1999	62.7	20.4	83.1	140.8	256.4	397.2	0.02	0.03	0.05	480.4	57.7
2000	85.8	11.7	97.5	91.5	166.2	257.7	0.07	0.09	0.16	355.4	58.4
2001	56.7	16.7	73.4	71.4	160.5	231.9	0.04	0.03	0.07	305.4	68.4
2002	75.2	19.0	94.2	131.5	246.3	377.8	0.06	0.06	0.12	472.1	72.5
2003	64.5	22.5	87.1	125.5	256.3	381.8	0.13	0.14	0.27	469.1	65.5
2004	40.4	10.0	50.3	46.9	126.2	173.1	0.66	0.91	1.56	225.0	60.0
2005	55.8	30.8	86.6	59.8	294.7	354.5	0.28	0.42	0.69	441.9	53.6
2006	253.4	29.0	282.5	141.6	406.5	548.1	0.10	0.17	0.27	830.8	116.6
2007	158.0	18.9	176.9	73.6	227.6	301.1	0.23	0.32	0.56	478.6	155.8
2008	241.7	29.6	271.4	91.2	293.7	385.0	0.47	0.59	1.05	657.4	217.7

Notes: Total equals sum of males and females plus unsexed dogfish. Data for dogfish prior to 1980 are currently not available by sex.

Estimated derived from the FSV Bigelow using a weight specific calibration to convert to Albatross equivalents.

Year	Lengths >= 80 cm			Lengths 36 to 79 cm			Length <= 35 cm			All Lengths	3-pt Average Female SSB
	Females	Males	Total	Females	Males	Total	Females	Males	Total		
2009	148.3	21.9	170.2	54.9	326.1	381.0	2.95	3.76	6.71	557.9	182.7
2010	160.6	18.3	178.8	64.0	287.3	351.3	1.15	1.44	2.59	532.7	183.5
2011	213.9	26.7	240.6	60.0	408.6	468.6	0.99	2.48	3.47	712.6	174.2

Table 7. Summary of swept area biomass estimates (mt) based on stochastic population Estimator, 1991-2011. Exploitable biomasses are based on year-specific selectivity functions based on 3 year moving averages. Female spawning stock biomass is base on sum of female spiny dogfish above 80 cm TL. The target spawning stock biomass is 30.343 kg/tow or 159,288 mt (using the 0.0119 nm^2 trawl footprint).

Terminal Year	Mid Year	Total Exploitable Biomass	Exploitable Female Biomass	Exploitable Male Biomass	Tot Biomass	Female Spawning Stock Biomass
1991	1990	570,113	339,405	230,208	582,274	234,229
1992	1991	532,641	278,419	253,722	664,850	269,624
1993	1992	379,501	169,227	209,773	553,731	220,002
1994	1993	322,345	93,716	228,128	544,415	186,132
1995	1994	261,387	55,102	205,785	460,932	133,264
1996	1995	329,048	77,600	250,948	519,920	120,664
1997	1996	316,075	81,413	234,162	520,782	114,091
1998	1997	319,828	69,005	250,323	489,233	91,458
1999	1998	185,468	77,142	107,825	406,287	51,821
2000	1999	167,483	66,023	100,960	358,185	52,562
2001	2000	286,458	96,233	189,725	343,602	61,552
2002	2001	291,695	107,026	184,169	337,686	64,844
2003	2002	278,283	63,794	213,989	371,200	58,376
2004	2003	241,697	39,745	201,452	347,176	53,625
2005	2004	237,536	17,432	219,604	338,170	47,719
2006	2005	327,077	54,587	271,991	453,881	106,180
2007	2006	233,662	90,651	142,511	524,205	141,351
2008	2007	423,273	123,742	299,031	586,413	194,616
2009	2008	361,040	89,151	271,390	505,116	163,256
2010	2009	377,034	87,984	288,549	521,494	164,066
2011	2010	410,490	88,702	321,288	557,059	169,415

Table 8. Summary of fishing mortality rates expressed as the full F on the exploitable biomass of female and male spiny dogfish. Year represents the year of the catch (landings plus dead discards).

Year	F1: Female Catch on exploitable female biomass	F2: Male Catch on exploitable male biomass
1990	0.088	0.044
1991	0.082	0.026
1992	0.177	0.040
1993	0.327	0.021
1994	0.465	0.018
1995	0.418	0.014
1996	0.355	0.031
1997	0.234	0.038
1998	0.306	0.025
1999	0.289	0.043
2000	0.152	0.007
2001	0.109	0.005
2002	0.165	0.003
2003	0.168	0.004
2004	0.474	0.008
2005	0.128	0.007
2006	0.088	0.012
2007	0.090	0.005
2008	0.110	0.004
2009	0.113	0.006
2010	0.093	0.005

Table 9. Projected percentiles of fishing mortality rate on females, total catch , landings , discards and female spawning stock biomass in 2011. Catches in 2011 are assumed to be equal to those observed in 2010.

	2011				
Percentile	***F***	***Catch (mt)***	***Landings (mt)***	***Discards (mt)***	***Female SSB (mt)***
1	0.1931	10,226	6,062	4,164	102,318
2	0.1858	10,247	6,075	4,171	106,458
3	0.1792	10,223	6,060	4,163	109,928
4	0.1740	10,215	6,054	4,161	112,940
5	0.1704	10,239	6,070	4,169	115,616
10	0.1557	10,232	6,065	4,166	126,020
15	0.1462	10,220	6,058	4,162	133,788
20	0.1396	10,238	6,070	4,169	140,231
25	0.1338	10,220	6,058	4,162	145,886
30	0.1294	10,238	6,070	4,168	151,036
35	0.1250	10,218	6,057	4,162	155,851
40	0.1213	10,219	6,057	4,162	160,445
45	0.1184	10,249	6,077	4,172	164,905
50	0.1147	10,212	6,052	4,160	169,301
55	0.1118	10,214	6,054	4,160	173,698
60	0.1089	10,209	6,050	4,159	178,158
65	0.1067	10,256	6,081	4,174	182,752
70	0.1037	10,245	6,074	4,171	187,566
75	0.1008	10,236	6,069	4,168	192,716
80	0.0979	10,237	6,069	4,168	198,372
85	0.0950	10,255	6,081	4,174	204,814
90	0.0913	10,243	6,073	4,170	212,583
95	0.0869	10,237	6,069	4,168	222,987
96	0.0854	10,197	6,042	4,155	225,663
97	0.0847	10,237	6,069	4,168	228,674
98	0.0832	10,219	6,057	4,162	232,145
99	0.0818	10,221	6,058	4,163	236,284

Table 10. Summary of stochastic projections of F, SSB, catch, landings and discards by sex, and comparisons with biomass reference points for spiny dogfish under a constant F harvest strategy equal to the target F=Fmsy proxy = 0.2439 for 2012 to 2039. The estimated F in 2011 is estimated by assuming that the catch in 2011 is equal to the observed catch in 2010. Table entries are means of predicted values.

	Average											Probability			
Year	F on females	F on males	SSB (mt)	Total Catch (mt)	Total Landing (mt)	Female Landings (mt)	Male Landings (mt)	Total Discards (mt)	Female Discards (mt)	Male Discards (mt)	SSB(t)/ SSB_target	SSB<SSB_target	SSB< SSB_thresh	F>=Fthresh	F>=Ftarget
2011	0.119634	0.00413	169,446	10,231	6,065	5,595	471	4,166	2,836	1,330	1.001	0.386	0.000	0.000	0.022
2012	0.2439	0.01258	190,433	25,146	14,526	13,122	1,404	10,620	6,652	3,968	1.125	0.224	0.000	1.000	1.000
2013	0.2439	0.01258	180,807	25,363	14,729	13,364	1,365	10,634	6,775	3,859	1.068	0.292	0.000	1.000	1.000
2014	0.2439	0.01258	164,406	24,928	14,501	13,175	1,326	10,427	6,679	3,748	0.971	0.444	0.000	1.000	1.000
2015	0.2439	0.01258	145,648	24,067	13,984	12,694	1,290	10,082	6,435	3,647	0.861	0.668	0.000	1.000	1.000
2016	0.2439	0.01258	130,683	23,076	13,373	12,113	1,260	9,703	6,140	3,563	0.772	0.850	0.018	1.000	1.000
2017	0.2439	0.01258	119,607	22,042	12,730	11,497	1,232	9,312	5,828	3,484	0.707	0.950	0.046	1.000	1.000
2018	0.2439	0.01258	110,265	21,152	12,183	10,979	1,204	8,970	5,565	3,404	0.652	1.000	0.088	1.000	1.000
2019	0.2439	0.01258	106,743	20,541	11,830	10,661	1,169	8,710	5,404	3,306	0.631	1.000	0.108	1.000	1.000
2020	0.2439	0.01258	104,857	20,264	11,708	10,578	1,130	8,556	5,362	3,194	0.620	1.000	0.122	1.000	1.000
2021	0.2439	0.01258	111,867	20,322	11,809	10,720	1,089	8,513	5,434	3,078	0.661	0.996	0.076	1.000	1.000
2022	0.2439	0.01258	123,080	20,612	12,064	11,015	1,048	8,548	5,584	2,964	0.727	0.928	0.032	1.000	1.000
2023	0.2439	0.01258	133,651	21,005	12,385	11,375	1,009	8,620	5,767	2,854	0.790	0.820	0.010	1.000	1.000
2024	0.2439	0.01258	141,369	21,369	12,683	11,711	973	8,686	5,937	2,750	0.835	0.726	0.000	1.000	1.000
2025	0.2439	0.01258	145,347	21,602	12,890	11,951	939	8,712	6,059	2,654	0.859	0.674	0.000	1.000	1.000
2026	0.2439	0.01258	145,926	21,665	12,978	12,070	909	8,687	6,118	2,569	0.862	0.666	0.000	1.000	1.000
2027	0.2439	0.01258	143,700	21,558	12,947	12,064	883	8,611	6,116	2,496	0.849	0.694	0.000	1.000	1.000
2028	0.2439	0.01258	139,643	21,333	12,831	11,969	861	8,503	6,068	2,435	0.825	0.746	0.002	1.000	1.000
2029	0.2439	0.01258	134,781	21,025	12,653	11,810	843	8,371	5,987	2,385	0.796	0.804	0.010	1.000	1.000
2030	0.2439	0.01258	129,863	20,690	12,455	11,626	829	8,236	5,894	2,342	0.767	0.860	0.018	1.000	1.000
2031	0.2439	0.01258	126,020	20,391	12,276	11,460	816	8,116	5,809	2,306	0.745	0.900	0.026	1.000	1.000
2032	0.2439	0.01258	123,918	20,170	12,147	11,343	804	8,024	5,750	2,274	0.732	0.918	0.032	1.000	1.000
2033	0.2439	0.01258	123,814	20,050	12,084	11,290	793	7,966	5,723	2,243	0.732	0.920	0.032	1.000	1.000
2034	0.2439	0.01258	125,289	20,026	12,085	11,302	783	7,942	5,729	2,212	0.740	0.908	0.028	1.000	1.000
2035	0.2439	0.01258	127,776	20,081	12,137	11,365	772	7,944	5,761	2,182	0.755	0.884	0.022	1.000	1.000
2036	0.2439	0.01258	130,548	20,180	12,219	11,457	762	7,961	5,808	2,153	0.771	0.854	0.016	1.000	1.000
2037	0.2439	0.01258	133,045	20,290	12,307	11,556	752	7,983	5,858	2,125	0.786	0.826	0.012	1.000	1.000
2038	0.2439	0.01258	134,821	20,380	12,382	11,639	742	7,999	5,900	2,098	0.797	0.806	0.010	1.000	1.000
2039	0.2439	0.01258	135,659	20,431	12,428	11,694	734	8,003	5,928	2,075	0.802	0.796	0.008	1.000	1.000
2040	0.2439	0.01258	135,517	20,433	12,440	11,713	727	7,993	5,938	2,055	0.801	0.798	0.008	1.000	1.000
Grand Total	0.239758	0.012298	135,617	21,014	12,461	11,497	964	8,553	5,828	2,725	0.801	0.778	0.024	0.967	0.967
Ave '11-20	0.231	0.012	142,289	21,681	12,563	11,378	1,185	9,118	5,768	3,350	0.841	0.681	0.038	0.900	0.902
Ave '21-30	0.244	0.013	134,923	21,118	12,569	11,631	938	8,549	5,896	2,653	0.797	0.791	0.015	1.000	1.000
Ave '31-40	0.244	0.013	129,640	20,243	12,250	11,482	768	7,993	5,821	2,172	0.766	0.861	0.019	1.000	1.000

Table 11. Projected percentiles of total catch , landings , discards and female spawning stock biomass in 2012-2104 with an fishing mortality rate equal to the Fmsy proxy of 0.2439. The initial condition for these projections assumes that catches in 2011 are to those observed in 2010 (see Table 9).

	2012				2013				2014			
Percentile	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***
1	16,902	9,055	7,847	111,067	16,982	9,167	7,814	105,591	16,669	9,025	7,644	96,118
2	17,408	9,391	8,017	115,936	17,496	9,509	7,987	110,207	17,176	9,361	7,815	100,310
3	17,837	9,676	8,162	120,066	17,932	9,798	8,134	114,121	17,606	9,646	7,959	103,862
4	18,208	9,922	8,286	123,637	18,309	10,048	8,261	117,504	17,977	9,892	8,085	106,934
5	18,534	10,138	8,396	126,772	18,640	10,268	8,372	120,476	18,304	10,109	8,195	109,633
10	19,812	10,986	8,826	139,081	19,940	11,131	8,810	132,142	19,585	10,958	8,626	120,224
15	20,768	11,620	9,147	148,280	20,912	11,775	9,137	140,859	20,542	11,593	8,949	128,138
20	21,557	12,144	9,413	155,876	21,714	12,307	9,406	148,059	21,332	12,117	9,215	134,675
25	22,254	12,607	9,647	162,586	22,422	12,778	9,645	154,416	22,030	12,580	9,451	140,447
30	22,884	13,025	9,859	168,654	23,063	13,203	9,860	160,168	22,662	12,999	9,664	145,669
35	23,478	13,419	10,059	174,370	23,667	13,603	10,063	165,584	23,257	13,393	9,864	150,586
40	24,042	13,793	10,249	179,802	24,240	13,984	10,256	170,733	23,822	13,768	10,055	155,260
45	24,586	14,154	10,432	185,041	24,794	14,351	10,443	175,699	24,368	14,129	10,238	159,769
50	25,131	14,516	10,615	190,284	25,347	14,719	10,629	180,665	24,913	14,491	10,422	164,277
55	25,671	14,874	10,797	195,479	25,896	15,083	10,813	185,589	25,454	14,849	10,604	168,747
60	26,219	15,238	10,981	200,760	26,454	15,453	11,001	190,593	26,003	15,214	10,789	173,290
65	26,778	15,609	11,169	206,138	27,022	15,830	11,192	195,692	26,563	15,585	10,978	177,921
70	27,370	16,002	11,368	211,844	27,624	16,230	11,395	201,099	27,157	15,979	11,178	182,829
75	28,004	16,422	11,582	217,944	28,268	16,657	11,611	206,880	27,792	16,399	11,392	188,077
80	28,699	16,883	11,815	224,633	28,975	17,126	11,849	213,218	28,488	16,861	11,627	193,832
85	29,488	17,407	12,081	232,230	29,777	17,658	12,119	220,419	29,278	17,385	11,893	200,369
90	30,444	18,041	12,402	241,431	30,749	18,303	12,446	229,138	30,236	18,020	12,216	208,285
95	31,723	18,890	12,833	253,742	32,049	19,166	12,883	240,804	31,517	18,869	12,648	218,876
96	32,056	19,112	12,945	256,955	32,388	19,391	12,997	243,847	31,851	19,091	12,760	221,637
97	32,421	19,354	13,068	260,469	32,759	19,637	13,122	247,178	32,217	19,333	12,884	224,663
98	32,850	19,638	13,212	264,594	33,195	19,926	13,269	251,087	32,646	19,618	13,028	228,211
99	33,358	19,975	13,383	269,488	33,712	20,269	13,443	255,725	33,155	19,956	13,200	232,422

Table 12 Summary of stochastic projections of F, SSB, catch, landings and discards by sex, and comparisons with biomass reference points for spiny dogfish under a constant F harvest strategy equal to 0.1829 which is 75% of Fmsy proxy (0.2439) for 2012 to 2039. Table entries are means of predicted values.

	Average											Probability			
Year	F on females	F on males	SSB (mt)	Total Catch (mt)	Total Landing (mt)	Female Landings (mt)	Male Landings (mt)	Total Discards (mt)	Female Discards (mt)	Male Discards (mt)	SSB(t)/ SSB_target	SSB<SSB_target	SSB< SSB_thresh	F>=Fthresh	F>=Ftarget
2011	0.119634	0.00413	169,446	10,231	6,065	5,595	471	4,166	2,836	1,330	1.001	0.386	0.000	0.000	0.022
2012	0.18293	0.00943	190,433	19,063	11,027	9,973	1,054	8,036	5,055	2,981	1.125	0.224	0.000	0.000	1.000
2013	0.18293	0.00943	186,240	19,722	11,504	10,475	1,029	8,218	5,310	2,908	1.100	0.250	0.000	0.000	1.000
2014	0.18293	0.00943	174,729	19,901	11,664	10,661	1,002	8,238	5,405	2,833	1.032	0.342	0.000	0.000	1.000
2015	0.18293	0.00943	159,963	19,725	11,583	10,605	978	8,141	5,376	2,765	0.945	0.492	0.000	0.000	1.000
2016	0.18293	0.00943	148,179	19,390	11,392	10,434	958	7,998	5,289	2,709	0.876	0.636	0.000	0.000	1.000
2017	0.18293	0.00943	139,468	18,934	11,117	10,176	941	7,818	5,159	2,659	0.824	0.748	0.004	0.000	1.000
2018	0.18293	0.00943	131,691	18,499	10,855	9,931	923	7,645	5,035	2,610	0.778	0.840	0.014	0.000	1.000
2019	0.18293	0.00943	129,328	18,212	10,698	9,796	901	7,514	4,966	2,548	0.764	0.868	0.018	0.000	1.000
2020	0.18293	0.00943	128,252	18,150	10,695	9,819	876	7,455	4,978	2,478	0.758	0.880	0.020	0.000	1.000
2021	0.18293	0.00943	136,333	18,348	10,866	10,015	851	7,482	5,077	2,405	0.806	0.790	0.006	0.000	1.000
2022	0.18293	0.00943	148,879	18,753	11,173	10,348	826	7,580	5,246	2,334	0.880	0.630	0.000	0.000	1.000
2023	0.18293	0.00943	161,766	19,283	11,562	10,760	802	7,721	5,455	2,267	0.956	0.472	0.000	0.000	1.000
2024	0.18293	0.00943	172,568	19,840	11,965	11,185	780	7,874	5,670	2,204	1.020	0.360	0.000	0.000	1.000
2025	0.18293	0.00943	180,087	20,336	12,325	11,565	760	8,011	5,863	2,148	1.064	0.294	0.000	0.000	1.000
2026	0.18293	0.00943	184,355	20,727	12,610	11,868	743	8,116	6,016	2,100	1.089	0.262	0.000	0.000	1.000
2027	0.18293	0.00943	185,666	20,994	12,809	12,080	729	8,185	6,124	2,062	1.097	0.252	0.000	0.000	1.000
2028	0.18293	0.00943	184,855	21,172	12,943	12,224	719	8,229	6,197	2,033	1.092	0.258	0.000	0.000	1.000
2029	0.18293	0.00943	182,872	21,272	13,020	12,308	712	8,252	6,239	2,013	1.081	0.272	0.000	0.000	1.000
2030	0.18293	0.00943	180,466	21,335	13,068	12,361	708	8,266	6,266	2,000	1.066	0.292	0.000	0.000	1.000
2031	0.18293	0.00943	178,830	21,405	13,118	12,413	705	8,286	6,293	1,994	1.057	0.304	0.000	0.000	1.000
2032	0.18293	0.00943	178,751	21,521	13,197	12,493	704	8,324	6,333	1,991	1.056	0.304	0.000	0.000	1.000
2033	0.18293	0.00943	180,694	21,708	13,321	12,618	704	8,386	6,396	1,990	1.068	0.288	0.000	0.000	1.000
2034	0.18293	0.00943	184,423	21,974	13,498	12,794	704	8,476	6,486	1,991	1.090	0.260	0.000	0.000	1.000
2035	0.18293	0.00943	189,525	22,315	13,723	13,018	705	8,591	6,599	1,992	1.120	0.226	0.000	0.000	1.000
2036	0.18293	0.00943	195,286	22,710	13,984	13,279	705	8,726	6,731	1,994	1.154	0.190	0.000	0.000	1.000
2037	0.18293	0.00943	201,119	23,136	14,265	13,559	707	8,871	6,873	1,998	1.188	0.160	0.000	0.000	1.000
2038	0.18293	0.00943	206,454	23,567	14,548	13,840	708	9,019	7,016	2,003	1.220	0.136	0.000	0.000	1.000
2039	0.18293	0.00943	210,955	23,982	14,820	14,109	711	9,163	7,152	2,010	1.246	0.120	0.000	0.000	1.000
2040	0.18293	0.00943	214,450	24,370	15,071	14,356	715	9,298	7,278	2,021	1.267	0.106	0.000	0.000	1.000
Grand Total	0.18082	0.009253	173,869	20,352	12,283	11,489	794	8,070	5,824	2,246	1.027	0.388	0.002	0.000	0.967
Ave '11-20	0.177	0.009	155,773	18,183	10,660	9,747	913	7,523	4,941	2,582	0.920	0.567	0.006	0.000	0.902
Ave '21-30	0.183	0.009	171,785	20,206	12,234	11,471	763	7,972	5,815	2,157	1.015	0.388	0.001	0.000	1.000
Ave '31-40	0.183	0.009	194,049	22,669	13,955	13,248	707	8,714	6,716	1,998	1.147	0.209	0.000	0.000	1.000
Formula	*A*	*B*	*C*	*D=E+H*	*E=F+G*	*F*	*G*	*H=I+J*	*I*	*J*	*K*	*L*	*M*	*N*	*O*

Table13. Projected percentiles of total catch , landings , discards and female spawning stock biomass in 2012-2104 with an fishing mortality rate equal to the 0.1829 which is 75% of Fmsy proxy of 0.2439. The initial condition for these projections assume that catches in 2011 are to those observed in 2010.

	2012				2013				2014			
Percentile	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***
1	12,798	6,869	5,928	111,067	13,151	7,144	6,008	108,759	13,217	7,231	5,985	102,143
2	13,182	7,124	6,058	115,936	13,555	7,411	6,144	113,514	13,627	7,503	6,124	106,598
3	13,508	7,341	6,167	120,066	13,896	7,638	6,259	117,545	13,975	7,734	6,241	110,374
4	13,790	7,528	6,262	123,637	14,192	7,834	6,358	121,031	14,275	7,933	6,342	113,639
5	14,037	7,692	6,346	126,772	14,452	8,006	6,445	124,093	14,540	8,109	6,431	116,508
10	15,009	8,337	6,672	139,081	15,471	8,683	6,788	136,109	15,576	8,796	6,780	127,765
15	15,735	8,819	6,917	148,280	16,232	9,188	7,044	145,089	16,351	9,310	7,042	136,178
20	16,335	9,217	7,118	155,876	16,861	9,605	7,256	152,506	16,991	9,734	7,257	143,127
25	16,865	9,568	7,297	162,586	17,416	9,974	7,443	159,055	17,556	10,109	7,448	149,261
30	17,344	9,886	7,458	168,654	17,919	10,307	7,612	164,979	18,067	10,448	7,620	154,812
35	17,795	10,186	7,610	174,370	18,392	10,621	7,771	170,559	18,549	10,767	7,782	160,039
40	18,224	10,470	7,754	179,802	18,842	10,920	7,922	175,862	19,006	11,070	7,936	165,007
45	18,637	10,745	7,893	185,041	19,276	11,207	8,068	180,978	19,448	11,363	8,085	169,800
50	19,051	11,019	8,032	190,284	19,709	11,495	8,214	186,094	19,889	11,655	8,234	174,592
55	19,461	11,291	8,170	195,479	20,140	11,781	8,359	191,166	20,326	11,945	8,381	179,343
60	19,878	11,568	8,310	200,760	20,577	12,071	8,506	196,321	20,771	12,240	8,531	184,172
65	20,303	11,850	8,453	206,138	21,022	12,366	8,656	201,573	21,224	12,541	8,684	189,094
70	20,753	12,149	8,605	211,844	21,494	12,680	8,815	207,143	21,705	12,859	8,846	194,312
75	21,235	12,468	8,767	217,944	21,999	13,015	8,984	213,098	22,219	13,200	9,019	199,890
80	21,763	12,819	8,944	224,633	22,553	13,382	9,171	219,627	22,782	13,574	9,209	206,007
85	22,363	13,217	9,146	232,230	23,182	13,800	9,382	227,045	23,422	13,998	9,424	212,956
90	23,089	13,699	9,391	241,431	23,944	14,305	9,639	236,026	24,197	14,512	9,685	221,370
95	24,061	14,344	9,717	253,742	24,963	14,982	9,981	248,044	25,234	15,199	10,035	232,628
96	24,315	14,512	9,803	256,955	25,229	15,158	10,071	251,178	25,504	15,378	10,126	235,563
97	24,592	14,696	9,896	260,469	25,520	15,351	10,169	254,610	25,800	15,575	10,226	238,779
98	24,918	14,912	10,006	264,594	25,861	15,578	10,284	258,637	26,148	15,805	10,343	242,551
99	25,304	15,169	10,136	269,488	26,266	15,847	10,420	263,414	26,560	16,078	10,481	247,026

Table 14 Summary of stochastic projections of F, SSB, catch, landings and discards by sex, and comparisons with biomass reference points for spiny dogfish under a constant F harvest strategy equal to 0.177 which is the is 35th percentile of the Fmsy proxy of 0.2439 assuming a CV of 100% and a lognormal distribution. Projections are for 2012 to 2039. Table entries are means of predicted values. The initial conditions for this projection assume that catches in 2011 are equal to those observed in 2010.

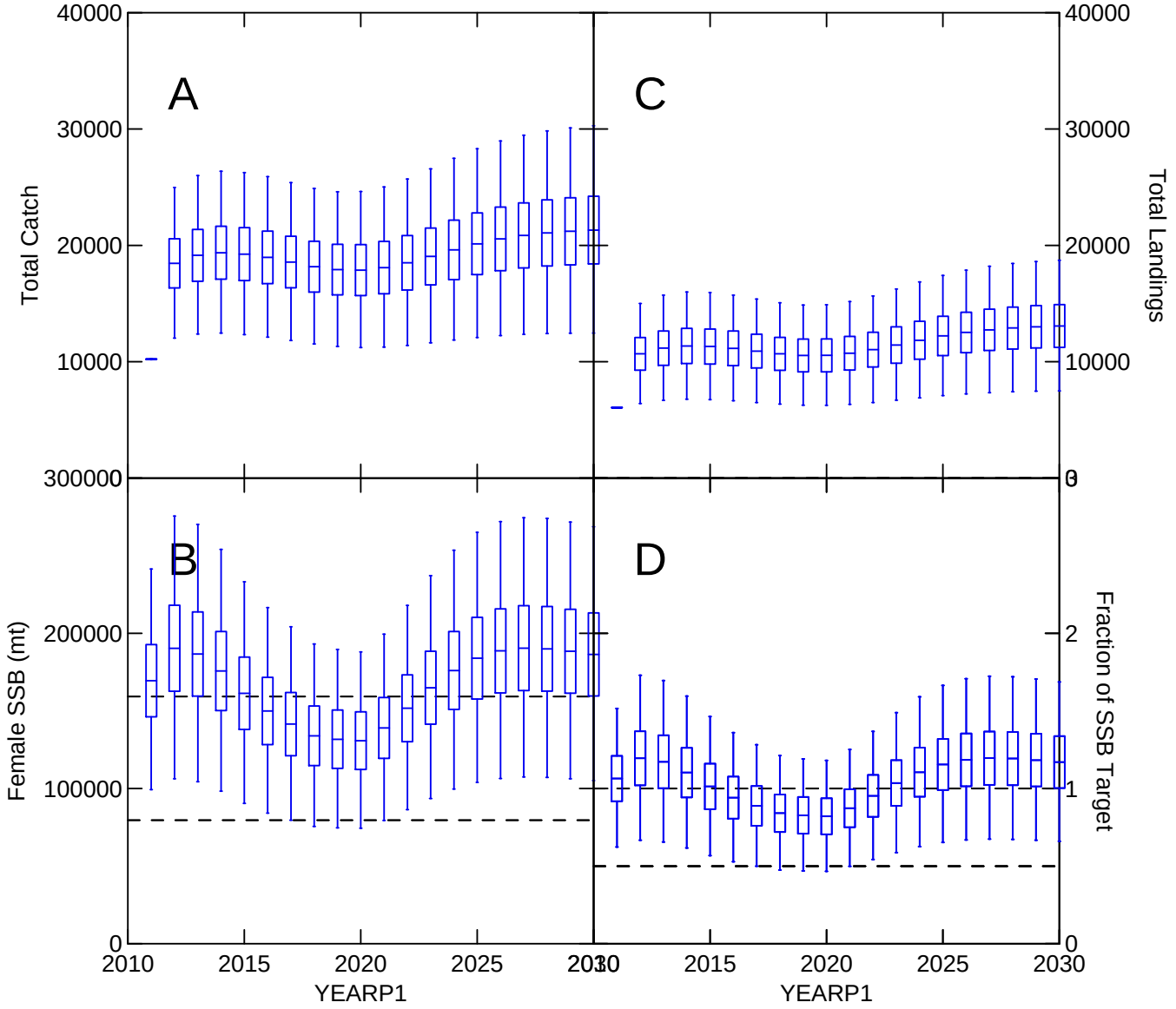
	Average											Probability			
Year	F on females	F on males	SSB (mt)	Total Catch (mt)	Total Landing (mt)	Female Landings (mt)	Male Landings (mt)	Total Discards (mt)	Female Discards (mt)	Male Discards (mt)	SSB(t)/ SSB_target	SSB<SSB_target	SSB< SSB_thresh	F>=Fthresh	F>=Ftarget
2011	0.11947	0.00413	169,588	10,232	6,065	5,595	471	4,166	2,836	1,330	1.002	0.503	1.000	0.000	0.020
2012	0.177	0.00913	190,433	18,465	10,682	9,662	1,020	7,783	4,898	2,885	1.125	0.696	1.000	0.000	0.000
2013	0.177	0.00913	186,777	19,151	11,175	10,179	996	7,976	5,160	2,815	1.104	0.668	1.000	0.000	0.000
2014	0.177	0.00913	175,767	19,375	11,363	10,393	971	8,012	5,268	2,744	1.039	0.568	1.000	0.000	0.000
2015	0.177	0.00913	161,430	19,254	11,318	10,371	947	7,936	5,257	2,678	0.954	0.410	1.000	0.000	0.000
2016	0.177	0.00913	150,006	18,975	11,162	10,234	929	7,813	5,188	2,625	0.886	0.274	0.998	0.000	0.000
2017	0.177	0.00913	141,582	18,571	10,920	10,008	912	7,651	5,073	2,578	0.837	0.178	0.988	0.000	0.000
2018	0.177	0.00913	134,012	18,179	10,685	9,790	895	7,494	4,963	2,531	0.792	0.102	0.974	0.000	0.000
2019	0.177	0.00913	131,814	17,924	10,548	9,674	875	7,376	4,904	2,472	0.779	0.082	0.968	0.000	0.000
2020	0.177	0.00913	130,866	17,885	10,558	9,708	851	7,326	4,921	2,405	0.773	0.074	0.968	0.000	0.000
2021	0.177	0.00913	139,094	18,097	10,737	9,910	827	7,360	5,024	2,337	0.822	0.146	0.986	0.000	0.000
2022	0.177	0.00913	151,810	18,512	11,048	10,246	803	7,463	5,194	2,270	0.897	0.292	1.000	0.000	0.000
2023	0.177	0.00913	164,967	19,054	11,443	10,662	780	7,611	5,405	2,206	0.975	0.450	1.000	0.000	0.000
2024	0.177	0.00913	176,123	19,625	11,854	11,094	759	7,771	5,624	2,147	1.041	0.572	1.000	0.000	0.000
2025	0.177	0.00913	184,051	20,143	12,226	11,485	741	7,917	5,822	2,095	1.087	0.646	1.000	0.000	0.000
2026	0.177	0.00913	188,756	20,562	12,528	11,803	725	8,033	5,984	2,050	1.115	0.686	1.000	0.000	0.000
2027	0.177	0.00913	190,501	20,863	12,747	12,035	713	8,115	6,101	2,014	1.126	0.698	1.000	0.000	0.000
2028	0.177	0.00913	190,106	21,078	12,904	12,201	703	8,174	6,185	1,989	1.123	0.696	1.000	0.000	0.000
2029	0.177	0.00913	188,513	21,217	13,006	12,309	697	8,211	6,240	1,971	1.114	0.684	1.000	0.000	0.000
2030	0.177	0.00913	186,466	21,320	13,080	12,386	694	8,240	6,279	1,961	1.102	0.666	1.000	0.000	0.000
2031	0.177	0.00913	185,164	21,428	13,154	12,462	692	8,274	6,317	1,957	1.094	0.656	1.000	0.000	0.000
2032	0.177	0.00913	185,401	21,581	13,255	12,563	692	8,325	6,369	1,957	1.095	0.658	1.000	0.000	0.000
2033	0.177	0.00913	187,663	21,802	13,401	12,708	693	8,401	6,442	1,959	1.109	0.678	1.000	0.000	0.000
2034	0.177	0.00913	191,732	22,101	13,597	12,903	694	8,503	6,541	1,962	1.133	0.710	1.000	0.000	0.000
2035	0.177	0.00913	197,214	22,473	13,842	13,147	696	8,631	6,664	1,967	1.165	0.748	1.000	0.000	0.000
2036	0.177	0.00913	203,398	22,901	14,124	13,426	698	8,778	6,806	1,972	1.202	0.786	1.000	0.000	0.000
2037	0.177	0.00913	209,698	23,363	14,426	13,727	700	8,937	6,958	1,978	1.239	0.820	1.000	0.000	0.000
2038	0.177	0.00913	215,534	23,832	14,733	14,030	703	9,099	7,112	1,986	1.274	0.848	1.000	0.000	0.000
2039	0.177	0.00913	220,558	24,287	15,029	14,323	706	9,258	7,261	1,997	1.303	0.868	1.000	0.000	0.000
2040	0.177	0.00913	224,584	24,718	15,308	14,597	711	9,410	7,400	2,010	1.327	0.882	1.000	0.000	0.000
Grand Total	0.175086	0.008964	178,454	20,233	12,231	11,455	776	8,002	5,807	2,195	1.054	0.558	0.996	0.000	0.001
Ave '11-20	0.171	0.009	157,227	17,801	10,448	9,561	887	7,353	4,847	2,506	0.929	0.356	0.990	0.000	0.002
Ave '21-30	0.177	0.009	176,039	20,047	12,157	11,413	744	7,890	5,786	2,104	1.040	0.554	0.999	0.000	0.000
Ave '31-40	0.177	0.009	202,095	22,849	14,087	13,388	698	8,762	6,787	1,975	1.194	0.765	1.000	0.000	0.000
Formula	*A*	*B*	*C*	*D=E+H*	*E=F+G*	*F*	*G*	*H=I+J*	*I*	*J*	*K*	*L*	*M*	*N*	*O*

Table 15. Projected percentiles of total catch, landings, discards and female spawning biomass in 2012-2014 with a fishing mortality rate equal to 0.177 which is 35th percentile of the Fmsy proxy of 0.2439. The initial condition for this projection assume that catches in 2011 are equal to those observed in 2010.

	2012				2013				2014			
Percentile	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***
1	12,395	6,654	5,741	111,067	12,766	6,938	5,828	109,072	12,859	7,043	5,816	102,749
2	12,767	6,901	5,866	115,936	13,158	7,198	5,959	113,841	13,259	7,308	5,951	107,230
3	13,083	7,111	5,972	120,066	13,490	7,419	6,071	117,884	13,598	7,533	6,065	111,029
4	13,356	7,292	6,064	123,637	13,777	7,609	6,168	121,379	13,891	7,727	6,164	114,313
5	13,596	7,451	6,145	126,772	14,029	7,777	6,253	124,450	14,149	7,898	6,251	117,200
10	14,538	8,076	6,462	139,081	15,020	8,434	6,586	136,501	15,159	8,568	6,591	128,524
15	15,241	8,543	6,698	148,280	15,760	8,925	6,835	145,507	15,915	9,069	6,846	136,987
20	15,822	8,929	6,894	155,876	16,371	9,330	7,040	152,945	16,538	9,482	7,056	143,977
25	16,335	9,269	7,066	162,586	16,910	9,689	7,222	159,513	17,089	9,847	7,242	150,148
30	16,799	9,577	7,222	168,654	17,399	10,013	7,386	165,455	17,587	10,178	7,410	155,732
35	17,237	9,867	7,369	174,370	17,859	10,318	7,541	171,050	18,057	10,489	7,568	160,989
40	17,652	10,143	7,509	179,802	18,296	10,608	7,688	176,369	18,503	10,785	7,718	165,987
45	18,053	10,409	7,644	185,041	18,717	10,887	7,830	181,499	18,933	11,070	7,863	170,809
50	18,454	10,675	7,779	190,284	19,139	11,167	7,972	186,630	19,363	11,355	8,008	175,629
55	18,851	10,939	7,913	195,479	19,557	11,445	8,112	191,717	19,790	11,638	8,152	180,409
60	19,255	11,207	8,048	200,760	19,982	11,726	8,255	196,887	20,223	11,926	8,298	185,267
65	19,666	11,480	8,187	206,138	20,414	12,014	8,401	202,154	20,665	12,218	8,447	190,218
70	20,103	11,769	8,334	211,844	20,873	12,318	8,555	207,740	21,134	12,529	8,605	195,467
75	20,569	12,079	8,491	217,944	21,364	12,644	8,720	213,712	21,634	12,861	8,773	201,078
80	21,081	12,418	8,663	224,633	21,902	13,001	8,901	220,260	22,184	13,225	8,958	207,231
85	21,662	12,804	8,858	232,230	22,513	13,407	9,107	227,699	22,807	13,639	9,169	214,222
90	22,366	13,271	9,095	241,431	23,254	13,898	9,356	236,707	23,563	14,140	9,423	222,686
95	23,308	13,896	9,412	253,742	24,244	14,555	9,689	248,759	24,574	14,810	9,764	234,011
96	23,553	14,059	9,494	256,955	24,502	14,726	9,776	251,903	24,837	14,985	9,852	236,963
97	23,822	14,237	9,585	260,469	24,785	14,914	9,871	255,345	25,126	15,176	9,950	240,199
98	24,138	14,447	9,691	264,594	25,117	15,134	9,983	259,383	25,464	15,401	10,064	243,993
99	24,512	14,695	9,817	269,488	25,511	15,396	10,115	264,174	25,866	15,667	10,199	248,495

Figure 6. Projection model estimates of (A) Total catch (mt), (B) Female spawning stock biomass (mt), (C) Total Landings(mt), and (D) fraction of target SSB, 2011-2030 for a harvest scenario based on a constant fishing mortality rate equal to 0.177 which is the 35% -ile of the Fmsy Proxy target F (0.2439). Panel D represents the probabilities of overfishing and being overfished, respectively.

Scenario: F = 0.177=35%ile of Fmsy proxy



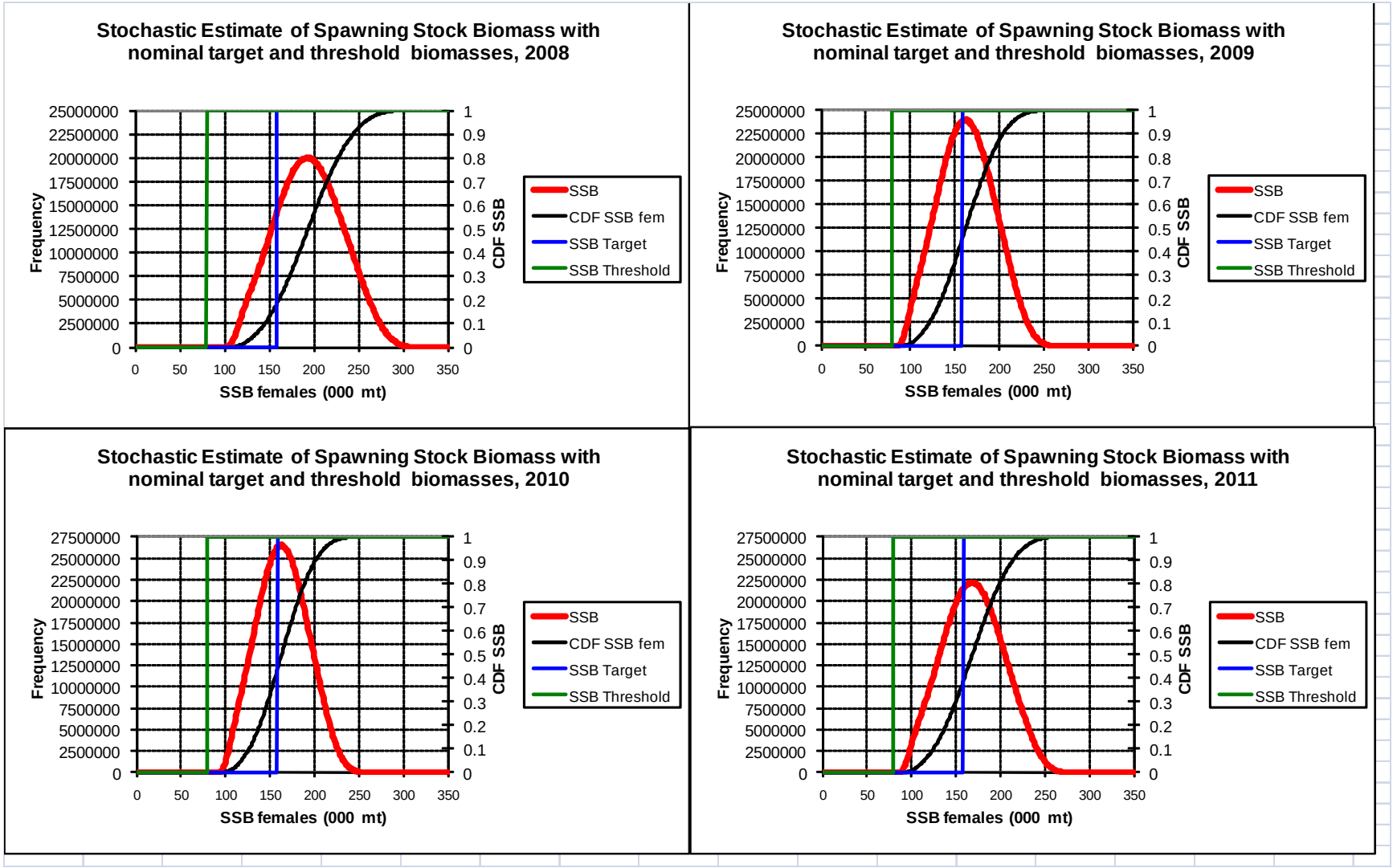


Figure 1. Stochastic estimates of female spiny dogfish spawning stock biomass , 2008 to 2011, and comparison with target and threshold biomass reference points. Year refers to terminal year of 3 point moving average of swept area estimate.

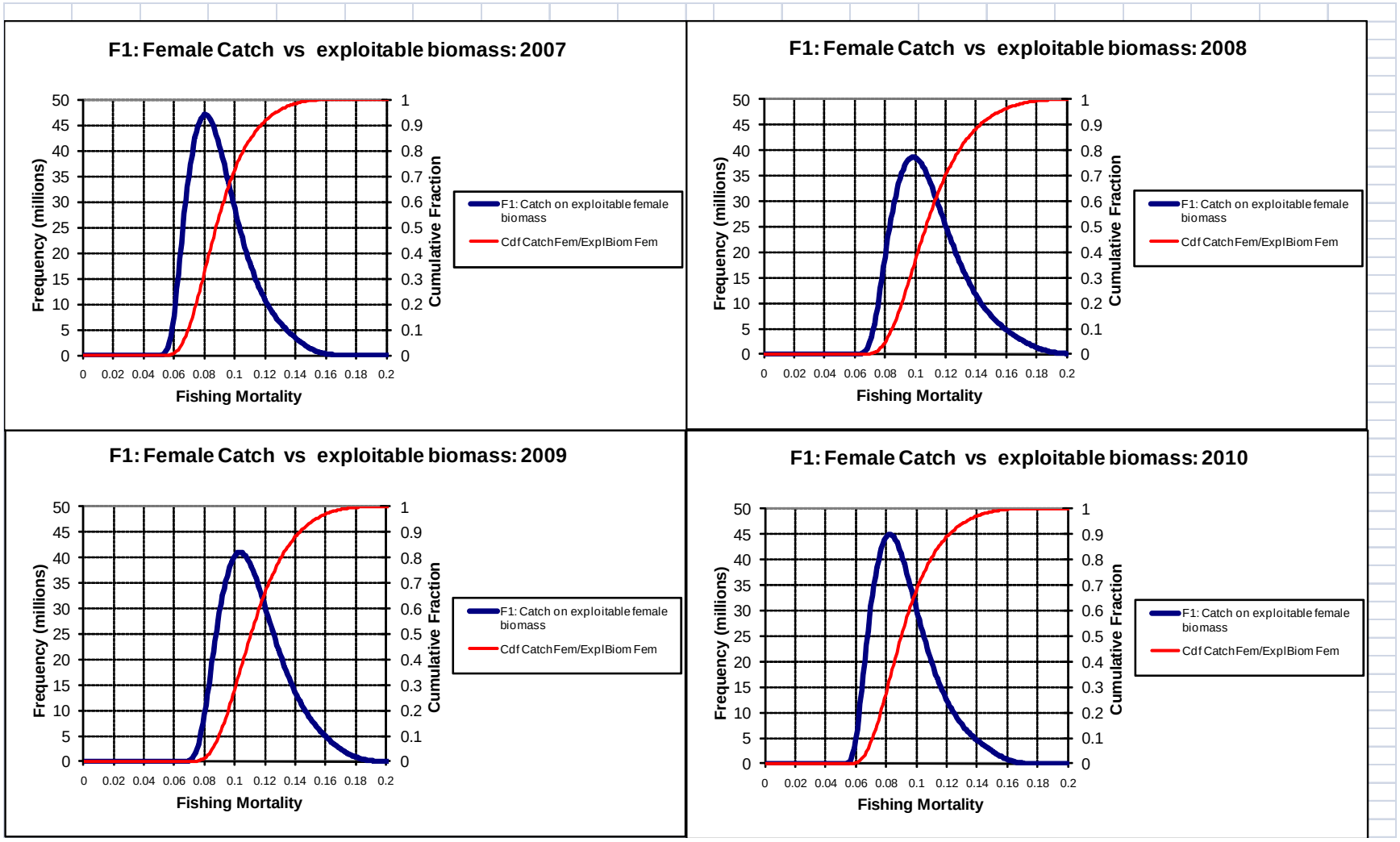


Figure 2. Stochastic estimates of fishing mortality rates on female spiny dogfish, 2007 to 2010. Year refers to the calendar year in which catches occurred. Fishing mortality rates are based on the ratio for total catch in year to the 3 point moving average from year t-1 to t+1.

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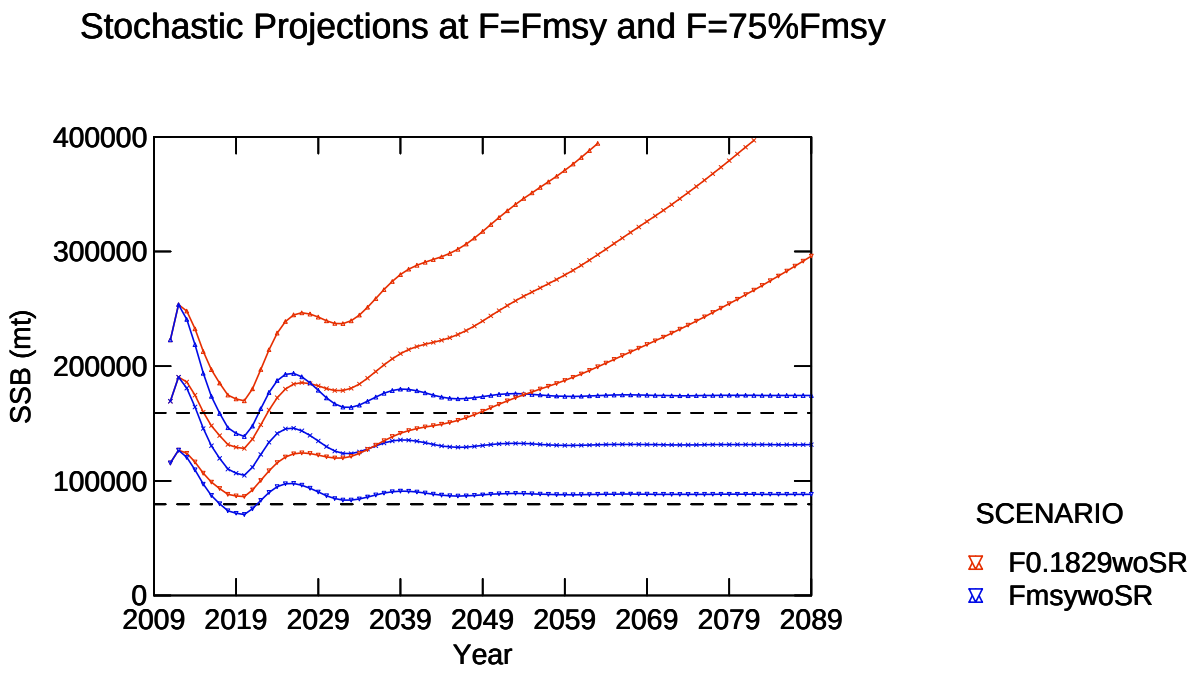


Figure 3. Stochastic projections of SSB at current fishing mortality MSY proxy (F=0.2439) and at 75% of this value et (F=0.1829). Fmsy proxies are based on results in Rago(2011). Horizontal dashed lines represent biomass target and threshold values of 159,288 mt and 79644 mt, respectively. Projections depict 5%, 50% and 95% iles for each scenario. The expected finite rate of population increase at F=0.2439 is 1.000 or 0% change per year. The finite rate of population increase at F=0.1829 is 1.01527 or about a 1.52% increase per year.

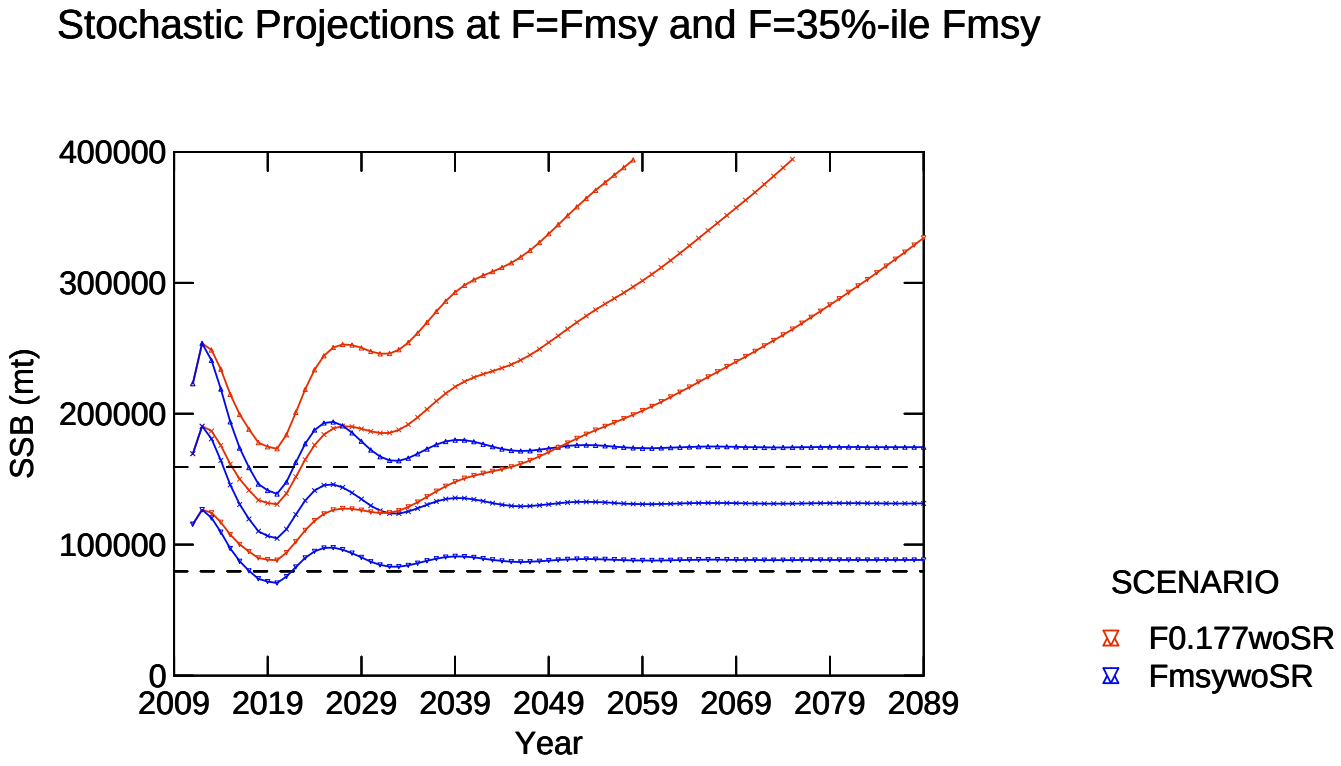


Figure 3A. Stochastic projections of SSB at current fishing mortality MSY proxy (F=0.2439) and at the 35th percentile this value (F=0.177, assuming a lognormal distribution and 100% CV). Fmsy proxies are based on results in Rago (2011). Horizontal dashed lines represent biomass target and threshold values of 159,288 mt and 79644 mt, respectively. Projections depict 5%, 50% and 95% iles for each scenario. The expected finite rate of population increase at F=0.2439 is 1.000 or 0% change per year. The finite rate of population increase at F=0.177 is 1.0168 or about a 1.68% increase per year.

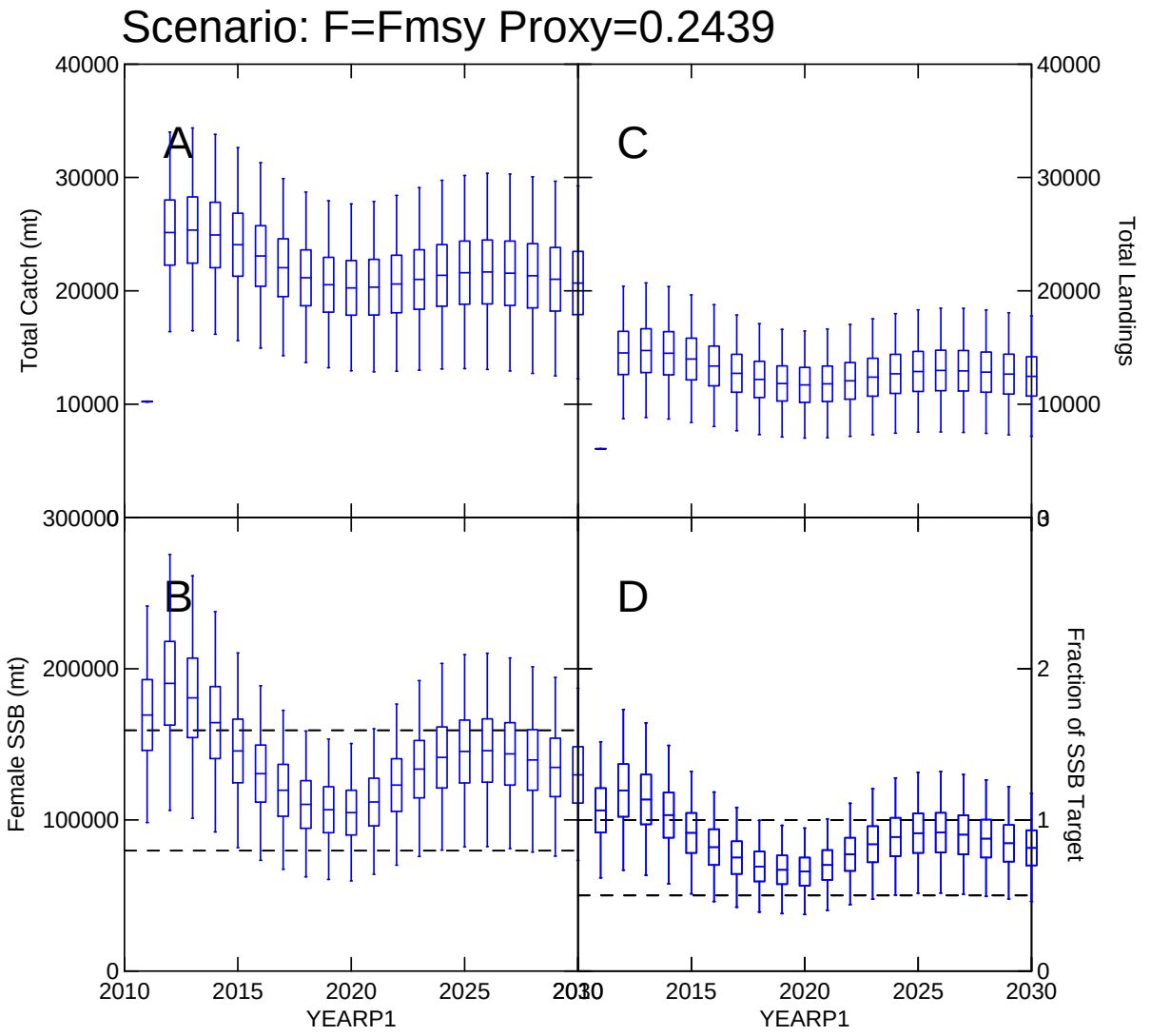


Figure 4. Projection model estimates of (A) Total catch (mt), (B) Female spawning stock biomass (mt), (C) Total Landings(mt), and (D) fraction of target SSB, 2011-2030 for a harvest scenario based on a constant fishing mortality rate equal to the target F = 0.2439. Panel D represents the probabilities of overfishing and being overfished, respectively

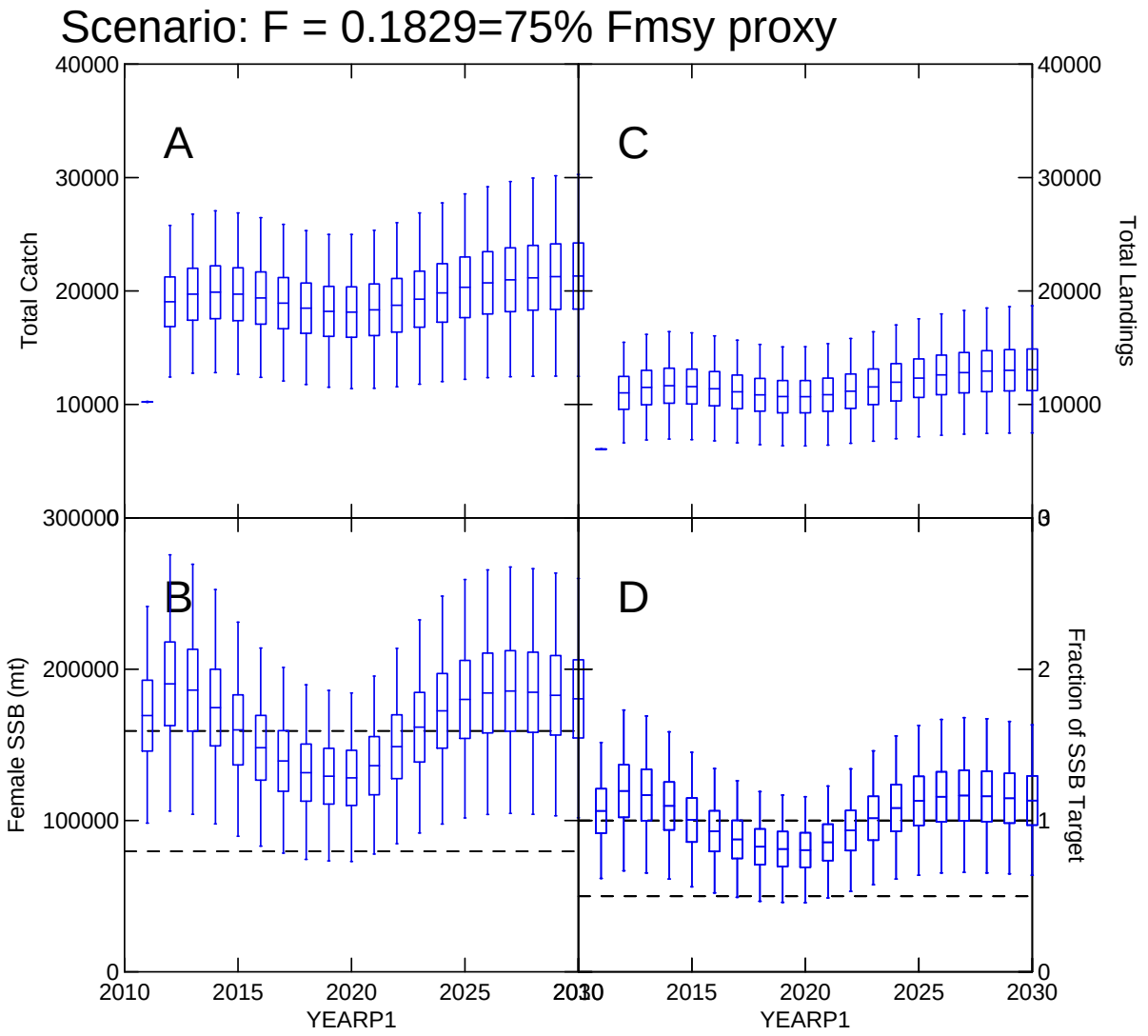


Figure 5. Projection model estimates of (A) Total catch (mt), (B) Female spawning stock biomass (mt), (C) Total Landings(mt), and (D) fraction of target SSB, 2011-2030 for a harvest scenario based on a constant fishing mortality rate equal to 0.1829 which is 75% of the Fmsy Proxy target F (0.2439). Panel D represents the probabilities of overfishing and being overfished, respectively.

Appendix 1. Approximate upper bound on efficiency of R/V Albatross for capturing spiny dogfish derived from comparison of capture rates with the FSV Bigelow.

An inter-vessel calibration experiment attempts to relate the average catchability of vessel A to vessel B by comparing paired tow catch rates over a variety of habitats, bottom types and species densities. If we conveniently let subscript A refer to the Albatross and B refer to the Bigelow, then the expected index catch rate I can be expressed as

$$I_A = e_A a_A D$$
$$I_B = e_B a_B D$$

Where ***e*** represents efficiency, ***a*** is the average area swept and D is the true density. The ratio of the index catches can be used to compute a calibration coefficient□□ expressed as the ratio of I_B to I_A.

$$\frac{I_B}{I_A} = \gamma = \frac{e_B a_B D}{e_A a_A D} = \frac{e_B a_B}{e_A a_A}$$

The estimate area swept per tow can be expressed as a function of the distance between the wings of the new or as a function of the distance between the doors. The latter distance is important for schooling species like dogfish that herd between the sand clouds created by the trawl doors. The nominal areas swept by the Bigelow and Albatross nets are provided below.

Parameter	***Albatross***	***Bigelow***
Tow speeds(knots)	3.8	3
Tow duration (min)	33	20
Door width (ft)	68.6	104.9867
Wing width(ft)	35.93	39.37
Door Swept area ft ^2	871140.4	637899
Wing Swept area ft^2	456269.3	239212.1

Plugging the swept areas into the equation for □ gives:

$$\gamma = 1.1468 = \frac{e_B a_B}{e_A a_A} = \frac{e_B\ 637{,}899}{e_A\ 871{,}140}$$

$$\frac{e_A}{e_B} = 0.6385$$

If the Bigelow net were 100% efficient for spiny dogfish between the doors then the maximum possible Albatross efficiency would be 64%.

Appendix 2. Goodness-of-Fit tests for projected total yield (Overfishing Limit) in 2012.

Variable Name: YTOT = Total Catch (mt)

Distribution: **Normal**

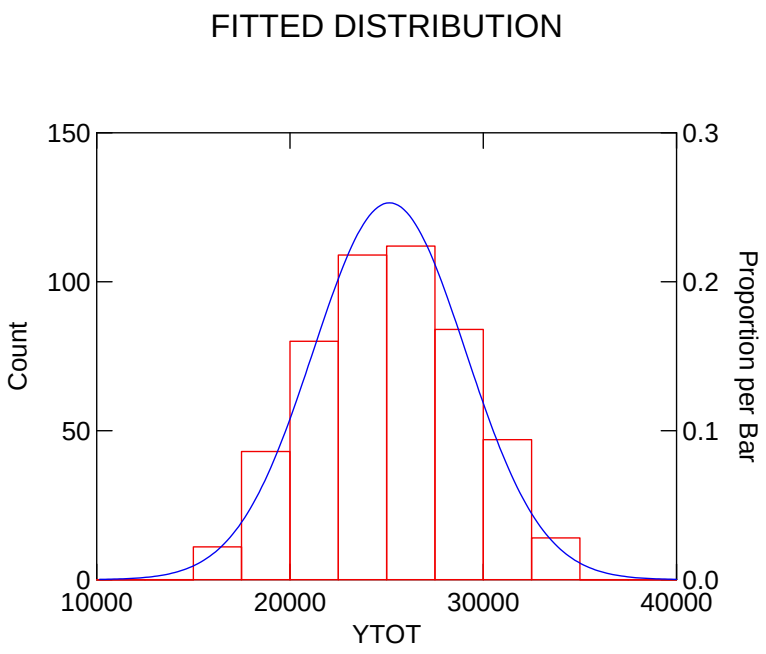
Estimated: Location or mean (mu) = 25146.263000 Scale or SD (sigma) = 3941.611428

Estimation of parameter(s): Maximum likelihood method.

Test Results:

LimitL	LimitU	Observed	Expected
.	16405.900	1.0	6.648
16405.900	18164.760	18.0	12.483
18164.760	19923.620	33.0	27.162
19923.620	21682.480	52.0	48.588
21682.480	23441.340	69.0	71.455
23441.340	25200.200	80.0	86.393
25200.200	26959.060	79.0	85.876
26959.060	28717.920	68.0	70.179
28717.920	30476.780	50.0	47.151
30476.780	32235.640	32.0	26.044
32235.640	33994.500	18.0	11.826
33994.500	.	0.0	6.195
Total		500.000	500.000

Chi-square test statistic = 20.859765 df = 9 p-value = 0.013288



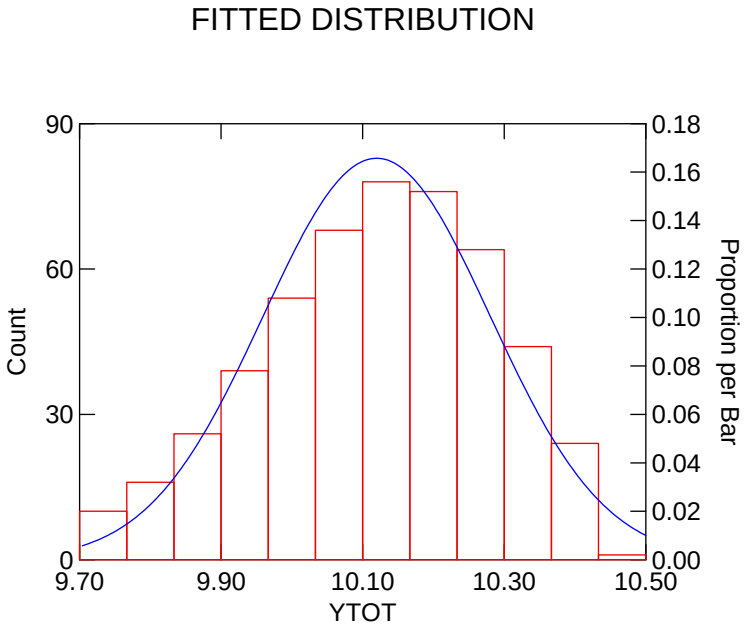
Kolmogorov-Smirnov test statistic = 0.019020 Lilliefors Probability (2-tail) = 1.000000

Shapiro-Wilk test statistic for normality = 0.990637 p-value = 0.002908

Variable Name: YTOT= Total Catch (mt)
Distribution: Lognormal
Estimated: Location (mu) = 10.119820 Scale (sigma) = 0.160481
Estimation of parameter(s): Maximum likelihood method.
Test Results:
Log transformation is used on data.

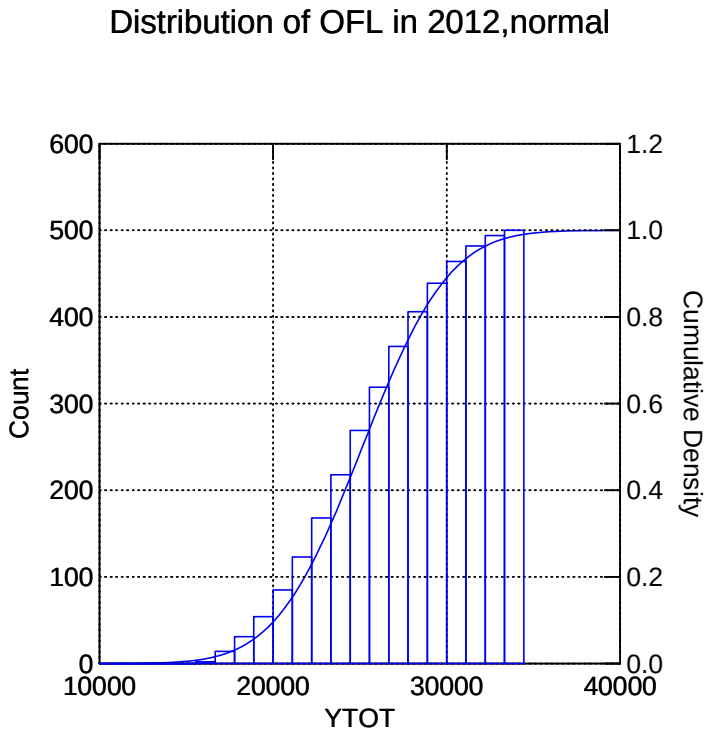
LimitL	LimitU	Observed	Expected
.	9.778	12.0	8.326
9.778	9.851	20.0	15.186
9.851	9.924	33.0	32.063
9.924	9.997	48.0	55.277
9.997	10.070	68.0	77.819
10.070	10.143	81.0	89.463
10.143	10.215	85.0	83.988
10.215	10.288	74.0	64.388
10.288	10.361	52.0	40.309
10.361	10.434	27.0	20.606
10.434	.	0.0	12.574
		500.000	500.000

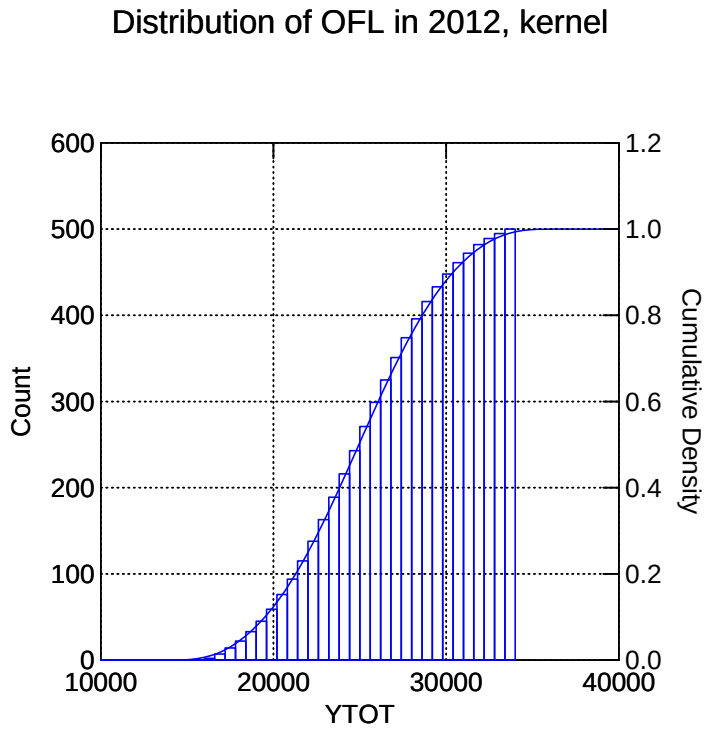
Chi-square test statistic = 25.567360 df = 8 p-value = 0.001245



Kolmogorov-Smirnov test statistic = 0.034815 Lilliefors Probability (2-tail) = 0.147946

Shapiro-Wilk test statistic for normality = 0.984201 p-value = 0.000030





Appendix Figure 1. Cumulative Distribution of the Overfishing limit (YTOT) in 2012, with Normal and kernel distribution overlays (solid line).

Appendix 3

Table 1. Summary of average catch rate of female and male spiny dogfish in NEFSC spring bottom trawl survey.

	Female Number per Tow				Male Number per Tow			
year	*3-yrMean*	*3-yrVar*	*3-yr SE*	*3-yrCV*	*3-yrMean*	*3-yrVar*	*3-yr SE*	*3-yrCV*
1991	33.706	83.772	9.153	27.155	36.553	264.203	16.254	44.468
1992	38.436	108.291	10.406	27.075	39.436	260.409	16.137	40.920
1993	33.210	51.384	7.168	21.585	34.362	124.089	11.140	32.418
1994	35.917	55.805	7.470	20.799	41.395	122.204	11.055	26.705
1995	30.492	33.013	5.746	18.843	37.238	108.926	10.437	28.027
1996	35.924	121.007	11.000	30.621	43.926	99.099	9.955	22.663
1997	32.905	113.778	10.667	32.417	35.994	82.357	9.075	25.213
1998	28.275	104.634	10.229	36.177	38.193	96.530	9.825	25.724
1999	20.517	12.907	3.593	17.510	32.466	45.638	6.756	20.808
2000	15.972	13.574	3.684	23.068	30.015	47.662	6.904	23.001
2001	15.885	16.390	4.048	25.485	26.012	35.641	5.970	22.951
2002	15.025	17.836	4.223	28.109	24.920	34.523	5.876	23.578
2003	15.709	11.709	3.422	21.783	28.323	31.235	5.589	19.732
2004	15.417	9.718	3.117	20.221	27.647	29.073	5.392	19.503
2005	12.610	8.016	2.831	22.453	29.580	131.932	11.486	38.831
2006	16.287	19.015	4.361	26.773	35.521	194.964	13.963	39.309
2007	18.618	22.879	4.783	25.691	38.873	194.480	13.946	35.875
2008	23.214	23.687	4.867	20.965	38.628	87.551	9.357	24.223
2009	22.528	21.958	4.686	20.801	38.805	42.131	6.491	16.727
2010	23.933	19.818	4.452	18.601	42.684	56.562	7.521	17.620
2011	24.233	27.798	5.272	21.758	49.269	74.682	8.642	17.540

Appendix 3

Table 2. Summary of total dead discards and standard errors for trawl, gill net and recreational discards for spiny dogfish by gender for 1990 to 2010.

	Trawl Discards (mt)				***Gill Net Discards (mt)***				***Recreational Discards (mt)***				***Landings (mt)***	
	Male		***Female***		***Male***		***Female***		***Male***		***Female***			
Year	***Total***	***SE***	***Total***	***SE***	***Total***	***SE***	***Total***	***SE***	***Total***	***SE***	***Total***	***SE***	***Males***	***Females.***
1990	7636.00	1918.55	9485.0	2382.9	256.00	65.12	1563.00	397.55	58.068	8.478	354.497	51.757	61.9	16378.1
1991	4309.00	843.49	5352.0	1047.6	466.00	54.53	2843.00	332.91	56.413	7.616	344.394	46.493	824.4	12878.6
1992	7274.00	1971.88	9034.0	2449.1	251.00	24.09	1535.00	147.10	58.890	6.242	359.514	38.108	32.5	17721.5
1993	3855.00	993.13	4788.0	1233.5	414.00	78.23	2530.00	477.57	48.101	7.456	293.651	45.516	173.0	21908.0
1994	3102.00	786.56	3852.0	976.9	122.00	36.74	744.00	224.31	48.975	7.444	298.982	45.445	266.3	20354.7
1995	2275.00	444.94	6224.0	1217.3	957.00	314.93	1062.00	349.68	90.048	10.356	99.983	11.498	137.0	23536.0
1996	1683.00	465.96	3018.0	835.9	599.00	181.61	568.00	172.39	53.432	6.839	50.719	6.492	4679.8	23213.2
1997	1716.00	566.41	1637.0	540.4	220.00	54.14	478.00	117.73	67.339	8.215	146.416	17.863	6941.6	12070.4
1998	1077.00	363.50	1558.0	525.9	239.00	69.66	351.00	102.48	65.098	8.593	95.770	12.642	1254.4	21059.6
1999	982.00	340.73	2860.0	992.3	117.00	31.19	485.00	129.44	30.914	3.586	128.314	14.884	3082.3	14798.7
2000	644.00	156.37	720.0	174.7	149.00	43.50	1256.00	367.38	13.277	2.191	112.138	18.503	543.8	11792.2
2001	428.00	68.78	2031.0	326.2	185.00	55.76	1977.00	596.91	38.062	3.464	407.459	37.079	242.3	6483.7
2002	533.00	168.91	2237.0	708.6	107.00	23.23	1392.00	301.06	40.479	4.291	524.542	55.601	114.7	5954.3
2003	524.00	101.64	1402.0	272.0	172.00	22.41	1452.00	189.62	67.346	5.455	569.759	46.150	63.1	3053.9
2004	1261.00	201.44	2888.0	461.3	127.00	11.85	1083.00	101.38	81.937	7.374	700.708	63.064	26.3	3623.7
2005	994.46	111.79	2762.9	310.6	192.57	24.29	808.89	102.03	125.441	15.053	526.908	63.229	488.4	2491.6
2006	790.81	88.89	2123.0	238.6	244.21	29.30	655.59	78.67	177.048	21.246	475.301	57.036	385.6	4330.3
2007	704.25	84.51	3353.0	376.9	290.54	34.86	1383.29	166.00	155.874	18.705	742.126	89.055	512.5	5339.9
2008	589.80	97.20	2212.2	364.6	307.15	55.13	1152.02	206.79	131.127	12.510	491.818	46.919	242.0	5652.1
2009	883.00	90.36	2895.0	296.4	361.00	52.52	1185.00	172.28	134.000	16.490	439.745	54.100	396.0	5201.0
2010	893.00	70.86	2036.0	161.6	234.00	23.19	533.00	52.89	118.000	13.130	268.687	29.950	440.0	5154.0

Appendix 3.

Table 3. Summary of selectivity parameters used to estimate length-specific fishing mortality for spiny dogfish.

	Females			*Males*			
	a	***b***	***L50***	***a***	***b***	***L50***	***Comment***
1991	2.777	-0.025	111.1	20.25	-0.45	45.0	
1992	4.762	-0.043	110.7	20.25	-0.45	45.0	
1993	7.397	-0.067	110.4	28.32	-0.593	47.8	
1994	8.831	-0.08	110.4	43.75	-0.879	49.8	
1995	11.99	-0.137	87.5	24.67	-0.533	46.3	
1996	11.85	-0.137	86.5	41.27	-0.829	49.8	
1997	11.59	-0.135	85.9	41.27	-0.812	50.8	
1998	10.69	-0.138	77.5	7.626	-0.076	100.3	Lack of fit for male data
1999	9.083	-0.116	78.3	7.699	-0.077	100.0	Lack of fit for male data
2000	11.27	-0.155	72.7	760.7	-16.9	45.0	
2001	15.72	-0.218	72.1	549.4	-12.21	45.0	
2002	17.34	-0.217	79.9	549.4	-12.21	45.0	
2003	14.83	-0.175	84.7	547.4	-12.16	45.0	
2004	15.57	-0.17	91.6	548	-12.18	45.0	
2005	12.45	-0.14	88.9	28.23	-0.627	45.0	
2006	10.35	-0.12	86.3	8.513	-0.085	100.2	Lack of fit for male data
2007	9.722	-0.113	86.0	32.97	-0.733	45.0	
2008	8.867	-0.099	89.6	32.99	-0.733	45.0	
2009	8.867	-0.099	89.6	32.99	-0.733	45.0	
2010	8.867	-0.099	89.6	32.99	-0.733	45.0	