Update on the Status of Spiny Dogfish in 2013 and Projected Harvests at the Fmsy Proxy and Pstar of 40%

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Scientific and Statistical Committee
September 12, 2013
Last Update: September 12, 2013

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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 2013. 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.

US landings increased modestly 9,480 mt in 2011 to 10,660 mt in 2012. Canadian landings have averaged about 77 mt per year since 2009. In contrast, Canadian landings between 2005 and 2008 were 2,166 mt. The recreational, Canadian and foreign fleets in 2012 collectively accounted for only 221 mt.

Estimates of recreational landings were updated for the period 2004 to 2011 to account for changes resulting from the application of an alternative estimator to the historical data collected under the Marine Recreational Fisheries Statistics Survey (MRFSS). Differences between the Recreational landings and discard estimates for 2004 to 2010 were relatively minor. MRIP estimates of landings are about 18% lower than MRFSS. MRIP estimates of discards are about 7% lower. In view of the small overall magnitude of the change and the minor contribution of recreational catch to the total removals, NO historical adjustments of recreational catches were made.

Total discards in 2012 of 11,626 mt were about equal to the average of total discards in 2010 (10,584 mt) and 12,264 mt in 2011. Total dead discards in 2012 (4,848 mt) were statistically equivalent to dead discards in 2011 (4,787 mt). Total discards in US otter trawl fleet and sink gill nets in 2012 were about the same as in 2011. The ratio of dead discards to landings in 2012 of 0.45 is the lowest value since the closure of the fishery in 2000. These data suggest a general improvement in the utilization of the spiny dogfish resource (ie. landings/catch)

Overall survey abundance for 2013 fell about 30% from the record high levels observed in 2012. The raw 3-yr average of female SSB swept area biomass in 2013 of 235,900 mt was about the same as the 241,000 mt in

2012. Pup production was the highest observed in the time series since 1968. Male biomass in the 36 to 79 cm size range was the highest observed in the time series.

Female spawning stock biomass estimates from 2009 onward have exceeded the biomass reference point. Therefore, the stock is not overfished and is rebuilt. Stochastic model estimates of median female spawning stock biomass in 2013 was 211,372 mt (compared to 215,444 mt in 2012). The probability of stock size being below the SSB target is less than 25%. The sampling distribution of SSB in 2013 suggested that the probability of SSB being below the SSB threshold is less than 3%.

Estimated fishing mortality rates in 2011 and 2012 were 0.114 and 0.149, respectively. Increased variability the stochastic biomass estimate led to increased dispersion in the stochastic estimate of F. The sampling distribution for F on exploitable female biomass was estimates suggested about a 21% chance of exceeding the P_star adjusted F of 0.19235 and about an 9% chance of exceeding Fmsy proxy of 0.2439. In the mid 1990's F on fully recruited spiny dogfish was about 2 to 3 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).

This report examines a two harvest scenarios based on fishing mortality rates at the Fmsy proxy (0.2439) and a Pstar adjusted estimate of 0.19235. The Pstar estimate, based on an assumed lognormal distribution with a CV of 100% has a 40% chance of exceeding the OFL. 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 provide guidance on projected landings, probabilities of overfishing and probabilities of falling below SSB targets and thresholds. A common feature of these projections and earlier updates 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. Given the state of the resource in 2012, it appears that the likelihood of falling below the threshold biomass level is relatively low even when fishing at Fmsy. Increased recruitment, especially in the past 4 years, has resulted in an increased abundance of fish under 60 cm. This "filling out" of the size frequency distribution tends to diminish the expected oscillations in future population trajectories. However, it should be noted that all of these conclusions are conditional on little change in the selectivity patterns over time.

Assuming that the 2013 ABC of 24,709 mt is achieved, the projected median OFL for 2014 is 32,166 mt with a 90% confidence interval of 18,063 to 46,300. By way of comparison, results prepared in September 2012 suggested a projected median OFL for 2014 (i.e., 2 step ahead forecast) of 30,971 mt with a 90% CI of 21,932 to 40,022 mt.

If a fishing morality rate of 0.19235 is used as a basis for setting the ABC, the projected ABCs and confidence intervals are as follows:

Year	Median (50th percentile)	5th Percentile	95th Percentile	Recommendation from 2012 SSC
2014	27,596	16,344	38,872	25,154
2015	28,310	16,612	40,029	25,057
2016	28,664	16,705	40,642	NA

Background

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.

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, 2011 by the SSC.

A. Catch Trends

1. This document summarizes the most recent information on spiny dogfish stock status using survey data from the spring 2013 NEFSC bottom trawl survey and catch data from 2012. 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 and Fig. 1. US landing increased by 74% between 2010 and 2011 to 9,480 mt. Landings again increased slightly (11%) to 10,881 mt in 2012. Canadian landings declined from by 93% to 113 mt in 2009, and have averaged only 65 mt in the past 3 years (2010-2012). Recreational, Canadian and foreign fleets in 2012 collectively accounted for only 221 mt.

3. The estimates of recreational landings were updated for the period 2004 to 2011 (Table 2). The changes represent the application of an alternative estimator to the historical data collected under the Marine Recreational Fisheries Statistics Survey (MRFSS). The new program, known as the Marine Recreational Information Program (MRIP) is in the process of revising the historical data as well as advancing an improved sampling design for future surveys. At the time this report was prepared, the changes in the historical data bases were restricted to 2004 to 2011. To be clear, the re-estimation of recreational catch estimates for 2004 onward represents the application of a revised estimator to the historical MRFSS data. The revised estimates are now consistent with the actual sampling collection program employed under MRFSS.

4. Differences between the Recreational landings and discard estimates for 2004 to 2010 were relatively minor (Table 2). MRIP estimates of landings are about 18% lower than MRFSS. MRIP estimates of discards are about 7% lower (Fig. 2). In view of the small overall magnitude of the change and the minor contribution of recreational catch to the total removals, NO historical adjustment of recreational catches were made. In 2011 the ratio of recreational catch to total catch was 3.3%. Hence changes of 18% and 7%, respectively to recreational landings and discards would represent negligible changes to the historical catch series (Fig. 3).

5. Total discards in 2012 of 11,626 mt were about equal to the average of total discards in 2010 (10,584 mt) and 12,264 mt in 2011 (Table 3). Total dead discards in 2012 (4,848 mt) were statistically equivalent to dead discards in 2011 (4,787 mt) .

6. Total discards in US otter trawl fleet and sink gill nets in 2012 were about the same as in 2011. (Table 3). The ratio of dead discards to landings in 2012 of 0.45 is the lowest value since the closure of the fishery in 2000 (Table 4, Fig. 5). These data suggest a general improvement in the utilization of the spiny dogfish resource (ie. landings/catch)

7. Biological samples collected by port agents are used to estimate size composition and sex ratios for spiny dogfish in landings (Table 5). Overall Landings are dominated by females, a trend that has persisted since the US EEZ fishery began (Fig. 6). Most fishing takes place near shore where females are more abundant. Despite the large increase in landings in 2011 the fraction of females in the landings (92%) was nearly equal to the landings fractions in the previous two years. In 2012 landings were about 97% females (Table 5). The average weights of female dogfish landed in 2012 was about 5% higher than the average of the previous 5 years. The estimated increase in total numbers landed was 90% between 2010 and 2011(vs a +74% increase in total landings by weight). This may represent a change in the selection pattern of the fleet but

these data were not reviewed as part of this assessment update. Total numbers harvested in 2012 were nearly equal to estimates for 2011 (Table 5).

8. The sex ratios of discarded fish are similarly dominated by females, but represent only 77% of total discards by weight (Table 6). This difference, compared to landings, is likely due to the much higher rate of discarding of male fish. On a numerical basis, 20% of the males caught in 2012 were landed; for females this fraction was 70% in 2011(Table 5, 6).

9. Discard rates are declining as a fraction of total catch. The decrease in discards represents an improvement in the utilization of the spiny dogfish resource (Table 4, Fig. 4, 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 (Miller et al. 2010). 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 2012 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. Overall swept area biomass estimates, using a nominal trawl survey footprint of 0.010 nm^2 declined about 30% from record high levels in 2012 (Table 7). This table is included to facilitate comparisons with previous summaries of this information. The raw 3-yr average of female SSB swept area biomass remained about the same in 2013 235,900 mt as compared to 241,000 mt in 2012. Pup Production in 2013 was the highest on record (Fig. 7) in the NEFSC spring survey. Stochastic estimates of swept area biomass given in Table 8, suggest little change in population size of females SSB or exploitable biomass.
5. Size frequency plots for males and females were not plotted at the time this report was prepared.

6. The stochastic estimates of stock size and fishing mortality, described in the following sections, explicitly takes the variability into account and dampens the interannual changes by using a 3-year moving average of survey estimates.

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 8 and Fig. 8. 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 8 while Fig. 8a and 8b depict the variability in biomass estimates for 2008-13.

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. Dogfish in schools are known to herd between trawl doors. An external mass balance model was first applied at SARC 43 and has been recently updated in 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 2012 and 2013 were nearly equal. (Table 8). The magnitude of the increase between 2011 and 2012 is improbable given the biology of spiny dogfish. However, the estimated biomass in 2012 is within the interquartile range of population sizes projected by the model in 2011 (i.e., the median biomass in 2012 is approximately the 74th percentile of SSB forecasted on September 2011 (See Rago and Sosebee, 2011). The stochastic estimate of SSB suggests an increase in the variance of the estimate (Fig. 8). A comparison of the raw, 3-yr moving average and stochastic estimators are shown in Fig. 9.

4. The probability that female spiny dogfish SSB exceeds the biomass reference point is about 75% (Fig. 8, Table 10). Dogfish continue to exceed the rebuilding target biomass.

5. 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 9 and 10, and Figure 11. Fishing mortality rates for female spiny dogfish are less than 1/2 of the F msy proxy. The likelihood that F on the exploitable stock of female biomass exceeds the Fmsy threshold is about 9%.

6. Additional details on the variability in survey indices and discard estimation may be found in Appendix 2.

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) it is assumed that the F on males would increase proportionally to 0.013 (Table 11).

D.1 Scenarios

All of the scenarios assumed that the 2013 fishery had the same selectivity and fishing mortality properties as the 2012 fishery. Catch in 2013 was assumed to be equal to the MAFMC recommended ACL of 24,709 mt. The implications of this assumption are illustrated in Table 10, which demonstrates that the there is about a 50% chance that the fishing mortality rate would exceed the Fmsy proxy in 2013. However there is at least a 75% chance that the population would exceed the Bmsy proxy of 159 kt. The scenario planning horizon was 30 years (2013-2042). 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. An F-based scenario with F= Fmsy proxy =0.2439 was used to create a sampling distribution of catch (Fig. 13 Panel A), total landings (Panel C) and a sampling distribution of female SSB (Panel B) and fraction of the SSB target (Panel D).

A second scenario was based on a Pstar adjusted F =0.19235. This adjustment is based on an assumed lognormal distribution of F with a 100% CV and a 40% chance of exceeding the OFL. The same assumptions about 2013 fishery were used to initialize these projections. Results of this scenario are given in Table 13 and 14, and Figures 12 and 13.

D.2 Results

The constant F harvest policies lead to a static population and catch when F=Fmsy proxy (Fig. 12) . The short term response is dominated by oscillations that are primarily a function of the contemporary size structure of the population. A common feature of these projections and earlier updates 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. Given the state of the resource in 2012, it appears that the likelihood of falling below the threshold biomass level is relatively low even when fishing at Fmsy. Increased recruitment, especially in the past 4 years, has resulted in an increased abundance of fish under 60 cm. This "filling out" of the size frequency distribution (Fig. 18) tends to diminish the expected oscillations in future population trajectories. However, it should be noted that all of these conclusions are conditional on little change in the selectivity patterns over time.

Box plots are used to convey the predicted uncertainty in catch, landings, and female SSB (Fig. 13); numerical details are provided in Tables 11 and 12. Table 12 provides detailed information on the percentiles of catch, landings, discards and female SSB for 2014 to 2016. The 40%-ile of catch under F=0.2439 averages 29,983 mt for 2014 to 2016 with no meaningful variation between years.

Table 12 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 median of the Overfishing Limit (OFL) for 2014 is 32,166 mt. The 90% confidence interval for the 2014 OFL is 18,063 to 46,300 mt. Assuming the same ratio of landings to total catch as in recent years, the corresponding confidence interval on landings would be 8,603 to 29,473 mt.

Figure 13a illustrates the expected increases in uncertainty over time. The expectations for SSB (panels B and D) are particularly instructive for selection of harvest policies. The last four columns of Table 11 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. Decrease in stock size may occur by 2020 but current runs suggest the stock has a low probability of declining below the threshold biomass.

The Pstar harvest based policy is evaluated in Tables 13 and 14 and depicted in Figure 13b. Median projected catches for 2014 to 2016 are 27,596, 28,310, and 28,664 mt, respectively (Table 14). The population is expected to grow (Fig 12, Fig 13 b) at about 1.3% per year.

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. The sharp increase in survey abundance in 2012 may represent increased availability to the survey area or concentrations of the resource in larger offshore strata. Such changes in resource allocation are, in theory, not expected to alter abundance indices. However, even slight changes in catchability among strata and high sampling variability could lead to very high or low abundance estimates in a given year.

4. Changes in discard patterns could become extremely important. In 2012, discard mortality presently constitutes 66% of fishing mortality by weight on male dogfish and 26% 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. While the sex ratio of mature male to mature female dogfish has declined, the higher than expected ratio may reflect the persistent effects of the 1990s fisheries (Fig. 15). A targeted fishery to land male dogfish would not be detrimental to the population in the short run but the consequences for changes in selectivity for co-occurring female populations should be evaluated.

5. Other important source of uncertainty include
    a. Potential changes in fishery selectivity. Large increases in catches could induce changes in the overall selectivity pattern in the fishery.
    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

Potential Indicator	***Metric***	***Evaluation***	***Reference***
Discards	Changes in ratio of discard to landings	Ratio has been steadily declining since 2004 suggesting more efficient utilization of the resource	Figure 5, Table 4
	Changes by gear type	Sink gill net discard rates have declined over time. Otter trawl discards have remained steady at about 3000 mt in last 5 years-	Table 3.
Survey Abundance Trends	Average Size of Mature females	Mean length of mature females has been increasing since 1999. Average size of mature females is still well below rates observed in mid 1980s.	Figure 16
	Ratio of mature males to females	Ratio has decreased to between 3 to 4 from earlier ratios near 7. Expected ratio, based on growth and maturity rates should be about 2.	Figure 15.
	Recruitment	Recruitment indices have been steadily increasing in recent years	Table 7. Figure 7.
	Pup Size	Average length of male and female pups have increased steadily from a low of 26 cm in 1997 to about 29 in last 3 years. Average size is approaching level observed in the 1980s.	Figure 17.
	Size composition	Sizes of mature females are increasing slightly; males are relatively unchanged. Size composition of sub adults is broadening and approaching distribution seen prior to major fisheries in 1990s.	Figure 18.
Commercial Landings	Average Size	Average weight of landed females of about 2.7 kg has been steady since 2004.	Table 5
	Sex ratio	Landings remain dominated by females with no apparent trend.	Table 5
	Changes in Canadian Landings	Landings remain low. In last 4 years landings have averaged about 77 mt compared to 2,166 mt in previous 4 year period.	Table 1.
Forecast accuracy	Comparison of OFL and ABC predictions between assessments	Median ABC projections from the 2012 assessment with projections in this assessment are within 10 to 13% of each other. This assessment suggests slightly higher values.	Executive summary, page 3.

G. References

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Table 1. Total spiny dogfish landings (mt, live) in NAFO Areas 2 to 6, 1962-2012

	United States				
Year	Commer-cial	Recre-ational	Canada	Distant Water Fleets	Total Landings
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
2011	9,480	32	124	143	9,779
2012	10,660	19	65	137	10,881

Table 2. Summary of spiny dogfish landings and discard estimates based on Marine Recreational Information Program estimates. As in previous assessments, the average weight of landed discarded spiny dogfish is assumed to be 2.5 kg. Discard mortality is assumed to be 20%. The revised MRIP estimator was used for 2004 to 2012. Differences between MRFSS and MRIP were considered minor relative to total catch (ie Commercial landings and discards); no adjustments were made to historical recreational data.

	Catch in Numbers								Numbers		*Weight (mt)*			Estimates used in Previous assessments				
Year	Observed Harvest (A)	PSE	Reported Harvest (B1)	PSE	Released Alive (B2)	PSE	Total Catch A+B1+B2	PSE	Total Landings A+B1 (number)	Discards B2 (number)	Landings (A+B1) (mt)	Discards (B2) (mt)	Dead Discards (mt)	Landings (mt)	Discards (mt)	% dif Landings	% dif Discard	Estimator
1981	5,943	49.1	591,300	52.1	118,440	31.3	715,683	43.4	597,243	118,440	1493	296	59	1,493	59	0.0	0.4	MRFSS
1982	12,460	38.6	15,712	45.5	139,730	21.4	167,902	18.5	28,172	139,730	70	349	70	70	70	0.6	-0.2	MRFSS
1983	13,154	36.3	13,675	34.1	215,973	23.7	242,803	21.2	26,829	215,973	67	540	108	67	108	0.1	0.0	MRFSS
1984	9,606	48.1	26,918	45.1	169,574	35.1	206,099	29.6	36,524	169,574	91	424	85	91	85	0.3	-0.3	MRFSS
1985	5,495	47.7	30,172	38.3	385,745	41.8	421,412	38.4	35,667	385,745	89	964	193	89	193	0.2	-0.1	MRFSS
1986	11,598	26.5	61,688	22.8	474,930	17.7	548,216	15.6	73,286	474,930	183	1187	237	182	237	0.7	0.2	MRFSS
1987	14,286	44	108,171	28.9	422,387	21.6	544,844	17.8	122,457	422,387	306	1056	211	306	211	0.0	0.1	MRFSS
1988	46,068	30.6	98,002	19.8	350,410	24.4	494,480	18	144,070	350,410	360	876	175	359	175	0.3	0.1	MRFSS
1989	63,031	40.6	104,511	34.4	539,731	17.2	707,273	14.5	167,542	539,731	419	1349	270	418	269	0.2	0.3	MRFSS
1990	22,364	26.1	49,045	28.6	468,085	14.6	539,494	13	71,409	468,085	179	1170	234	179	234	-0.3	0.0	MRFSS
1991	30,459	21.9	21,884	22.7	539,883	13.5	592,227	12.4	52,343	539,883	131	1350	270	131	270	-0.1	0.0	MRFSS
1992	46,753	22.8	50,483	23.1	407,485	10.6	504,721	9.1	97,236	407,485	243	1019	204	215	204	11.6	-0.1	MRFSS
1993	23,350	21.6	24,535	30.8	444,077	15.5	491,963	14.1	47,885	444,077	120	1110	222	120	222	-0.2	0.0	MRFSS
1994	17,714	34	44,230	35.6	387,274	15.2	449,218	13.6	61,944	387,274	155	968	194	155	194	-0.1	-0.2	MRFSS
1995	15,447	31.2	11,583	37.2	261,465	11.5	288,496	10.7	27,030	261,465	68	654	131	68	131	-0.6	-0.2	MRFSS
1996	8,500	29.8	1,843	48.4	131,672	12.7	142,015	11.9	10,343	131,672	26	329	66	25	66	3.3	-0.2	MRFSS
1997	21,017	24.4	5,582	54.9	337,431	12.1	364,030	11.3	26,599	337,431	66	844	169	66	167	0.7	1.0	MRFSS
1998	14,831	28.7	9,445	78.2	243,988	13.2	268,264	12.4	24,276	243,988	61	610	122	39	122	35.7	0.0	MRFSS
1999	11,995	52.5	9,710	68.2	214,974	11.5	236,679	11.1	21,705	214,974	54	537	107	53	106	2.3	1.4	MRFSS
2000	1,773	46.6	271	89.5	276,258	16.3	278,302	16.2	2,044	276,258	5	691	138	5	137	2.2	0.8	MRFSS
2001	7,771	39.7	3,459	44.6	842,583	9.1	853,812	9	11,230	842,583	28	2106	421	28	420	0.3	0.3	MRFSS
2002	2,281	32.3	79,691	43.8	669,469	10.6	751,440	10.5	81,972	669,469	205	1674	335	205	335	0.0	-0.1	MRFSS
2003	8,314	36.2	7,560	33.9	1,199,490	8	1,215,364	7.9	15,874	1,199,490	40	2999	600	40	597	-0.8	0.5	MRFSS
2004	19,328	44.7	28,761	38.9	1,315,796	14.1	1,363,885	13.6	48,089	1,315,796	120	3289	658	105	698	12.7	-6.1	MRIP
2005	6,894	33.5	7,230	37.9	1,339,412	19.9	1,353,536	19.7	14,124	1,339,412	35	3349	670	45	702	-27.4	-4.8	MRIP
2006	7,592	40.1	24,221	65.7	1,420,564	11.6	1,452,377	11.4	31,813	1,420,564	80	3551	710	94	768	-18.2	-8.1	MRIP
2007	2,134	44.2	32,352	67.3	1,557,079	12.7	1,591,565	12.5	34,486	1,557,079	86	3893	779	84	860	2.6	-10.5	MRIP
2008	10,930	35.3	34,701	38	1,078,307	12.6	1,123,938	12.2	45,631	1,078,307	114	2696	539	214	623	-87.6	-15.6	MRIP
2009	6,155	40.3	10,929	31.9	1,031,866	13	1,048,951	12.8	17,084	1,031,866	43	2580	516	34	574	20.4	-11.3	MRIP
2010	2,270	34.4	4,158	60.3	790,412	20.7	796,840	20.6	6,428	790,412	16	1976	395	21	386	-30.7	2.3	MRIP
2011	5,742	42.6	7,063	48.6	924,891	14.8	937,696	14.6	12,805	924,891	32	2312	462	NA	NA	NA	NA	MRIP
2012	3,413	65.7	4,103	63.6	549,820	18	557,336	17.7	7,516	549,820	19	1375	275	NA	NA	NA	NA	MRIP

Table 3. Estimated total discards of spiny dogfish (mt) from commercial and recreational US fisheries, 1981-2012. The values for otter trawl and gill net from 1981-1989 are hindcast estimates (see SARC 43)

							Assumed Discard Mortality Rate					
							0.50	0.30	0.75	0.10	0.20	
	Total Discards						Dead Discards					
Year	Otter Trawl	Sink Gill Net	Scallop Dredge	Line gear	Recreational	Total	Otter Trawl	Sink Gill Net	Scallop Dredge	Line gear	Recreational	Total Dead
1981	36,360	5,360	na	na	296	42,016	18,180	1,608	na	na	59	19,847
1982	42,910	4,454	na	na	349	47,713	21,455	1,336	na	na	70	22,861
1983	42,188	4,042	na	na	540	46,770	21,094	1,213	na	na	108	22,415
1984	39,625	4,918	na	na	424	44,967	19,813	1,475	na	na	85	21,373
1985	33,354	4,539	na	na	964	38,857	16,677	1,362	na	na	193	18,232
1986	31,745	4,883	na	na	1,187	37,815	15,873	1,465	na	na	237	17,575
1987	29,050	4,864	na	na	1,056	34,970	14,525	1,459	na	na	211	16,195
1988	28,951	5,132	na	na	876	34,959	14,476	1,540	na	na	175	16,190
1989	28,286	5,360	na	na	1,344	34,990	14,143	1,608	na	na	269	16,020
1990	34,242	6,062	na	na	1,170	41,474	17,121	1,819	na	na	234	19,174
1991	19,322	11,030	32	97	1,350	31,831	9,661	3,309	24	10	270	13,274
1992	32,617	5,953	827	650	1,019	41,066	16,309	1,786	620	65	204	18,983
1993	17,284	9,814	209	44	1,110	28,461	8,642	2,944	157	4	222	11,969
1994	13,908	2,887	723	na	968	18,486	6,954	866	542	na	194	8,556
1995	16,997	6,731	378	na	654	24,760	8,499	2,019	284	na	131	10,932
1996	9,402	3,890	121	na	329	13,742	4,701	1,167	91	na	66	6,025
1997	6,704	2,326	198	na	837	10,065	3,352	698	149	na	167	4,366
1998	5,268	1,965	120	na	610	7,963	2,634	590	90	na	122	3,435
1999	7,685	2,005	41	na	532	10,263	3,843	602	31	na	106	4,581
2000	2,728	4,684	14	na	685	8,111	1,364	1,405	11	na	137	2,917
2001	4,919	7,204	30	na	2,099	14,252	2,460	2,161	23	na	420	5,063
2002	5,540	4,997	58	4,015	1,673	16,283	2,770	1,499	44	402	335	5,049
2003	3,853	5,413	103	2	2,987	12,358	1,927	1,624	77	0	597	4,225
2004	8,299	4,031	53	497	3,490	16,370	4,150	1,209	40	50	698	6,146
2005	7,515	3,338	15	1,175	3,509	15,552	3,758	1,001	11	118	702	5,589
2006	7,773	3,369	14	131	3,840	15,126	3,886	1,011	10	13	768	5,688
2007	8,115	5,133	61	73	4,300	17,681	4,058	1,540	45	7	860	6,510
2008	5,604	4,864	237	260	3,115	14,080	2,802	1,459	178	26	623	5,088
2009	7,010	4,874	364	835	2,869	15,952	3,505	1,462	273	84	574	5,897
2010	5,564	2,385	196	509	1,930	10,584	2,782	716	147	51	386	4,081
2011	6,540	2,831	226	356	2,312	12,264	3,270	849	170	36	462	4,787
2012	6,687	2,959	432	172	1,375	11,626	3,344	888	324	17	275	4,848

Table 4. Total landings, discards and total catch for spiny dogfish, 1989-2012.

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
2011	12,264	4,787	9,779	0.49	1.25	14,566
2012	11,626	4,848	10,881	0.45	1.07	15,729

Table 5. Summary of estimated landings of US, Canadian and foreign fisheries by sex, 1982-2012. US recreational landings included. Estimated total weights based on sum of estimated weights from sampled length frequency distributions from port samples. Estimated weights computed for female as W = exp(-15.025)^L^3.606935 and males as 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	1213.4	1.478	4963	14217.4	2.865	0.9214	5594	440	5154	298	1799	2097
2011	868	1109.9	1.279	4800	12786.8	2.664	0.9201	9779	781	8998	611	3378	3989
2012	213	371.8	1.746	3763	10727.9	2.851	0.9665	10881	365	10516	209	3689	3898
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 . Summary of estimated discards of combined US fleets by sex, 1991-2012. 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
2011	2286	2920	1.278	2428	5864	2.415	0.6675	4787	1591	3196	1246	1323	2569
2012	734	1010	1.376	1384	3302	2.386	0.766	4848	1136	3712	825	1556	2381
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 7. Biomass estimates for spiny dogfish (thousands of metric tons) based on area swept by NEFSC trawl during spring surveys, 1968-2013.

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
2012	348.4	44.5	399.0	72.6	584.7	723.0	4.06	5.04	9.16	1131.1	241.0
2013	145.6	57.2	202.7	133.1	444.3	577.4	5.25	6.48	11.73	791.8	235.9

Data have been adjusted to AL IV equivalents using HB Bigelow calibration coefficients.

Table 8. Summary of swept area biomass estimates (mt) based on stochastic population Estimator, 1991-2013. 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
2012	2011	518,504	111,692	406,311	688,632	215,744
2013	2012	567,696	110,296	456,899	766,064	211,372

Table 9. Summary of stochastic fishing mortality rates expressed as the mean of full F on the exploitable biomass of female and male spiny dogfish, 1990-2012. Year represents the year of the catch (landings plus dead discards). Sampling distribution of F estimates for females are given in Figure 11a,b.

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
2011	0.114	0.006
2012	0.149	0.003

Table 10. Projected percentiles of fishing mortality rate on females, total catch , landings , discards, female spawning stock and exploitable biomass in 2013. Catches in 2013 are assumed to be equal to MAFMC ACL=24,709 mt.

	2013					
Percentile	***F***	***Catch (mt)***	***Landings (mt)***	***Discards (mt)***	***Female SSB (mt)***	***Exploitable Female Biomass (mt)***
1	0.950	24,930	17,146	7,785	64,477	29,779
2	0.811	24,940	17,153	7,787	73,530	33,960
3	0.723	24,935	17,149	7,786	81,120	37,466
4	0.660	24,939	17,152	7,787	87,707	40,508
5	0.613	24,943	17,155	7,788	93,559	43,211
10	0.480	24,924	17,141	7,783	116,313	53,720
15	0.414	24,929	17,145	7,784	133,303	61,567
20	0.371	24,944	17,156	7,788	147,393	68,074
25	0.340	24,949	17,160	7,790	159,762	73,787
30	0.316	24,935	17,149	7,786	171,025	78,989
35	0.296	24,916	17,135	7,781	181,555	83,852
40	0.280	24,944	17,156	7,788	191,603	88,493
45	0.266	24,920	17,138	7,782	201,357	92,998
50	0.253	24,946	17,158	7,789	210,972	97,438
55	0.241	24,937	17,150	7,786	220,587	101,879
60	0.230	24,913	17,133	7,780	230,341	106,384
65	0.220	24,897	17,121	7,776	240,389	111,025
70	0.211	24,910	17,131	7,779	250,918	115,888
80	0.192	24,892	17,117	7,774	274,550	126,802
95	0.159	24,926	17,143	7,783	328,384	151,666
96	0.156	24,920	17,138	7,782	334,237	154,369
97	0.154	24,947	17,158	7,789	340,823	157,411
98	0.150	24,917	17,136	7,781	348,413	160,916
99	0.146	24,954	17,163	7,791	357,467	165,098

Table 11. 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 2013 to 2039. The estimated F in 2013 is estimated by assuming that the catch in 2013 is equal to MAFMC ACL=24,709 mt. 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
2013	0.298683	0.00340	211,288	24,932	17,147	16,520	627	7,785	5,832	1,953	1.326	0.246	0.026	0.538	0.844
2014	0.2439	0.01258	207,198	32,210	19,059	16,735	2,324	13,151	5,908	7,244	1.301	0.284	0.052	1.000	1.000
2015	0.2439	0.01258	188,581	32,519	19,333	17,031	2,302	13,186	6,012	7,174	1.184	0.352	0.066	1.000	1.000
2016	0.2439	0.01258	170,200	32,390	19,311	17,045	2,266	13,079	6,017	7,062	1.069	0.438	0.084	1.000	1.000
2017	0.2439	0.01258	154,106	32,069	19,180	16,966	2,214	12,889	5,989	6,900	0.967	0.534	0.108	1.000	1.000
2018	0.2439	0.01258	155,130	31,867	19,150	16,995	2,155	12,717	5,999	6,718	0.974	0.528	0.102	1.000	1.000
2019	0.2439	0.01258	162,589	31,723	19,177	17,087	2,090	12,546	6,031	6,515	1.021	0.480	0.086	1.000	1.000
2020	0.2439	0.01258	170,913	31,739	19,340	17,324	2,016	12,399	6,115	6,283	1.073	0.430	0.072	1.000	1.000
2021	0.2439	0.01258	184,016	31,804	19,563	17,632	1,931	12,242	6,224	6,017	1.155	0.362	0.054	1.000	1.000
2022	0.2439	0.01258	188,746	31,953	19,856	18,016	1,841	12,097	6,359	5,737	1.185	0.338	0.048	1.000	1.000
2023	0.2439	0.01258	193,794	32,106	20,149	18,396	1,753	11,957	6,494	5,464	1.217	0.316	0.044	1.000	1.000
2024	0.2439	0.01258	198,432	32,124	20,330	18,660	1,670	11,793	6,587	5,207	1.246	0.300	0.042	1.000	1.000
2025	0.2439	0.01258	200,669	32,041	20,423	18,828	1,595	11,618	6,646	4,972	1.260	0.294	0.042	1.000	1.000
2026	0.2439	0.01258	199,227	31,780	20,368	18,841	1,528	11,412	6,651	4,761	1.251	0.300	0.046	1.000	1.000
2027	0.2439	0.01258	194,705	31,380	20,195	18,728	1,468	11,185	6,611	4,574	1.222	0.320	0.050	1.000	1.000
2028	0.2439	0.01258	189,044	30,889	19,942	18,528	1,414	10,947	6,540	4,407	1.187	0.344	0.056	1.000	1.000
2029	0.2439	0.01258	183,774	30,380	19,664	18,299	1,366	10,716	6,459	4,256	1.154	0.366	0.062	1.000	1.000
2030	0.2439	0.01258	180,104	29,948	19,435	18,114	1,321	10,513	6,394	4,119	1.131	0.384	0.064	1.000	1.000
2031	0.2439	0.01258	178,811	29,622	19,277	17,996	1,281	10,345	6,352	3,993	1.123	0.390	0.066	1.000	1.000
2032	0.2439	0.01258	179,188	29,408	19,195	17,951	1,244	10,213	6,337	3,877	1.125	0.388	0.064	1.000	1.000
2033	0.2439	0.01258	180,735	29,297	19,183	17,973	1,209	10,114	6,345	3,769	1.135	0.380	0.062	1.000	1.000
2034	0.2439	0.01258	183,021	29,267	19,226	18,048	1,177	10,041	6,371	3,670	1.149	0.368	0.058	1.000	1.000
2035	0.2439	0.01258	185,689	29,284	19,298	18,151	1,148	9,985	6,407	3,578	1.166	0.356	0.056	1.000	1.000
2036	0.2439	0.01258	188,101	29,315	19,377	18,257	1,121	9,938	6,445	3,493	1.181	0.344	0.052	1.000	1.000
2037	0.2439	0.01258	189,819	29,334	19,442	18,346	1,096	9,893	6,476	3,417	1.192	0.338	0.052	1.000	1.000
2038	0.2439	0.01258	190,542	29,319	19,475	18,401	1,074	9,843	6,496	3,348	1.196	0.334	0.052	1.000	1.000
2039	0.2439	0.01258	190,289	29,261	19,473	18,418	1,055	9,789	6,502	3,287	1.195	0.336	0.052	1.000	1.000
2260	0.2439	0.01258	186,647	28,383	19,165	18,278	887	9,218	6,452	2,766	1.172	0.352	0.056	1.000	1.000
2261	0.2439	0.01258	186,648	28,383	19,165	18,278	887	9,218	6,452	2,766	1.172	0.352	0.056	1.000	1.000
2262	0.2439	0.01258	186,649	28,383	19,165	18,278	887	9,218	6,452	2,766	1.172	0.352	0.056	1.000	1.000
Average	0.2457	0.01227	185,288	30,437	19,435	17,937	1,498	11,001	6,332	4,670	1.163	0.364	0.060	0.985	0.995
Ave '13-22	0.249	0.012	179,277	31,321	19,112	17,135	1,976	12,209	6,049	6,160	1.125	0.399	0.070	0.954	0.984
Ave '23-32	0.244	0.013	189,775	30,968	19,898	18,434	1,464	11,070	6,507	4,563	1.191	0.340	0.054	1.000	1.000
Ave '32-39	0.244	0.013	185,923	29,311	19,334	18,193	1,141	9,977	6,422	3,555	1.167	0.356	0.056	1.000	1.000
Formula	*A*	*B*	*C*	*D=E+H*	*E=F+G*	*F*	*G*	*H=I+J*	*I*	*J*	*K*	*L*	*M*	*N*	*O*

Table 12. Projected percentiles of total catch , landings , discards and female spawning stock biomass in 2014-2016 with an fishing mortality rate equal to the Fmsy proxy of 0.2439. Catches in 2013 are assumed to be equal to MAFMC ACL=24,709 mt (see Table 10).

	2014				2015				2016			
Percentile	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***
1	14,595	6,040	8,555	45,766	14,680	6,148	8,532	41,981	14,621	6,192	8,429	38,331
2	15,671	6,835	8,836	55,631	15,771	6,955	8,816	50,949	15,709	6,995	8,714	46,407
3	16,577	7,505	9,072	63,939	16,689	7,633	9,056	58,499	16,624	7,671	8,953	53,203
4	17,363	8,086	9,278	71,151	17,486	8,222	9,264	65,051	17,419	8,258	9,161	59,100
5	18,063	8,603	9,460	77,564	18,195	8,746	9,449	70,877	18,125	8,779	9,346	64,342
10	20,792	10,620	10,172	102,578	20,959	10,789	10,170	93,595	20,879	10,813	10,067	84,781
15	22,831	12,127	10,704	121,260	23,024	12,315	10,709	110,560	22,935	12,331	10,605	100,040
20	24,521	13,376	11,145	136,753	24,736	13,580	11,156	124,628	24,640	13,590	11,051	112,693
25	26,007	14,474	11,533	150,367	26,240	14,692	11,548	136,989	26,138	14,696	11,443	123,810
30	27,363	15,476	11,886	162,789	27,613	15,707	11,906	148,267	27,505	15,705	11,800	133,952
35	28,631	16,414	12,217	174,411	28,897	16,656	12,241	158,819	28,783	16,648	12,135	143,440
40	29,836	17,305	12,532	185,451	30,117	17,557	12,559	168,842	29,998	17,546	12,453	152,455
45	31,012	18,174	12,839	196,227	31,307	18,437	12,870	178,625	31,184	18,421	12,763	161,252
50	32,166	19,026	13,140	206,794	32,475	19,300	13,175	188,219	32,346	19,279	13,067	169,879
55	33,324	19,882	13,442	217,404	33,647	20,167	13,481	197,851	33,513	20,141	13,373	178,540
60	34,501	20,752	13,749	228,184	34,838	21,047	13,791	207,637	34,699	21,016	13,683	187,339
65	35,712	21,647	14,065	239,279	36,064	21,953	14,111	217,709	35,919	21,917	14,002	196,396
70	36,977	22,582	14,395	250,872	37,345	22,900	14,445	228,234	37,195	22,859	14,336	205,860
80	39,824	24,686	15,137	276,951	40,226	25,029	15,197	251,908	40,063	24,977	15,087	227,146
95	46,300	29,473	16,827	336,278	46,782	29,874	16,908	305,765	46,590	29,795	16,794	275,574
96	47,005	29,994	17,011	342,740	47,496	30,402	17,094	311,631	47,300	30,320	16,980	280,848
97	47,795	30,578	17,217	349,972	48,295	30,993	17,302	318,198	48,096	30,908	17,189	286,753
98	48,712	31,256	17,457	358,379	49,224	31,679	17,545	325,828	49,020	31,590	17,431	293,613
99	49,798	32,058	17,740	368,321	50,322	32,491	17,831	334,854	50,115	32,398	17,717	301,730

Table 13. 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 Pstar derived target F=0.19235 for 2013 to 2039. The estimated F in 2013 is estimated by assuming that the catch in 2013 is equal to MAFMC ACL=24,709 mt. 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
2013	0.298683	0.0034	211,288	24,932	17,147	16,520	627	7,785	5,832	1,953	1.326	0.246	0.026	0.538	0.844
2014	0.19235	0.01258	207,198	27,631	15,675	13,351	2,324	11,956	4,713	7,244	1.301	0.284	0.052	0.000	1.000
2015	0.19235	0.01258	193,617	28,346	16,248	13,947	2,302	12,097	4,923	7,174	1.216	0.332	0.062	0.000	1.000
2016	0.19235	0.01258	179,615	28,700	16,584	14,319	2,266	12,116	5,054	7,062	1.128	0.390	0.074	0.000	1.000
2017	0.19235	0.01258	167,125	28,855	16,804	14,591	2,214	12,050	5,151	6,900	1.049	0.454	0.088	0.000	1.000
2018	0.19235	0.01258	171,577	29,052	17,069	14,913	2,156	11,983	5,264	6,719	1.077	0.430	0.078	0.000	1.000
2019	0.19235	0.01258	182,191	29,231	17,333	15,241	2,091	11,899	5,380	6,519	1.144	0.374	0.064	0.000	1.000
2020	0.19235	0.01258	193,344	29,490	17,672	15,653	2,019	11,818	5,525	6,293	1.214	0.324	0.050	0.000	1.000
2021	0.19235	0.01258	209,324	29,760	18,040	16,103	1,937	11,720	5,684	6,036	1.314	0.264	0.038	0.000	1.000
2022	0.19235	0.01258	216,451	30,099	18,466	16,616	1,850	11,633	5,865	5,767	1.359	0.240	0.032	0.000	1.000
2023	0.19235	0.01258	223,800	30,464	18,906	17,139	1,767	11,558	6,050	5,508	1.405	0.218	0.026	0.000	1.000
2024	0.19235	0.01258	230,575	30,743	19,270	17,580	1,690	11,472	6,206	5,267	1.448	0.204	0.026	0.000	1.000
2025	0.19235	0.01258	235,487	30,970	19,580	17,960	1,620	11,390	6,340	5,051	1.478	0.194	0.026	0.000	1.000
2026	0.19235	0.01258	236,958	31,067	19,776	18,217	1,560	11,291	6,430	4,861	1.488	0.194	0.026	0.000	1.000
2027	0.19235	0.01258	235,390	31,059	19,877	18,371	1,507	11,181	6,485	4,696	1.478	0.198	0.028	0.000	1.000
2028	0.19235	0.01258	232,619	30,971	19,907	18,446	1,461	11,064	6,511	4,553	1.460	0.206	0.030	0.000	1.000
2029	0.19235	0.01258	230,156	30,862	19,908	18,487	1,421	10,954	6,526	4,428	1.445	0.212	0.032	0.000	1.000
2030	0.19235	0.01258	229,316	30,820	19,949	18,564	1,385	10,871	6,553	4,318	1.440	0.214	0.032	0.000	1.000
2031	0.19235	0.01258	230,994	30,871	20,051	18,697	1,354	10,820	6,600	4,220	1.450	0.210	0.030	0.000	1.000
2032	0.19235	0.01258	234,477	31,023	20,220	18,894	1,326	10,803	6,669	4,134	1.472	0.202	0.028	0.000	1.000
2033	0.19235	0.01258	239,203	31,269	20,451	19,149	1,302	10,817	6,760	4,058	1.502	0.190	0.026	0.000	1.000
2034	0.19235	0.01258	244,701	31,591	20,734	19,454	1,280	10,857	6,867	3,990	1.536	0.178	0.024	0.000	1.000
2035	0.19235	0.01258	250,637	31,964	21,048	19,786	1,261	10,916	6,985	3,931	1.573	0.166	0.020	0.000	1.000
2036	0.19235	0.01258	256,381	32,360	21,374	20,129	1,245	10,986	7,105	3,881	1.610	0.156	0.018	0.000	1.000
2037	0.19235	0.01258	261,505	32,758	21,696	20,464	1,232	11,063	7,224	3,839	1.642	0.148	0.018	0.000	1.000
2038	0.19235	0.01258	265,661	33,139	21,998	20,777	1,221	11,141	7,334	3,806	1.668	0.142	0.016	0.000	1.000
2039	0.19235	0.01258	268,839	33,495	22,277	21,064	1,213	11,218	7,435	3,782	1.688	0.138	0.016	0.000	1.000
2040	0.19235	0.01258	271,218	33,826	22,532	21,323	1,208	11,294	7,527	3,767	1.703	0.136	0.016	0.000	1.000
2261	0.19235	0.01258	4,488,039	552,462	372,484	354,939	17,545	179,979	125,292	54,687	28.176	0.000	0.000	0.000	1.000
2262	0.19235	0.01258	4,545,634	559,552	377,264	359,494	17,770	182,289	126,900	55,388	28.537	0.000	0.000	0.000	1.000
Average	0.19589	0.01227	511,444	65,579	43,011	40,340	2,672	22,567	14,240	8,328	3.211	0.221	0.033	0.018	0.995
Ave '13-22	0.203	0.012	193,173	28,610	17,104	15,125	1,978	11,506	5,339	6,167	1.213	0.334	0.056	0.054	0.984
Ave '23-32	0.192	0.013	231,977	30,885	19,744	18,235	1,509	11,141	6,437	4,703	1.456	0.205	0.028	0.000	1.000
Ave '32-40	0.192	0.013	257,268	32,550	21,514	20,268	1,245	11,036	7,155	3,882	1.615	0.157	0.019	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*

Table 14. Projected percentiles of total catch , landings , discards and female spawning stock biomass in 2014-2016 with an fishing mortality rate equal to the Pstar based target F = 0.19235. Catches in 2013 are assumed to be equal to MAFMC ACL=24,709 mt (see Table 10).

	2014				2015				2016			
Percentile	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***	***Catch***	***Landings***	***Discards***	***Female SSB***
1	13,578	5,288	8,290	45,766	13,733	5,448	8,285	43,089	13,759	5,555	8,204	40,419
2	14,436	5,922	8,514	55,631	14,626	6,108	8,518	52,297	14,673	6,230	8,443	48,943
3	15,158	6,456	8,702	63,939	15,378	6,664	8,714	60,048	15,443	6,798	8,645	56,116
4	15,786	6,920	8,866	71,151	16,031	7,147	8,884	66,776	16,111	7,291	8,820	62,340
5	16,344	7,332	9,012	77,564	16,612	7,576	9,036	72,758	16,705	7,730	8,975	67,874
10	18,521	8,942	9,580	102,578	18,876	9,250	9,627	96,085	19,021	9,439	9,582	89,447
15	20,148	10,144	10,004	121,260	20,567	10,499	10,068	113,504	20,750	10,715	10,034	105,555
20	21,497	11,141	10,356	136,753	21,970	11,536	10,434	127,949	22,184	11,774	10,410	118,911
25	22,682	12,017	10,665	150,367	23,202	12,447	10,755	140,641	23,443	12,704	10,740	130,646
30	23,764	12,816	10,947	162,789	24,326	13,278	11,049	152,222	24,593	13,552	11,041	141,352
35	24,776	13,564	11,211	174,411	25,378	14,055	11,323	163,056	25,668	14,346	11,322	151,367
40	25,737	14,275	11,462	185,451	26,378	14,794	11,584	173,349	26,689	15,100	11,590	160,883
45	26,676	14,968	11,707	196,227	27,353	15,515	11,838	183,394	27,686	15,836	11,851	170,169
50	27,596	15,649	11,947	206,794	28,310	16,222	12,088	193,245	28,664	16,557	12,107	179,277
55	28,520	16,331	12,188	217,404	29,270	16,931	12,339	203,135	29,645	17,282	12,364	188,419
60	29,458	17,025	12,433	228,184	30,245	17,652	12,593	213,183	30,642	18,018	12,625	197,707
65	30,425	17,739	12,685	239,279	31,250	18,394	12,855	223,526	31,669	18,775	12,893	207,267
70	31,434	18,486	12,949	250,872	32,299	19,170	13,129	234,333	32,741	19,567	13,174	217,258
80	33,705	20,164	13,541	276,951	34,659	20,915	13,745	258,642	35,153	21,348	13,806	239,728
95	38,872	23,983	14,889	336,278	40,029	24,883	15,146	313,943	40,642	25,399	15,243	290,848
96	39,435	24,399	15,036	342,740	40,614	25,316	15,299	319,966	41,239	25,840	15,399	296,416
97	40,065	24,865	15,200	349,972	41,269	25,800	15,469	326,709	41,909	26,334	15,574	302,649
98	40,797	25,406	15,391	358,379	42,030	26,362	15,668	334,544	42,686	26,908	15,778	309,891
99	41,663	26,046	15,617	368,321	42,930	27,027	15,903	343,812	43,606	27,587	16,019	318,459

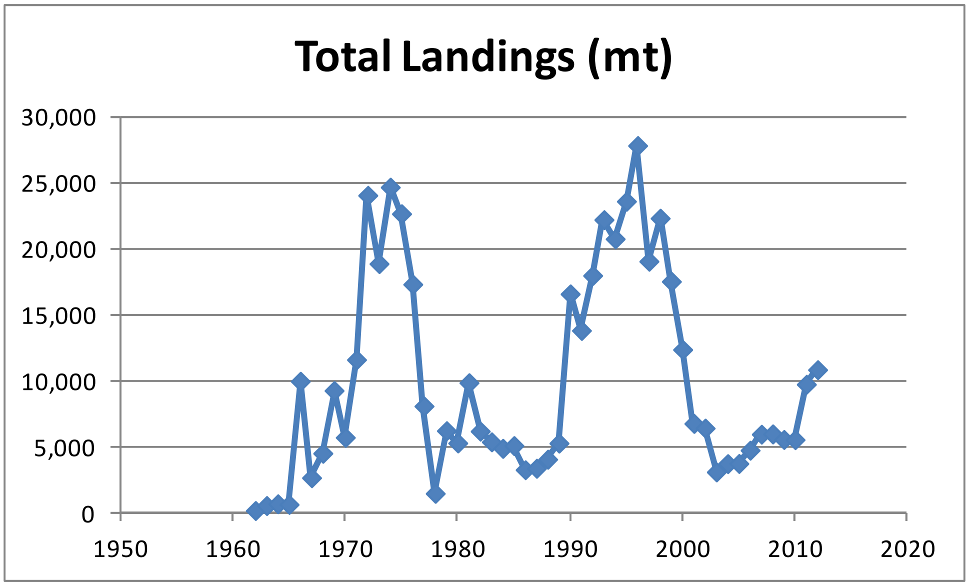
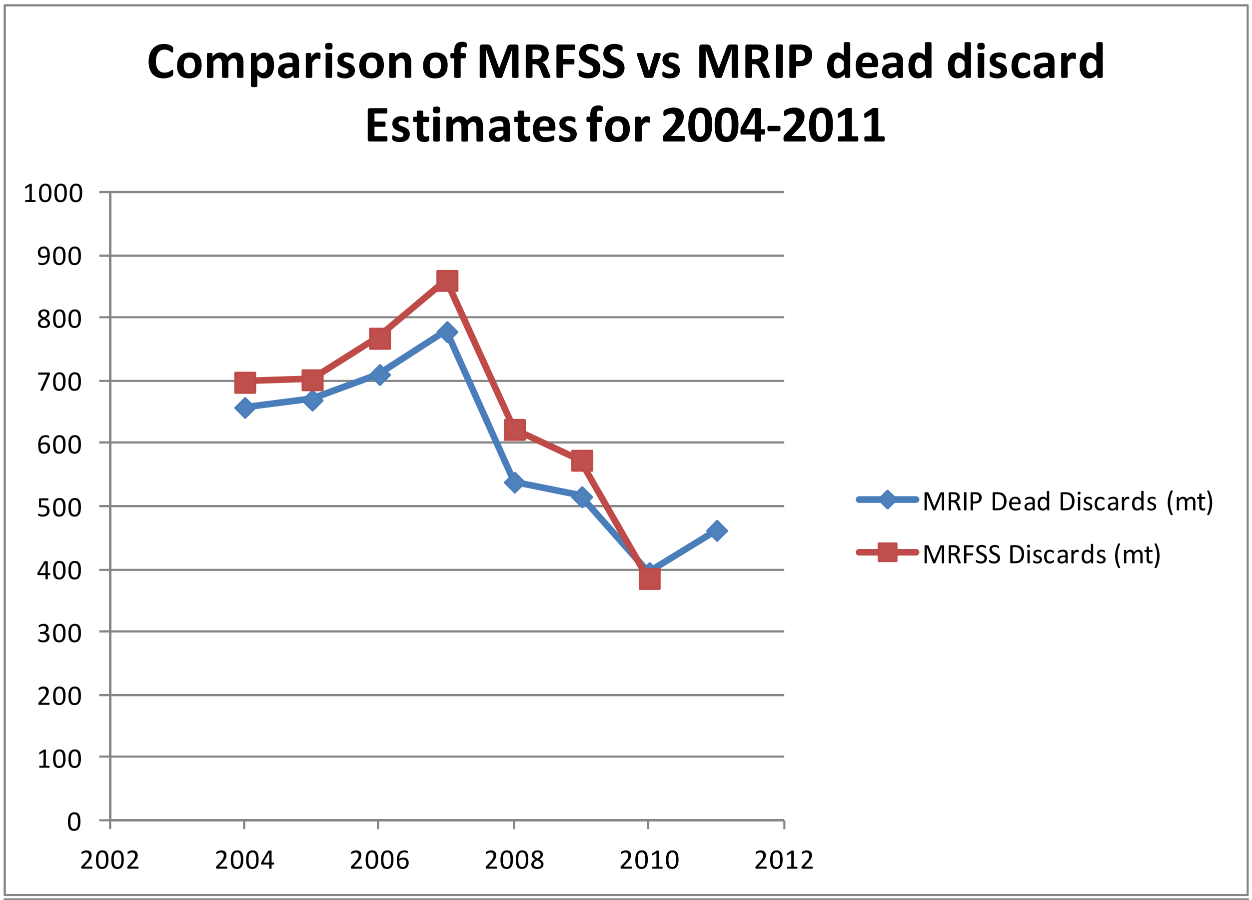


Figure 1. Estimated total landings (mt, live) of spiny dogfish in NAFO Areas 2 to 6, 1962-2012.



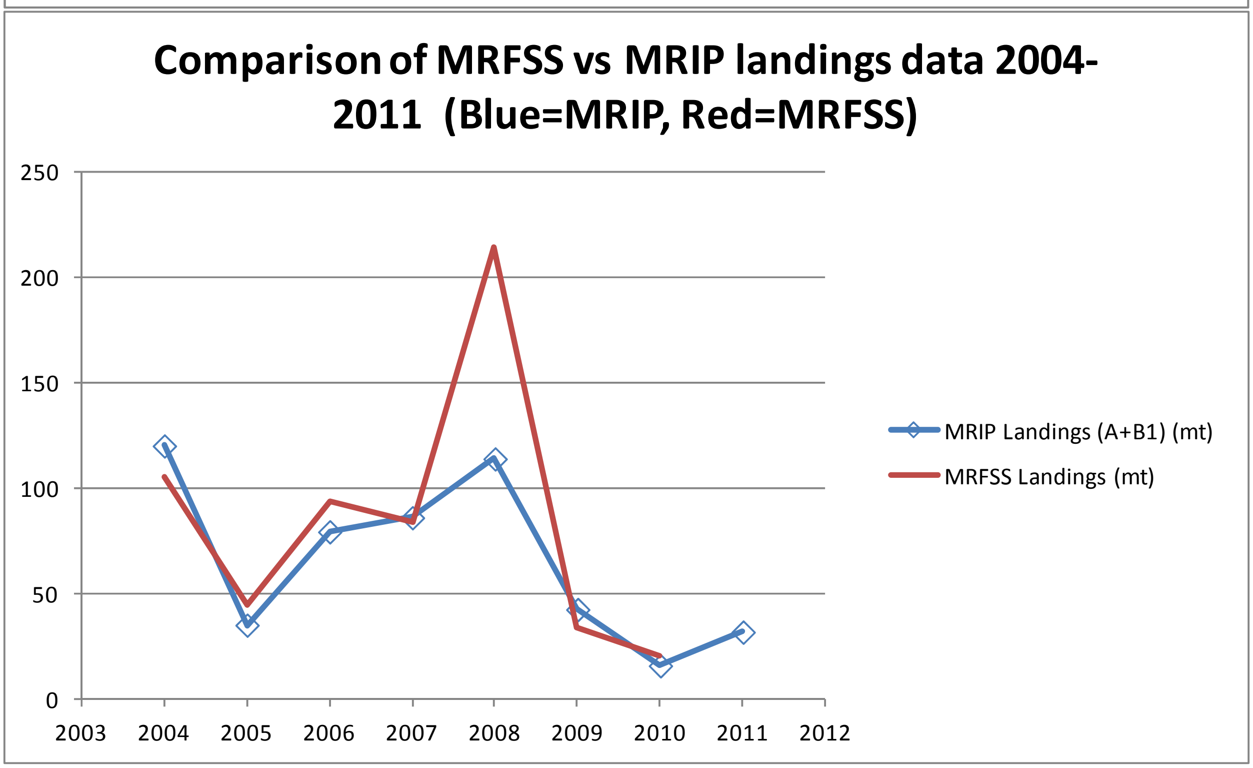


Figure 2. Comparison of MRFSS and MRIP estimates of total recreational landings and dead discards, 2004-2011.

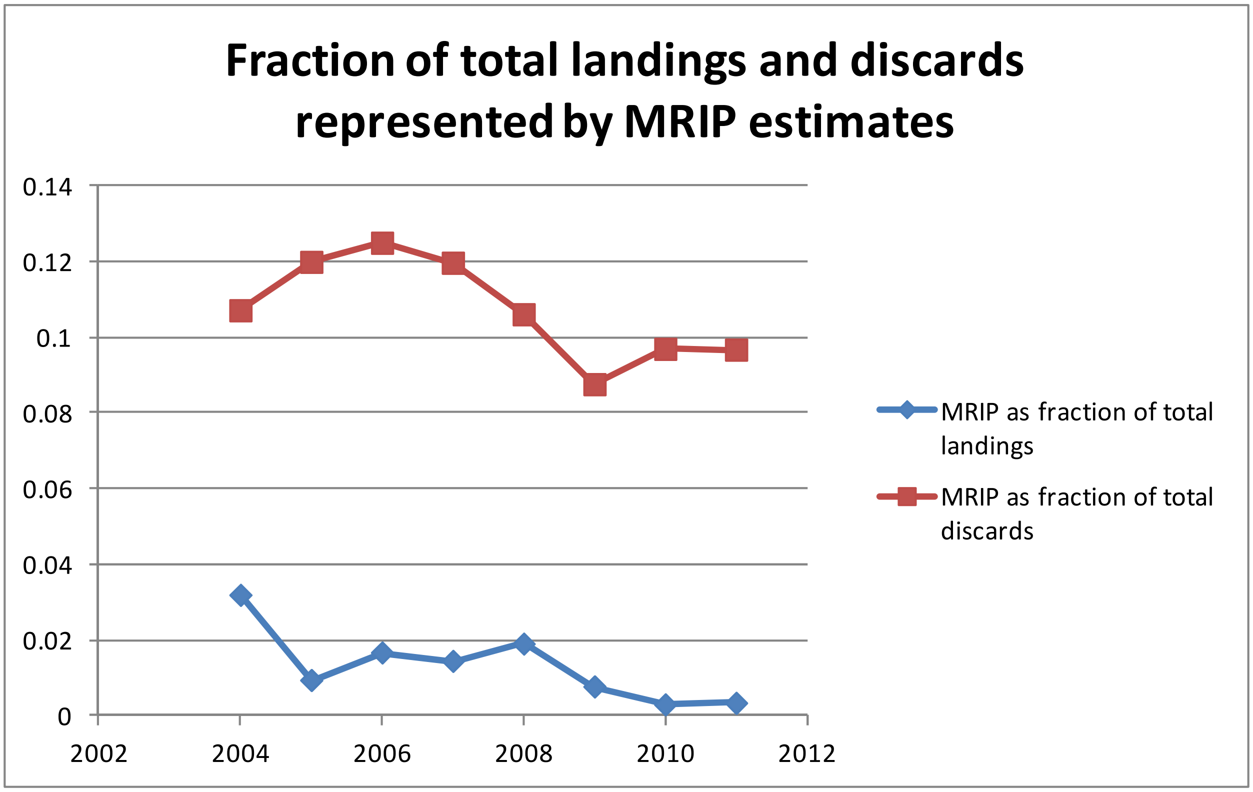


Figure 3. Estimated fraction of landings and discards in recreational fisheries relative to total landings and total discards respectively.

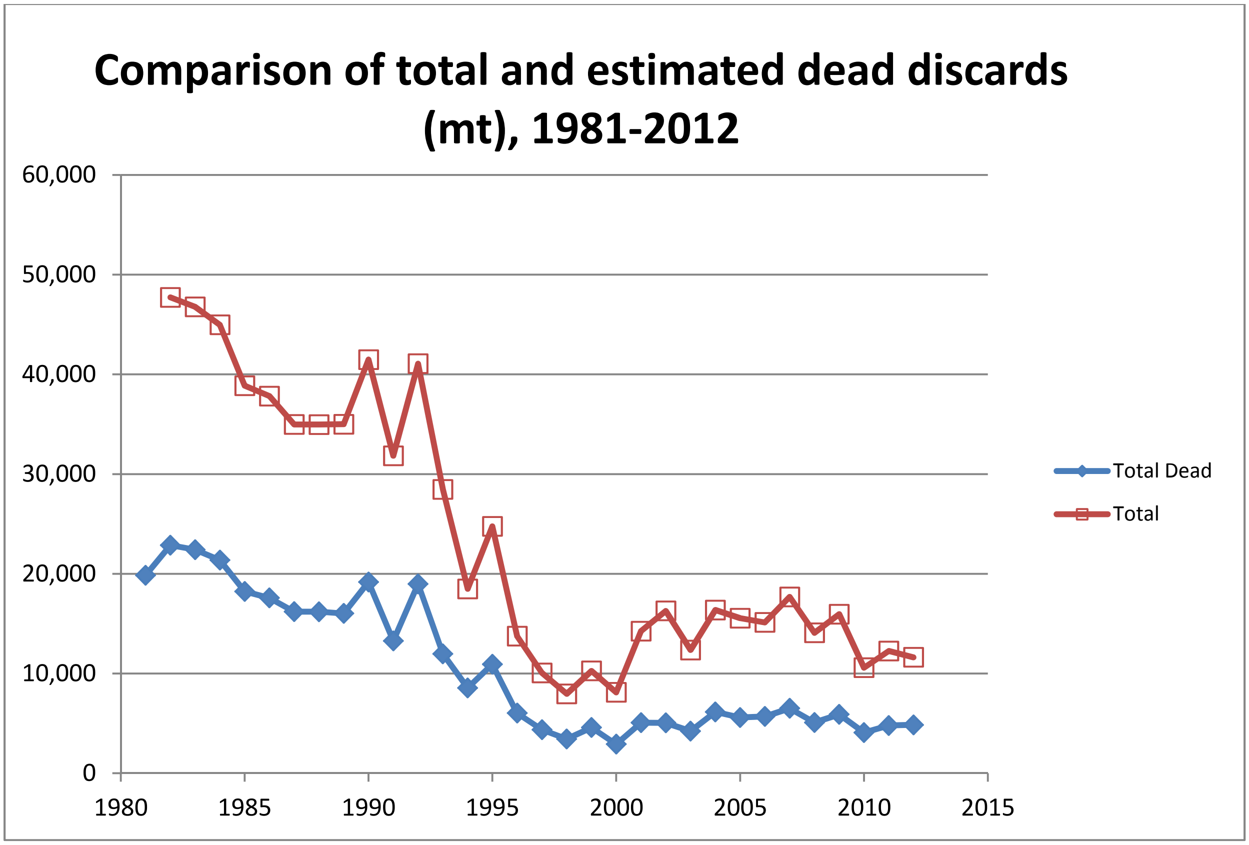


Figure 4. Estimated total and total dead discards in US, 1981-2012. Estimates for 1981 to 1989 are hindcast estimates rather than direct observations.

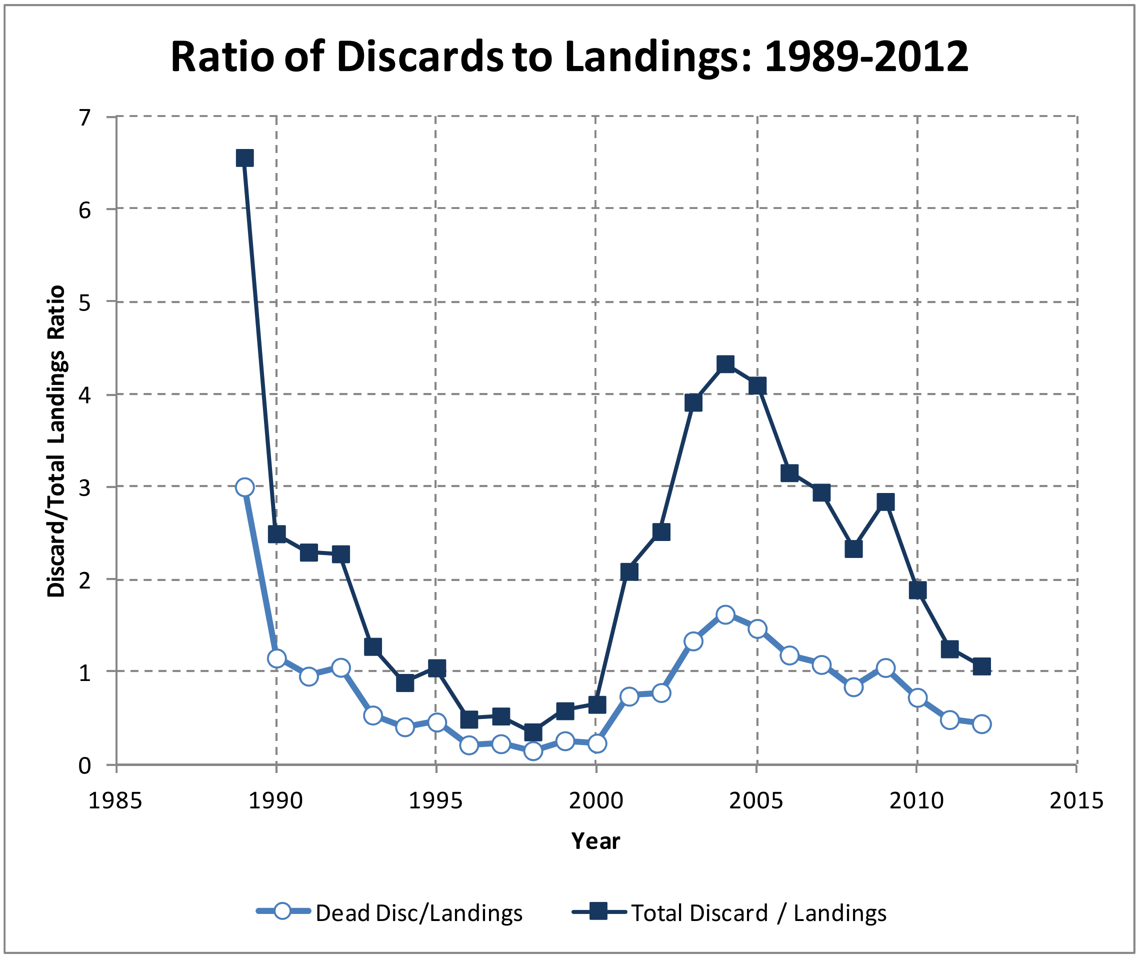
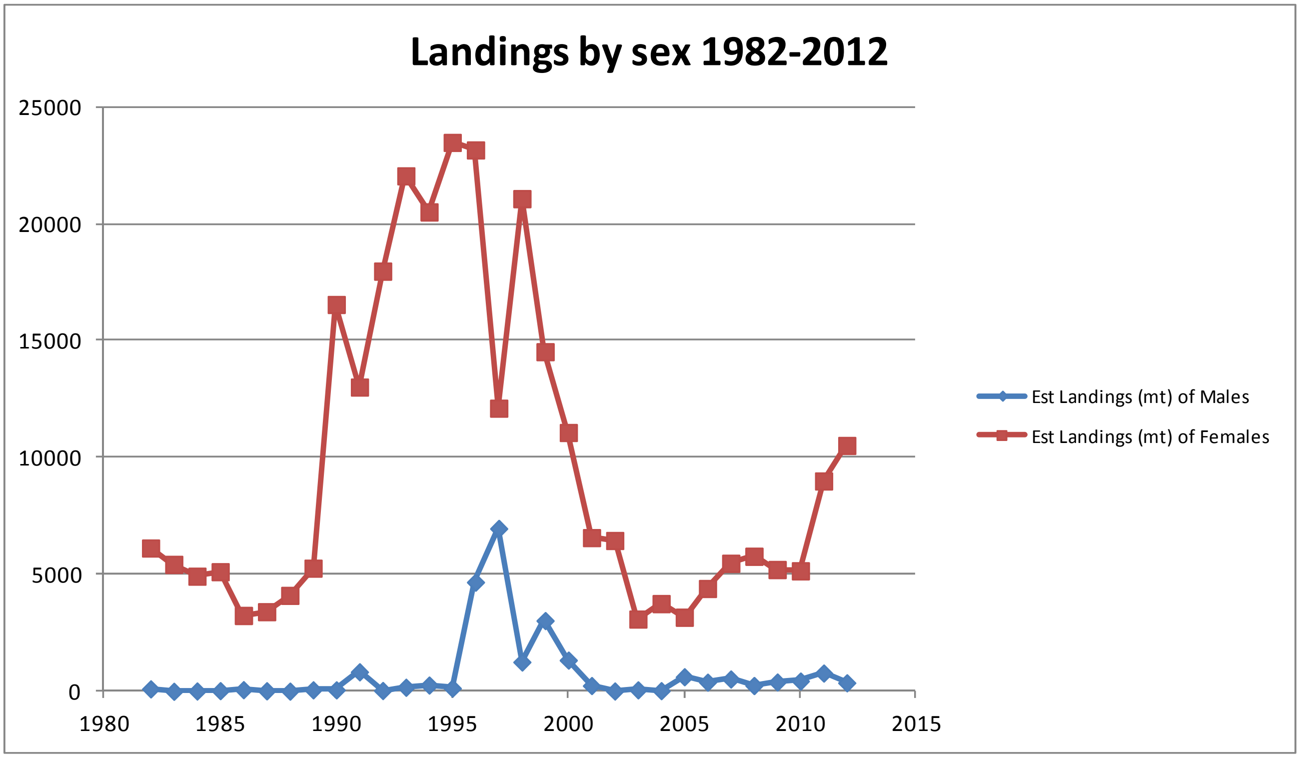


Figure 5. Trends in the ratio of total discards to landings and total dead discards to landings for spiny dogfish, 1989-2012.



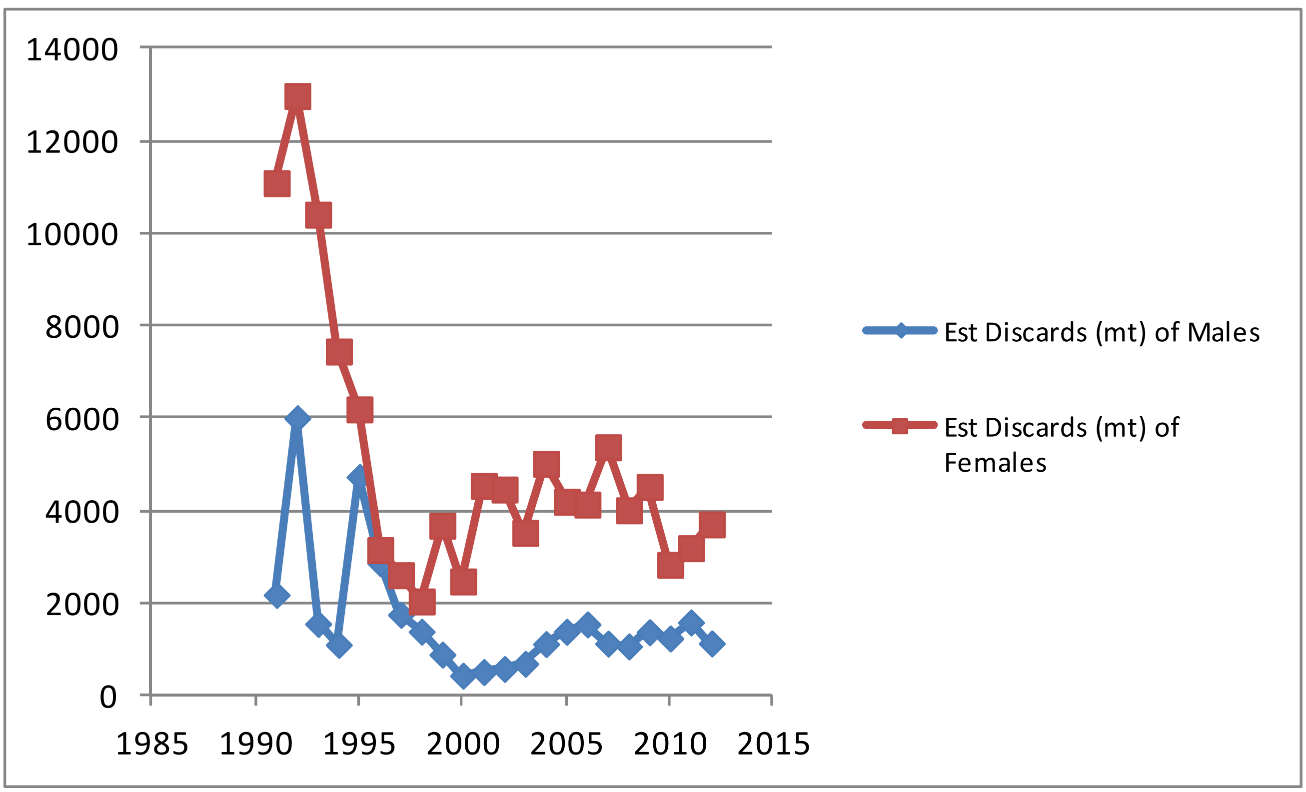


Figure 6. Estimated total landings(top) and total dead discards (bottom) by sex, 1991-2012.

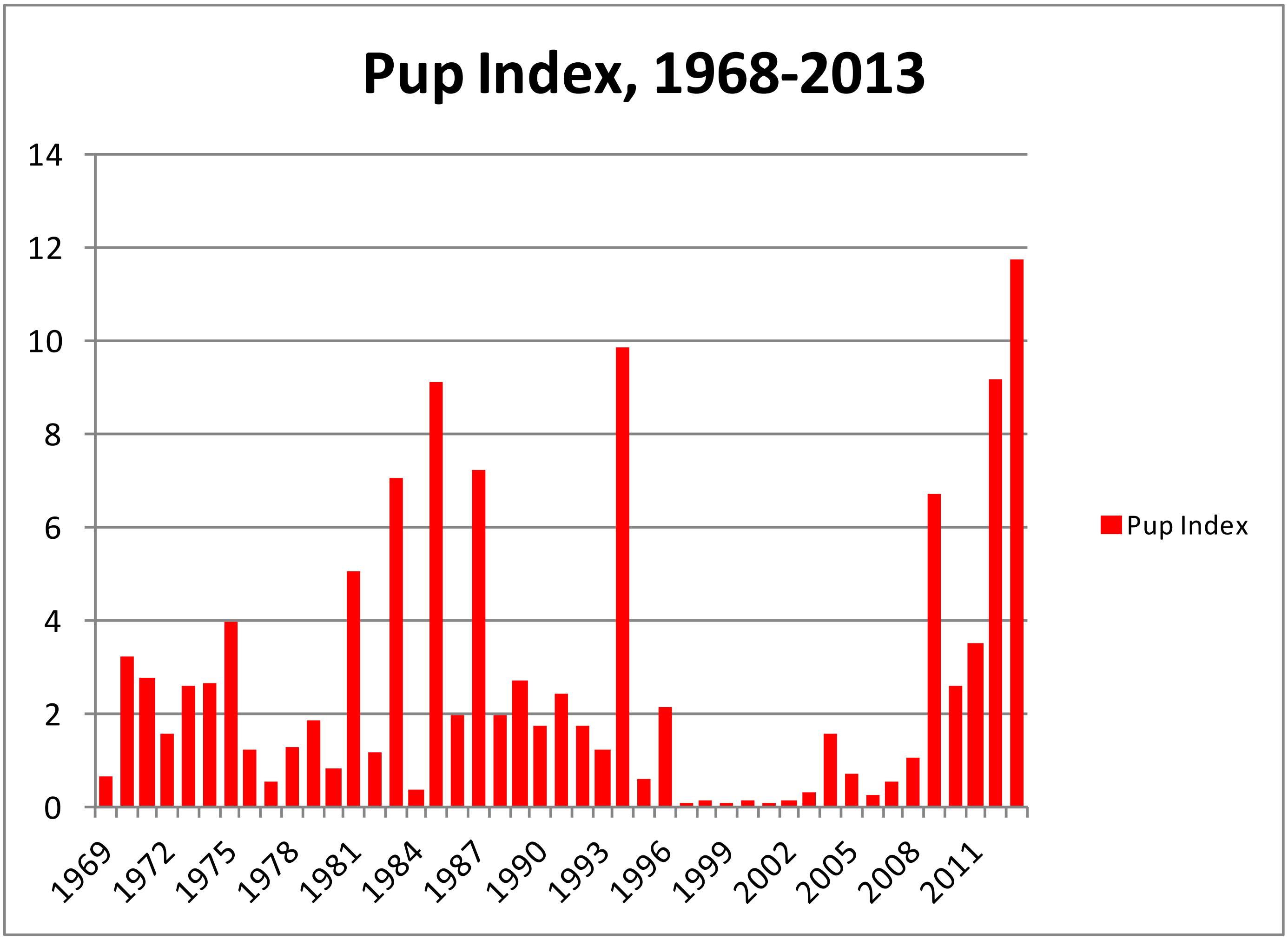


Figure 7. Estimated swept area biomass (mt) of total pups (spiny dogfish<36 cm) captured in the NEFSC spring bottom trawl survey, 1968-2013.

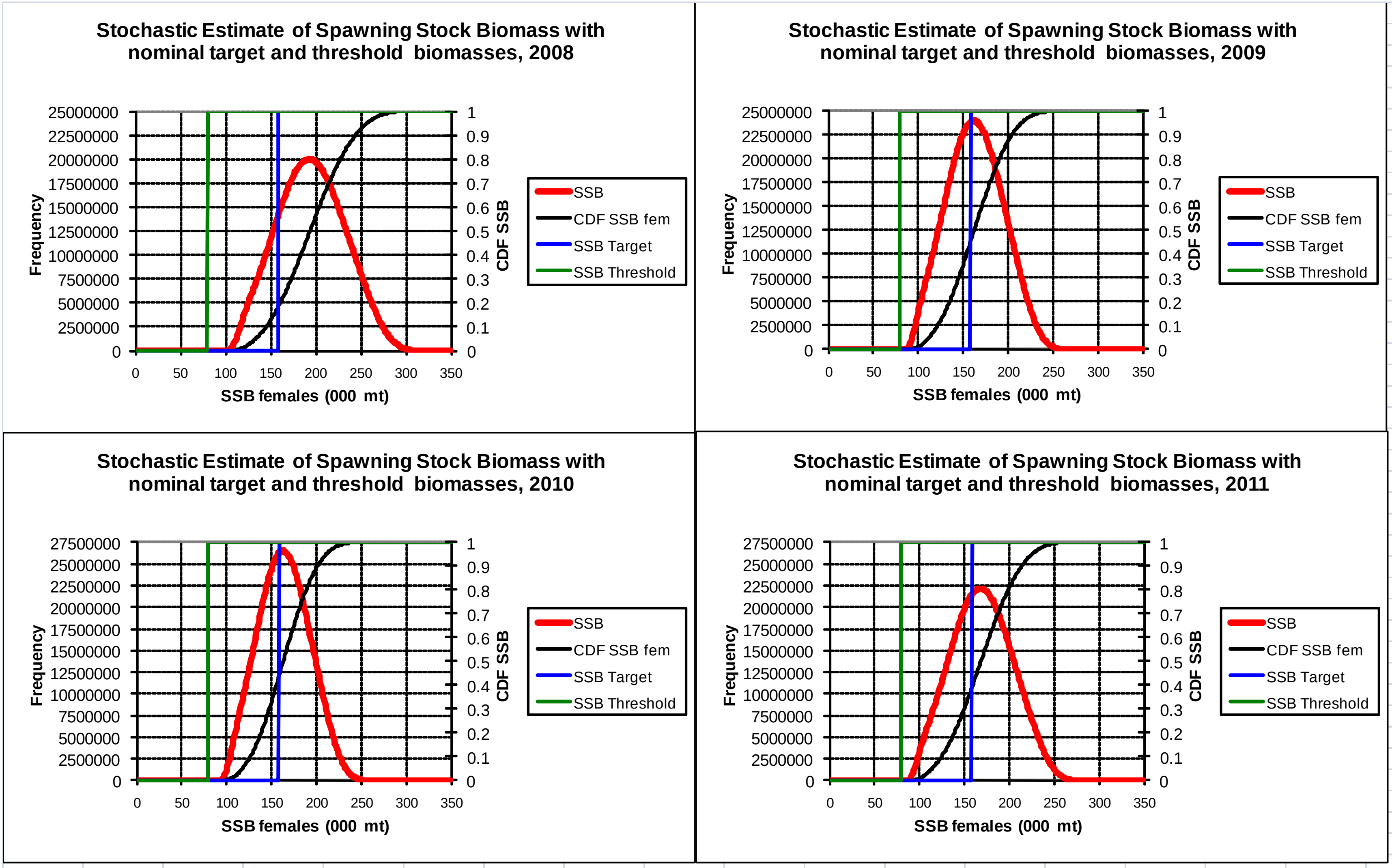


Figure 8a. Stochastic estimates of female spiny dogfish spawning stock biomass , 2008 to 2011, and comparison with target and threshold biomass reference points.   Year refers to terminal year of 3 point moving average of swept area estimate.

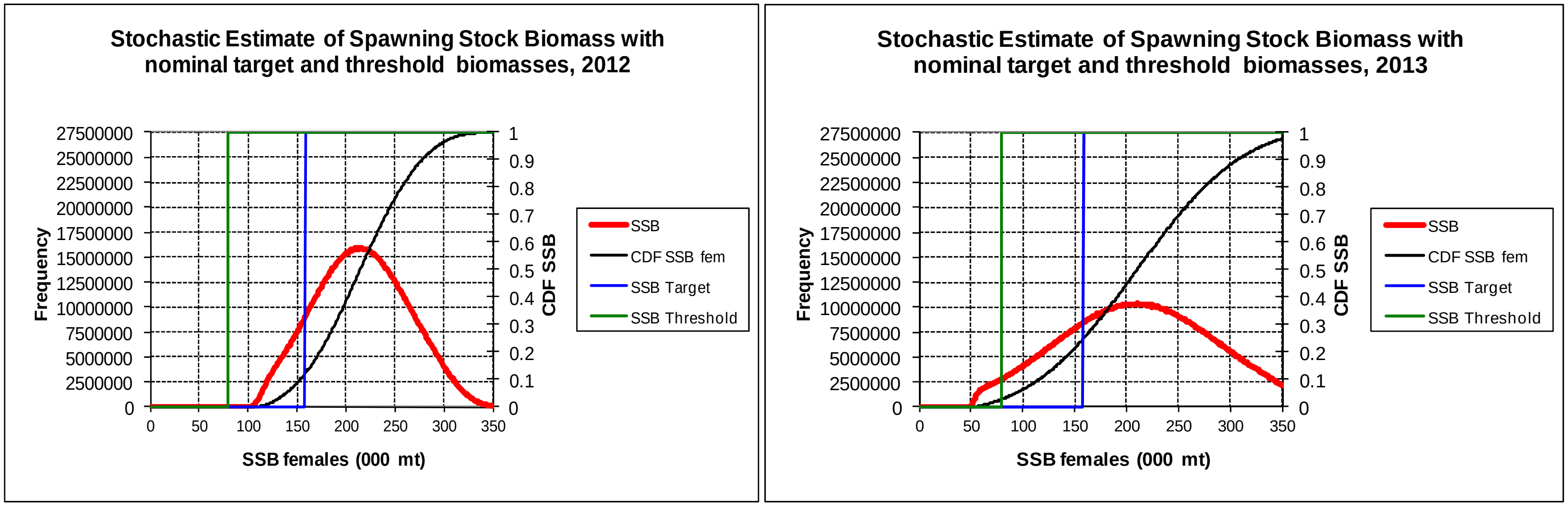


Figure 8b. Stochastic estimates of female spiny dogfish spawning stock biomass , 2012 and 2013, and comparison with target and threshold biomass reference points. Year refers to terminal year of 3 point moving average of swept area estimate.

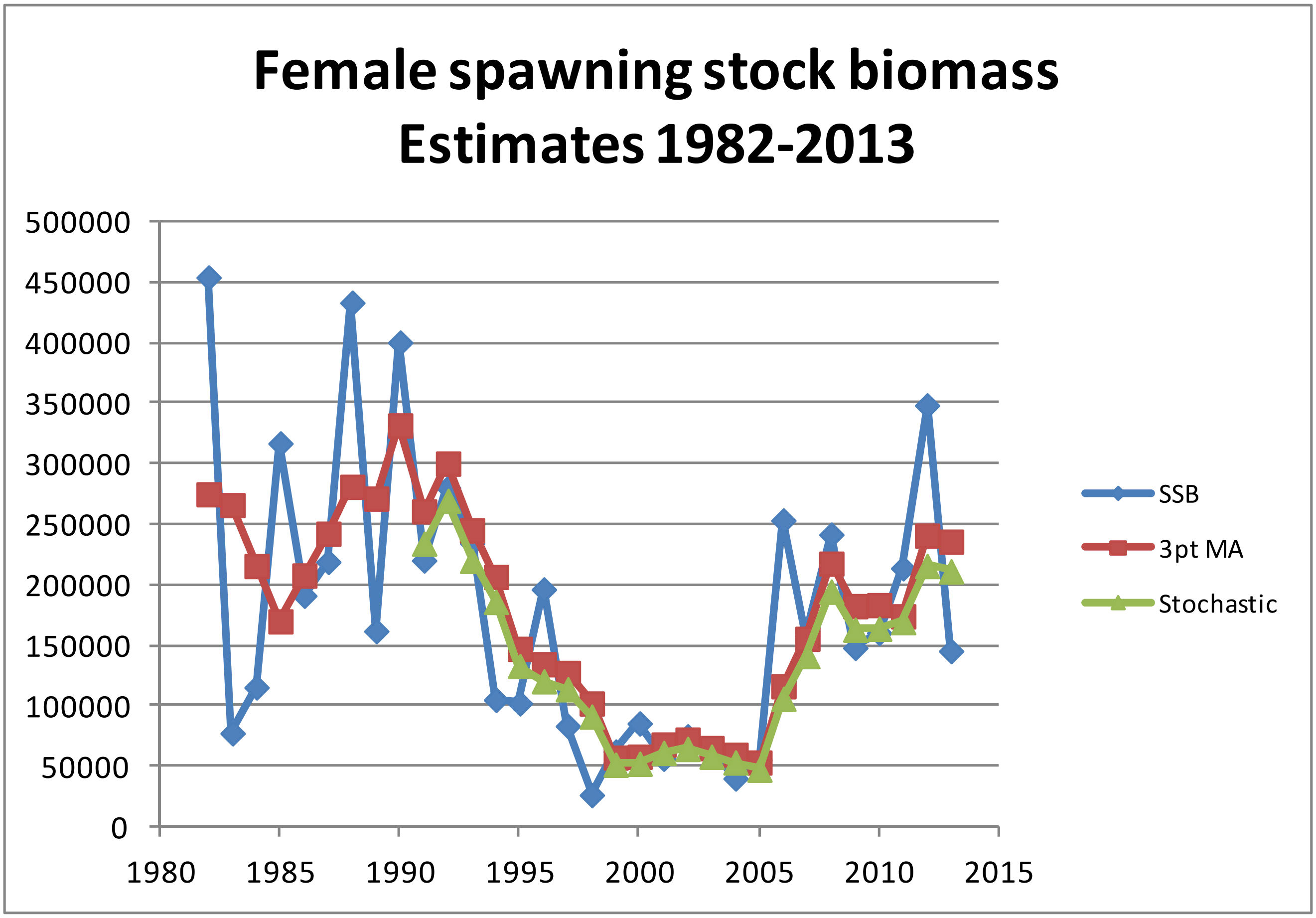


Figure 9. Comparison of alterative swept area estimates of female spawning stock biomass, 1982-2013. Stochastic SSB estimates are available for 1991 to 2013. Year refers to the terminal year in a 3 point moving average.

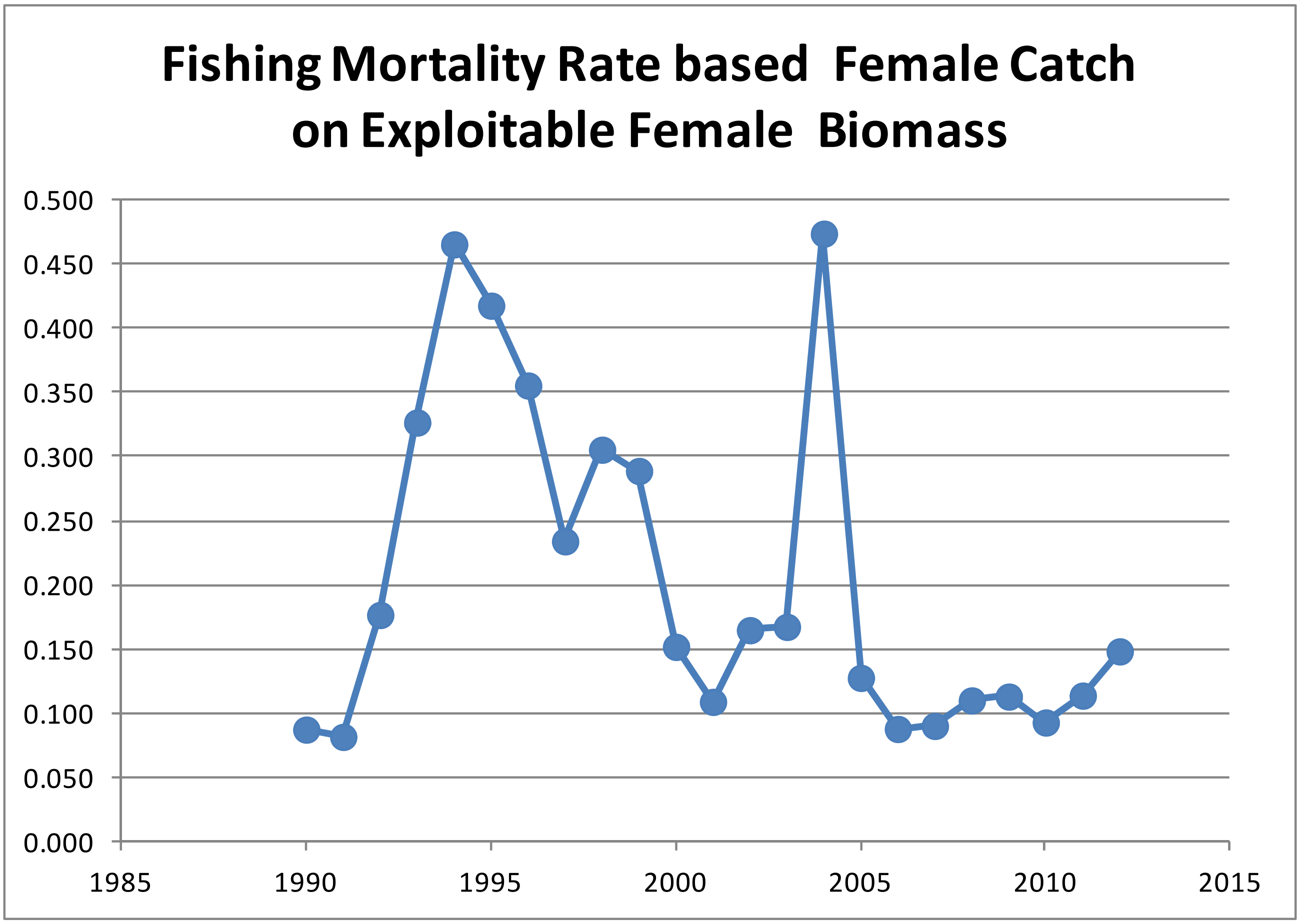


Figure 10. Estimated stochastic fishing mortality rates for female catch from the exploitable female stock biomass, 1990-2012.

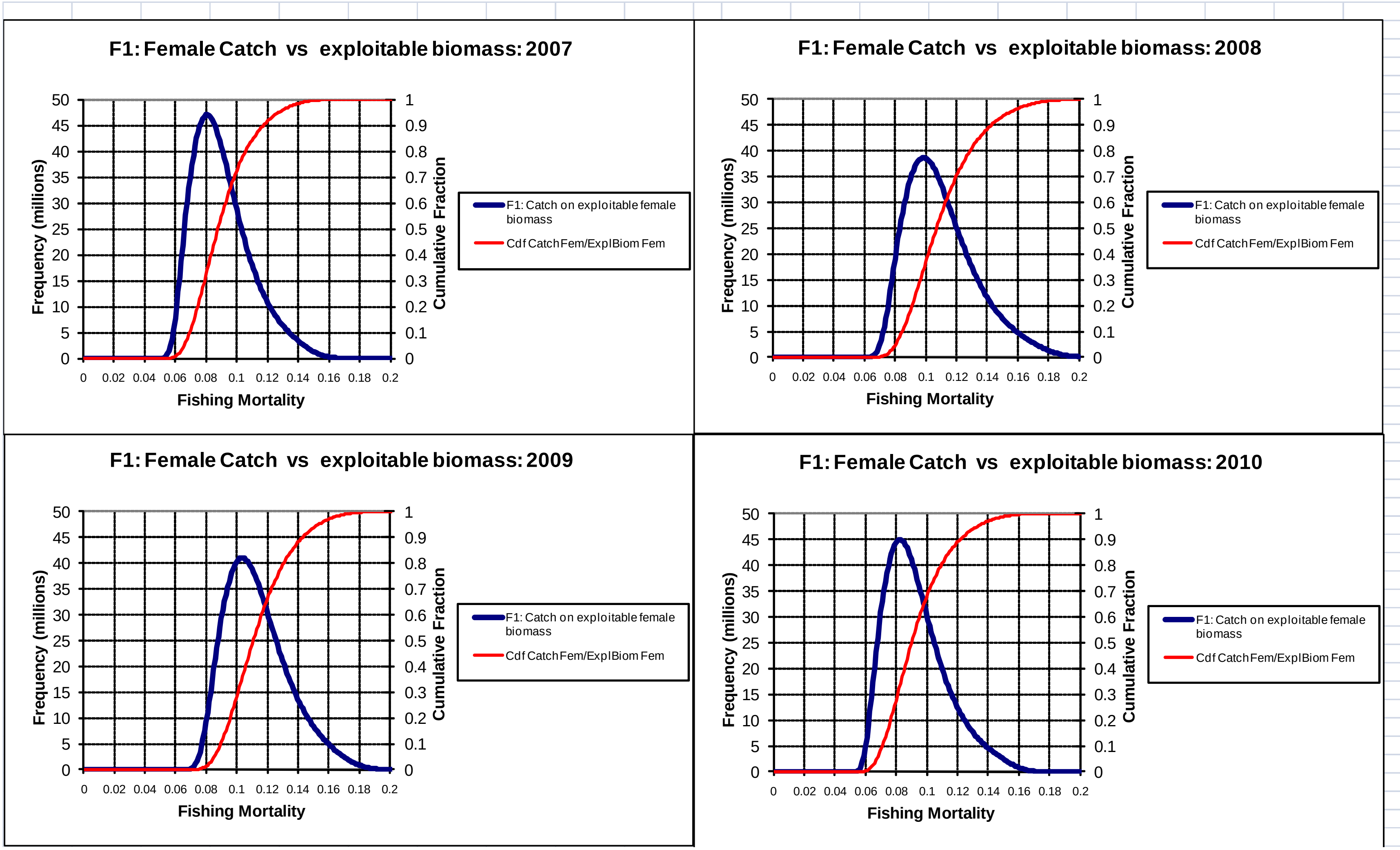
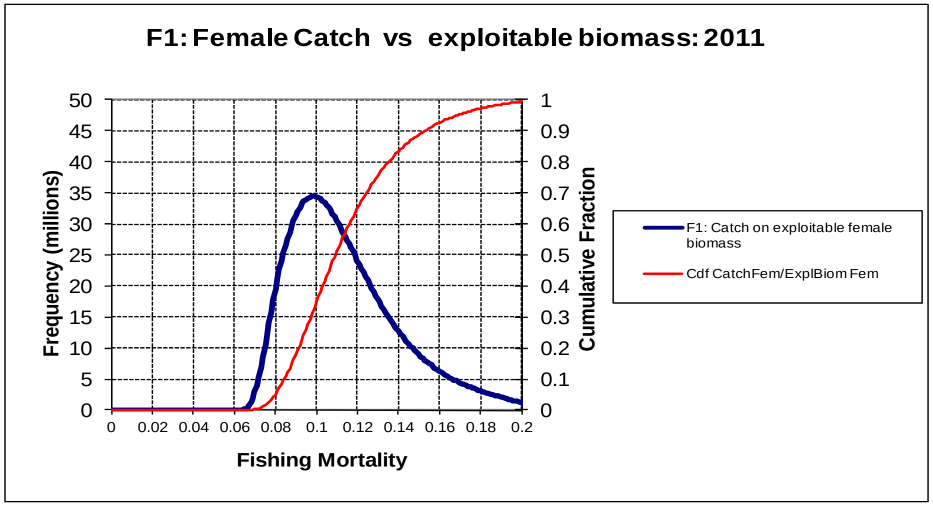


Figure 11a. Stochastic estimates of fishing mortality rates on female spiny dogfish, 2007 to 2010. Year refers to the calendar year in which catches occurred. Fishing mortality rates are based on the ratio for total catch in year to the 3 point moving average from year t-1 to t+1.



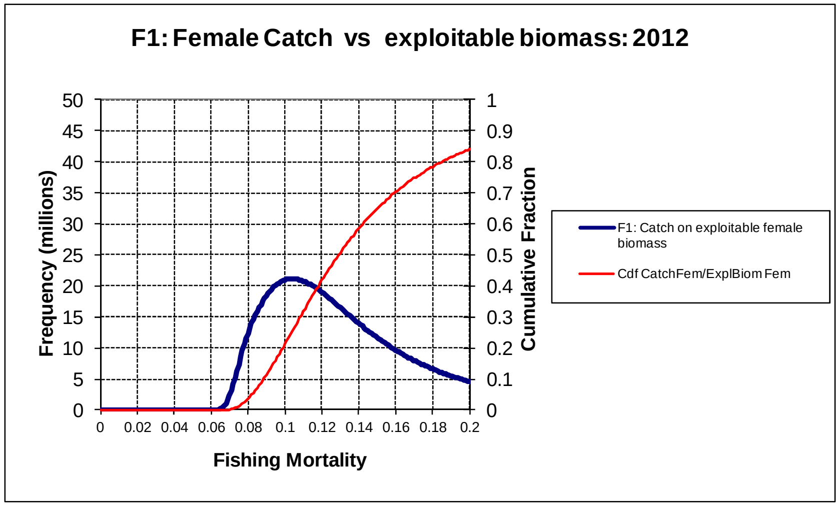
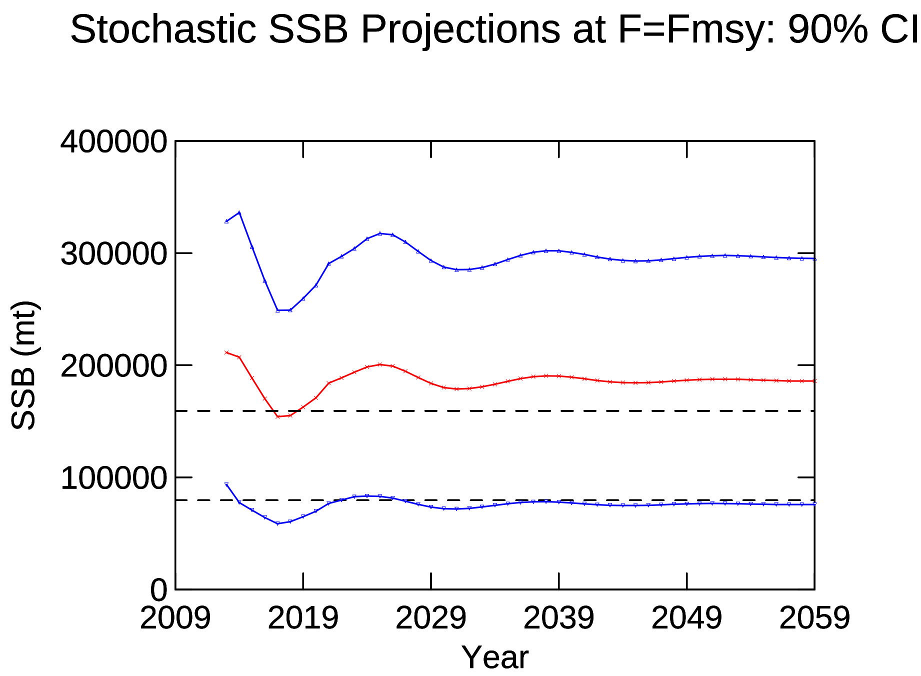


Figure 11b. Stochastic estimates of fishing mortality rates on female spiny dogfish, 2011 and 2012. Year refers to the calendar year in which catches occurred. Fishing mortality rates are based on the ratio for total catch in year to the 3 point moving average from year t-1 to t+1.



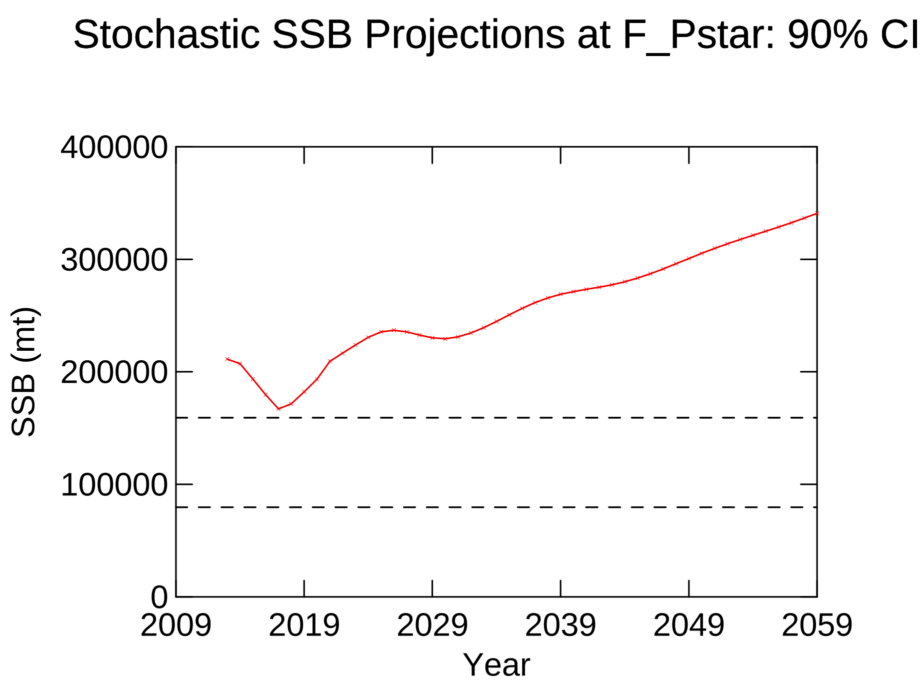


Figure 12. Stochastic projections of SSB at current fishing mortality MSY proxy (F=0.2439). Fmsy proxies are based on results in Rago(2011). Horizontal dashed lines represent biomass target and threshold values of 159,288 mt and 79,644 mt, respectively. Projections depict 5%, 50% and 95% iles for each 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=0.19235 is 1.01283 or about a 1.28% increase per year.

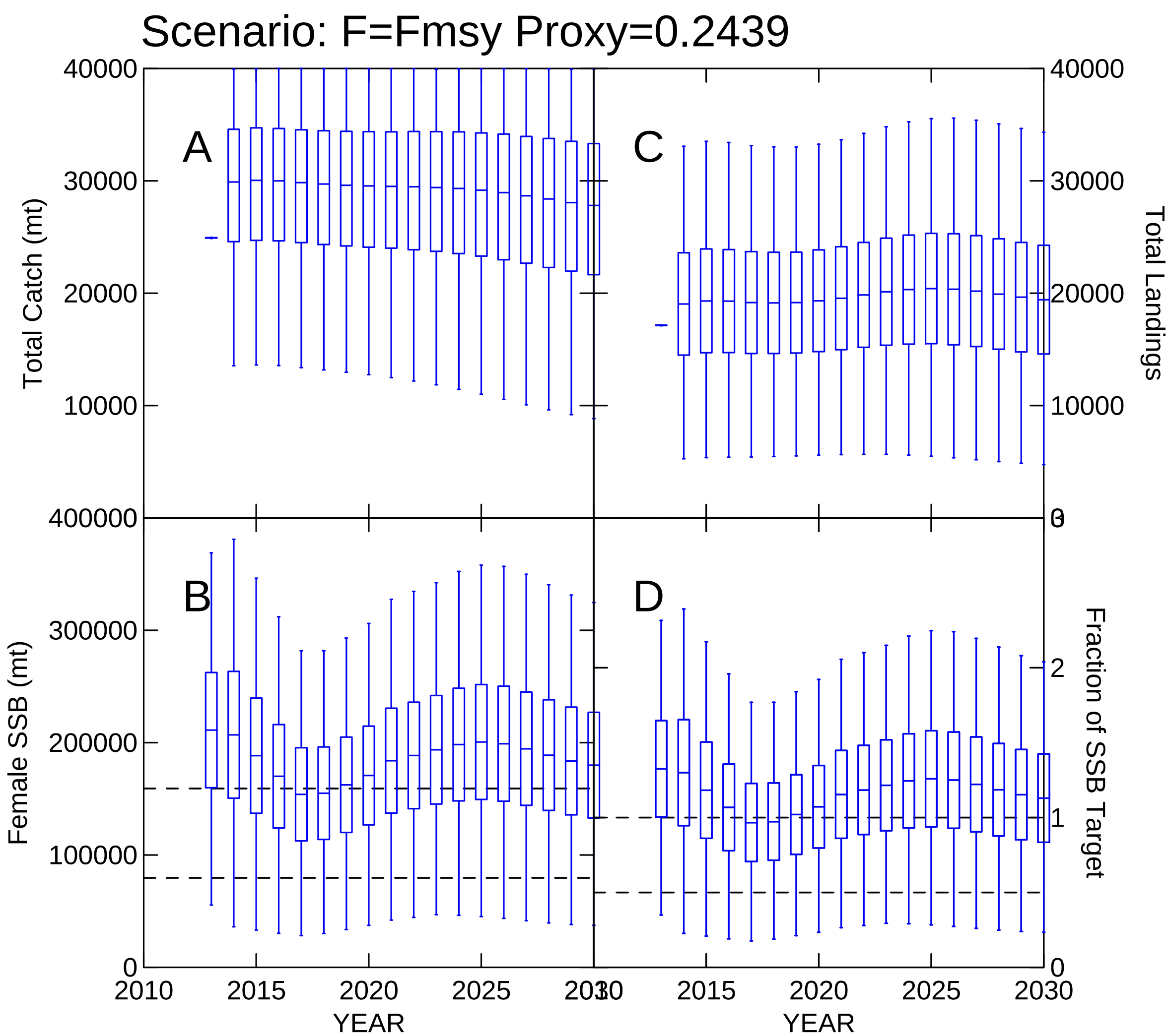


Figure 13a. Projection model estimates of (A) Total catch (mt), (B) Female spawning stock biomass (mt), (C) Total Landings(mt), and (D) fraction of target SSB, 2013-2030 for a harvest scenario based on a constant fishing mortality rate equal to the target F = 0.2439. Panel D reflects the probability of being overfished.

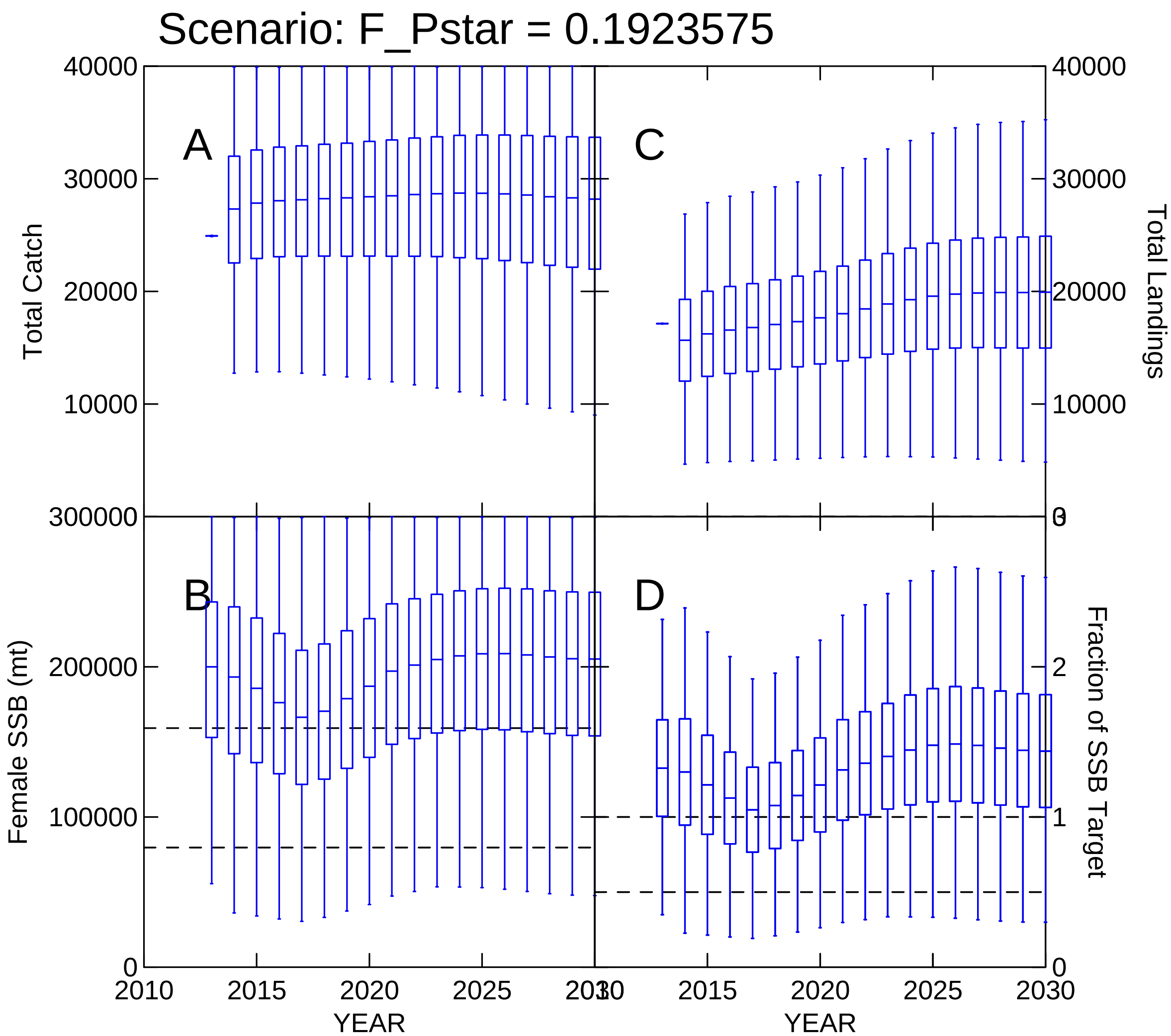
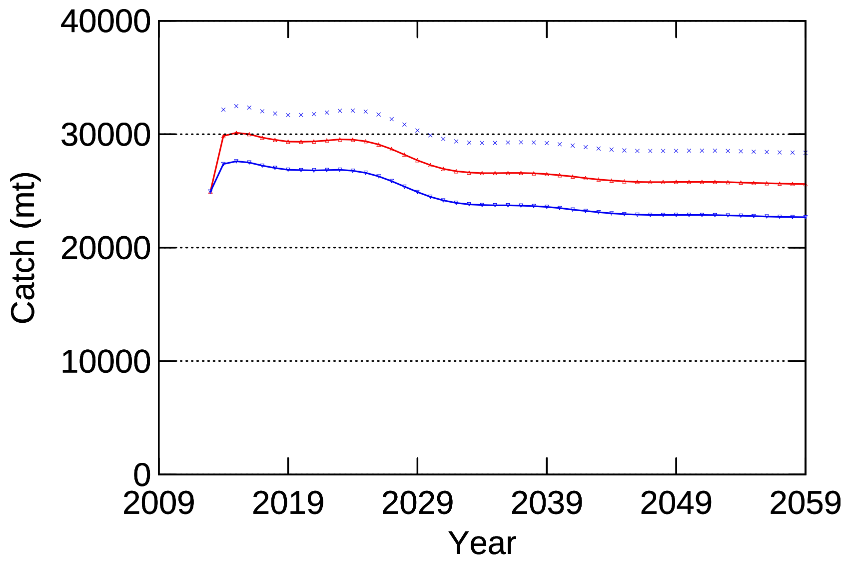


Figure 13b. Projection model estimates of (A) Total catch (mt), (B) Female spawning stock biomass (mt), (C) Total Landings(mt), and (D) fraction of target SSB, 2013-2030 for a harvest scenario based on a constant fishing mortality rate equal to the target F = 0.19235. Panel D reflects the probability of being overfished.

Stochastic Catch Projections at F=Fmsy: 50, 40, 30%iles



Stochastic Landings Projections at F=Fmsy: 50, 40, 30%iles

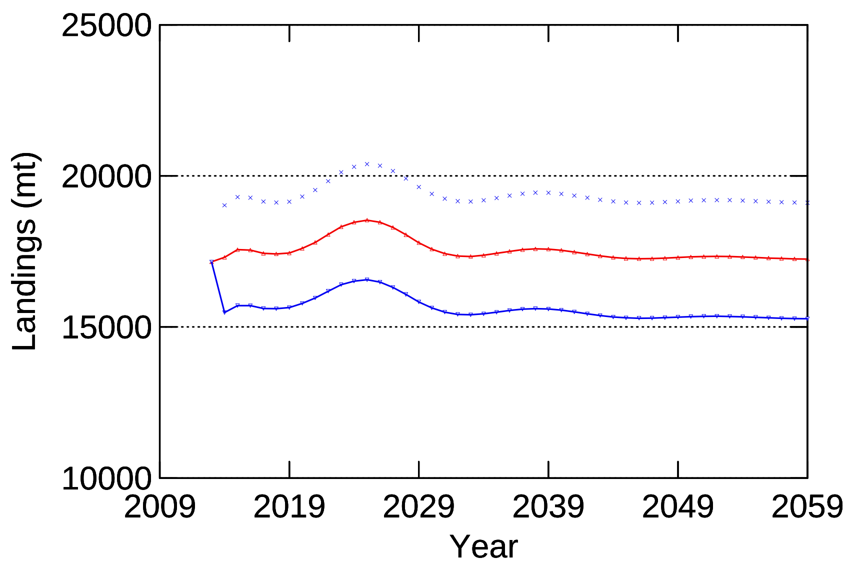


Figure 14. Long term catch and landings projections at percentiles of 50%, 40% and 30%, based on F= Fmsy proxy of 0.2439.

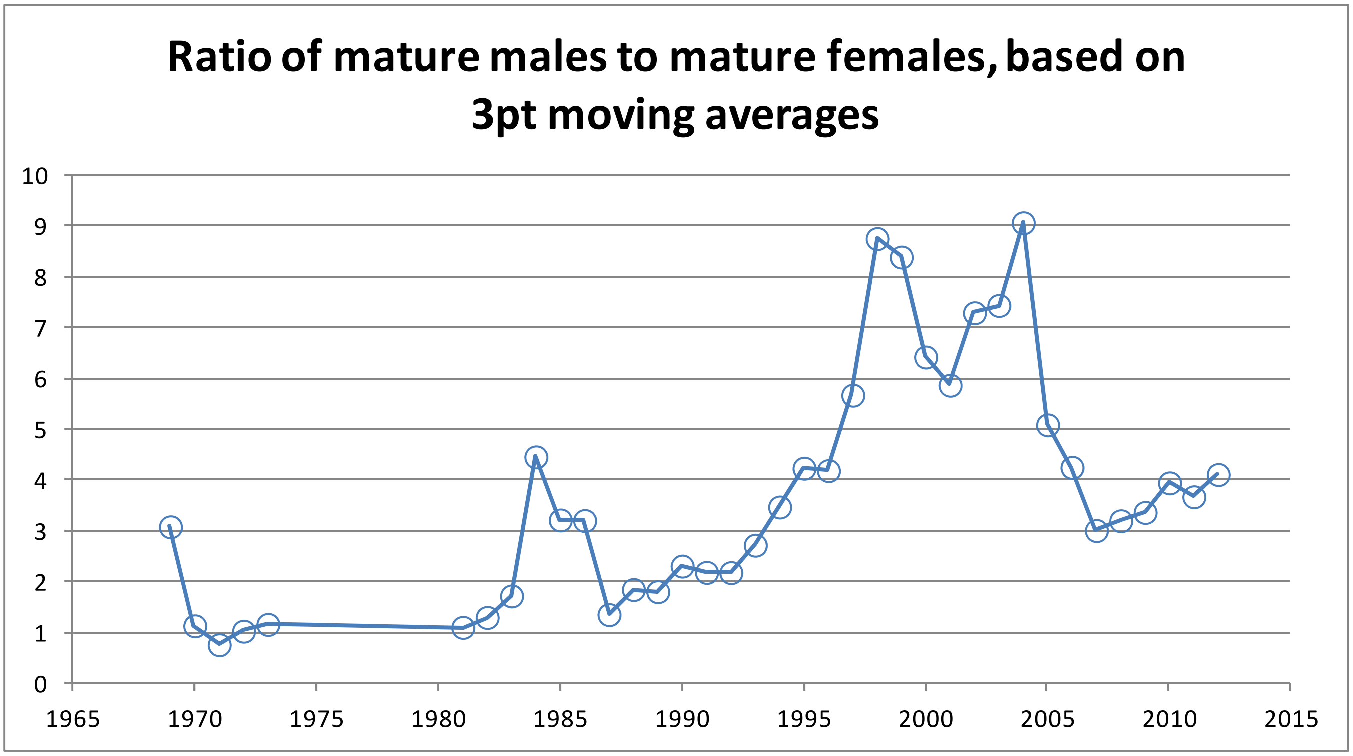


Figure 15. Ratio of mature males (>60 cm) to mature females (>80 cm) in NEFSC spring bottom trawl survey, 1968-1972, and 1980-2013. Year represents the mid-point of 3 year average. Spiny dogfish sex was not recorded in the NEFSC database for 1973 to 1979.

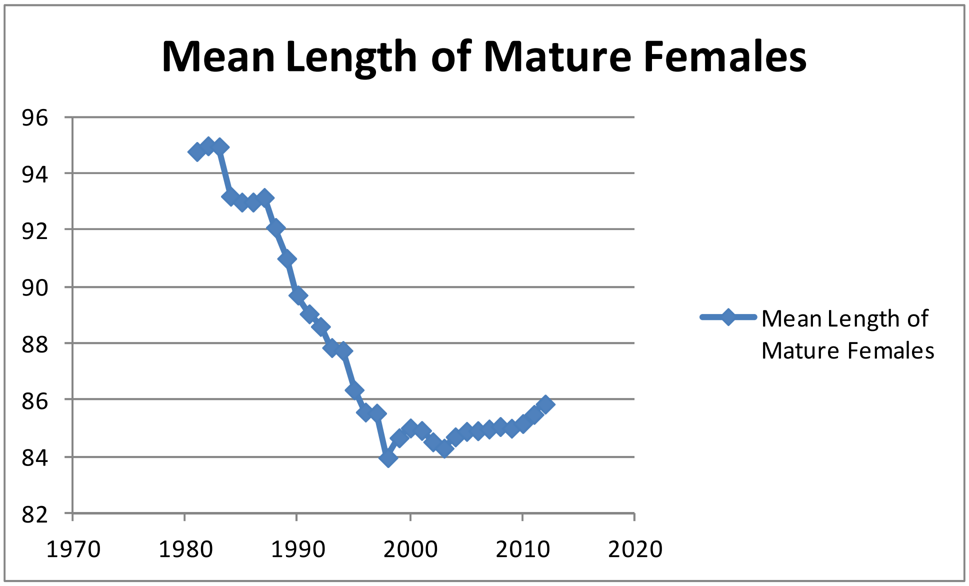


Figure 16. Mean Length of mature female spiny dogfish in NEFSC Spring bottom trawl survey, 1980-2013.

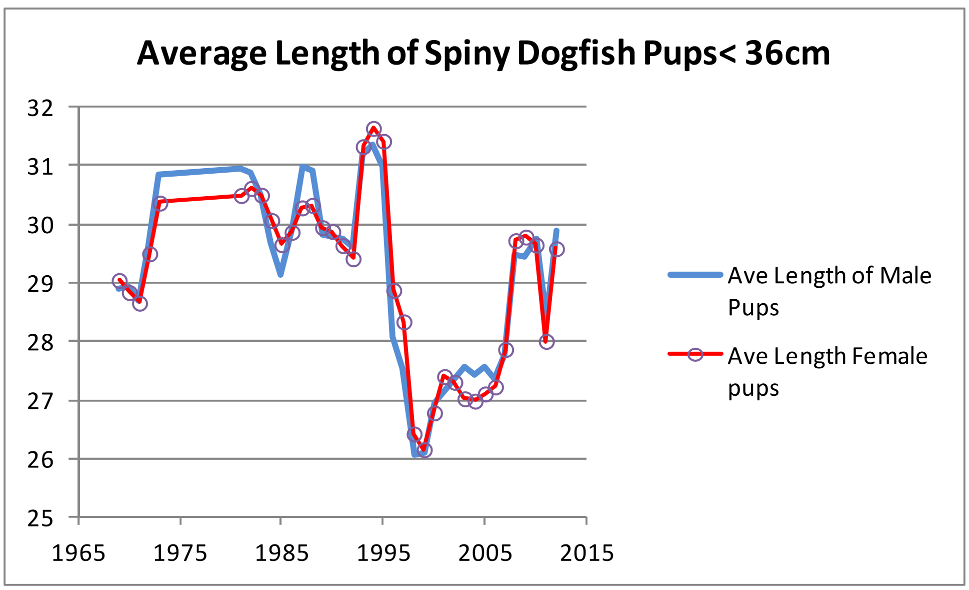


Figure 17. Three year moving average of mean length of male and female spiny dogfish pups (<36 cm) in spring bottom trawl survey 1968-2012. Sex data unavailable for 1973 to 1979.

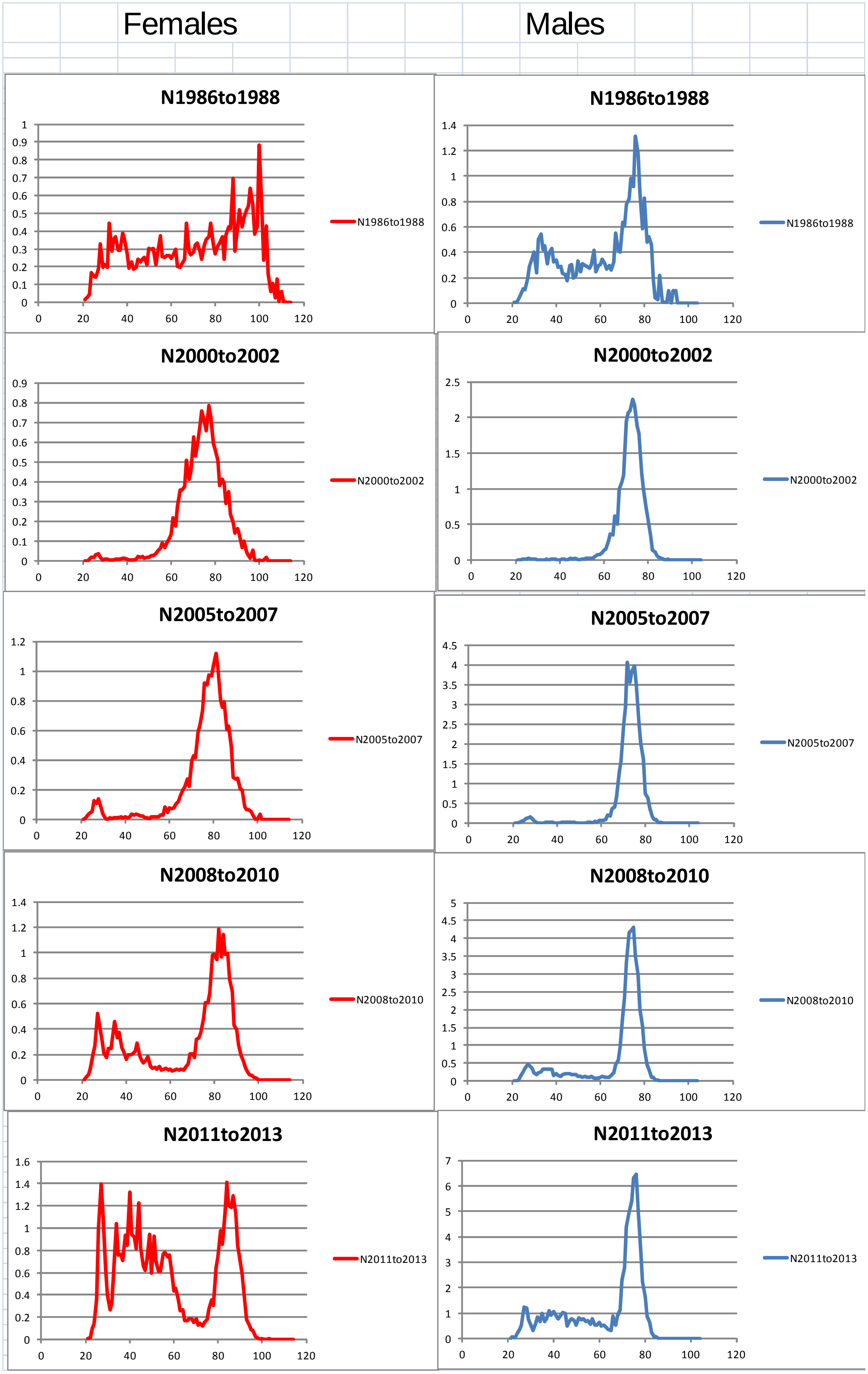


Figure 18. Composite size frequencies for female and male spiny dogfish in NEFSC spring bottom trawl survey.

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

Table 1. Summary of average and precision of female and male spiny dogfish numbers per tow in NEFSC spring bottom trawl survey, 1991-2013.

	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
2012	30.915	54.960	7.414	23.981	65.949	584.183	24.170	36.649
2013	47.612	330.553	18.181	38.186	82.130	718.985	26.814	32.648

Appendix 2. Table 2. Summary of total dead discards and standard errors for trawl, gill net and recreational discards for spiny dogfish by sex for 1990 to 2012.

	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
2011	1143.00	110.49	2296.0	222.0	294.00	15.27	591.00	30.67	154.000	22.440	309.000	45.070	781.0	8998.0
2012	859.00	77.80	2808.0	254.3	212.00	13.35	693.00	43.64	64.000	11.400	210.000	37.260	364.0	10516.5

Appendix 2.

Table 3. Summary of selectivity parameters used to estimate length-specific fishing mortality for spiny dogfish, 1991-2012.

	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	
2011	8.867	-0.099	89.6	32.99	-0.733	45.0	
2012	8.867	-0.099	89.6	32.99	-0.733	45.0	