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# Changes to Survey Indices and Implications for Assessment of Spiny Dogfish (*Squalus acanthias)* in the Northwest Atlantic

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Canada

**Foreword**

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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## ABSTRACT

Spiny Dogfish in NAFO areas 2–6 are considered to be one stock, with the greatest concentration of the population in US territorial waters. The main index of abundance used for assessment by the US and Canada derives from the National Marine Fisheries Service (NMFS) Spring trawl survey, where a new vessel with new monitoring protocols has been used in recent years.

This document provides information on the data that will be used to assess Spiny Dogfish in Part II of a new Assessment Framework. It includes summaries of commercial catch and survey abundance indices relative to the dogfish stock definition. Also, it provides a comprehensive evaluation of factors that may influence dogfish catchability and discusses their effects to the NMFS Spring survey and their implications for population assessment. Differences in catchability owing to survey vessel, sampling strata, dogfish life stage, sex, day/night patterns, and combinations thereof were explored. A calibration approach specific to life stage is proposed to relate catches from the new survey vessel to the older one, and this results in a more biologically realistic trend in the abundance index for recent years. This calibrated index of stratified abundance at length will be compared using a split uncalibrated series in the stage-based population dynamics model in Part II of the Framework. Other changes to the structure of the assessment model suggested by the data were the need to incorporate sex-specific sampling error for the survey catches and to make process error proportional to the realized level of sampling in influential strata for Spiny Dogfish along the outer slope.

# INTRODUCTION

Spiny Dogfish (*Squalus acanthias*) are small squaloid sharks found throughout coastal temperate oceans. The population in the Northwest Atlantic typically ranges from Newfoundland to Georgia and is most abundant along the continental shelf from Nova Scotia to Cape Hatteras (Nammack et al. 1985, NEFSC 2006). The population migrates seasonally, concentrating in mid-Atlantic waters to southern Georges Bank in the Winter and Spring, moving northward in the summer, and returning to Southern New England, Georges Bank and the Gulf of Maine in autumn (Fowler and Campana 2015). However, historical (DFO 2007), as well as more contemporary (Carlson et al. 2014), tagging suggests population structuring throughout their range, with resident and migratory components to the population. Movement between Canadian and US waters is not the predominant pattern. Throughout their distribution, dogfish tend to school by size and by sex as they approach maturity. In the Northwest Atlantic, dogfish occur in water temperatures from 0–12 °C (6–11 °C preferred) and depths of 0–350 m (50–200 m preferred). Reproductive potential for the population is low due to slow growth rates, late age-at-maturity, and a 22–24 month gestation period for females (Jensen et al. 1961, Nammack et al. 1985, Campana et al. 2009), making them vulnerable to exploitation. In Canada, Spiny Dogfish have been designated ‘Special Concern’ by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010).

Spiny Dogfish are considered to be a unit stock in NAFO areas 2–6 (Figure 1) with the majority of the population found in US waters. Originally, the US and Canadian components of the stock were assessed independently. In 2010, an attempt was made to model the entire Northwest Atlantic population in a joint Canada-US Transboundary Resources Assessment Committee (TRAC) meeting, but consensus on an assessment model was not reached (Rago and Sosebee 2010). Since that time, the US has elected to meet its domestic management requirements by proceeding with a US-only stock assessment. Canada has attempted to continue with the population-level assessment. The last DFO framework review and assessment of Northwest Atlantic Spiny Dogfish occurred in 2014, using data up to 2010 (Fowler and Campana 2015). The accepted model was a forward-projecting stage-based, spatially explicit population dynamics model with two time steps.

Efforts to incorporate more recent data into the framework model have not been successful, in that abundance estimates for dogfish became implausibly high (DFO 2016). Because the main index used to scale commercial catches to total abundance in the model is derived from the National Marine Fisheries Service (NMFS) Spring survey, changes to the survey index that influence dogfish catchability could explain this discrepancy.

The objectives of the Data Inputs component of the Northwest Atlantic Spiny Dogfish Framework Review are to: (1) describe the fishery-dependent and fishery-independent data sources from the US and Canada used to assess the population, (2) evaluate factors affecting dogfish catchability in the NMFS Spring survey and describe their implications for stock assessment, and (3) propose methods to standardize the abundance index from the NMFS Spring survey for input into a population-level assessment model. The assessment model will be developed for, and reviewed at, a separate meeting.

# FISHERY

Total landings of dogfish were comparatively small throughout 1922–1955 (Jensen et al. 1961), remaining below 100 mt in most years prior to 1956. The first significant exploitation of dogfish was a US government-subsidized World War II vitamin A fishery that was conducted primarily during 1940–1941. Industrial (or trash) fishing between the mid-1950s and mid-1960s represented the largest directed fishery conducted on dogfish at that time, and led to the highest bycatch levels of dogfish in the time series, but these declined due to market competition as the Peruvian anchovy fishery grew in the 1960s (DFO 2014). Commercial interest in dogfish expanded considerably with the arrival of foreign fishing fleets in the Northwest Atlantic, which caught appreciable numbers of dogfish between 1966 and 1977. Reported landings prior to extension of jurisdiction in 1977 were dominated by USSR (Russia) and other European countries, and they peaked at about 25,000 mt in 1975 (Figure 2). Since 1977, US commercial landings have accounted for most of the reported catch. A sharp intensification of the US commercial fishery began in 1990, peaking at more than 28,000 mt in 1996 (NEFSC 2006). Canadian landings were a relatively small proportion of the total catch until 2000, at which point the introduction of restrictive quotas in the US made Canadian landings a significant portion of the total (DFO 2014).

Canadian landings of Spiny Dogfish were unrestricted prior to 2002 and mostly occurred in commercial longline and gillnet fisheries for groundfish (Fowler and Campana 2015). The total allowable catch (TAC) from 2004 through 2013 was set at 2,500 mt. A 10,000 mt TAC was set for 2015 (approximately equivalent to US landings during 2013 and 2014), with no restrictions on discarding or by-catch of Spiny Dogfish in other fisheries (DFO 2016). Spiny Dogfish are primarily sold to European markets, which have a requirement for Ecological Certification of landings. The US directed fleet obtained Marine Stewardship Council (MSC) certification in 2012, but the Canadian fleet has yet to obtain MSC. Thus, landings since 2009 from Canadian fleets have never exceeded 200 mt; making the Canadian TAC non-restrictive (DFO 2016).

## DATA INPUTS

This document considers the data sources that were incorporated in the most recent Canadian framework assessment for Spiny Dogfish (Fowler and Campana 2015). These include abundance indices and size sampling from the Fisheries and Oceans Canada (DFO) Summer survey and the NMFS Spring survey, as well as landings data and total discard estimates from commercial fleets in both countries. The US commercial catch data were provided from NEFSC in advance of this assessment.

The commercial catches, landings and discards of Spiny Dogfish, partitioned by season (November to April; May to October) and fishery, are processed into numbers of fishery removals by sex and maturity stage for input into the current framework assessment model (Fowler and Campana 2015). Similarly, sex-specific maturity-at-length proportions are applied to the stratified abundance at length from the surveys to produce abundance indices by sex and maturity stage. The maturity stages are determined by dogfish length, where stage 1 represents juveniles and stage 2 represents adults. Further details on the delineation of maturity stage are given in Fowler and Campana (2015).

The biological characteristics of the US fishery (to determine catch at length) have been well sampled since 1989, while Canadian fisheries were adequately sampled from 1998 until 2006, when the directed fishery declined. To estimate the commercial catch composition for poorly sampled years, we used nearest-neighbour length-frequencies of well-sampled years, partitioned by individual fisheries, if possible. This becomes pure assumption where little or no sampling was conducted over long contiguous periods of time, such as 1922–1982. The survey catches in both countries have been well-sampled with respect to the biological characteristics of dogfish since 1970 for the Summer survey and since 1990 for the Spring survey. We see no individual fish sampling in the Spring survey until 1990, but consider that more data might exist than the database provides (e.g., the Nammack et al. 1985) life-history sampling came primarily from the Spring survey during 1980–1981, but these data do not appear in the database).

Length compositions are available for both surveys in all years with the exception of 1973–1979 in the NMFS Spring survey, where sexed length measurements of dogfish were not taken.

For the assessment model, growth and maturity equations are applied to survey abundance at length to determine abundance by maturity stage (juvenile, adult), as well as annual maturity transition thetas (the proportion of the population maturing from juvenile to adult). Dogfish exhibit sexually dimorphic growth, with females exhibiting later age at maturity and larger maximum sizes than males (Campana et al. 2009). Different Von Bertalanffy growth curves are used for data from Canada and the US (Table 1). The Canadian model is derived from the survey and commercial catch data collected during 2002–2005, updated to 2012 (Fowler and Campana 2015). The US model comes from NEFSC Spring survey data collected during 1980–1981 (Nammack et al. 1985). Similarly, the maturity ogives representing the proportion of Spiny Dogfish mature at length differ for Canada and the US (Figure 3). Length at 50% maturity ($L_{50\%}$) was determined using logistic regression for Canadian data (Campana et al. 2009), while the US used an arcsine function on fork length rather than total length. It was not possible to replicate the US methodology relative to total length to make relationships for Canadian and US data comparable (Fowler and Campana 2015). Therefore, a logistic function assuming the same intercept as the Canadian data and the $L_{50\%}$values for males and females from the US arcsine analysis was fit to the US data (Figure 3).

## COMMERCIAL CATCH

Landings of Spiny Dogfish from commercial fleets in Canada are 100% dockside monitored and the biological characteristics of the landed catch are determined through port sampling. Information on landings in the US comes from the NEFSC commercial fisheries database. In the US, there is a substantial recreational fishery for Spiny Dogfish, where recreational landings and discards are estimated from logbook reports through the Marine Recreational Information Program. Recreational landings of Spiny Dogfish in Canada are minimal and are not considered in this assessment.

Information on discards comes from fisheries observer programs for commercial vessels, initiated in 1977 in Canada and fully implemented in US waters by 1989. Observed discards by year, fishery, and season are scaled up to fishery-wide totals using a ratio estimator of discarded to kept (landed) catch, where the kept component is scaled to the total landings of dogfish within fishery components (NEFSC 2006). A similar methodology (i.e., a d/k ratio) is used to estimate total Canadian discards from observed trips, but ratios are specific to dogfish discarded versus kept catch (Fowler and Campana 2015). Observer coverage is variable among Canadian fleets that intercept dogfish. For each gear type that intercepts dogfish, both countries calculate dead discards by multiplying annual totals by gear-specific mortality rates. These mortality rates were accepted during the 2010 TRAC meeting (TRAC 2010) and are reproduced in Table 2. Although mortality would be expected to be 100% from scallop dredge in Canada, discards are minimal and have not been incorporated into this assessment. As an example of magnitude, 12,000 mt of scallop landings were observed in the Maritimes Region in 2014, with 2 mt of dogfish by-catch. Total mortality of Spiny Dogfish would have been estimated as 11 mt.

### Canada

Canadian landings of Spiny Dogfish were usually low in years prior to 1999 (Table 3). Foreign fleets fishing in Canadian waters landed substantial amounts of dogfish during the 1970s, peaking just under 10,000 mt in 1974 (Table 3, Figure 4). During 1998–2008, landings by Canadian fleets increased by an order of magnitude, peaking at 3,578 mt in 2001 and averaging 2,300 mt across years. Most of these were taken in the directed longline fishery for Spiny

Dogfish, with lesser amounts from gillnets and otter trawl. Since 2009, landings from all Canadian fisheries have been very low (< 125 mt) and were essentially zero in 2015 (Table 3).

Discard estimates from Canadian otter trawl, gillnet and longline fisheries for groundfish are available from the early 1960s. From 1946 to 1962, total annual discards were assumed to remain about 3,500 mt (Figure 4). In Canadian waters, discards are the primary source of fishing mortality, with the exceptions of the foreign directed fishery in the 1970s and the Canadian directed fishery in the early 2000s (Table 3, Figure 4). Total discard estimates have been declining since the 1990s, presumably due to more stringent management measures and lower TACs being implemented in groundfish fisheries. The lowest discard estimate in the time series was in 2015, at 51 mt (Table 3). After accounting for gear-specific discard mortality, dead discards by individual Canadian fleets have not exceeded 2,000 mt in any year (Figure 4).

### United States

During 1962–1979, US landings averaged about 400 mt annually, while landings by foreign fleets operating in US waters increased to upwards of 25,000 mt by the early 1970s (Table 4; Figure 4). With the advent of the USA directed fishery in 1990, landings averaged 17,900 mt from 1990–2000, but they dropped to an average of 2,200 mt during 2001–2008 due to quota restrictions. Since obtaining MSC certification in 2012, US landings of Spiny Dogfish have increased to approximately 10,000 mt annually (DFO 2016). Recreational landings have always been very low (averaging 200 mt from 1981–2008), although recreational discards have been much higher (averaging 1,500 mt from 1981–2008). Quantitative estimates of discards are available for individual US fisheries from 1989 onwards (TRAC 2010). Discards during 1964–1988 were approximated using the ratio of dogfish discards to total landings of dogfish. Estimated discard mortalities range from 2,900 mt to 22,800 mt assuming gear-specific mortality rates. In recent years, US discards have been much lower than before the mid-1990s (Table 4).

### Fisheries Removals

Total fisheries removals are higher in US territorial waters than Canadian throughout the time series (Table 5; Figure 5). The contribution to total removals from discarding is substantial and results in US removals remaining high throughout the 1960s to late 1990s, even though landings were low during the 1980s (cf. Figure 4 and Figure 5). Comparing the Canadian and US catch composition, annual fishery removals for each maturity stage and sex are substantially higher in US waters (Figure 6). Juvenile females are more abundant in the US catch composition than juvenile males, with the opposite pattern for adult males and females (Figure 6).

## RESEARCH VESSEL SURVEYS

Two Research Vessel (RV) surveys provide estimates of Spiny Dogfish abundance. The NMFS Spring survey in US waters serves as the primary index of population abundance, as most of the population is considered to be available to this survey. The Fisheries and Oceans Canada (DFO) Summer survey in Canadian waters serves as an index of migration and local stock abundance. Preliminary assessments and modelling during the 2010 TRAC review considered up to twelve surveys as candidate indices for Spiny Dogfish, but only the NMFS Spring and DFO Summer surveys were retained for the population-level assessment (Fowler and Campana 2015). Since the TRAC review, only the NMFS Spring survey has been used in US assessments (e.g., Rago and Sosebee 2015). The two bottom trawl surveys are conducted using stratified random sampling, with coverage that partially overlaps on Georges Bank. Abundance or biomass estimates for Spiny Dogfish are calculated as the stratified number or weight per tow, after standardizing for the distance towed.

## DFO Summer RV Survey

Stratified abundance estimates for all sex/stage groups of Spiny Dogfish were low at the beginning of the survey time series, increasing during the 1980s to the late 1990s, before gradually declining until 2010 (Figure 7). In the most recent years, there was an extremely large peak in 2012–2013, which has since declined. The majority of survey catches in Canada are adult males, with lower but similar numbers of female and male juveniles. Female adults form the smallest component of the survey catches throughout the time series. The DFO Summer survey is thought to primarily index changes in distribution as the population moves northward in the summer months (Fowler and Campana 2015).

## NMFS Spring RV Survey

Abundance trends for Spiny Dogfish from the US Spring survey increased throughout the 1980s, gradually declined from the early 1990s until the early 2000s, increased rapidly from the mid-2000s through 2013, and then declined rapidly in the last two years. Since the late 1990s, adult males have been the dominant component of survey catches, with more similar abundances of juveniles and adult females (Figure 7). The highest abundances in the time series occurred in 2012 and 2013, dropping sharply in 2014 and again in 2015. Mechanical problems prevented sampling in several strata in 2014, which has led to the exclusion of 2014 from the most recent US assessments for Spiny Dogfish (Rago and Sosebee 2014, 2015).

# EVALUATION OF DATA INPUTS

The assessment framework for Spiny Dogfish (Fowler and Campana, 2015) was developed using United States (US) and Canadian survey and commercial catch composition data through 2010. Since that time two major developments related to the US survey index have occurred that have implications for the assessment of Spiny Dogfish. One has been the implementation of a new research vessel with a new type of gear to conduct surveys since 2009 (Miller et al. 2010). The second was a determination of diel differences in catchability of dogfish that applies to all years in the survey, thus impacting the historical time series (Sagarese et al. 2016). These developments altered our perceptions of the population dynamics of Spiny Dogfish relative to the assessment framework, and the changes were sufficient to warrant a call for review of the data inputs.

## INCORPORATING RECENT DATA

### Survey Time Series

Prior to 2015, the NMFS Spring survey series was updated for Canadian assessments by obtaining biomass estimates and size compositions from NMFS, and deriving annual abundances at length from sex-specific length-weight relationships for dogfish (Fowler and Campana 2015). In 2015, direct access to NMFS survey databases was obtained and stratified abundance at length was estimated directly for the NMFS Spring survey time series.

The survey abundance time series derived for previous assessments from biomass data did not match the abundance time series calculated in 2015 (Figure 8). This would result from the length-weight relationships being used to convert abundance to biomass by NMFS and back to abundance by DFO. Comparing the two data series, the mean divergence of 1980–1981 estimates is much less than in later years, (almost 0 before splitting by stage). This suggests the length-weight relationship used to calculate the abundance series for the previous Canadian framework may derive from Nammack et al. (1985). This published relationship was also used to convert biomass back to abundance for the Canadian assessment. Although most of the data used by Nammack et al. (1985) were collected from the Spring survey, the current database to which we have access does not include any individual sampling data for dogfish until 1992.

If the length-weight relationship was assumed to be static across all years, changes in the relationship between length and weight of dogfish over time may explain the divergence in estimates. For example, the predicted weight of a 65 cm dogfish (the most abundant length in the time series) can exhibit substantial inter-annual and long-term variation from that of Nammack et al. (1985) in years for which we have data from individual fish (Figure 9). For this assessment framework, we propose using stratified abundance at length estimates for all years that dogfish length data are available, as opposed to updating the previous series derived from biomass estimates. This is consistent with the estimation method used for the Canadian Summer survey and with the structure of the Canadian population model. During the years where no length information is available (1973–1979), estimates will remain as provided for the original framework model (Fowler and Campana 2015).

During this investigation, we also noticed that the coefficient of variation (CV) for survey abundance at length could diverge considerably between sexes (Figure 10). In addition to annual variability, there were contiguous periods of time when one sex is better estimated than the other. In the Spring survey, females are typically better estimated than males during 1984 to 1993, while males are better estimated in most years since 2007. In the Canadian Summer survey females are usually better estimated than males throughout. Although the current framework model estimates abundance separately by sex, males and females shared the same error structure. For this assessment framework, we propose to allow for separate error structures by sex as well.

### Commercial Catch Composition

There has been no formal data-sharing agreement between the US and Canada for Spiny Dogfish since the 2010 TRAC assessment. However, the US commercial catch composition up until 2015 was provided for this assessment. For assessment updates undertaken by Canada in the intervening years (DFO 2014, DFO 2016, Fowler and Campana 2015), the commercial catch composition from US fisheries was approximated from summary statistics in US assessment documentation (Rago and Sosebee 2013, 2014, 2015). The actual sex and size composition of removals during 2011–2014 differed substantially from those assumed, with discrepancies as high as 50% for a given sex and maturity stage (Figure 11). Possibly different approaches to approximating catch composition from summary statistics might improve the representation of removals in years for which the underlying data are unavailable. We have not explored this, and propose that future updates should be based solely on trends in the Spring survey indices when catch composition data are unavailable.

## FACTORS AFFECTING DOGFISH CATCHABILITY

### Survey Vessel

A new survey vessel, the *Henry B. Bigelow*, employing a new type of trawl, replaced the *Albatross IV* beginning in 2009. The Bigelow is larger, quieter, tows a larger net, and follows different sampling protocols than the Albatross (Rago and Sosebee 2015). A large-scale paired-tow calibration study was conducted in 2008 to compare catches between the two vessels, with the Bigelow mirroring the tows of the Albatross as the Albatross conducted the Spring, Summer (site-specific tows in June and July) and Fall surveys. The paired tows were temporally and spatially offset by enough to minimize the effect of one tow on the other, while keeping the fish densities available to each vessel equivalent.

The original design of the calibration study recommended using an estimate of the ratio of stratified mean catches between the two vessels as the calibration factor, but it did not specify the appropriate estimator. Spiny Dogfish were observed at more than 30 stations during each of the Spring and Fall surveys (i.e., were abundant and common), leading to the recommendation to use a beta-binomial estimator for the calibration factor for counts (Miller et al. 2010). However, it was recognized that the applicability of this estimator would partially depend on the magnitude of station-to-station variability, as well as whether differences in the ratio of Bigelow to Albatross catchability among strata were expected. Subsequently, Miller (2013) proposed a methodological framework for estimating relative catch efficiency by size, allowing for extra-binomial variation in means among paired observations using the NMFS paired-trawl study as an example. Accounting for random variation in relative efficiency among pairs using hierarchical mixed effects was important for all species considered, while models allowing for extra-binomial dispersion (conditional beta-binomial) performed better for more than half.

The calibration methods proposed by Miller (2013) were of particular interest for Spiny Dogfish given differences in the size distribution of the catches between vessels and surveys. Survey catchability encompasses three components: the presence of a species in an area, the proportion encountered by the gear, and the proportion caught when encountered (Sagarese et al. 2016). Thus, changes in seasonal distribution or in pelagic versus demersal behaviour might be expected to influence catch at length of Spiny Dogfish in the Spring and Fall NMFS surveys. Also, diet analyses suggest that immature and small Spiny Dogfish are predominantly pelagic, while mature and large individuals shift to being demersal (Alonso et al. 2002). However, the length distribution of survey catches in the Spring is bimodal, containing relatively high numbers of newborn offspring and young juveniles in some strata, particularly when sampled using the Bigelow (Figure 12). The Spring survey is believed to be concurrent with pupping, and survey catches suggest that newborn Spiny Dogfish are also briefly demersal, before shifting to a more pelagic existence. In contrast, survey catches in the summer and fall rarely exhibit substantial bimodality with length.

### Diel Patterns

Another factor influencing survey estimates came to light in a recent study that evaluated dogfish catchability patterns in NMFS Spring and Fall surveys (Sagarese et al. 2016). This analysis used a quasibinomial Generalized Linear Model (GLM) to estimate relative survey catchability for Spiny Dogfish during the day (Benoit and Swain 2003, Casey and Myers 1998, Sagarese et al. 2016). The proportion caught during the day in each year and strata combination was the response, and the model incorporated an offset to represent the proportion of sets that took place during the day. Observed Catch Per Unit Effort (CPUE) in the survey in each year was adjusted to account for any significant day-night effect, leading to the conclusion that CPUE in the Spring survey may be overestimated by 41% (all age classes combined) or up to 49.8% for adult males. The authors suggested that vertical migration could account for Spiny Dogfish being less available to the demersal trawl during the night, in addition to daytime increases in availability due to feeding, aggregation behavior, or any visual herding on the bottom.

The coefficient estimates for relative daytime catchability of each maturity stage and sex of Spiny Dogfish from Sagarese et al. (2016) could not be applied directly to the NMFS Spring survey time series used here to account for diel catchability. For each stage and sex, one conversion factor was estimated for all years using survey data up to 2009. Including data up to 2015 would be expected to change these coefficients, particularly given that recent sampling was conducted using a different survey vessel with different protocols. In addition, Sagarese et al. (2016) did not evaluate any variability in the proportion of day/night sets over strata or year, instead assuming that diel survey catchability in each year approximated mean conditions.

## Outer Slope Sampling

The largest catches of dogfish in the Spring survey have occurred in strata along the edge of the continental shelf, hereafter called outer slope strata (Figure 13). Sampling of outer slope strata was higher in the early years of the survey (1968–1987), dropped until 2008, and then increased when the Bigelow took over in 2009 (Table 6). Similarly, the relative contribution of outer slope strata to the dogfish abundance index appears to have changed throughout the survey time series. During 1988–2008, 2009 strata accounted for 50% of dogfish abundance overall, none of them outer slope strata. Since 2009, 6 of these 9 strata remain associated with high dogfish abundance, while 2 outer slope strata have become important. Both these strata were skipped in about half the years during 1988–2008 (zero sets), and minimally sampled (1 set) in other years. The same is true for other outer slope strata, having zero or 1 set during 1988–2008, yet 2–3 sets in the early survey time period as well as since the Bigelow was deployed in 2009.

Four of the outer slope strata can make huge contributions to abundance in years they are sampled. For example, stratum 1,120 was 53% of the total abundance in 2003, stratum 1,150 was 44% in 1994, stratum 1,720 was 38% in 1,986, and stratum 1,760 was 39% in 2012. Three of these strata are major contributors to abundance (at least 15%) in at least one year during the Bigelow period. Most were sampled in at least 14 of the 21 years from 1988 to 2008, while stratum 1,120 was only sampled in 7 years. Also, with the exception of 2007, the sampling was always a single set. Thus the contribution of outer slope strata to survey estimates changed considerably during the Bigelow period.

Data are collected for a wide range of species from the NMFS Spring and DFO Summer surveys, meaning that sample allocation in either survey cannot be optimized for a single species to minimize within-stratum variance. In other words, variable catch rates of the target species among tows leads to increased uncertainty in the resulting abundance index (Nelson 2006). Besides having low precision, small samples taken from populations with highly variable densities tend to produce underestimates of available biomass (Schnute and Haigh 2003). To demonstrate this characteristic, we first assigned each outer slope strata a probability of being sampled in a given year, based on the actual number of sets completed by the Albatross during 1988–2008 (values ranged from 0.2 to 0.7). Catches in each stratum by the Bigelow were randomly selected according to these probabilities and were used to calculate weighted mean abundance estimates in each year (1,000 iterations). Plotting actual survey abundance estimates from 2009–2015 relative to the mean of the randomizations demonstrates systematic underestimation of juveniles (males and females), with differences up to 29% (Figure 14). The randomized mean values for adults were much closer to the actual survey estimates.

The actual sampling that has taken place each year during the NMFS Spring survey does not necessarily meet the minimum number of observations per strata required to estimate a mean and variance under the current survey design and stratification scheme. Although these sampling limitations could be addressed by developing a post-stratification scheme for the entire survey (e.g., Gavaris and Smith 1987), it would be simpler to allow process error to vary in the framework model in a manner proportional to the number of missed outer slope strata. Four outer slope strata are considered critical to Spiny Dogfish abundance estimates (1,120, 1,150, 1,720, and 1,760). Instead of keeping process error constant at 0.2, one option would be to attribute a process error of 0.025 for each missing set (relative to a minimum stratified sampling limit of 2 sets) in a key outer slope stratum, effectively according higher weights to years characterized by better sampling. For example, if sampling was missed in all four outer slope strata, process error would become 0.2 for that year. If one sample was taken in two of these strata and zero in the other two, process error would become 0.15. This adjustment would apply to all years characterized by poor sampling in the outer slope strata. In the previous assessment (Fowler and Campana 2015), process errors of 0.6 had been assumed for the survey years 1973 to 1979 on the basis that length data were missing. Here, we propose that values should be 0.2 for those years, reflecting the adequate sampling of outer slope strata.

The sensitivity of the assessment model to this weighting approach for process error will be evaluated at the assessment meeting. There is the possibility that more strata may be considered when setting process errors.

## METHODOLOGICAL EVALUATION

As detailed in the previous section, dogfish catchability is expected to vary between sexes, as well as among life stages, seasons, and times of day. Each of these factors could influence the abundance index derived from stratified random sampling, in isolation or in addition to changes in the sampling or vessel used during a survey. Because the Canadian assessment model uses NMFS survey data from the Spring season exclusively, it would be beneficial to have calibration factors specific to the Spring survey. It would also be beneficial to exclude strata that are not part of the stock definition used in previous assessments by the US (Figure 15; NEFSC 2006) and Canada (Figure 16; Fowler and Campana 2015) when calculating stratified abundance or biomass. Lastly, the current framework model splits data by life stage and sex, so an appropriate calibration is unlikely to be general to the entire population.

### Survey Vessel

As a starting point, we obtained dogfish data from the paired-tow calibration study and the modelling script used in Miller (2013) to evaluate relative catchability at length. Initial fits combined data from both sexes as well as from all NMFS surveys (Figure 17). Based on marginal Akaike Information Criterion (AIC) (Miller 2013), the chosen model incorporated a conditional beta-binomial distribution for data within each tow pair, included random variation in the mean relationship between pairs (cubic spline smoother for mean) and included variation among pairs in the relationship of size to relative catch efficiency (cubic spline smoother of size for mean and dispersion).

Restricting the data to tow-pairs conducted during the Spring survey reduced the number of observations of the smallest and largest sizes of Spiny Dogfish (Figure 18). To ensure that enough observations existed at a given length, we only included sizes where a minimum of 10 fish had been captured by either vessel. This had a relatively small effect on the length range; going from 21–104 cm to 22–98 cm. On the basis of marginal AIC, the same model structure was selected as optimal for this reduced dataset; however, mean relative catchability of the Bigelow increased substantially for the smallest lengths (Figure 19).

Male dogfish mature at smaller lengths than females. If their transition to demersal behaviour is governed primarily by life stage rather than size, earlier maturation would affect their catchability by demersal trawl. Because the Bigelow is more effective at catching smaller dogfish, relative catchability at length could vary between sexes. As a first step, we split the survey data into catches of males and females and re-fit the suite of models. Mean relative catchability is similar over a different size range for males than females: approximately 40–80 cm vs. 60–98 cm, respectively (Figures 20 and 21). This supports the idea that Bigelow catches should be calibrated separately for adults of each sex.

## Diel Patterns

The analysis by Sagarese et al. (2016) suggests that day-night catchability varies so markedly for dogfish that it should not be ignored when calculating abundance indices from surveys. Relative to the vessel calibration for the NMFS Spring survey, we wanted to evaluate how markedly catch at length differed between daytime and nighttime paired tows. Although the paired-tow calibration study data did not include local time, the sets were also regular survey tows. By matching station numbers, we assigned local time and survey stratum to each paired tow. Using the approximate timing of dawn and dusk from Sagarese et al (2016), sets occurring from 05:01–19:00 were categorized as daytime sets, while those occurring from 19:01–05:00 were categorized as nighttime. The proportion of paired tows that took place at night was 0.37, compared to an average of 0.42 in the Spring survey generally.

Dogfish catch at length varied substantially for daytime and nighttime tows conducted by the Albatross (Figure 22) and the Bigelow (Figure 23). For both vessels, relatively few strata had sets that occurred in the day and night, and total catches tended to be higher during the day. Summing over strata, such diel differences in catch at length were pronounced, particularly for juveniles.

Bigelow catches of juveniles could be an order of magnitude higher than those by the Albatross, in both the day and night (Figure 24). This fits with the hypothesis that the Bigelow fishes pelagically during haul-back because it maintains a fishing configuration throughout the duration of each tow (R. Johnston, NOAA, pers. comm.). The net configuration of the Albatross did not fish during haul-back.

If diel patterns were explicitly incorporated into a vessel-based standardization for catch at length during 2009–2015, it would become necessary to account for day-night differences in catchability throughout the survey time series. As a starting point, we redid the analyses presented in Sagarese et al. (2016) to estimate relative catchability coefficients for pups, juveniles and adults (split into male and female), using data from all survey years. The quasibinomial GLM estimated intercepts (calibration coefficients) for each life stage, combining data from all years. We subsequently evaluated sensitivity of the estimates to a range of factors, including: (1) the strata used in the calculation, where Sagarese et al. (2016) used all strata rather than the dogfish stock definition, (2) the years contributing to the estimates, where Sagarese et al. (2016) included 2009, the first year of sampling by the Bigelow; and (3) the life stage partitions, where Sagarese et al. (2016) used length at 50% maturity (L50) to separate juveniles from adults even though females appear to transition between more pelagic to more demersal behaviour at much smaller (immature) sizes.

Here we present five examples of how daytime catchability coefficients change with different ways of partitioning the data: (1) defining life stage relative to L50 and using data from the stock definition (Table 7; Stock definition strata only), (2) defining life stage relative to the apparent switch from pelagic to demersal behaviour suggested by survey catch at length for males and females (Table 7; Demersal length cutpoints), (3) using only data from the Albatross and demersal cutpoints to define life stage (Table 7; Demersal length cutpoints, drop 2009 Bigelow), (4) restrict the data to sampling done by the Bigelow and define life stage relative to maturity (Table 7; Bigelow years), and (5) restrict the data to sampling done by the Bigelow and define life stage relative to demersal behaviour (Table 7; Bigelow years, demersal cutpoints). The switch from pelagic to demersal behaviour was only approximate, taken as the inflection point in catchabilty at length for juvenile (> 26 cm) and adult male or female dogfish. For males, the demersal and maturity cutpoints are essentially the same (59 cm and 60 cm, respectively), but the demersal cutpoint is at a much smaller length for females (65 cm and 80 cm, respectively).

Pups—neonates in Sagarese et al. (2016)—represent dogfish ≤ 26 cm as opposed to 25 to 31 cm used elsewhere in this document.

Adult catchability (both sexes) was similar in day or night sets when only those strata in the dogfish stock definition were included. This suggests that the large and significant increase to catchability during the day for adult males reported by Sagarese et al. (2016) may have been primarily a result of herding in shallow and constrained inshore strata. For example, relative catchability of adult males dropped from 2.0 across all strata to 1.09 for the dogfish stock definition. When sampling was conducted exclusively by the Bigelow, relative catchability of adult males dropped to 0.81, suggesting higher catchability at night than during the day (Table 7). Also, relative catchability coefficients substantially increased for juveniles and pups when data from the Bigelow were included. For example, relative catchability for juvenile males (assuming demersal cutpoints) went from 1.48 (Albatross data only) to 1.70 (including 2009) to 5.16 (only Bigelow data) (Table 7). Thus, an appropriate diel calibration would have to be applied to the pup and pelagic life stages and would need to be specific to each survey vessel.

Most strata were sampled during either the day or night (not both), which means that the diel calibration could be sensitive to the manner in which dawn and dusk are identified. Sagarese et al. (2016) differentiated day and night based on constant time blocks. Given the broad longitudinal range of the Spring survey, using constant times to differentiate day and night could misclassify sets that were conducted close to twilight. To evaluate the sensitivity of a diel calibration to the definition of day and night, we calculated dusk and dawn relative using the astronomical methodology presented in Jacobson et al. (2011) and recalculated relative catchability by life stage. Coefficients were very similar for the relatively well represented demersal lengths, but results changed considerably for the poorly sampled pup and pelagic lengths (Table 13). This is mostly attributable to a single set switching diel definition, highlighting the sensitivity of catchability estimates to the poor representation of small dogfish. We would expect calibration estimates based on set-specific calculation of astronomical twilight to be better than those based on generalized dusk-dawn cutpoints, but the accuracy of pup and pelagic lengths is questionable.

## Slope strata

Differences in slope sampling could affect the estimation of diel catchability, especially for the Albatross. Breaking the time series into 1980–1987 (two to three set sampling along the outer slope) and 1988–2008 (one or zero set sampling) and using the quasibinomial GLM described in Sagarese et al. (2016) to estimate daytime differences in catchability, suggests higher coefficients for pups and pelagic lengths for the earlier data (Table 8). This could occur if catchability of these life stages differed in the outer slope strata specifically, or if daytime catchability is better estimated by the greater number of samples. To evaluate the former, we compared relative catchability coefficients (day/night) over all strata, only slope strata, and only non-slope strata for fishing by the Bigelow (2009–2015), Albatross (1988–2008), and Albatross (1980–1987). Coefficients are variable when comparing data from slope with other strata (Table 9A and B), suggesting that the sampling design alone does not account for the variation in daytime catchability by the Albatross.

## Combined Approaches

The paired-tow calibration data appear to be too sparse to support the inclusion of additional predictors for sex and diel period directly into the length-based calibration models developed by Miller (2013). For example, there is only one observation (a single tow pair) of non-zero catch of male dogfish (31–58 cm and ≥ 86 cm) or female dogfish (31–60 cm) at night for a large proportion of their length distribution (Table 10). If the data were to be split into subsets and re-modelled, the results suggest that catchability is similar for each vessel when fishing either sex during the day (Figures 24 and 25). However, the same comparison for sets completed during the night demonstrates much higher relative catchability of smaller dogfish of both sexes, coupled with lower relative catchability of larger lengths (Figures 26 and 27). This suggests that diel period has a much greater influence on relative catchability by the Bigelow as compared to differences between the sexes.

The extreme paucity of data for pelagic lengths in the vessel catchability study seemed inconsistent with the large and significant coefficients for juvenile daytime catchability estimated from the Albatross data in the diel analysis. Large catches of pelagic lengths of dogfish typically occur in outer slope strata, and these strata were poorly sampled in the paired-tow study. Also, the length composition of the Bigelow catches in the calibration study does not reflect those of the Bigelow in other survey years (Table 11). Catches of pup and demersal lengths appear proportionate, but the Bigelow catches far more dogfish at pelagic lengths during survey years than in the calibration study. The calibration study sampling might be missing the main strata associated with pelagic catches (Table 12). Over 50% of the pelagic length catches for the Bigelow during 2009–2015 derive from just 4 strata, 3 of them outer slope (1,120, 1,150, 1,760) and 1 inner slope (1,110). All three of the primary outer slope strata were missed by the Bigelow during the calibration study, and the primary inner slope stratum was represented by a single night tow. This may be because the sharp depth gradients of slope strata are difficult to accommodate when attempting paired tows. Virtually all the outer slope strata associated with tallies over a thousand were sampled by the Albatross alone in 2008 (Table 12).

The low catches of pelagic lengths in the paired-tow calibration study in 2008 raises the question of comparability if data were to be used to standardize recent catches by the Bigelow (2009–2015). The length distribution caught during the Spring survey each year (separated into day and night catches) indicates extremely low catches of dogfish < 65 cm from 1996 until 2008 (Figure 28). The size composition of the catch during 2012 and 2013 by the Bigelow stands out as something we have never seen before. Increases of this magnitude from the 2011 survey year are biologically implausible given the life history of dogfish (Rago and Sosebee 2013), and they are very unlikely to come from recruitment alone.

## Calibration Approach

Given that catchability varies by sex and with diel period, one option for calibration would be to incorporate these additional factors as predictors directly into the beta-binomial modeling framework proposed by Miller (2013). However, this would likely lead to less complex binomial or beta-binomial model from the suite of models being selected as optimal given the characteristics of the paired tow data. For example, there is only one observation (a single tow pair) of non-zero catch of male dogfish (31–58 cm and ≥ 86 cm) or female dogfish (31–60 cm) at night for a large proportion of their length distribution (Table 10). A simpler method for calibration would be to partition the data into subsets and calculate a calibration factor for each subset. The significance of specific partitions could be evaluated using summed marginal AIC provided the model being applied to all subsets was the same. For example, fitting an intercept-only beta-binomial or quasibinomial GLM to data partitioned by life stage (pups juveniles, and adults) versus data partitioned by life stage and sex (pups, pelagic lengths, demersal males and demersal females) and comparing summed AIC between the two groups will give information on the importance of considering sex in the calibration model.

There are three main factors: life stage (pups, pelagic and demersal lengths), sex, and diel period. A simple (no smoothing) beta-binomial model with station-specific random effects intercepts fit to the entire data set gives a marginal AIC of 6,207.1. Fitting data partitioned by sex, life stage and diel period with the equivalent model and summing the marginal AIC gives

5816.7. Attempts to extend this comparison to more specifically address the roles of diel period (as a factor in sex-stage partitions) or life stage (as a factor within sex-diel partitions) were confounded by failures of some partitions to fit with the simple model (or any common model). We did, however, fit binomial Generalized Additive Models (GAMs) to assess the roles of diel (AIC of 6,902.4 versus 6,948.7) and life stage (AIC of 7,191.6 versus 7,202.1) factors. The AIC comparisons suggest that both factors significantly affect catchability.

Moving forward, it would be possible to make a vessel calibration conditional on the diel catchability pattern. However, our evaluation of this scenario produced calibration coefficients that were extremely large. Estimating relative daytime catchability of each life stage of dogfish from the Albatross (1980–2008) and Bigelow (2009–2015) using the quasibinomial model described in Sagarese et al. (2016) and then multiplying the paired-tow survey night sets by the significant relative daytime catchability coefficients (Table 7, demersal cutpoint results; pup and pelagic life stages, and demersal males for the Bigelow alone) gave factors of 1/10.3 and 1/29.3 to equate Bigelow night catches of pup and pelagic lengths to the Albatross. Demersal adult males drop slightly from 1/2.0 to 1/1.6.

Although differences in day or night catchability would affect the variance and relative magnitude of the survey index, diel patterns should not cause systematic bias provided the proportion of day and night sets did not change systematically over time. There was no evidence of substantial change in the proportion of daytime sets in the NMFS Spring survey (Figure 29). Furthermore, a comparison of the resulting survey index using calibration coefficients determined from quasibinomial GLMs of data partitioned only by life stage with data partitioned by diel period and life stage revealed very minor differences (Figure 30).

Relative to uncalibrated data, partitioning the data by life stage and estimating relative catchability of the Bigelow to the Albatross produces large differences in abundances relative to uncalibrated estimates (Figure 31). The effect of this calibration is most pronounced in 2012 and 2013, where the survey caught extremely large numbers of small dogfish (Figures 32), which are subject to the highest Bigelow catchabilities. Such variability in the length distribution of the survey catches would be a critical consideration if NMFS Spring survey estimates were to be interpreted directly (outside a model that estimates catchability).

## CONCLUSIONS

We propose to use the same data sources and stock definition for the dogfish assessment as in the most recent Canadian framework (Fowler and Campana 2015). However, the NMFS Spring survey index will be calculated directly as stratified abundance at length rather than being converted from the stratified biomass estimates as has been done in the past.

For the commercial catch data from the US, there is no formal data-sharing agreement to obtain annual updates. The method used in previous assessment updates to approximate the catch composition from summary statistics gave results that were very different from the actual data. If the commercial inputs to the population model cannot be updated annually, it would be better to interpret Spring survey trends rather than update the population model with assumed catch inputs.

There were three changes to the structure of the dogfish population model suggested at the data inputs meeting. First, process error associated with the surveys will be allowed to vary depending on the realization of stratified sampling of strata. Second, the observation error associated with survey catches will become sex-specific. Third, a model that incorporates the calibrated Spring survey index with one estimate for catchability (q) will be compared with a model that splits the Spring survey index into the Bigelow and Albatross time periods and estimates two survey q's.

For the calibrated Spring survey index, the calibration constant recommended originally to standardize dogfish catches from the Bigelow relative to the Albatross (Miller et al. 2010) would adjust juvenile and adult components of the population equally. These analyses suggest that the largest differences in catchability between vessels pertain to juveniles, while the more demersal adult components of the population pose much smaller differences. To calibrate between vessels, the intercepts estimated from quasibinomial GLM fits to data portioned by sex and stage (pup, pelagic and demersal lengths) will be applied to total survey catches of the Bigelow as divisors within these partitions to relate Bigelow catches to the Albatross.

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# TABLES

*Table 1. Von Bertalanffy growth parameters for dogfish in Canada and the US as reported in Fowler and Campana (2015). Values represent total length (TL) for length at birth ($L_0$) and asymptotic length ($L_\infty$). The curvature parameter ($K$) representing how quickly the fish grows is also given.*

| Country | Sex | $L_\infty$ | $K$ | $L_0$ |
|---|---|---|---|---|
| Canada | Male | 83.0 | 0.126 | 30.35 |
| Canada | Female | 106.0 | 0.066 | 30.35 |
| US | Male | 82.5 | 0.148 | 30.35 |
| US | Female | 100.5 | 0.106 | 30.35 |

*Table 2. Discard mortality estimates determined during the 2010 Spiny Dogfish TRAC meeting. "NA" = data not available.*

| Country | Longline | Otter Trawl | Gillnet | Recreational Landings | Foreign Otter Trawl | Other Gear* | Scallop Dredge |
|---|---|---|---|---|---|---|---|
| Canada | 0.1 | 0.25 | 0.55 | NA | 0.25 | 0.1 | NA |
| USA | 0.1 | 0.5 | 0.3 | 0.25 | 0.5 | 0.5 | 0.75 |

*Other Gear = groundfish-directed longline for Canada

*Table 3. Canadian dogfish landings and discards in metric tons by fishery, year and time period (1 = November–April, 2 = May–October). "NA" = data not available.*

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Foreign otter trawl landings | Groundfish longline landings | Directed longline discards | Otter trawl discards | Gillnet discards | Foreign otter trawl discards | Groundfish longline discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1922–1945 | 1+2 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1946–1962 | 1+2 | 8 | 1 | 0 | 0 | NA | NA | 1,326 | 1,433 | NA | 824 | 3,592 |
| 1963 | 1+2 | 8 | 1 | 0 | 0 | NA | NA | 1,420 | 1,535 | NA | 882 | 3,846 |
| 1964 | 1+2 | 8 | 1 | 0 | 0 | NA | NA | 1,392 | 1,505 | NA | 866 | 3,772 |
| 1965 | 1+2 | 8 | 1 | 0 | 76 | NA | NA | 1,479 | 1,598 | NA | 919 | 4,081 |
| 1966 | 1+2 | 33 | 5 | 1 | 3,110 | NA | NA | 1,594 | 1,723 | NA | 991 | 7,458 |
| 1967 | 1+2 | 0 | 0 | 0 | 620 | NA | NA | 1,526 | 1,650 | NA | 949 | 4,744 |
| 1968 | 1+2 | 0 | 0 | 0 | 540 | NA | NA | 1,609 | 1,739 | NA | 1,000 | 4,888 |
| 1969 | 1+2 | 0 | 0 | 0 | 363 | NA | NA | 1,571 | 1,698 | NA | 977 | 4,609 |
| 1970 | 1 | 0 | 1 | 0 | 143 | NA | NA | 165 | 437 | NA | 307 | 1,052 |
| 1970 | 2 | 16 | 1 | 0 | 553 | NA | NA | 1,331 | 1,180 | NA | 623 | 3,705 |
| 1971 | 1 | 0 | 0 | 0 | 197 | NA | NA | 162 | 429 | NA | 301 | 1,089 |
| 1971 | 2 | 3 | 0 | 0 | 758 | NA | NA | 1,308 | 1,160 | NA | 612 | 3,842 |
| 1972 | 1 | 0 | 0 | 0 | 1,021 | NA | NA | 148 | 393 | NA | 276 | 1,839 |
| 1972 | 2 | 2 | 0 | 0 | 3,935 | NA | NA | 1,198 | 1,063 | NA | 561 | 6,759 |
| 1973 | 1 | 0 | 1 | 0 | 1,275 | NA | NA | 154 | 409 | NA | 288 | 2,127 |
| 1973 | 2 | 17 | 1 | 0 | 4,910 | NA | NA | 1,247 | 1,106 | NA | 584 | 7,866 |
| 1974 | 1 | 1 | 2 | 0 | 1,965 | NA | NA | 119 | 316 | NA | 222 | 2,625 |
| 1974 | 2 | 30 | 3 | 1 | 7,572 | NA | NA | 964 | 855 | NA | 451 | 9,876 |
| 1975 | 1 | 0 | 0 | 0 | 1,560 | NA | NA | 123 | 325 | NA | 229 | 2,237 |
| 1975 | 2 | 1 | 0 | 0 | 6,009 | NA | NA | 992 | 880 | NA | 464 | 8,346 |
| 1976 | 1 | 0 | 0 | 0 | 1,220 | NA | NA | 134 | 355 | NA | 249 | 1,958 |
| 1976 | 2 | 2 | 0 | 0 | 4,700 | NA | NA | 1082 | 959 | NA | 506 | 7,250 |
| 1977 | 1 | 0 | 0 | 0 | 288 | NA | NA | 146 | 386 | NA | 271 | 1,091 |
| 1977 | 2 | 1 | 0 | 0 | 1,111 | NA | NA | 1,178 | 1,044 | NA | 551 | 3,886 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Foreign otter trawl landings | Groundfish longline landings | Directed longline discards | Otter trawl discards | Gillnet discards | Foreign otter trawl discards | Groundfish longline discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1978 | 1 | 1 | 5 | 0 | 8 | NA | NA | 172 | 455 | NA | 320 | 961 |
| 1978 | 2 | 70 | 6 | 2 | 29 | NA | NA | 1,388 | 1,231 | NA | 650 | 3,376 |
| 1979 | 1 | 23 | 74 | 0 | 5 | NA | NA | 198 | 526 | NA | 370 | 1,195 |
| 1979 | 2 | 1,109 | 99 | 27 | 30 | NA | NA | 1,603 | 1,422 | NA | 750 | 5,039 |
| 1980 | 1 | 11 | 37 | 0 | 74 | NA | NA | 210 | 557 | NA | 391 | 1,279 |
| 1980 | 2 | 550 | 49 | 13 | 293 | NA | NA | 1,697 | 1,505 | NA | 794 | 4,900 |
| 1981 | 1 | 10 | 32 | 0 | 67 | NA | NA | 220 | 583 | NA | 410 | 1,321 |
| 1981 | 2 | 470 | 42 | 11 | 491 | NA | NA | 1,779 | 1,578 | NA | 833 | 5,203 |
| 1982 | 1 | 7 | 22 | 0 | 25 | NA | NA | 231 | 614 | NA | 431 | 1,329 |
| 1982 | 2 | 324 | 29 | 8 | 27 | NA | NA | 1,871 | 1,659 | NA | 876 | 4,793 |
| 1983 | 1 | 0 | 0 | 0 | 151 | NA | NA | 217 | 576 | NA | 405 | 1,350 |
| 1983 | 2 | 0 | 0 | 0 | 233 | NA | NA | 1,758 | 1,559 | NA | 822 | 4,372 |
| 1984 | 1 | 0 | 0 | 0 | 6 | NA | NA | 209 | 553 | NA | 389 | 1,157 |
| 1984 | 2 | 2 | 0 | 0 | 307 | NA | NA | 1,687 | 1,496 | NA | 790 | 4,282 |
| 1985 | 1 | 0 | 1 | 0 | 33 | NA | NA | 215 | 571 | NA | 401 | 1,222 |
| 1985 | 2 | 11 | 1 | 0 | 379 | NA | NA | 1,741 | 1,544 | NA | 815 | 4,492 |
| 1986 | 1 | 0 | 0 | 0 | 21 | NA | NA | 698 | 341 | NA | 180 | 1,240 |
| 1986 | 2 | 8 | 2 | 0 | 216 | NA | NA | 1,668 | 1,862 | NA | 913 | 4,669 |
| 1987 | 1 | 3 | 1 | 0 | 1 | NA | NA | 811 | 347 | NA | 458 | 1,621 |
| 1987 | 2 | 223 | 25 | 5 | 93 | NA | NA | 1,630 | 2,083 | NA | 934 | 4,993 |
| 1988 | 1 | 13 | 0 | 0 | 275 | NA | NA | 590 | 134 | NA | 403 | 1,415 |
| 1988 | 2 | 0 | 0 | 0 | 272 | NA | NA | 1,676 | 1,741 | NA | 1,010 | 4,699 |
| 1989 | 1 | 0 | 0 | 0 | 96 | NA | NA | 832 | 149 | NA | 372 | 1,449 |
| 1989 | 2 | 123 | 37 | 2 | 68 | NA | NA | 1,279 | 2,344 | NA | 927 | 4,780 |
| 1990 | 1 | 0 | 61 | 0 | 108 | NA | NA | 562 | 381 | NA | 403 | 1,515 |
| 1990 | 2 | 566 | 17 | 13 | 276 | NA | NA | 968 | 2,510 | NA | 1,100 | 5,450 |
| 1991 | 1 | 36 | 5 | 0 | 99 | NA | NA | 714 | 214 | NA | 409 | 1,477 |
| 1991 | 2 | 138 | 10 | 0 | 107 | NA | NA | 1,676 | 1,979 | NA | 1,121 | 5,031 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Foreign otter trawl landings | Groundfish longline landings | Directed longline discards | Otter trawl discards | Gillnet discards | Foreign otter trawl discards | Groundfish longline discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 1 | 0 | 0 | 0 | 45 | NA | NA | 738 | 151 | NA | 428 | 1,362 |
| 1992 | 2 | 515 | 38 | 2 | 0 | NA | NA | 1,854 | 1,475 | NA | 1,199 | 5,083 |
| 1993 | 1 | 2 | 1 | 1 | 27 | NA | NA | 478 | 115 | NA | 321 | 945 |
| 1993 | 2 | 590 | 24 | 112 | 0 | NA | NA | 1342 | 1,137 | NA | 820 | 4,025 |
| 1994 | 1 | 1 | 0 | 5 | 0 | NA | NA | 311 | 27 | NA | 105 | 449 |
| 1994 | 2 | 791 | 0 | 26 | 0 | NA | NA | 888 | 851 | NA | 629 | 3,185 |
| 1995 | 1 | 22 | 2 | 0 | 0 | NA | NA | 262 | 13 | NA | 102 | 401 |
| 1995 | 2 | 328 | 3 | 42 | 0 | NA | NA | 741 | 854 | NA | 372 | 2,340 |
| 1996 | 1 | 1 | 1 | 0 | 0 | NA | NA | 323 | 2 | NA | 67 | 394 |
| 1996 | 2 | 25 | 6 | 27 | 0 | NA | NA | 862 | 545 | NA | 426 | 1,891 |
| 1997 | 1 | 29 | 1 | 0 | 0 | NA | NA | 342 | 8 | NA | 92 | 472 |
| 1997 | 2 | 125 | 8 | 107 | 7 | NA | NA | 1,232 | 788 | NA | 378 | 2,645 |
| 1998 | 1 | 24 | 10 | 0 | 0 | NA | NA | 495 | 15 | NA | 98 | 642 |
| 1998 | 2 | 732 | 13 | 92 | 0 | NA | NA | 1,263 | 795 | NA | 289 | 3,184 |
| 1999 | 1 | 38 | 2 | 16 | 0 | NA | NA | 262 | 17 | NA | 75 | 410 |
| 1999 | 2 | 1,658 | 7 | 169 | 0 | NA | NA | 982 | 492 | NA | 253 | 3,561 |
| 2000 | 1 | 7 | 6 | 0 | 0 | NA | NA | 357 | 90 | NA | 88 | 548 |
| 2000 | 2 | 2,339 | 37 | 150 | 0 | NA | NA | 785 | 434 | NA | 220 | 3,965 |
| 2001 | 1 | 44 | 4 | 26 | 0 | NA | NA | 375 | 74 | NA | 76 | 599 |
| 2001 | 2 | 2,978 | 18 | 508 | 0 | NA | NA | 800 | 505 | NA | 199 | 5,008 |
| 2002 | 1 | 68 | 2 | 31 | 0 | NA | NA | 328 | 107 | NA | 70 | 606 |
| 2002 | 2 | 2,838 | 7 | 492 | 0 | NA | NA | 995 | 527 | NA | 153 | 5,012 |
| 2003 | 1 | 1 | 1 | 0 | 0 | NA | NA | 300 | 147 | NA | 73 | 522 |
| 2003 | 2 | 868 | 5 | 418 | 0 | NA | NA | 887 | 515 | NA | 134 | 2,827 |
| 2004 | 1 | 0 | 1 | 0 | 0 | NA | NA | 344 | 120 | NA | 62 | 527 |
| 2004 | 2 | 1,945 | 1 | 343 | 0 | NA | NA | 698 | 668 | NA | 99 | 3,754 |
| 2005 | 1 | 86 | 1 | 0 | 0 | NA | NA | 346 | 71 | NA | 35 | 539 |
| 2005 | 2 | 1,926 | 4 | 294 | 0 | NA | NA | 779 | 449 | NA | 93 | 3,545 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Foreign otter trawl landings | Groundfish longline landings | Directed longline discards | Otter trawl discards | Gillnet discards | Foreign otter trawl discards | Groundfish longline discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 1 | 31 | 1 | 0 | 0 | NA | NA | 226 | 59 | NA | 44 | 361 |
| 2006 | 2 | 1,896 | 1 | 513 | 0 | NA | NA | 597 | 276 | NA | 104 | 3,387 |
| 2007 | 1 | 26 | 1 | 0 | 0 | NA | NA | 271 | 9 | NA | 46 | 353 |
| 2007 | 2 | 1,926 | 8 | 426 | 0 | NA | NA | 703 | 313 | NA | 121 | 3,497 |
| 2008 | 1 | 23 | 0 | 0 | 0 | NA | NA | 242 | 16 | NA | 47 | 328 |
| 2008 | 2 | 1,395 | 2 | 126 | 0 | NA | NA | 695 | 295 | NA | 110 | 2,623 |
| 2009 | 1 | 12 | 0 | 0 | 0 | NA | NA | 276 | 3 | NA | 55 | 346 |
| 2009 | 2 | 152 | 1 | 0 | 0 | NA | NA | 860 | 259 | NA | 83 | 1,355 |
| 2010 | 1 | 0 | 0 | 0 | 0 | NA | NA | 254 | 12 | NA | 49 | 315 |
| 2010 | 2 | 5 | 0 | 0 | 0 | NA | NA | 842 | 265 | NA | 91 | 1,203 |
| 2011 | 1 | 0 | 4 | 0 | 0 | NA | NA | 201 | 4 | NA | 47 | 256 |
| 2011 | 2 | 94 | 26 | 0 | 0 | NA | NA | 846 | 204 | NA | 82 | 1,252 |
| 2012 | 1 | 0 | 8 | 0 | 0 | NA | NA | 266 | 9 | NA | 41 | 324 |
| 2012 | 2 | 0 | 57 | 0 | 0 | NA | NA | 954 | 153 | NA | 70 | 1,234 |
| 2013 | 1 | 5 | 0 | 0 | 0 | NA | NA | 171 | 2 | NA | 32 | 210 |
| 2013 | 2 | 0 | 0 | 0 | 0 | NA | NA | 595 | 128 | NA | 60 | 783 |
| 2014 | 1 | 0 | 3 | 0 | 0 | NA | NA | 103 | 0 | NA | 10 | 116 |
| 2014 | 2 | 13 | 38 | 0 | 0 | NA | NA | 120 | 46 | NA | 15 | 232 |
| 2015 | 1 | 0 | 0 | 0 | 0 | NA | NA | 14 | 6 | NA | 1 | 21 |
| 2015 | 2 | 0 | 1 | 0 | 0 | NA | NA | 24 | 0 | NA | 6 | 31 |

*Table 4. US dogfish landings and discards in metric tons by fishery, year and time period (1 = November–April, 2 = May–October). "NA" = data not available.*

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Rec landings | Foreign otter trawl landings | Other gear landings | Directed longline discards | Otter trawl discards | Gillnet discards | Rec discards | Scallop dredge discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1922 | 1+2 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1923 | 1+2 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 0 | NA | NA | 0 |
| 1924 | 1+2 | 1 | 3 | 6 | NA | NA | NA | 66 | 2,305 | 17 | NA | NA | 2,398 |
| 1925 | 1+2 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 0 | NA | NA | 0 |
| 1926 | 1+2 | 0 | 1 | 2 | NA | NA | NA | 20 | 709 | 5 | NA | NA | 738 |
| 1927 | 1+2 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 0 | NA | NA | 0 |
| 1928 | 1+2 | 8 | 33 | 53 | NA | NA | NA | 623 | 21,662 | 160 | NA | NA | 22,539 |
| 1929 | 1+2 | 9 | 40 | 65 | NA | NA | NA | 760 | 26,451 | 196 | NA | NA | 27,521 |
| 1930 | 1+2 | 4 | 17 | 27 | NA | NA | NA | 320 | 11,118 | 82 | NA | NA | 11,568 |
| 1931 | 1+2 | 2 | 8 | 13 | NA | NA | NA | 148 | 5,158 | 38 | NA | NA | 5,367 |
| 1932 | 1+2 | 1 | 6 | 9 | NA | NA | NA | 106 | 3,695 | 27 | NA | NA | 3,844 |
| 1933 | 1+2 | 1 | 3 | 5 | NA | NA | NA | 61 | 2,118 | 16 | NA | NA | 2,203 |
| 1934 | 1+2 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 0 | NA | NA | 0 |
| 1935 | 1+2 | 5 | 24 | 39 | NA | NA | NA | 455 | 15,834 | 117 | NA | NA | 16,475 |
| 1936 | 1+2 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 0 | NA | NA | 0 |
| 1937 | 1+2 | 3 | 14 | 23 | NA | NA | NA | 270 | 9377 | 69 | NA | NA | 9,756 |
| 1938 | 1+2 | 5 | 24 | 38 | NA | NA | NA | 448 | 15,582 | 115 | NA | NA | 16,213 |
| 1939 | 1+2 | 5 | 21 | 35 | NA | NA | NA | 403 | 14,018 | 104 | NA | NA | 14,585 |
| 1940 | 1+2 | 23 | 100 | 163 | NA | NA | NA | 1,893 | 65,867 | 488 | NA | NA | 68,533 |
| 1941 | 1+2 | 23 | 100 | 163 | NA | NA | NA | 1,893 | 65,867 | 488 | NA | NA | 68,533 |
| 1942 | 1+2 | 5 | 20 | 33 | NA | NA | NA | 384 | 13,367 | 99 | NA | NA | 13,908 |
| 1943 | 1+2 | 5 | 22 | 35 | NA | NA | NA | 413 | 14,385 | 106 | NA | NA | 14,967 |
| 1944 | 1+2 | 2 | 10 | 16 | NA | NA | NA | 181 | 6,290 | 47 | NA | NA | 6,544 |
| 1945 | 1+2 | 2 | 10 | 16 | NA | NA | NA | 187 | 6,521 | 48 | NA | NA | 6,784 |
| 1946 | 1+2 | 6 | 26 | 42 | NA | NA | NA | 488 | 16,989 | 126 | NA | NA | 17,677 |
| 1947 | 1+2 | 2 | 7 | 12 | NA | NA | NA | 136 | 4,746 | 35 | NA | NA | 4,938 |
| 1948 | 1+2 | 2 | 9 | 15 | NA | NA | NA | 175 | 6,101 | 45 | NA | NA | 6,347 |
| 1949 | 1+2 | 25 | 108 | 176 | NA | NA | NA | 2,054 | 71,474 | 529 | NA | NA | 74,366 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Rec landings | Foreign otter trawl landings | Other gear landings | Directed longline discards | Otter trawl discards | Gillnet discards | Rec discards | Scallop dredge discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1950 | 1+2 | 5 | 24 | 38 | NA | NA | NA | 448 | 15,582 | 115 | NA | NA | 16,213 |
| 1951 | 1+2 | 4 | 16 | 27 | NA | NA | NA | 312 | 10,847 | 80 | NA | NA | 11,286 |
| 1952 | 1+2 | 2 | 9 | 14 | NA | NA | NA | 163 | 5,660 | 42 | NA | NA | 5,889 |
| 1953 | 1+2 | 3 | 12 | 19 | NA | NA | NA | 223 | 7,770 | 58 | NA | NA | 8,085 |
| 1954 | 1+2 | 2 | 10 | 16 | NA | NA | NA | 190 | 6,615 | 49 | NA | NA | 6,883 |
| 1955 | 1+2 | 3 | 15 | 24 | NA | NA | NA | 281 | 9,765 | 72 | NA | NA | 10,160 |
| 1956 | 1+2 | 20 | 87 | 141 | NA | NA | NA | 1,648 | 57,330 | 424 | NA | NA | 59,651 |
| 1957 | 1+2 | 49 | 214 | 348 | NA | NA | NA | 4,050 | 140,910 | 1,043 | NA | NA | 146,614 |
| 1958 | 1+2 | 34 | 150 | 244 | NA | NA | NA | 2,846 | 99,015 | 733 | NA | NA | 103,023 |
| 1959 | 1+2 | 30 | 133 | 216 | NA | NA | NA | 2,517 | 87,570 | 648 | NA | NA | 91,115 |
| 1960 | 1+2 | 30 | 133 | 216 | NA | NA | NA | 2,517 | 87,570 | 648 | NA | NA | 91,115 |
| 1961 | 1+2 | 30 | 133 | 216 | NA | NA | NA | 2,517 | 87,570 | 648 | NA | NA | 91,115 |
| 1962 | 1+2 | 19 | 78 | 129 | NA | 0 | 8 | 1,554 | 51,716 | 380 | NA | 937 | 54,822 |
| 1963 | 1+2 | 50 | 86 | 436 | NA | 1 | 39 | 1,554 | 51,716 | 380 | NA | 937 | 55,198 |
| 1964 | 1+2 | 13 | 75 | 619 | NA | 16 | 23 | 1,554 | 51,716 | 380 | NA | 937 | 55,333 |
| 1965 | 1+2 | 55 | 52 | 358 | NA | 198 | 22 | 1,554 | 50,908 | 345 | NA | 922 | 54,415 |
| 1966 | 1+2 | 85 | 95 | 358 | NA | 9,389 | 40 | 1,554 | 48,730 | 531 | NA | 883 | 61,665 |
| 1967 | 1+2 | 24 | 111 | 98 | NA | 2,436 | 45 | 1,554 | 44,018 | 516 | NA | 797 | 49,599 |
| 1968 | 1+2 | 3 | 78 | 54 | NA | 4,404 | 23 | 1,554 | 42,748 | 713 | NA | 774 | 50,351 |
| 1969 | 1+2 | 2 | 88 | 6 | NA | 9,190 | 17 | 1,554 | 39,654 | 500 | NA | 718 | 51,730 |
| 1970 | 1 | 0 | 32 | 0 | NA | 4,003 | 4 | 173 | 18,202 | 91 | NA | 264 | 22,769 |
| 1970 | 2 | 2 | 48 | 12 | NA | 1,637 | 7 | 3,278 | 18,202 | 365 | NA | 396 | 23,945 |
| 1971 | 1 | 0 | 21 | 0 | NA | 9,265 | 6 | 269 | 16,512 | 98 | NA | 239 | 26,411 |
| 1971 | 2 | 0 | 32 | 4 | NA | 2,301 | 10 | 5,119 | 16,512 | 391 | NA | 359 | 24,727 |
| 1972 | 1 | 0 | 21 | 0 | NA | 12,357 | 6 | 266 | 14,322 | 159 | NA | 208 | 27,337 |
| 1972 | 2 | 1 | 32 | 1 | NA | 11,634 | 9 | 5,048 | 14,322 | 636 | NA | 311 | 31,993 |
| 1973 | 1 | 0 | 31 | 0 | NA | 12,599 | 2 | 276 | 14,246 | 166 | NA | 206 | 27,526 |
| 1973 | 2 | 0 | 46 | 4 | NA | 6,194 | 3 | 5,241 | 14,246 | 663 | NA | 310 | 26,707 |
| 1974 | 1 | 0 | 32 | 3 | NA | 17,094 | 14 | 274 | 13,108 | 279 | NA | 190 | 30,993 |
| 1974 | 2 | 2 | 48 | 10 | NA | 7,419 | 21 | 5,212 | 13,108 | 1,115 | NA | 285 | 27,219 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Rec landings | Foreign otter trawl landings | Other gear landings | Directed longline discards | Otter trawl discards | Gillnet discards | Rec discards | Scallop dredge discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 1 | 0 | 36 | 1 | NA | 14,384 | 17 | 264 | 11,598 | 311 | NA | 168 | 26,779 |
| 1975 | 2 | 0 | 54 | 2 | NA | 8,139 | 26 | 5,022 | 11,598 | 1,246 | NA | 252 | 26,339 |
| 1976 | 1 | 0 | 29 | 13 | NA | 12,025 | 14 | 168 | 12,326 | 473 | NA | 179 | 25,225 |
| 1976 | 2 | 5 | 43 | 438 | NA | 4,763 | 21 | 3,191 | 12,326 | 1,890 | NA | 268 | 22,945 |
| 1977 | 1 | 0 | 41 | 0 | NA | 2,247 | 11 | 117 | 14,291 | 637 | NA | 207 | 17,551 |
| 1977 | 2 | 3 | 62 | 799 | NA | 4,952 | 16 | 2,224 | 14,291 | 2,550 | NA | 311 | 25,207 |
| 1978 | 1 | 0 | 49 | 0 | NA | 572 | 7 | 202 | 16,914 | 860 | NA | 245 | 18,848 |
| 1978 | 2 | 3 | 73 | 675 | NA | 50 | 10 | 3,840 | 16,914 | 3,439 | NA | 368 | 25,371 |
| 1979 | 1 | 1 | 1,407 | 12 | NA | 187 | 7 | 267 | 17,790 | 807 | NA | 258 | 20,736 |
| 1979 | 2 | 17 | 2,111 | 1,170 | NA | 0 | 11 | 5,065 | 17,790 | 3,230 | NA | 387 | 29,779 |
| 1980 | 1 | 1 | 1,348 | 30 | NA | 599 | 26 | 137 | 19,311 | 1,108 | NA | 280 | 22,840 |
| 1980 | 2 | 11 | 2,022 | 638 | NA | 0 | 39 | 2,610 | 19,311 | 4,432 | NA | 420 | 29,483 |
| 1981 | 1 | 0 | 2,515 | 0 | 597 | 936 | 3 | 93 | 18,180 | 1,072 | 118 | 263 | 23,778 |
| 1981 | 2 | 1 | 3,772 | 568 | 896 | 38 | 5 | 1,768 | 18,180 | 4,288 | 178 | 395 | 30,089 |
| 1982 | 1 | 0 | 2,026 | 1 | 28 | 338 | 9 | 59 | 21,455 | 891 | 140 | 311 | 25,257 |
| 1982 | 2 | 3 | 3,039 | 319 | 42 | 26 | 13 | 1,126 | 21,455 | 3,563 | 209 | 466 | 30,263 |
| 1983 | 1 | 0 | 1,347 | 0 | 27 | 452 | 2 | 82 | 21,094 | 808 | 216 | 306 | 24,334 |
| 1983 | 2 | 0 | 2,021 | 230 | 40 | 12 | 3 | 1,567 | 21,094 | 3,234 | 324 | 459 | 28,984 |
| 1984 | 1 | 0 | 994 | 1,294 | 36 | 391 | 3 | 38 | 19,813 | 984 | 170 | 287 | 24,010 |
| 1984 | 2 | 1 | 1,492 | 1,955 | 55 | 0 | 5 | 727 | 19,813 | 3,934 | 254 | 431 | 28,666 |
| 1985 | 1 | 8 | 1,138 | 0 | 36 | 823 | 3 | 57 | 16,677 | 908 | 386 | 242 | 20,276 |
| 1985 | 2 | 151 | 1,707 | 1,017 | 53 | 189 | 5 | 1,076 | 16,677 | 3,631 | 578 | 363 | 25,447 |
| 1986 | 1 | 0 | 503 | 8 | 73 | 368 | 7 | 58 | 15,873 | 977 | 475 | 230 | 18,570 |
| 1986 | 2 | 2 | 755 | 1,462 | 109 | 0 | 10 | 1,095 | 15,873 | 3,906 | 712 | 345 | 24,269 |
| 1987 | 1 | 0 | 739 | 0 | 122 | 129 | 13 | 111 | 14,525 | 973 | 422 | 211 | 17,247 |
| 1987 | 2 | 7 | 1,109 | 678 | 184 | 10 | 20 | 2,113 | 14,525 | 3,891 | 634 | 316 | 23,486 |
| 1988 | 1 | 0 | 636 | 137 | 144 | 647 | 4 | 90 | 14,476 | 1,026 | 350 | 210 | 17,719 |
| 1988 | 2 | 4 | 954 | 1,495 | 215 | 0 | 5 | 1,702 | 14,476 | 4,106 | 526 | 315 | 23,797 |
| 1989 | 1 | 7 | 195 | 23 | 167 | 256 | 8 | 83 | 14,143 | 1,072 | 538 | 205 | 16,697 |
| 1989 | 2 | 131 | 292 | 3,789 | 251 | 0 | 12 | 1,578 | 14,143 | 4,288 | 806 | 307 | 25,598 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Rec landings | Foreign otter trawl landings | Other gear landings | Directed longline discards | Otter trawl discards | Gillnet discards | Rec discards | Scallop dredge discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1 | 1 | 2,804 | 174 | 72 | 393 | 1 | 57 | 17,121 | 1,212 | 468 | 248 | 22,551 |
| 1990 | 2 | 16 | 4,206 | 6,696 | 107 | 0 | 2 | 1,081 | 17,121 | 4,850 | 702 | 372 | 35,154 |
| 1991 | 1 | 2 | 2,083 | 3,194 | 52 | 234 | 9 | 89 | 9,661 | 2,206 | 540 | 13 | 18,084 |
| 1991 | 2 | 30 | 3,125 | 3,648 | 79 | 0 | 14 | 1,700 | 9,661 | 8,824 | 810 | 19 | 27,909 |
| 1992 | 1 | 0 | 1,914 | 6,413 | 86 | 67 | 101 | 30 | 16,309 | 1,191 | 408 | 331 | 26,849 |
| 1992 | 2 | 9 | 2,871 | 5,392 | 129 | 0 | 151 | 576 | 16,309 | 4,762 | 611 | 496 | 31,307 |
| 1993 | 1 | 13 | 2,040 | 6,505 | 48 | 27 | 9 | 0 | 8,642 | 1,963 | 444 | 84 | 19,774 |
| 1993 | 2 | 238 | 3,060 | 9,313 | 72 | 0 | 14 | 0 | 8,642 | 7,851 | 666 | 125 | 29,982 |
| 1994 | 1 | 41 | 1,198 | 6,453 | 62 | 2 | 55 | 160 | 6,954 | 577 | 387 | 289 | 16,179 |
| 1994 | 2 | 780 | 1,797 | 9,524 | 93 | 0 | 83 | 3,041 | 6,954 | 2,310 | 581 | 434 | 25,595 |
| 1995 | 1 | 84 | 952 | 5,243 | 27 | 14 | 135 | 187 | 8,499 | 1,346 | 262 | 151 | 16,901 |
| 1995 | 2 | 1,603 | 1,428 | 11,480 | 41 | 0 | 203 | 3,553 | 8,499 | 5,385 | 392 | 227 | 32,811 |
| 1996 | 1 | 80 | 1,341 | 8,986 | 10 | 236 | 40 | 174 | 4,701 | 778 | 132 | 48 | 16,527 |
| 1996 | 2 | 1,526 | 2,011 | 10,349 | 15 | 0 | 61 | 3,314 | 4,701 | 3,112 | 197 | 73 | 25,359 |
| 1997 | 1 | 70 | 711 | 11,535 | 26 | 214 | 40 | 235 | 3,352 | 465 | 335 | 79 | 17,062 |
| 1997 | 2 | 1,322 | 1,067 | 8,000 | 40 | 0 | 60 | 4,460 | 3,352 | 1,861 | 502 | 119 | 20,783 |
| 1998 | 1 | 74 | 1,043 | 7,219 | 16 | 607 | 46 | 49 | 2,634 | 393 | 244 | 48 | 12,373 |
| 1998 | 2 | 1,403 | 1,565 | 10,184 | 23 | 0 | 69 | 931 | 2,634 | 1,572 | 366 | 72 | 18,819 |
| 1999 | 1 | 88 | 897 | 6,938 | 21 | 554 | 106 | 267 | 3,843 | 401 | 213 | 16 | 13,344 |
| 1999 | 2 | 1,665 | 1,346 | 5,297 | 32 | 0 | 159 | 5,080 | 3,843 | 1,604 | 319 | 25 | 19,369 |
| 2000 | 1 | 89 | 1,270 | 2,117 | 2 | 402 | 30 | 192 | 1,364 | 937 | 274 | 6 | 6,683 |
| 2000 | 2 | 1,683 | 1,905 | 1,529 | 3 | 0 | 46 | 3,650 | 1,364 | 3,747 | 411 | 8 | 14,347 |
| 2001 | 1 | 66 | 96 | 199 | 11 | 677 | 10 | 119 | 2,460 | 1,441 | 840 | 12 | 5,930 |
| 2001 | 2 | 1,247 | 144 | 272 | 17 | 0 | 15 | 2,269 | 2,460 | 5,763 | 1,259 | 18 | 13,463 |
| 2002 | 1 | 52 | 95 | 464 | 82 | 474 | 12 | 578 | 2,770 | 999 | 669 | 23 | 6,219 |
| 2002 | 2 | 995 | 142 | 557 | 123 | 0 | 18 | 10,976 | 2,770 | 3,998 | 1,004 | 35 | 20,617 |
| 2003 | 1 | 32 | 15 | 291 | 16 | 643 | 31 | 16 | 1,927 | 1,083 | 1,195 | 41 | 5,290 |
| 2003 | 2 | 613 | 23 | 367 | 24 | 0 | 46 | 307 | 1,927 | 4,330 | 1,792 | 62 | 9,491 |
| 2004 | 1 | 1 | 60 | 379 | 42 | 330 | 20 | 130 | 4,150 | 806 | 1,396 | 21 | 7,335 |
| 2004 | 2 | 24 | 90 | 344 | 63 | 0 | 30 | 2,465 | 4,150 | 3,225 | 2,094 | 32 | 12,516 |

| Year | Period | Directed longline landings | Otter trawl landings | Gillnet landings | Rec landings | Foreign otter trawl landings | Other gear landings | Directed longline discards | Otter trawl discards | Gillnet discards | Rec discards | Scallop dredge discards | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 1 | 3 | 100 | 137 | 18 | 330 | 59 | 29 | 3,758 | 668 | 1,404 | 6 | 6,510 |
| 2005 | 2 | 53 | 150 | 585 | 27 | 0 | 89 | 546 | 3,758 | 2,670 | 2,105 | 9 | 9,992 |
| 2006 | 1 | 7 | 188 | 120 | 38 | 0 | 120 | 177 | 3,887 | 674 | 1,536 | 6 | 6,751 |
| 2006 | 2 | 131 | 281 | 691 | 56 | 0 | 181 | 3,357 | 3,887 | 2,695 | 2,304 | 8 | 13,592 |
| 2007 | 1 | 8 | 83 | 1,524 | 34 | 0 | 269 | 104 | 4,058 | 1,027 | 1,720 | 24 | 8,850 |
| 2007 | 2 | 158 | 125 | 971 | 50 | 0 | 403 | 1,972 | 4,058 | 4,106 | 2,580 | 37 | 14,460 |
| 2008 | 1 | 0 | 3 | 1,068 | 24 | 0 | 175 | 31 | 2,672 | 973 | 1,246 | 95 | 6,287 |
| 2008 | 2 | 265 | 271 | 1,521 | 121 | 0 | 427 | 591 | 2,672 | 3,891 | 1,869 | 142 | 11,771 |
| 2009 | 1 | 0 | 1 | 1,417 | 42 | 0 | 188 | 117 | 3,727 | 2,334 | 437 | 146 | 8,409 |
| 2009 | 2 | 127 | 559 | 2,293 | 20 | 0 | 598 | 499 | 1,751 | 5,324 | 1,290 | 218 | 12,679 |
| 2010 | 1 | 32 | 247 | 1,403 | 8 | 0 | 143 | 613 | 4,118 | 3,374 | 485 | 143 | 10,566 |
| 2010 | 2 | 572 | 349 | 2,723 | 14 | 0 | 339 | 252 | 1,651 | 2,330 | 854 | 75 | 9,159 |
| 2011 | 1 | 4 | 531 | 1,857 | 1 | 0 | 86 | 34 | 963 | 602 | 119 | 24 | 4,221 |
| 2011 | 2 | 495 | 547 | 4,098 | 8 | 0 | 620 | 379 | 3,503 | 3,021 | 1,002 | 138 | 13,811 |
| 2012 | 1 | 34 | 363 | 2,656 | 12 | 0 | 270 | 68 | 3,990 | 2,851 | 338 | 255 | 10,837 |
| 2012 | 2 | 1,735 | 427 | 4,104 | 12 | 0 | 933 | 163 | 4,390 | 2,957 | 554 | 170 | 15,445 |
| 2013 | 1 | 22 | 514 | 4,271 | 7 | 0 | 143 | 70 | 2,845 | 2,385 | 270 | 44 | 10,571 |
| 2013 | 2 | 537 | 250 | 1,869 | 13 | 0 | 547 | 219 | 3,545 | 3,515 | 885 | 73 | 11,453 |
| 2014 | 1 | 80 | 198 | 3,813 | 2 | 0 | 129 | 23 | 3,885 | 2,402 | 382 | 45 | 10,959 |
| 2014 | 2 | 1,580 | 202 | 2,714 | 9 | 0 | 737 | 13 | 2,454 | 3,117 | 351 | 62 | 11,239 |
| 2015 | 1 | 114 | 332 | 4,564 | 11 | 0 | 103 | 2 | 3,484 | 769 | 2,824 | 16 | 12,219 |
| 2015 | 2 | 1,274 | 163 | 2,019 | 24 | 0 | 632 | 175 | 1,967 | 1,692 | 293 | 18 | 8,257 |

*Table 5. Summary of fishing removals of dogfish since 1990. Grey shading encompasses the years for which Canadian catches were adequately sampled to reflect catch compositions. The US fishery has been adequately sampled since 1990. The commercial quota for the US is represented by the coast-wide allocation of dogfish reported by the Massachusetts Energy and Environmental Affairs website. Landings and discards are in tonnes. "NA" = data not available.*

| Year | US Quota (tonnes) | US landings | US discards | US proportion discarded | US proportion discarded dead | US total male discards (millions) | US total female discards (millions) | Canadian TAC (tonnes) | Canadian landings | Canadian discards | Canadian proportion discarded | Canadian proportion discarded dead | Canadian total male discards (millions) | Canadian total female discards (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | NA | 14,472 | 43,232 | 0.75 | 0.83 | 9.396 | 13.407 | NA | 1,041 | 5,924 | 0.85 | 0.32 | 1.088 | 1.933 |
| 1991 | NA | 12,470 | 33,523 | 0.73 | 0.74 | 5.190 | 8.969 | NA | 395 | 6,113 | 0.94 | 0.7 | 0.474 | 0.915 |
| 1992 | NA | 17,133 | 41,023 | 0.71 | 0.79 | 8.773 | 13.423 | NA | 600 | 5,845 | 0.91 | 0.81 | 0.420 | 0.985 |
| 1993 | NA | 21,339 | 28,417 | 0.57 | 0.66 | 5.014 | 12.665 | NA | 757 | 4,213 | 0.85 | 0.74 | 0.310 | 0.830 |
| 1994 | NA | 20,088 | 21,687 | 0.52 | 0.57 | 4.203 | 11.820 | NA | 823 | 2,811 | 0.77 | 0.63 | 0.236 | 0.632 |
| 1995 | NA | 21,210 | 28,501 | 0.57 | 0.59 | 8.575 | 13.336 | NA | 397 | 2,344 | 0.86 | 0.79 | 0.234 | 0.554 |
| 1996 | NA | 24,655 | 17,230 | 0.41 | 0.44 | 6.150 | 16.253 | NA | 60 | 2,225 | 0.97 | 0.94 | 0.239 | 0.231 |
| 1997 | NA | 23,085 | 14,760 | 0.39 | 0.32 | 6.427 | 12.520 | NA | 277 | 2,840 | 0.91 | 0.75 | 0.329 | 0.529 |
| 1998 | NA | 22,249 | 8,943 | 0.29 | 0.18 | 9.386 | 14.510 | NA | 871 | 2,955 | 0.77 | 0.56 | 0.544 | 0.682 |
| 1999 | NA | 17,103 | 15,611 | 0.48 | 0.24 | 7.068 | 13.373 | NA | 1,890 | 2,081 | 0.52 | 0.26 | 0.198 | 1.259 |
| 2000 | NA | 9,076 | 1,1953 | 0.57 | 0.26 | 4.131 | 9.029 | NA | 2,539 | 1,974 | 0.44 | 0.2 | 0.215 | 1.577 |
| 2001 | NA | 2,754 | 1,6641 | 0.86 | 0.22 | 5.835 | 8.006 | NA | 3,578 | 2,029 | 0.36 | 0.14 | 0.987 | 1.561 |
| 2002 | NA | 3,014 | 23,822 | 0.89 | 0.3 | 4.271 | 6.940 | NA | 3,438 | 2,180 | 0.39 | 0.18 | 0.407 | 1.713 |
| 2003 | NA | 2,101 | 12,680 | 0.86 | 0.25 | 5.887 | 7.453 | NA | 1,293 | 2,056 | 0.61 | 0.36 | 0.286 | 0.778 |
| 2004 | NA | 1,383 | 18,469 | 0.93 | 0.45 | 3.883 | 5.558 | 2,500 | 2,290 | 1,991 | 0.47 | 0.24 | 0.578 | 1.095 |
| 2005 | 1,816 | 1,551 | 14,953 | 0.91 | 0.38 | 3.715 | 4.919 | 2,500 | 2,311 | 1,773 | 0.43 | 0.2 | 0.497 | 1.110 |
| 2006 | 1,816 | 1,813 | 18,531 | 0.91 | 0.85 | 1.627 | 2.987 | 2,500 | 2,442 | 1,306 | 0.35 | 0.15 | 0.507 | 1.040 |
| 2007 | 1,405 | 3,625 | 19,686 | 0.84 | 0.73 | 1.802 | 3.623 | 2,500 | 2,387 | 1,463 | 0.38 | 0.16 | 0.524 | 1.026 |
| 2008 | 3,632 | 3,875 | 14,182 | 0.79 | 0.75 | 2.282 | 4.007 | 2,500 | 1,546 | 1,405 | 0.48 | 0.22 | 0.401 | 0.702 |
| 2009 | 5,448 | 5,245 | 15,843 | 0.75 | 0.74 | 2.651 | 5.364 | 2,500 | 165 | 1,536 | 0.9 | 0.73 | 0.123 | 0.223 |
| 2010 | 3,756 | 5,830 | 13,895 | 0.7 | 0.68 | 2.656 | 4.491 | 2,500 | 5 | 1,513 | 1 | 0.99 | 0.107 | 0.158 |
| 2011 | 5,060 | 8,346 | 9,785 | 0.54 | 0.36 | 1.760 | 4.263 | 2,500 | 124 | 1,384 | 0.92 | 0.77 | 0.128 | 0.186 |
| 2012 | 7,788 | 10,545 | 15,736 | 0.6 | 0.45 | 1.822 | 5.990 | 2,500 | 65 | 1,493 | 0.96 | 0.86 | 0.123 | 0.173 |
| 2013 | 10,755 | 8,173 | 13,851 | 0.63 | 0.59 | 2.229 | 5.585 | 2,500 | 5 | 988 | 0.99 | 0.98 | 0.072 | 0.102 |
| 2014 | 13,000 | 9,464 | 12,734 | 0.57 | 0.55 | 2.513 | 5.924 | 2,500 | 54 | 294 | 0.84 | 0.86 | 0.035 | 0.050 |
| 2015 | 13,327 | 9,235 | 11,240 | 0.55 | 0.41 | 2.330 | 4.561 | 10,000 | 1 | 51 | 0.98 | 0.99 | 0.004 | 0.005 |

*Table 6. Number of sampling tows undertaken in nine outer slope strata during the NMFS Spring survey since 1980.*

| Year | Outer Slope Strata | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1040** | **1080** | **1120** | **1150** | **1180** | **1640** | **1680** | **1720** | **1760** |
| 1980 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 1 | 1 | 3 | 2 | 0 | 1 | 2 | 1 | 2 |
| 1982 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 |
| 1983 | 3 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| 1984 | 2 | 2 | 1 | 0 | 2 | 0 | 1 | 2 | 2 |
| 1985 | 1 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 |
| 1986 | 3 | 3 | 2 | 3 | 1 | 0 | 0 | 2 | 2 |
| 1987 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 2 |
| 1988 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1989 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1990 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1991 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| 1992 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 1993 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1994 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 1995 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 1996 | 1 | 0 | 1 | 0 | 0 | 2 | 1 | 1 | 0 |
| 1997 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 |
| 1998 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 1999 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 2000 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 2001 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 2003 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2004 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2005 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2006 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 2007 | 3 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 3 |
| 2008 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 2009 | 3 | 2 | 1 | 0 | 0 | 2 | 2 | 2 | 2 |
| 2010 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 |
| 2011 | 3 | 3 | 2 | 3 | 0 | 1 | 3 | 3 | 3 |
| 2012 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |
| 2013 | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 |
| 2014 | 2 | 2 | 3 | 2 | 1 | 0 | 0 | 3 | 3 |
| 2015 | 3 | 3 | 3 | 2 | 0 | 2 | 3 | 2 | 3 |

*Table 7. A comparison of the catchability coefficients and relative catchability (by life stage and diel period) given in Sagarese et al. (2016) with those that would result from alternate ways of partitioning the data (e.g., using the stock definition for Spiny Dogfish: Stock definition strata only), alternate length at maturity estimates for defining life stages (e.g., Demersal length cutpoints), and considering recent years (2009–2015) sampled by the Bigelow (Bigelow years). The coefficient (Estimate) represents the intercept from a quasibinomial Generalized Linear Model along with the standard errors (SE), and significance level (P). Values > 1 for the relative catchability ratio (relative catchability) represent life stages that are more likely to be caught during the day and vice versa for values < 1. The amount of data available for each life stage is shown (N); note the decrease in sample size in more recent years sampled by the Bigelow. "NA" = data not available.*

| Life stage | Method | Estimate | SE | P | Relative Catchability (day /night) | N |
|---|---|---|---|---|---|---|
| Adult Males | Sagarese et al. (2016) | 0.70 | NA | 0.03 | 2.00 | 821 |
| Adult Females | Sagarese et al. (2016) | NA | NA | NA | NA | NA |
| Juvenile Males | Sagarese et al. (2016) | NA | NA | NA | NA | NA |
| Juvenile Females | Sagarese et al. (2016) | 0.40 | NA | 0.27 | 1.50 | 973 |
| Pups | Sagarese et al. (2016) | NA | NA | NA | NA | NA |
| Adult Males | Stock definition strata only | 0.09 | 0.06 | 0.16 | 1.09 | 710 |
| Adult Females | Stock definition strata only | -0.08 | 0.07 | 0.26 | 0.92 | 725 |
| Juvenile Males | Stock definition strata only | 0.52 | 0.08 | 0 | 1.68 | 513 |
| Juvenile Females | Stock definition strata only | 0.24 | 0.06 | 0 | 1.27 | 750 |
| Pups | Stock definition strata only | 0.76 | 0.13 | 0 | 2.13 | 252 |
| Adult Males | Demersal length cutpoints | 0.09 | 0.06 | 0.16 | 1.09 | 710 |
| Adult Females | Demersal length cutpoints | -0.08 | 0.06 | 0.19 | 0.92 | 786 |
| Juvenile Males | Demersal length cutpoints | 0.53 | 0.08 | 0 | 1.70 | 491 |
| Juvenile Females | Demersal length cutpoints | 0.43 | 0.07 | 0 | 1.54 | 610 |

| Life stage | Method | Estimate | SE | P | Relative Catchability (day /night) | N |
|---|---|---|---|---|---|---|
| Pups | Demersal length cutpoints | NA | NA | NA | NA | NA |
| Adult Males | Demeral length cutpoints, drop 2009 (Bigelow) | 0.10 | 0.06 | 0.13 | 1.10 | 696 |
| Adult Females | Demeral length cutpoints, drop 2009 (Bigelow) | -0.05 | 0.06 | 0.47 | 0.96 | 751 |
| Juvenile Males | Demeral length cutpoints, drop 2009 (Bigelow) | 0.39 | 0.08 | 0 | 1.48 | 473 |
| Juvenile Females | Demeral length cutpoints, drop 2009 (Bigelow) | 0.29 | 0.07 | 0 | 1.34 | 586 |
| Pups | Demeral length cutpoints, drop 2009 (Bigelow) | 0.62 | 0.13 | 0 | 1.86 | 234 |
| Adult Males | Bigelow years | -0.21 | 0.09 | 0 | 0.81 | 220 |
| Adult Females | Bigelow years | -0.16 | 0.12 | 0.20 | 0.86 | 183 |
| Juvenile Males | Bigelow years | 1.64 | 0.15 | 0 | 5.16 | 201 |
| Juvenile Females | Bigelow years | 1.34 | 0.13 | 0 | 3.81 | 243 |
| Pups | Bigelow years | 2.44 | 0.18 | 0 | 11.45 | 128 |
| Adult Males | Bigelow years; demersal cutpoints | -0.21 | 0.09 | 0.03 | 0.81 | 223 |
| Adult Females | Bigelow years; demersal cutpoints | -0.17 | 0.11 | 0.12 | 0.84 | 220 |
| Juvenile Males | Bigelow years; demersal cutpoints | 1.78 | 0.16 | 0 | 5.93 | 199 |
| Juvenile Females | Bigelow years; demersal cutpoints | 1.82 | 0.16 | 0 | 6.14 | 217 |
| Pups | Bigelow years; demersal cutpoints | NA | NA | NA | NA | NA |

*Table 8. Sensitivity of diel catchability estimates to the sampling scheme used in the Spring survey during three time periods (1980–20018, 1988–2008, and 1980–1987). "SE" is Standard Error (of the estimate in column 1), "P" is P-value (for the statistical test for day/night effect), and "N" is the number of observations.*

| Life stage | Method | Estimate | SE | P | Relative Catchability (day /night) | N |
|---|---|---|---|---|---|---|
| Adult Males | Albatross Years 1980–2008 | 0.10 | 0.06 | 0.13 | 1.10 | 696 |
| Adult Females | Albatross Years 1980–2008 | -0.05 | 0.06 | 0.47 | 0.96 | 751 |
| Juvenile Males | Albatross Years 1980–2008 | 0.39 | 0.08 | 0.00 | 1.48 | 473 |
| Juvenile Females | Albatross Years 1980–2008 | 0.29 | 0.07 | 0.00 | 1.34 | 586 |
| Pups | Albatross Years 1980–2008 | 0.62 | 0.13 | 0.00 | 1.86 | 234 |
| Adult Males | Albatross Years 1988–2008 | 0.16 | 0.08 | 0.03 | 1.18 | 503 |
| Adult Females | Albatross Years 1988–2008 | -0.04 | 0.08 | 0.57 | 0.96 | 547 |
| Juvenile Males | Albatross Years 1988–2008 | 0.18 | 0.09 | 0.05 | 1.20 | 328 |
| Juvenile Females | Albatross Years 1988–2008 | 0.19 | 0.08 | 0.02 | 1.20 | 414 |
| Pups | Albatross Years 1988–2008 | 0.43 | 0.16 | 0.01 | 1.53 | 160 |
| Adult Males | Albatross Years 1980–1987 | -0.18 | 0.11 | 0.10 | 0.84 | 187 |
| Adult Females | Albatross Years 1980–1987 | -0.05 | 0.12 | 0.65 | 0.95 | 204 |
| Juvenile Males | Albatross Years 1980–1987 | 0.64 | 0.14 | 0.00 | 1.89 | 144 |
| Juvenile Females | Albatross Years 1980–1987 | 0.44 | 0.13 | 0.00 | 1.55 | 172 |
| Pups | Albatross Years 1980–1987 | 0.96 | 0.24 | 0.00 | 2.61 | 74 |

*Table 9. Sensitivity runs of diel catchability models, comparing results for slope and non-slope data. "SE" is Standard Error (of the estimate in column 1), "P" is P-value (for the statistical test for day/night effect), and "N" is the number of observations. A = Albatross data and B = Bigelow data*

**A.**

| | | **Albatross All Strata** | | | | | **Albatross Slope Strata** | | | | | **Albatross Non-Slope Strata** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Life Stage** | Estimate | SE | P | Relative Catchability (day/night) | N | Estimate | SE | P | Relative Catchability (day/night) | N | Estimate | SE | P | Relative Catchability (day/night) | N |
| **1980–2008** | Adult Males | 0.1 | 0.06 | 0.13 | 1.1 | 696 | 0.17 | 0.15 | 0.28 | 1.18 | 119 | 0.06 | 0.07 | 0.39 | 1.06 | 571 |
| | Adult Females | -0.05 | 0.06 | 0.47 | 0.96 | 751 | 0.24 | 0.2 | 0.24 | 1.27 | 101 | -0.09 | 0.07 | 0.19 | 0.92 | 650 |
| | Juvenile Males | 0.39 | 0.08 | 0 | 1.48 | 473 | 0.52 | 0.17 | 0 | 1.69 | 101 | 0.2 | 0.08 | 0.02 | 1.22 | 372 |
| | Juvenile Females | 0.29 | 0.07 | 0 | 1.34 | 586 | 0.32 | 0.16 | 0.05 | 1.38 | 117 | 0.25 | 0.07 | 0 | 1.28 | 469 |
| | Pups | 0.62 | 0.13 | 0 | 1.86 | 234 | 0.38 | 0.27 | 0.16 | 1.47 | 55 | 0.81 | 0.16 | 0 | 2.25 | 179 |
| **1980–1987** | Adult Males | -0.18 | 0.11 | 0.1 | 0.84 | 187 | -0.69 | 0.24 | 0.01 | 0.5 | 51 | 0.14 | 0.12 | 0.26 | 1.14 | 140 |
| | Adult Females | -0.05 | 0.12 | 0.65 | 0.95 | 204 | -2.43 | 0.43 | 0 | 0.09 | 43 | 0.21 | 0.13 | 0.11 | 1.24 | 161 |
| | Juvenile Males | 0.64 | 0.14 | 0 | 1.89 | 144 | 0.81 | 0.26 | 0 | 2.24 | 52 | 0.36 | 0.15 | 0.02 | 1.44 | 92 |
| | Juvenile Females | 0.44 | 0.13 | 0 | 1.55 | 172 | 0.57 | 0.25 | 0.02 | 1.76 | 55 | 0.23 | 0.13 | 0.09 | 1.26 | 117 |
| | Pups | 0.96 | 0.24 | 0 | 2.61 | 74 | 1.71 | 0.54 | 0 | 5.51 | 26 | 0.69 | 0.27 | 0.01 | 1.99 | 48 |
| **1988–2008** | Adult Males | 0.16 | 0.08 | 0.03 | 1.18 | 503 | 0.58 | 0.19 | 0 | 1.79 | 68 | 0.04 | 0.08 | 0.64 | 1.04 | 431 |
| | Adult Females | -0.04 | 0.08 | 0.57 | 0.96 | 547 | 0.86 | 0.27 | 0 | 2.36 | 58 | -0.17 | 0.08 | 0.03 | 0.84 | 489 |
| | Juvenile Males | 0.18 | 0.09 | 0.05 | 1.2 | 328 | 0.26 | 0.24 | 0.27 | 1.3 | 49 | 0.07 | 0.1 | 0.5 | 1.07 | 280 |
| | Juvenile Females | 0.19 | 0.08 | 0.02 | 1.2 | 414 | 0.12 | 0.22 | 0.58 | 1.13 | 62 | 0.26 | 0.09 | 0 | 1.3 | 352 |
| | Pups | 0.43 | 0.16 | 0.01 | 1.53 | 160 | -0.02 | 0.37 | 0.95 | 0.98 | 29 | 0.93 | 0.21 | 0 | 2.53 | 131 |

**B.**

| | | **Bigelow All Strata** | | | | | **Bigelow Slope Strata** | | | | | **Bigelow Non-Slope Strata** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Life Stage** | Estimate | SE | P | Relative Catchability (day/night) | N | Estimate | SE | P | Relative Catchability (day/night) | N | Estimate | SE | P | Relative Catchability (day/night) | N |
| 2009–2015 | Adult Males | -0.21 | 0.09 | 0.03 | 0.81 | 223 | -0.57 | 0.16 | 0 | 0.57 | 72 | 0.08 | 0.12 | 0.5 | 1.08 | 151 |
| | Adult Females | -0.17 | 0.11 | 0.12 | 0.84 | 220 | 0.75 | 0.2 | 0 | 2.11 | 63 | -0.38 | 0.14 | 0.01 | 0.68 | 157 |
| | Juvenile Males | 1.78 | 0.16 | 0 | 5.93 | 199 | 1.87 | 0.27 | 0 | 6.47 | 78 | 1.61 | 0.2 | 0 | 5 | 121 |
| | Juvenile Females | 1.82 | 0.16 | 0 | 6.14 | 217 | 1.78 | 0.25 | 0 | 5.95 | 83 | 1.87 | 0.2 | 0 | 6.51 | 134 |
| | Pups | 2.44 | 0.18 | 0 | 11.45 | 128 | 3 | 0.44 | 0 | 20 | 64 | 2.01 | 0.16 | 0 | 7.42 | 64 |

*Table 10. Raw counts of dogfish at length and number of survey tow pairs contributing to counts.*

| Length (cm) | Bigelow counts; males, night | Bigelow counts; males, day | Albatross counts; males, night | Albatross counts; males, day | Tow-pairs, night | Tow-pairs, day | Bigelow counts; females, night | Bigelow counts; females, day | Albatross counts; females, night | Albatross counts; females, day | Tow-pairs, night | Tow-pairs, day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 1 | 2 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 1 | 2 | 2 |
| 23 | 3 | 1 | 0 | 3 | 2 | 2 | 2 | 2 | 0 | 5 | 2 | 3 |
| 24 | 5 | 3 | 1 | 5 | 4 | 3 | 6 | 8 | 0 | 2 | 3 | 6 |
| 25 | 6 | 14 | 0 | 12 | 4 | 6 | 6 | 19 | 0 | 12 | 4 | 10 |
| 26 | 15 | 16 | 1 | 30 | 5 | 9 | 8 | 20 | 0 | 19 | 6 | 10 |
| 27 | 12 | 37 | 2 | 50 | 6 | 11 | 18 | 53 | 0 | 46 | 8 | 13 |
| 28 | 15 | 42 | 1 | 50 | 6 | 13 | 4 | 49 | 2 | 55 | 5 | 13 |
| 29 | 2 | 37 | 0 | 44 | 2 | 10 | 8 | 49 | 0 | 45 | 7 | 8 |
| 30 | 5 | 22 | 0 | 25 | 4 | 4 | 5 | 25 | 1 | 36 | 4 | 6 |
| 31 | 1 | 7 | 0 | 9 | 1 | 3 | 1 | 6 | 0 | 3 | 1 | 2 |
| 32 | 1 | 2 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 1 |
| 33 | 4 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 34 | 8 | 1 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 |
| 35 | 6 | 0 | 1 | 1 | 1 | 1 | 11 | 0 | 1 | 1 | 2 | 1 |
| 36 | 7 | 2 | 0 | 1 | 1 | 1 | 3 | 1 | 1 | 4 | 2 | 3 |
| 37 | 6 | 1 | 1 | 0 | 1 | 1 | 5 | 2 | 0 | 1 | 1 | 2 |
| 38 | 1 | 0 | 0 | 1 | 1 | 1 | 6 | 2 | 1 | 2 | 1 | 1 |
| 39 | 3 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 1 |
| 41 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 2 |
| 45 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 | 0 | 3 |
| 47 | 0 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 |

| Length (cm) | Bigelow counts; males, night | Bigelow counts; males, day | Albatross counts; males, night | Albatross counts; males, day | Tow-pairs, night | Tow-pairs, day | Bigelow counts; females, night | Bigelow counts; females, day | Albatross counts; females, night | Albatross counts; females, day | Tow-pairs, night | Tow-pairs, day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| 49 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 3 |
| 50 | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 4 | 0 | 11 | 0 | 6 |
| 51 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 11 | 0 | 3 |
| 52 | 0 | 1 | 0 | 4 | 0 | 3 | 0 | 4 | 0 | 8 | 0 | 5 |
| 53 | 0 | 2 | 0 | 4 | 0 | 4 | 0 | 5 | 0 | 10 | 0 | 6 |
| 54 | 0 | 3 | 0 | 3 | 0 | 4 | 0 | 6 | 0 | 9 | 0 | 5 |
| 55 | 1 | 7 | 0 | 6 | 1 | 7 | 0 | 1 | 0 | 8 | 0 | 3 |
| 56 | 0 | 6 | 1 | 5 | 1 | 8 | 1 | 14 | 0 | 18 | 1 | 8 |
| 57 | 1 | 6 | 0 | 4 | 1 | 5 | 0 | 7 | 0 | 9 | 0 | 8 |
| 58 | 1 | 9 | 0 | 6 | 1 | 7 | 1 | 15 | 0 | 19 | 1 | 8 |
| 59 | 1 | 7 | 1 | 3 | 2 | 8 | 0 | 24 | 0 | 22 | 0 | 6 |
| 60 | 1 | 7 | 3 | 9 | 4 | 7 | 2 | 22 | 0 | 23 | 1 | 13 |
| 61 | 4 | 7 | 1 | 9 | 4 | 9 | 2 | 16 | 0 | 16 | 2 | 10 |
| 62 | 2 | 16 | 3 | 13 | 3 | 11 | 2 | 27 | 1 | 17 | 3 | 8 |
| 63 | 0 | 14 | 2 | 7 | 2 | 10 | 2 | 22 | 0 | 21 | 1 | 12 |
| 64 | 2 | 7 | 6 | 14 | 6 | 11 | 4 | 33 | 1 | 14 | 3 | 12 |
| 65 | 3 | 15 | 9 | 12 | 8 | 12 | 3 | 23 | 1 | 11 | 2 | 14 |
| 66 | 9 | 21 | 20 | 22 | 12 | 21 | 8 | 27 | 0 | 13 | 6 | 8 |
| 67 | 16 | 23 | 24 | 40 | 15 | 21 | 5 | 27 | 2 | 13 | 4 | 12 |
| 68 | 22 | 50 | 40 | 54 | 16 | 27 | 3 | 19 | 2 | 20 | 4 | 17 |
| 69 | 28 | 83 | 62 | 79 | 17 | 33 | 5 | 23 | 7 | 29 | 8 | 16 |
| 70 | 84 | 138 | 93 | 101 | 23 | 37 | 10 | 34 | 5 | 16 | 9 | 15 |
| 71 | 83 | 127 | 126 | 151 | 22 | 31 | 11 | 22 | 7 | 15 | 10 | 15 |
| 72 | 115 | 189 | 167 | 221 | 19 | 35 | 11 | 34 | 11 | 26 | 12 | 17 |
| 73 | 145 | 196 | 152 | 206 | 18 | 39 | 15 | 34 | 14 | 21 | 12 | 18 |
| 74 | 150 | 253 | 186 | 265 | 22 | 40 | 11 | 37 | 17 | 30 | 12 | 18 |
| 75 | 159 | 227 | 210 | 285 | 20 | 39 | 21 | 39 | 14 | 48 | 9 | 20 |
| 76 | 150 | 194 | 153 | 208 | 22 | 33 | 27 | 36 | 32 | 50 | 15 | 20 |

| Length (cm) | Bigelow counts; males, night | Bigelow counts; males, day | Albatross counts; males, night | Albatross counts; males, day | Tow-pairs, night | Tow-pairs, day | Bigelow counts; females, night | Bigelow counts; females, day | Albatross counts; females, night | Albatross counts; females, day | Tow-pairs, night | Tow-pairs, day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 77 | 117 | 167 | 142 | 144 | 20 | 37 | 44 | 49 | 31 | 47 | 19 | 23 |
| 78 | 89 | 99 | 86 | 86 | 17 | 28 | 38 | 53 | 45 | 66 | 17 | 26 |
| 79 | 76 | 99 | 59 | 95 | 17 | 30 | 60 | 62 | 69 | 73 | 18 | 23 |
| 80 | 41 | 61 | 49 | 55 | 16 | 23 | 38 | 60 | 70 | 69 | 19 | 25 |
| 81 | 31 | 42 | 21 | 33 | 16 | 21 | 54 | 68 | 58 | 82 | 21 | 24 |
| 82 | 19 | 27 | 12 | 27 | 12 | 19 | 64 | 81 | 87 | 71 | 21 | 26 |
| 83 | 5 | 5 | 3 | 7 | 7 | 8 | 64 | 58 | 50 | 66 | 17 | 21 |
| 84 | 4 | 6 | 7 | 3 | 8 | 7 | 88 | 90 | 64 | 57 | 21 | 21 |
| 85 | 3 | 2 | 1 | 4 | 4 | 5 | 37 | 51 | 64 | 55 | 16 | 25 |
| 86 | 0 | 1 | 1 | 1 | 1 | 2 | 54 | 38 | 61 | 46 | 17 | 18 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 58 | 56 | 36 | 15 | 18 |
| 88 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 30 | 60 | 31 | 19 | 16 |
| 89 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 22 | 29 | 34 | 15 | 17 |
| 90 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 26 | 24 | 28 | 17 | 16 |
| 91 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 13 | 19 | 20 | 14 | 12 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 18 | 15 | 14 | 14 | 13 |
| 93 | 0 | 1 | 0 | 0 | 0 | 1 | 12 | 8 | 9 | 9 | 10 | 7 |
| 94 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 6 | 5 | 8 | 7 | 5 |
| 95 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 | 6 | 5 | 6 |
| 96 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 4 | 3 | 4 | 4 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 5 | 2 | 7 | 4 |
| 98 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 1 | 5 | 3 |
| 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 3 |
| 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 101 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 2 |

*Table 11. Catch at length of male and female Spiny Dogfish by the Bigelow during the calibration study in 2008, compared with the subsequent survey years (2009–2015).*

| Length (cm) | Male 2008 | Male 2009 | Male 2010 | Male 2011 | Male 2012 | Male 2013 | Male 2014 | Male 2015 | Female 2008 | Female 2009 | Female 2010 | Female 2011 | Female 2012 | Female 2013 | Female 2014 | Female 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 2 | 0 | 10 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 7 | 1 | 0 | 5 | 0 | 0 |
| 22 | 3 | 6 | 4 | 11 | 32 | 7 | 1 | 3 | 3 | 7 | 28 | 3 | 5 | 4 | 0 | 1 |
| 23 | 4 | 30 | 41 | 12 | 37 | 3 | 2 | 1 | 4 | 14 | 43 | 16 | 28 | 5 | 5 | 4 |
| 24 | 8 | 76 | 95 | 25 | 74 | 22 | 5 | 6 | 14 | 38 | 46 | 28 | 49 | 18 | 12 | 5 |
| 25 | 20 | 91 | 185 | 44 | 109 | 27 | 34 | 12 | 25 | 84 | 139 | 78 | 102 | 55 | 23 | 15 |
| 26 | 31 | 90 | 256 | 89 | 159 | 58 | 53 | 35 | 28 | 97 | 175 | 88 | 146 | 64 | 52 | 45 |
| 27 | 49 | 132 | 253 | 151 | 324 | 234 | 113 | 61 | 71 | 202 | 252 | 134 | 331 | 150 | 102 | 64 |
| 28 | 57 | 156 | 208 | 97 | 335 | 170 | 132 | 76 | 53 | 201 | 166 | 104 | 276 | 208 | 134 | 57 |
| 29 | 39 | 105 | 92 | 67 | 191 | 163 | 94 | 34 | 57 | 69 | 71 | 43 | 100 | 176 | 92 | 42 |
| 30 | 27 | 63 | 89 | 50 | 86 | 156 | 53 | 15 | 30 | 42 | 72 | 18 | 83 | 113 | 62 | 19 |
| 31 | 8 | 28 | 96 | 23 | 51 | 293 | 10 | 12 | 7 | 42 | 53 | 14 | 73 | 150 | 16 | 14 |
| 32 | 3 | 87 | 85 | 37 | 119 | 326 | 10 | 30 | 3 | 78 | 59 | 40 | 143 | 237 | 8 | 20 |
| 33 | 4 | 88 | 64 | 66 | 123 | 219 | 4 | 30 | 1 | 121 | 65 | 61 | 69 | 344 | 6 | 30 |
| 34 | 9 | 240 | 55 | 49 | 102 | 395 | 18 | 43 | 3 | 173 | 36 | 31 | 140 | 387 | 21 | 43 |
| 35 | 6 | 216 | 34 | 55 | 81 | 379 | 35 | 36 | 11 | 349 | 38 | 68 | 146 | 431 | 26 | 36 |
| 36 | 9 | 319 | 16 | 111 | 108 | 426 | 30 | 28 | 4 | 245 | 29 | 52 | 143 | 291 | 36 | 21 |
| 37 | 7 | 298 | 39 | 137 | 229 | 358 | 47 | 17 | 7 | 411 | 28 | 54 | 250 | 560 | 46 | 27 |
| 38 | 1 | 253 | 43 | 123 | 145 | 430 | 60 | 32 | 8 | 277 | 22 | 74 | 173 | 629 | 57 | 28 |
| 39 | 3 | 85 | 60 | 64 | 145 | 497 | 56 | 25 | 1 | 179 | 45 | 127 | 307 | 538 | 79 | 31 |
| 40 | 0 | 100 | 64 | 104 | 323 | 596 | 76 | 59 | 3 | 100 | 54 | 73 | 447 | 473 | 82 | 23 |
| 41 | 1 | 114 | 54 | 71 | 209 | 409 | 88 | 55 | 1 | 103 | 68 | 60 | 291 | 442 | 61 | 30 |
| 42 | 0 | 51 | 53 | 65 | 262 | 392 | 88 | 40 | 2 | 118 | 53 | 59 | 409 | 452 | 82 | 30 |
| 43 | 0 | 87 | 37 | 63 | 332 | 296 | 66 | 34 | 0 | 110 | 52 | 5 | 330 | 436 | 60 | 21 |
| 44 | 0 | 80 | 38 | 23 | 402 | 283 | 71 | 42 | 1 | 128 | 51 | 31 | 444 | 291 | 56 | 20 |
| 45 | 1 | 120 | 46 | 64 | 465 | 121 | 72 | 24 | 1 | 181 | 42 | 33 | 434 | 204 | 53 | 23 |
| 46 | 0 | 85 | 49 | 21 | 475 | 194 | 56 | 29 | 2 | 133 | 45 | 30 | 404 | 191 | 56 | 15 |
| 47 | 0 | 59 | 40 | 27 | 314 | 259 | 100 | 27 | 1 | 51 | 41 | 43 | 592 | 206 | 91 | 22 |
| 48 | 0 | 63 | 54 | 62 | 585 | 187 | 75 | 18 | 2 | 45 | 46 | 58 | 441 | 243 | 64 | 22 |
| 49 | 1 | 50 | 35 | 54 | 647 | 223 | 66 | 17 | 2 | 51 | 33 | 50 | 651 | 264 | 55 | 20 |
| 50 | 2 | 38 | 33 | 19 | 786 | 285 | 84 | 14 | 4 | 45 | 47 | 63 | 884 | 337 | 106 | 33 |
| 51 | 1 | 20 | 33 | 43 | 575 | 404 | 86 | 31 | 3 | 24 | 25 | 61 | 628 | 301 | 100 | 34 |
| 52 | 1 | 26 | 42 | 65 | 688 | 325 | 110 | 44 | 4 | 26 | 22 | 74 | 630 | 470 | 156 | 35 |
| 53 | 2 | 52 | 24 | 64 | 752 | 416 | 111 | 43 | 5 | 32 | 18 | 62 | 610 | 383 | 134 | 62 |
| 54 | 3 | 45 | 28 | 65 | 839 | 490 | 113 | 66 | 6 | 23 | 20 | 79 | 516 | 452 | 174 | 81 |
| 55 | 8 | 31 | 22 | 64 | 473 | 353 | 100 | 72 | 1 | 24 | 41 | 56 | 489 | 464 | 138 | 79 |
| 56 | 6 | 45 | 35 | 58 | 593 | 494 | 147 | 99 | 15 | 21 | 22 | 87 | 404 | 433 | 184 | 128 |

| Length (cm) | Male 2008 | Male 2009 | Male 2010 | Male 2011 | Male 2012 | Male 2013 | Male 2014 | Male 2015 | Female 2008 | Female 2009 | Female 2010 | Female 2011 | Female 2012 | Female 2013 | Female 2014 | Female 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | 7 | 26 | 16 | 78 | 268 | 473 | 154 | 96 | 7 | 27 | 24 | 60 | 269 | 504 | 150 | 108 |
| 58 | 10 | 26 | 27 | 72 | 352 | 416 | 155 | 119 | 16 | 19 | 30 | 79 | 137 | 421 | 146 | 116 |
| 59 | 8 | 58 | 60 | 103 | 146 | 406 | 201 | 140 | 24 | 26 | 22 | 66 | 283 | 330 | 160 | 153 |
| 60 | 8 | 38 | 68 | 103 | 129 | 462 | 182 | 175 | 24 | 27 | 13 | 62 | 286 | 416 | 144 | 141 |
| 61 | 11 | 63 | 102 | 98 | 121 | 258 | 130 | 194 | 18 | 20 | 22 | 56 | 132 | 144 | 151 | 126 |
| 62 | 18 | 28 | 88 | 80 | 146 | 220 | 141 | 158 | 29 | 19 | 30 | 52 | 131 | 230 | 117 | 104 |
| 63 | 14 | 40 | 60 | 109 | 94 | 117 | 178 | 145 | 24 | 23 | 23 | 60 | 101 | 112 | 76 | 110 |
| 64 | 9 | 42 | 45 | 118 | 92 | 162 | 158 | 134 | 37 | 22 | 38 | 56 | 68 | 77 | 63 | 80 |
| 65 | 18 | 46 | 60 | 124 | 48 | 101 | 111 | 133 | 26 | 20 | 36 | 24 | 40 | 72 | 64 | 52 |
| 66 | 30 | 72 | 70 | 112 | 246 | 141 | 124 | 134 | 35 | 42 | 30 | 69 | 70 | 54 | 46 | 40 |
| 67 | 39 | 106 | 238 | 154 | 151 | 119 | 166 | 146 | 32 | 12 | 46 | 39 | 44 | 96 | 26 | 32 |
| 68 | 72 | 153 | 368 | 200 | 246 | 168 | 148 | 182 | 22 | 22 | 28 | 26 | 54 | 38 | 19 | 36 |
| 69 | 111 | 350 | 802 | 376 | 260 | 212 | 234 | 203 | 28 | 34 | 40 | 30 | 54 | 34 | 26 | 43 |
| 70 | 222 | 694 | 1,006 | 655 | 586 | 448 | 448 | 284 | 44 | 27 | 48 | 23 | 57 | 28 | 12 | 22 |
| 71 | 210 | 774 | 1,453 | 827 | 649 | 516 | 584 | 326 | 33 | 29 | 42 | 34 | 40 | 16 | 17 | 34 |
| 72 | 304 | 1,142 | 1,896 | 1,100 | 1,101 | 683 | 727 | 532 | 45 | 70 | 62 | 55 | 30 | 22 | 8 | 9 |
| 73 | 341 | 1,412 | 2,608 | 1,340 | 1,310 | 912 | 998 | 648 | 49 | 52 | 66 | 22 | 29 | 23 | 5 | 10 |
| 74 | 403 | 1,322 | 2,006 | 1,620 | 1,258 | 1,047 | 1,289 | 837 | 48 | 47 | 70 | 37 | 56 | 23 | 8 | 21 |
| 75 | 386 | 1,254 | 1,960 | 1,563 | 1,366 | 1,026 | 1,192 | 746 | 60 | 64 | 77 | 46 | 52 | 23 | 10 | 24 |
| 76 | 344 | 1,072 | 1,788 | 1,372 | 1,378 | 982 | 1,284 | 845 | 63 | 131 | 92 | 216 | 42 | 22 | 12 | 18 |
| 77 | 284 | 856 | 1,287 | 1,120 | 1,036 | 754 | 886 | 524 | 93 | 66 | 142 | 142 | 124 | 24 | 15 | 6 |
| 78 | 188 | 579 | 1,158 | 761 | 621 | 500 | 625 | 450 | 91 | 96 | 180 | 122 | 84 | 32 | 14 | 44 |
| 79 | 175 | 432 | 544 | 518 | 476 | 394 | 444 | 310 | 122 | 165 | 289 | 227 | 120 | 53 | 32 | 16 |
| 80 | 102 | 226 | 460 | 262 | 320 | 252 | 299 | 182 | 98 | 138 | 252 | 212 | 239 | 88 | 30 | 58 |
| 81 | 73 | 120 | 182 | 125 | 142 | 139 | 180 | 78 | 122 | 168 | 258 | 304 | 174 | 32 | 44 | 50 |
| 82 | 46 | 46 | 112 | 136 | 96 | 81 | 113 | 50 | 145 | 204 | 326 | 364 | 230 | 92 | 52 | 103 |
| 83 | 10 | 24 | 58 | 46 | 18 | 22 | 54 | 30 | 122 | 155 | 360 | 290 | 346 | 100 | 46 | 106 |
| 84 | 10 | 8 | 35 | 14 | 8 | 20 | 26 | 5 | 178 | 232 | 422 | 696 | 325 | 128 | 110 | 124 |
| 85 | 5 | 6 | 8 | 13 | 12 | 3 | 2 | 2 | 88 | 208 | 378 | 480 | 320 | 94 | 80 | 92 |
| 86 | 1 | 6 | 0 | 2 | 0 | 4 | 4 | 0 | 92 | 146 | 318 | 420 | 352 | 106 | 92 | 82 |
| 87 | 0 | 4 | 4 | 4 | 1 | 2 | 0 | 0 | 98 | 134 | 236 | 438 | 299 | 120 | 96 | 84 |
| 88 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 61 | 72 | 248 | 258 | 307 | 84 | 50 | 68 |
| 89 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | 62 | 195 | 188 | 216 | 68 | 70 | 92 |
| 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 58 | 152 | 295 | 162 | 72 | 42 | 40 |
| 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 91 | 58 | 94 | 124 | 48 | 36 | 46 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 35 | 28 | 96 | 117 | 70 | 30 | 25 | 38 |
| 93 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 27 | 34 | 74 | 45 | 28 | 12 | 10 |
| 94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 14 | 49 | 8 | 30 | 10 | 8 | 5 |

| Length (cm) | Male 2008 | Male 2009 | Male 2010 | Male 2011 | Male 2012 | Male 2013 | Male 2014 | Male 2015 | Female 2008 | Female 2009 | Female 2010 | Female 2011 | Female 2012 | Female 2013 | Female 2014 | Female 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 46 | 8 | 19 | 12 | 10 | 1 |
| 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 8 | 14 | 34 | 10 | 2 | 2 | 14 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 8 | 14 | 8 | 0 | 0 | 22 |
| 98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 6 | 35 | 3 | 0 | 2 | 2 |
| 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 2 | 0 | 0 |
| 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 101 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table 12. Bigelow catches of Spiny Dogfish pelagic lengths (32–58 cm males or 32–64 cm females) by day and night for National Marine Fisheries Services (NMFS) Spring survey years 2009 to 2015 and the calibration study (2008). Outer slope strata are identified by a bold font, and inner slope strata by italics. "NA" = data not available.*

| Strata | Night 2008 | Night 2009 | Night 2010 | Night 2011 | Night 2012 | Night 2013 | Night 2014 | Night 2015 | Day 2008 | Day 2009 | Day 2010 | Day 2011 | Day 2012 | Day 2013 | Day 2014 | Day 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1200 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1390 | NA | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1210 | NA | 0 | 0 | 0 | NA | 0 | NA | 0 | NA | 0 | 0 | 0 | 0 | NA | 1 | 0 | 1 |
| 1230 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| 1250 | NA | 0 | 0 | NA | 0 | 0 | NA | 0 | NA | 1 | 0 | 0 | 1 | NA | 0 | 0 | 2 |
| 1090 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 5 |
| 1300 | NA | 0 | 0 | 0 | 0 | 0 | 1 | NA | 1 | 0 | NA | NA | 5 | NA | NA | 0 | 6 |
| 1351 | NA | 0 | 0 | NA | 0 | NA | 1 | NA | NA | 0 | 0 | 5 | 0 | 0 | 0 | 1 | 7 |
| *1630* | NA | NA | 0 | NA | NA | 0 | NA | 0 | 3 | NA | 15 | 1 | 0 | 0 | NA | 0 | 16 |
| 1620 | NA | 0 | NA | 0 | 0 | 2 | NA | 3 | 0 | 0 | 8 | 1 | 0 | 0 | NA | 6 | 20 |
| *1670* | 6 | 0 | 1 | 0 | 0 | 3 | NA | NA | 9 | NA | 0 | 10 | 6 | 4 | NA | 0 | 24 |
| 1340 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 1 | 0 | 0 | 1 | 16 | 13 | 31 |
| 1660 | 1 | 0 | 0 | 0 | NA | 0 | NA | 1 | NA | 1 | 0 | 10 | 1 | 21 | NA | NA | 34 |
| 1010 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 4 | 7 | 5 | 14 | 12 | 0 | 2 | 9 | 52 |
| *1140* | 1 | 0 | 0 | 2 | 1 | 7 | 6 | 0 | NA | 0 | 0 | 2 | NA | 0 | 32 | 11 | 61 |
| 1380 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 22 | 7 | 11 | 0 | 17 | 4 | 61 |
| 1730 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 5 | 1 | 1 | 0 | 9 | 4 | 6 | 55 | 79 |
| 1650 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 1 | 1 | 2 | 12 | 0 | 63 | NA | 6 | 84 |
| 1610 | 0 | 0 | 0 | 2 | NA | 1 | NA | 2 | NA | 0 | 2 | 2 | 1 | 22 | NA | 54 | 86 |
| **1180** | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 100 | 0 | 29 | 22 | 0 | 0 | 151 |
| 1160 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 160 | 0 | 172 |
| 1690 | 1 | 0 | 0 | 0 | NA | 0 | 0 | 7 | 0 | 1 | 0 | 1 | 4 | 144 | 3 | 12 | 172 |
| *1750* | 2 | NA | 0 | 4 | 9 | 27 | 0 | NA | NA | 5 | 2 | 6 | 6 | 67 | 0 | 54 | 180 |
| *1710* | NA | 2 | 110 | 1 | 0 | 0 | 25 | NA | 0 | 0 | 8 | 2 | 2 | 13 | NA | 25 | 188 |
| 1220 | 0 | 0 | 0 | 0 | NA | NA | NA | 0 | 0 | 2 | 4 | 0 | 0 | 0 | 192 | 0 | 198 |
| 1190 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 305 | 0 | 306 |
| **1640** | NA | 2 | 6 | 31 | 3 | 0 | NA | 0 | 12 | NA | 15 | NA | 3 | 0 | NA | 268 | 328 |
| *1170* | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | NA | 0 | 0 | 9 | 243 | 1 | 63 | 14 | 330 |
| 1260 | NA | 0 | 0 | 0 | 0 | 65 | NA | 0 | NA | 0 | 3 | 9 | 1 | 251 | 2 | 0 | 331 |
| 1050 | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 0 | 343 | 0 | 0 | 0 | 343 |
| 1700 | NA | 0 | 2 | 0 | 0 | 7 | NA | 7 | 0 | 27 | 6 | 11 | 0 | 256 | 26 | 4 | 346 |
| 1360 | 1 | 4 | 1 | 0 | 0 | 0 | 21 | 3 | NA | 19 | 20 | 55 | 101 | 10 | 33 | 261 | 528 |
| 1280 | NA | 0 | 2 | 14 | 0 | 4 | 0 | 0 | NA | 411 | 54 | 40 | 27 | 20 | 9 | 4 | 585 |

| Strata | Night 2008 | Night 2009 | Night 2010 | Night 2011 | Night 2012 | Night 2013 | Night 2014 | Night 2015 | Day 2008 | Day 2009 | Day 2010 | Day 2011 | Day 2012 | Day 2013 | Day 2014 | Day 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1740 | 0 | 3 | 1 | 0 | 60 | 0 | 0 | 0 | 3 | 18 | 42 | 13 | 6 | 87 | 62 | 302 | 594 |
| 1270 | NA | 0 | 0 | NA | 0 | 3 | 0 | NA | NA | 0 | 45 | 38 | 0 | 416 | 297 | 34 | 833 |
| 1400 | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | NA | 0 | NA | NA | 0 | 980 | 0 | 0 | 980 |
| 1240 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 15 | 9 | 911 | 1 | 145 | 0 | 1,086 |
| *1030* | NA | 24 | 3 | 5 | 0 | 20 | 64 | 6 | 4 | 121 | 3 | 222 | 504 | 97 | 22 | 125 | 1,216 |
| 1130 | 0 | 0 | 0 | 10 | 0 | 1 | 47 | 0 | 0 | 114 | 0 | 0 | 44 | 259 | 788 | 2 | 1,265 |
| 1020 | 2 | 3 | 3 | 6 | 299 | 10 | 2 | 0 | 14 | 92 | 273 | 87 | 192 | 23 | 69 | 220 | 1,279 |
| 1370 | NA | 0 | 1 | 0 | 1 | 2 | 0 | 0 | NA | 0 | 106 | 1,314 | 26 | 19 | 9 | 1 | 1,479 |
| **1720** | NA | 0 | 12 | 2 | 4 | 0 | NA | 0 | 80 | 1 | 646 | 62 | 187 | 315 | 354 | 7 | 1,590 |
| **1680** | NA | 0 | 16 | 18 | 1 | 31 | NA | 7 | NA | 33 | 414 | 5 | 1,036 | 4 | NA | 98 | 1,663 |
| *1070* | NA | NA | 0 | 158 | 4 | NA | 271 | 176 | NA | 34 | 44 | NA | 901 | 58 | 11 | 23 | 1,680 |
| 1290 | 1 | 0 | 0 | 0 | 0 | 2 | 5 | 1 | 29 | 185 | 8 | 4 | 133 | 899 | 466 | 42 | 1,745 |
| **1150** | 73 | 0 | 2 | 6 | 15 | 21 | 0 | 0 | NA | 0 | NA | 1,474 | NA | 14 | 9 | 493 | 2,034 |
| 1060 | NA | 27 | 0 | 14 | 36 | 18 | 0 | NA | 8 | 344 | 40 | 257 | 13 | 1,241 | 226 | 15 | 2,231 |
| 1100 | NA | 0 | 0 | 0 | 10 | 1,398 | 0 | 0 | 18 | 0 | 2 | 0 | 474 | 2 | 868 | 2 | 2,756 |
| **1040** | NA | 193 | 434 | 26 | NA | 211 | 7 | 87 | 39 | 56 | NA | 137 | 990 | 1,954 | 208 | NA | 4,303 |
| **1080** | NA | 59 | 284 | NA | NA | 121 | 4 | 152 | NA | 1 | 6 | 47 | 4,998 | NA | 35 | 471 | 6,178 |
| *1110* | 0 | 0 | 2 | NA | NA | 985 | 183 | 1 | NA | 5,040 | 21 | 88 | 868 | 44 | 266 | 108 | 7,606 |
| **1120** | NA | 0 | 6 | NA | 45 | NA | 30 | 19 | NA | 61 | 91 | 2 | 470 | 9,048 | NA | 49 | 9,821 |
| **1760** | NA | NA | 538 | 8 | 101 | 99 | 18 | 3 | NA | 58 | 190 | 18 | 10,406 | 3,676 | 353 | 63 | 15,531 |

*Table 13. Relative vessel catchability estimates (Bigelow/Albatross) for Spiny Dogfish determined by quasibinomial modelling of paired-tow data, defining day and night according to the dusk-dawn cutpoints of Sagarese* et al. *(2016) (Cutpoint Diel), astronomical calculation of twilight as in Jacobson* et al. *(2011) (Twilight Diel). Significant estimates are shown in bold.*

| Size Class | Sex | Period | Cutpoint Diel | Twilight Diel |
|---|---|---|---|---|
| Pup | Both | Day | **1.5** | **2.9** |
| Pelagic | Both | Day | 1.3 | 0.8 |
| Demersal | Male | Day | **2.0** | **1.9** |
| Demersal | Female | Day | **2.1** | **2.2** |
| Pup | Both | Night | **29.8** | **1.6** |
| Pelagic | Both | Night | **13.5** | **6.6** |
| Demersal | Male | Night | **1.8** | **2.0** |
| Demersal | Female | Night | **2.0** | **2.2** |

## FIGURES

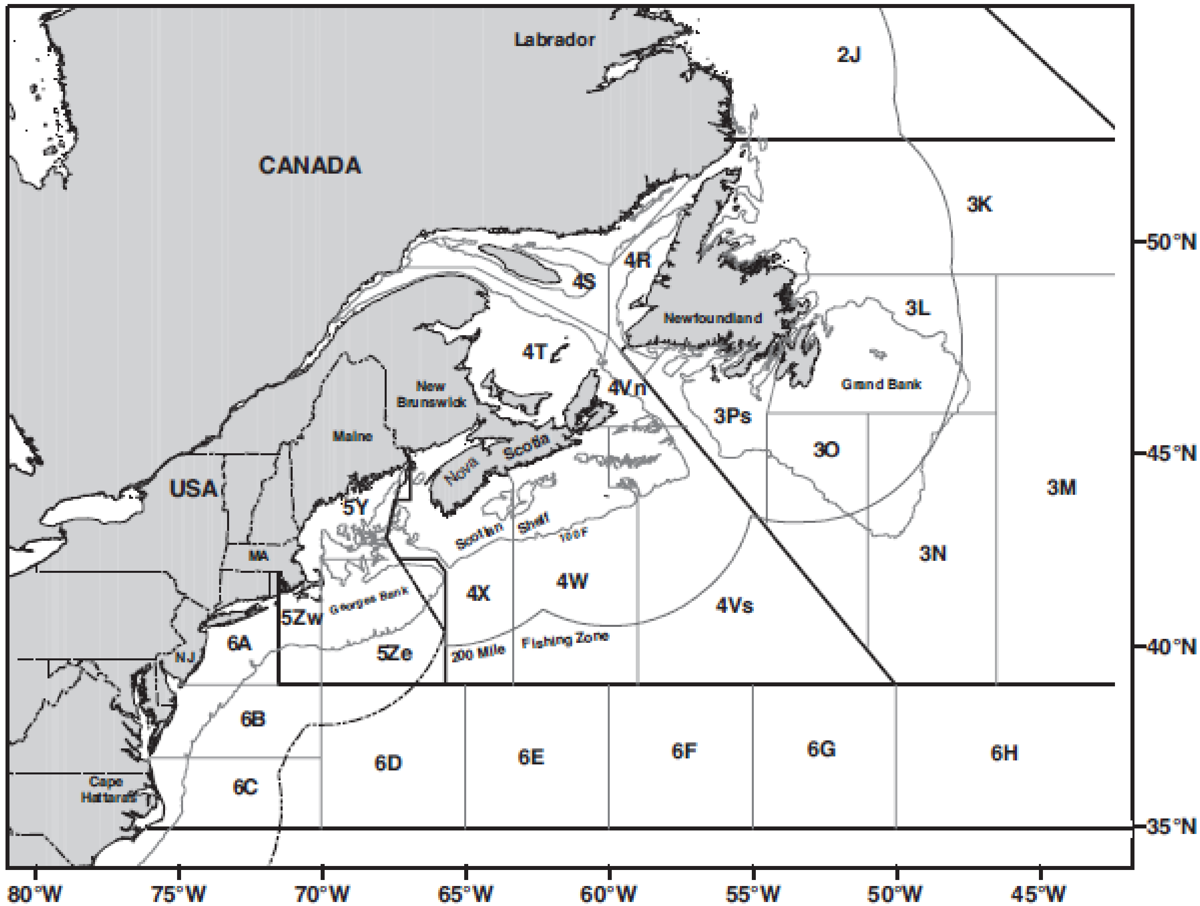



*Figure 1. NAFO Areas 2–6 which encompass the Spiny Dogfish stock in the North West Atlantic Ocean.*

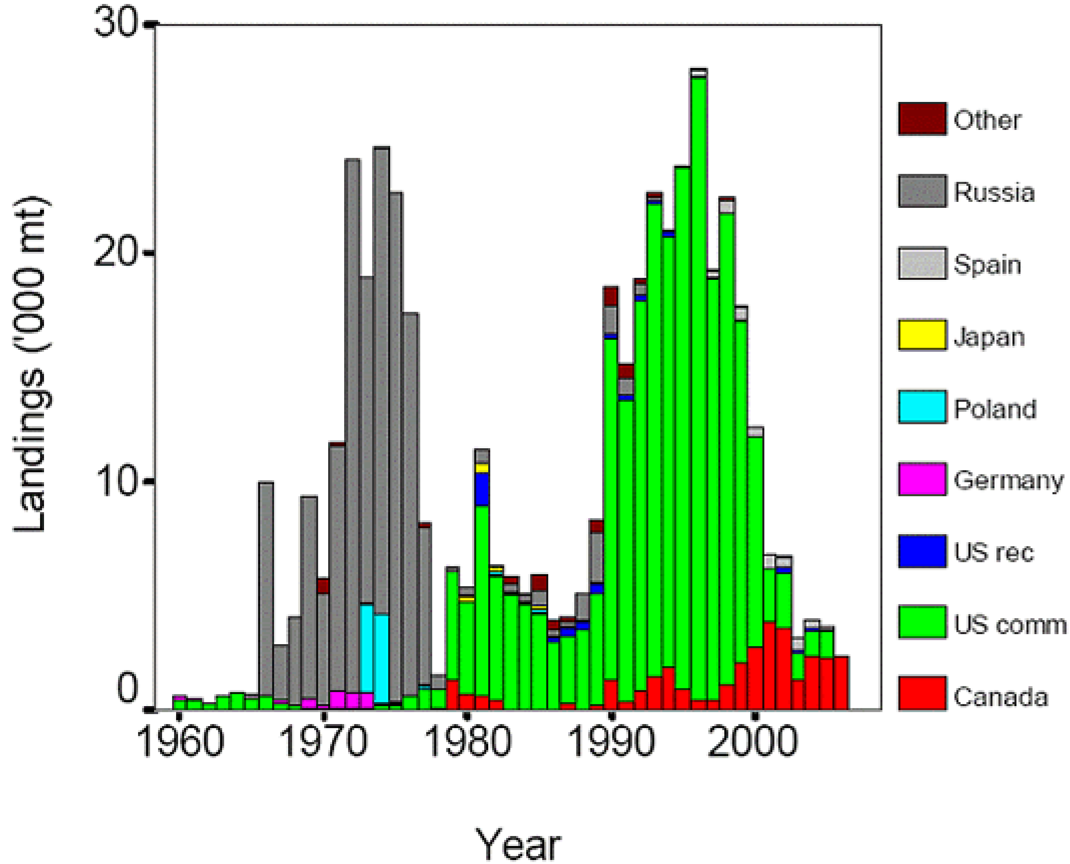



*Figure 2. Re-printed from DFO (2014). Landings of Spiny Dogfish reported to NAFO by country and year in NAFO Areas 2–6. At the time of printing, US data was not available after 2005.*

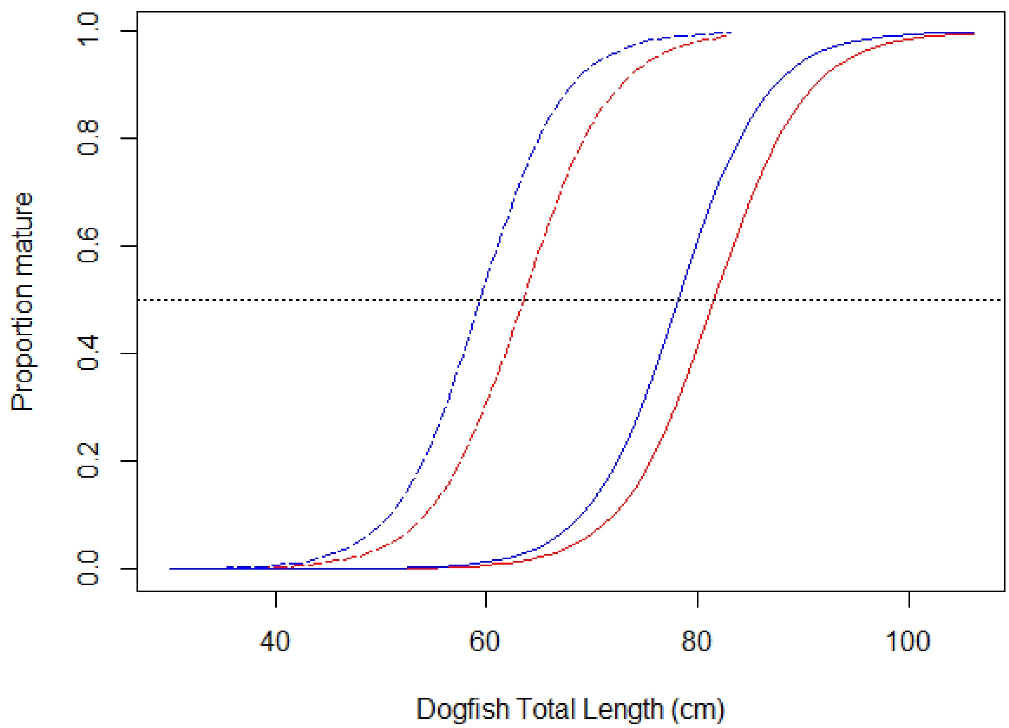



*Figure 3. Maturity ogives for Canadian (red lines) and US (blue lines) Spiny Dogfish for males (dashed lines) and females (solid lines). The dashed horizontal line intersects at $L_{50\%}$, the length at 50% maturity.*

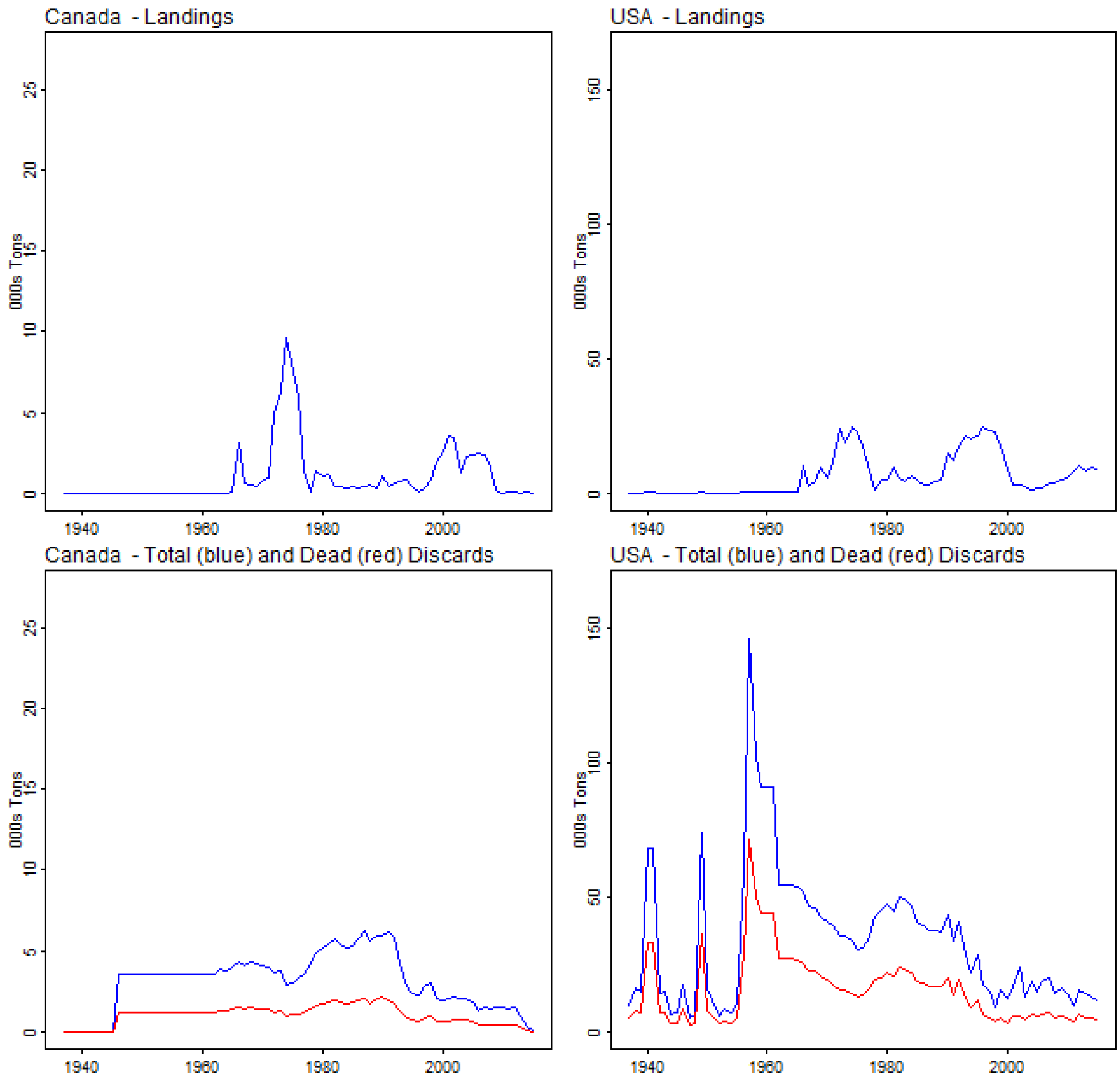



*Figure 4. Total landings and discards (blue lines) and dead discards red (lines) of Spiny Dogfish in thousands (000s) of metric tonnes from all fleets (foreign and domestic) operating in Canadian or US waters. Canadian catches for 1946–1961 are assumed equal to 1962, and earlier years are zero.*

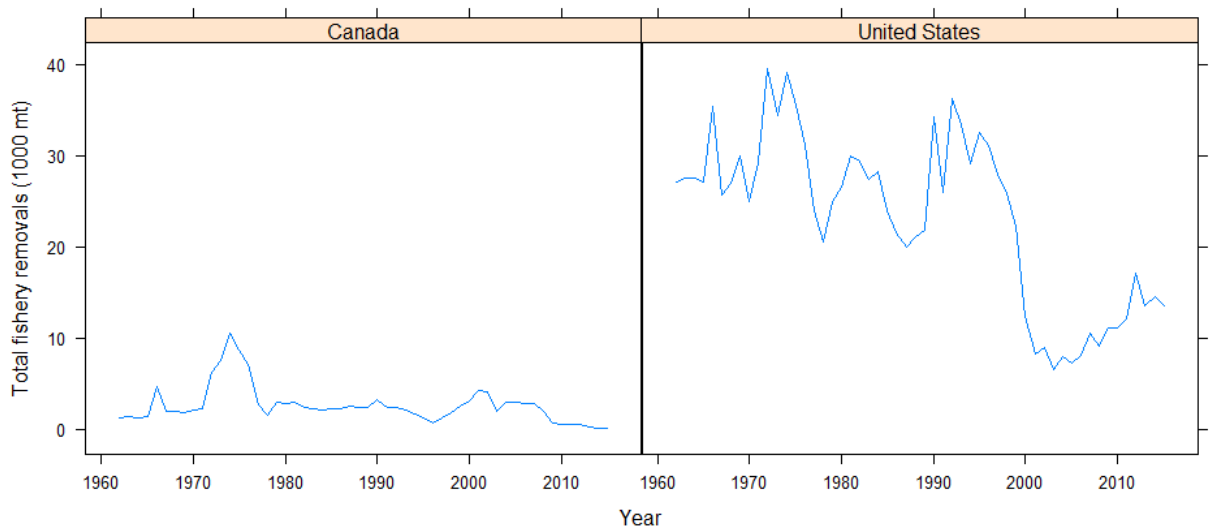



*Figure 5. Time series of total fishery removals (landings plus discards) of Spiny Dogfish in thousands of metric tonnes for Canadian (left panel) and US (right panel) territorial waters.*

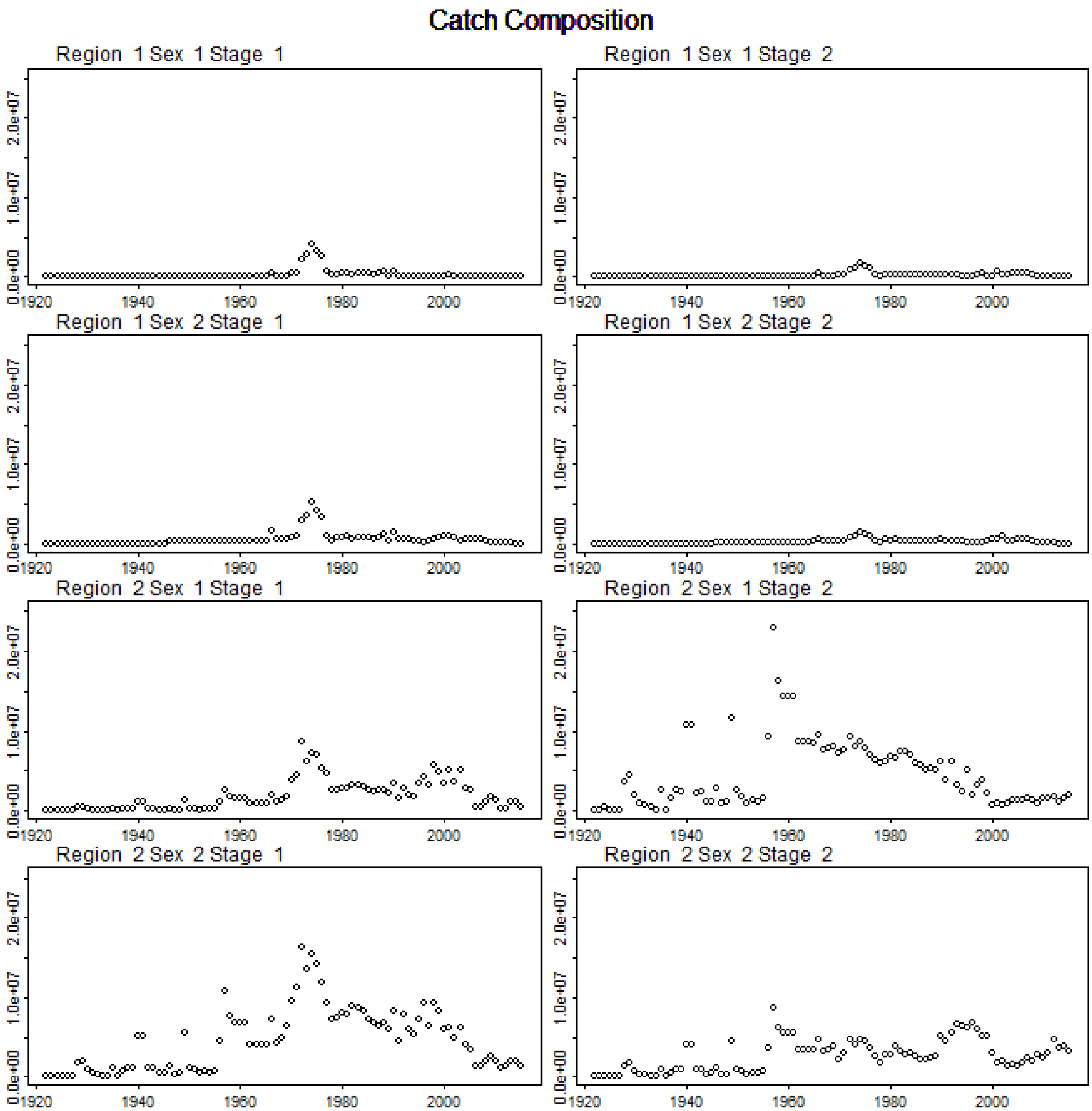



*Figure 6. Commercial catch composition in numbers of dogfish by region, sex, and maturity stage. Region 1 = Canada, 2 = US, Sex 1 = Male, Sex 2 = Female, Stage 1 = Juvenile, Stage 2 = Adult.*

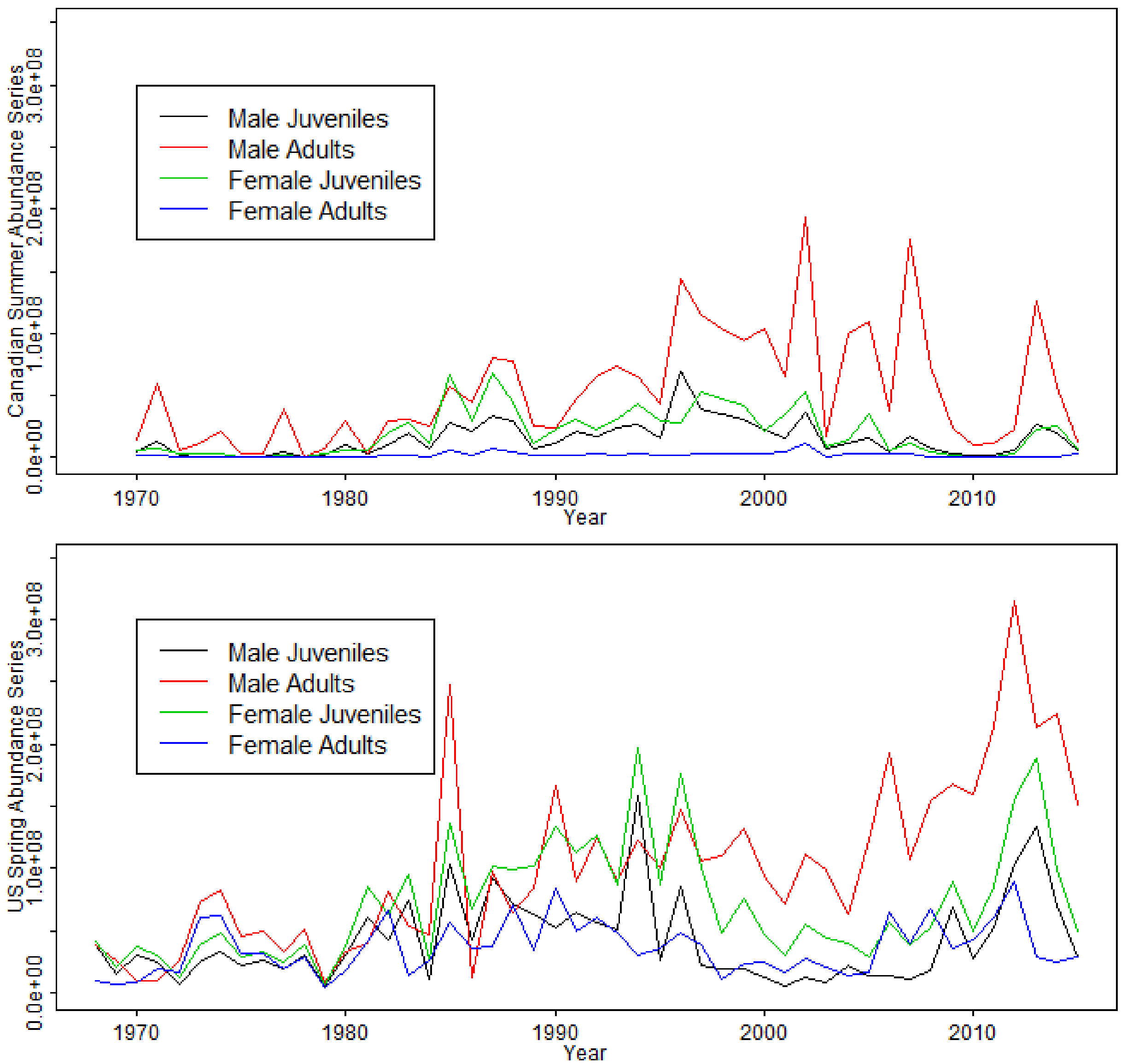



*Figure 7. Canadian Summer and US Spring survey stratified abundance estimates of Spiny Dogfish by sex and maturity stage.*

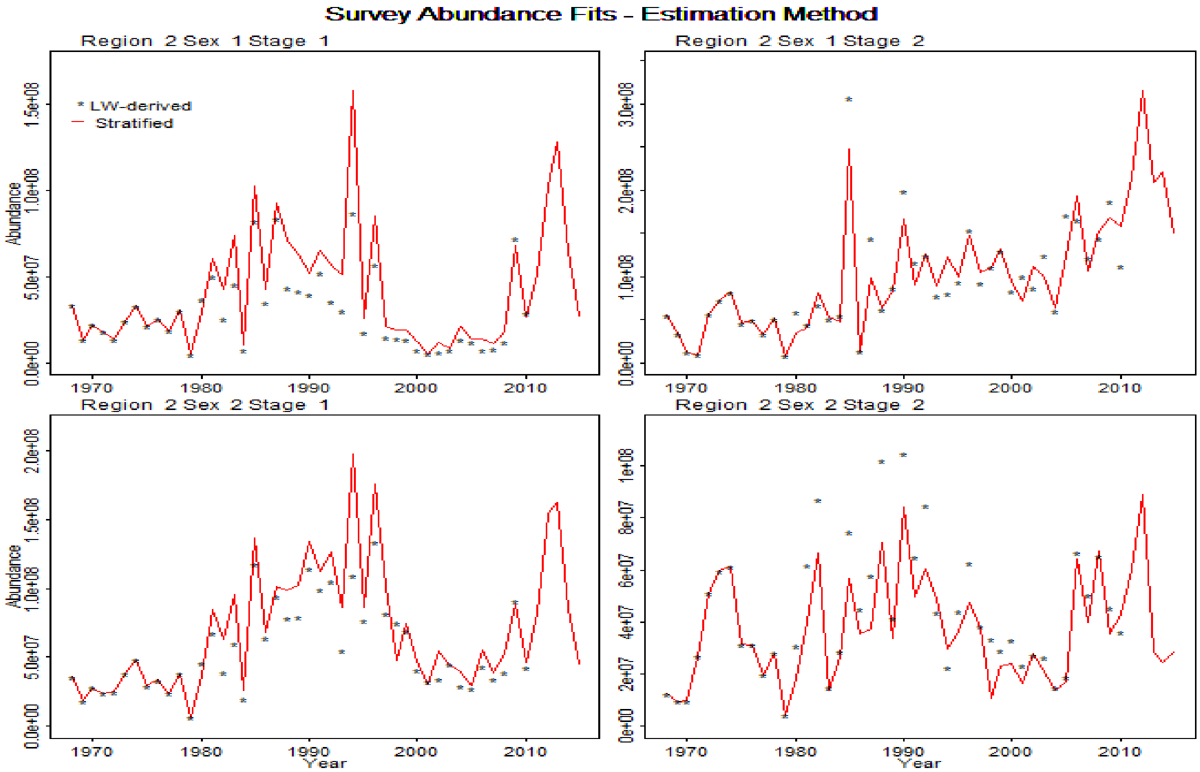



*Figure 8. A comparison of stratified abundance at length of Spiny Dogfish calculated directly from the NMFS Spring survey (red lines), with estimates calculated from biomass at length (points) as in the previous dogfish framework.*

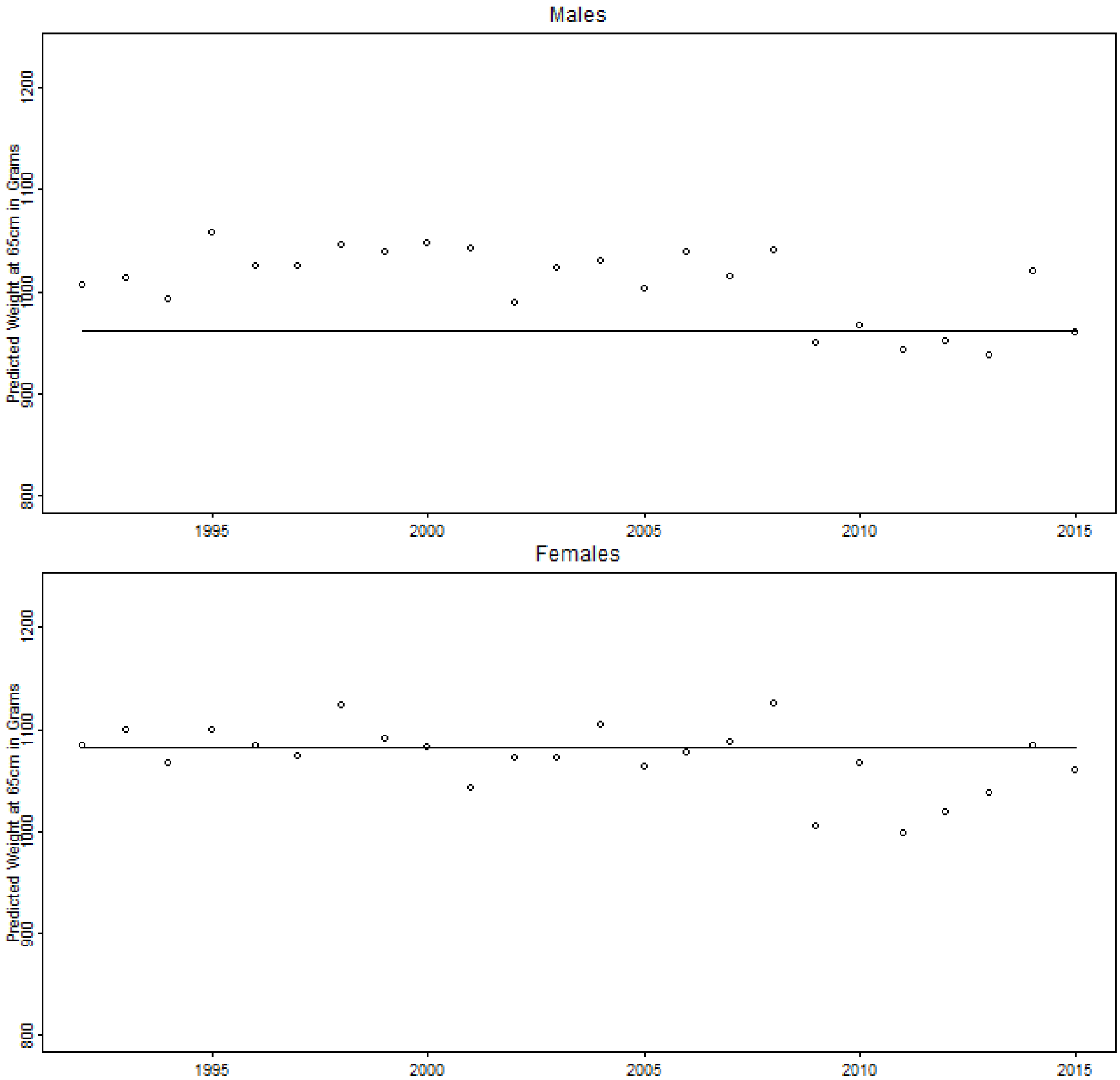



*Figure 9. An evaluation of variability in the length-weight relationship for Spiny Dogfish relative to the values reported in Nammack et al. (1985). Points represent predicted weights of a 65 cm dogfish from 1992–2015, while the 1980–1981 average is shown as a solid line.*

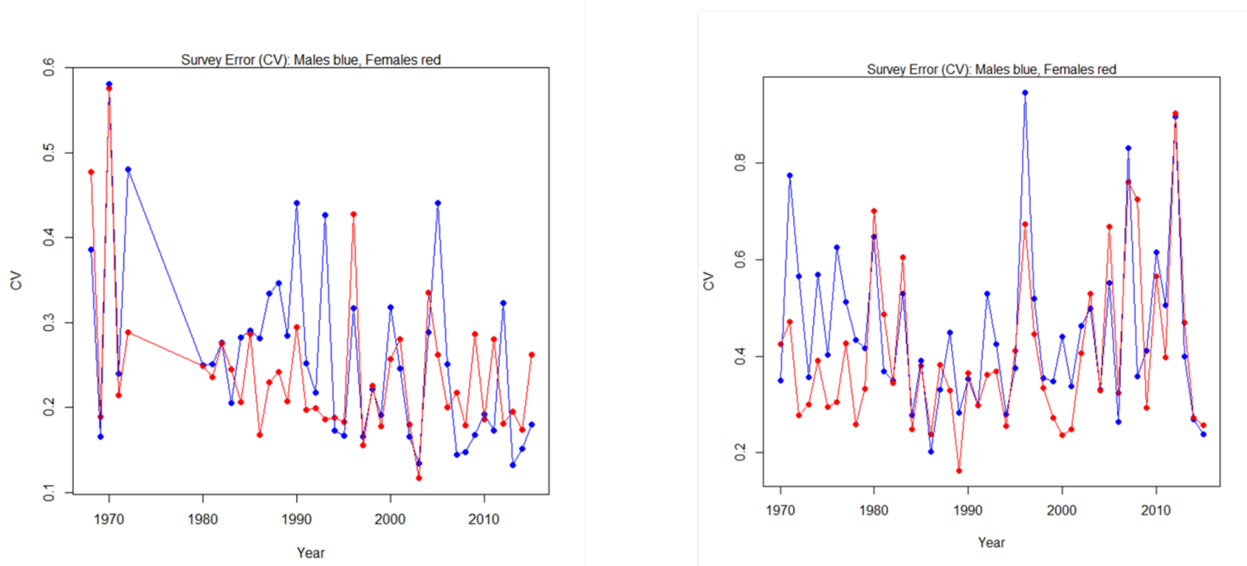



*Figure 10. The annual coefficient of variation (CV) for male (red lines) and female (blue lines) Spiny Dogfish for the NMFS Spring (left panel) and Canadian Summer RV (right panel) surveys.*

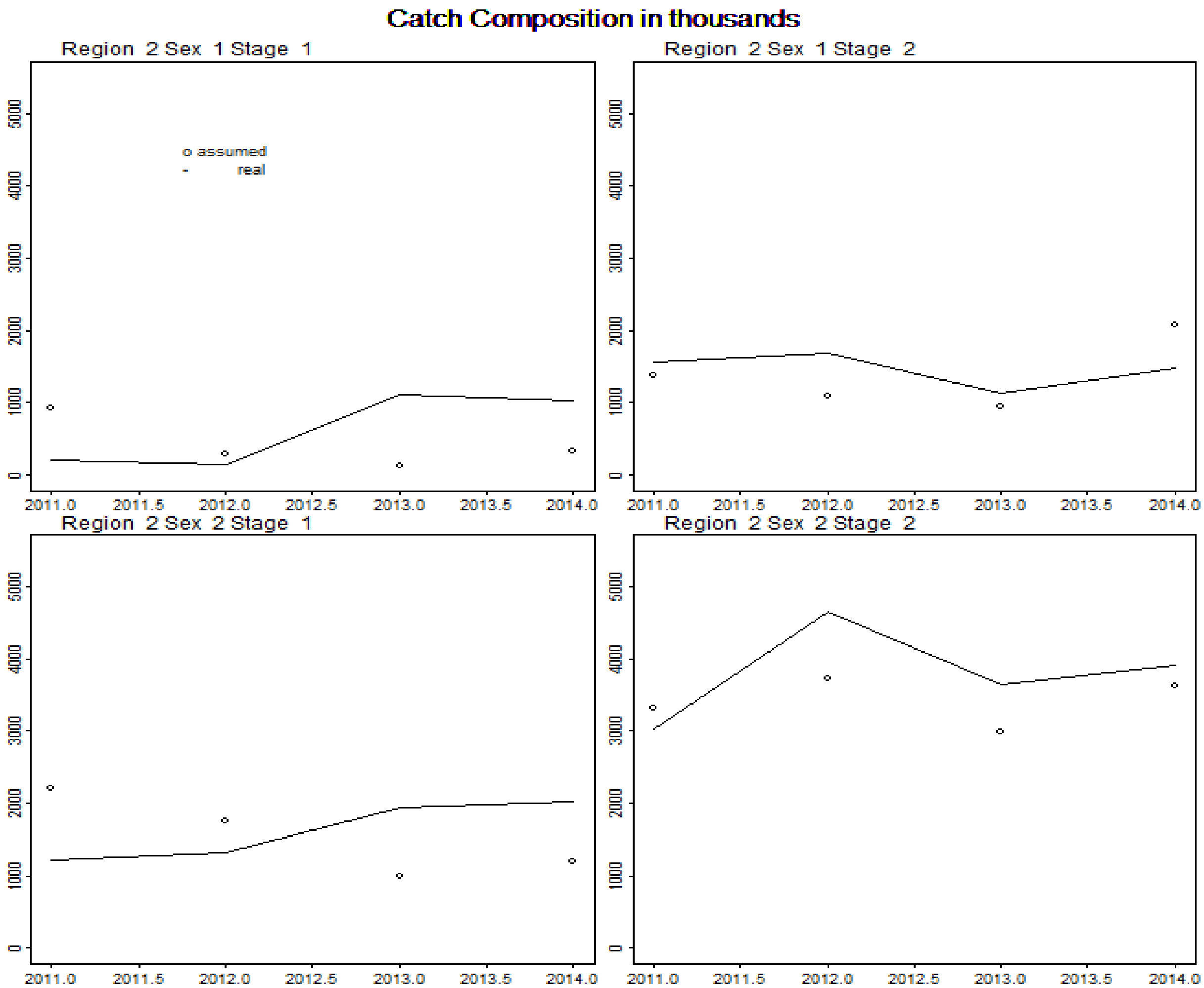



*Figure 11. A comparison of US dogfish commercial catch composition from 2011–2015 (lines) with the values assumed from summary statistics for the last assessment framework (points). Region 1 = Canada, 2 = US, Sex 1 = Male, Sex 2 = Female, Stage 1 = Juvenile, Stage 2 = Adult.*

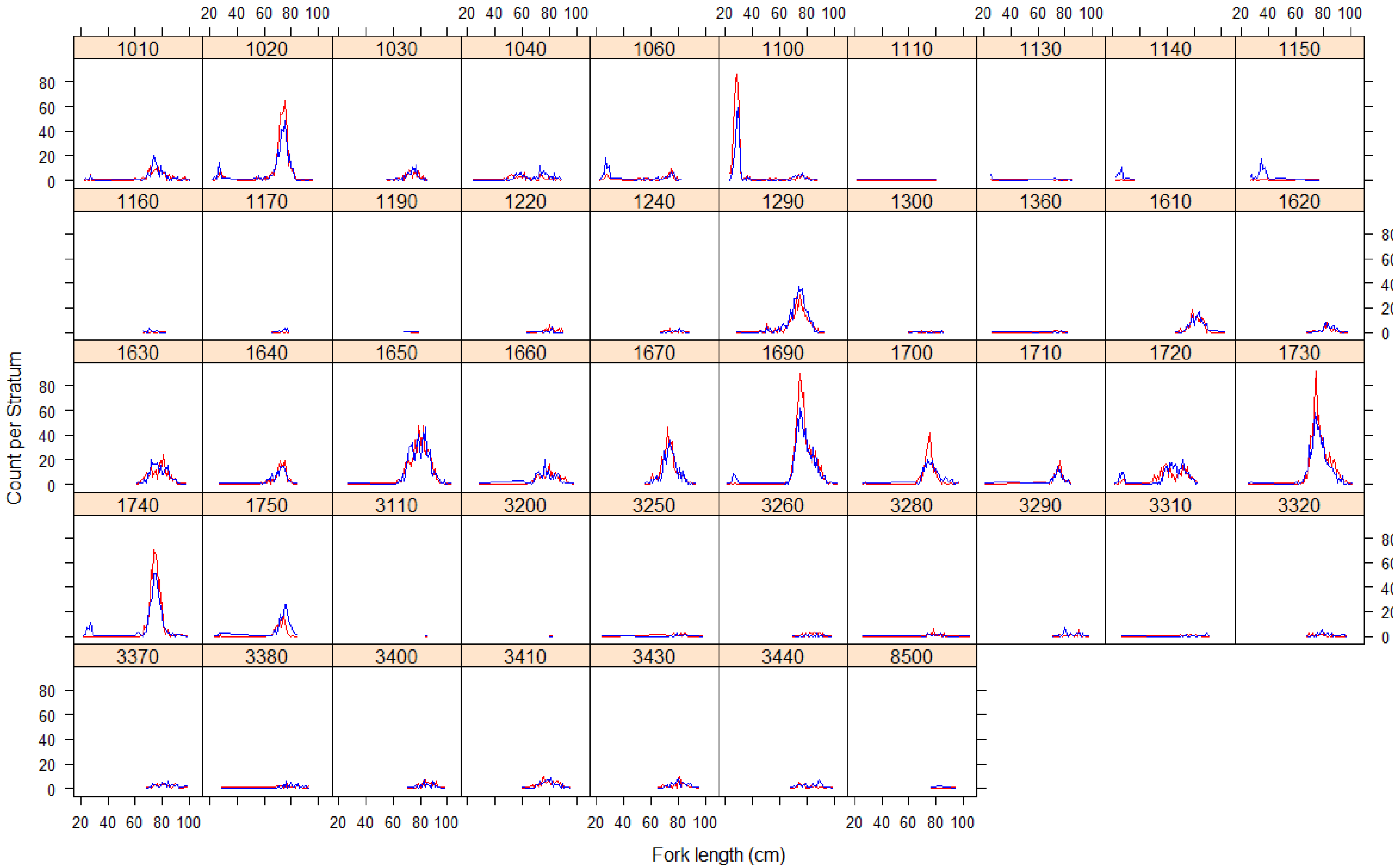



*Figure 12. Total counts at length of Spiny Dogfish from the NMFS Spring survey in strata sampled by the Albatross (red lines) and Bigelow (blue lines) during the paired-tow study in 2008.*

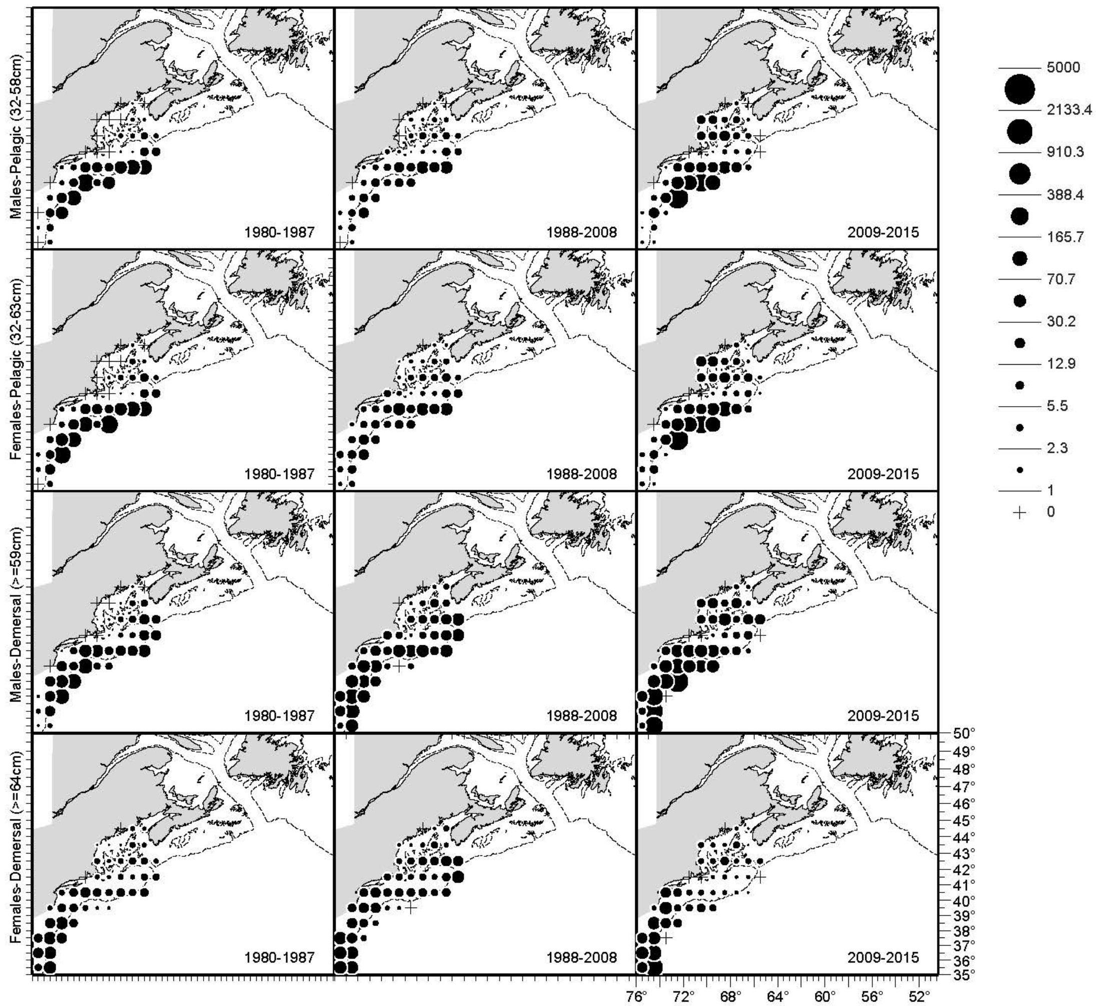



*Figure 13. Spiny Dogfish (numbers caught) by the Spring survey during 1980–1987, 1988–2008, and 2009–2015. Catches are averaged over 1 minute squares for each time period. The 200 m depth contour is shown as a dashed line.*

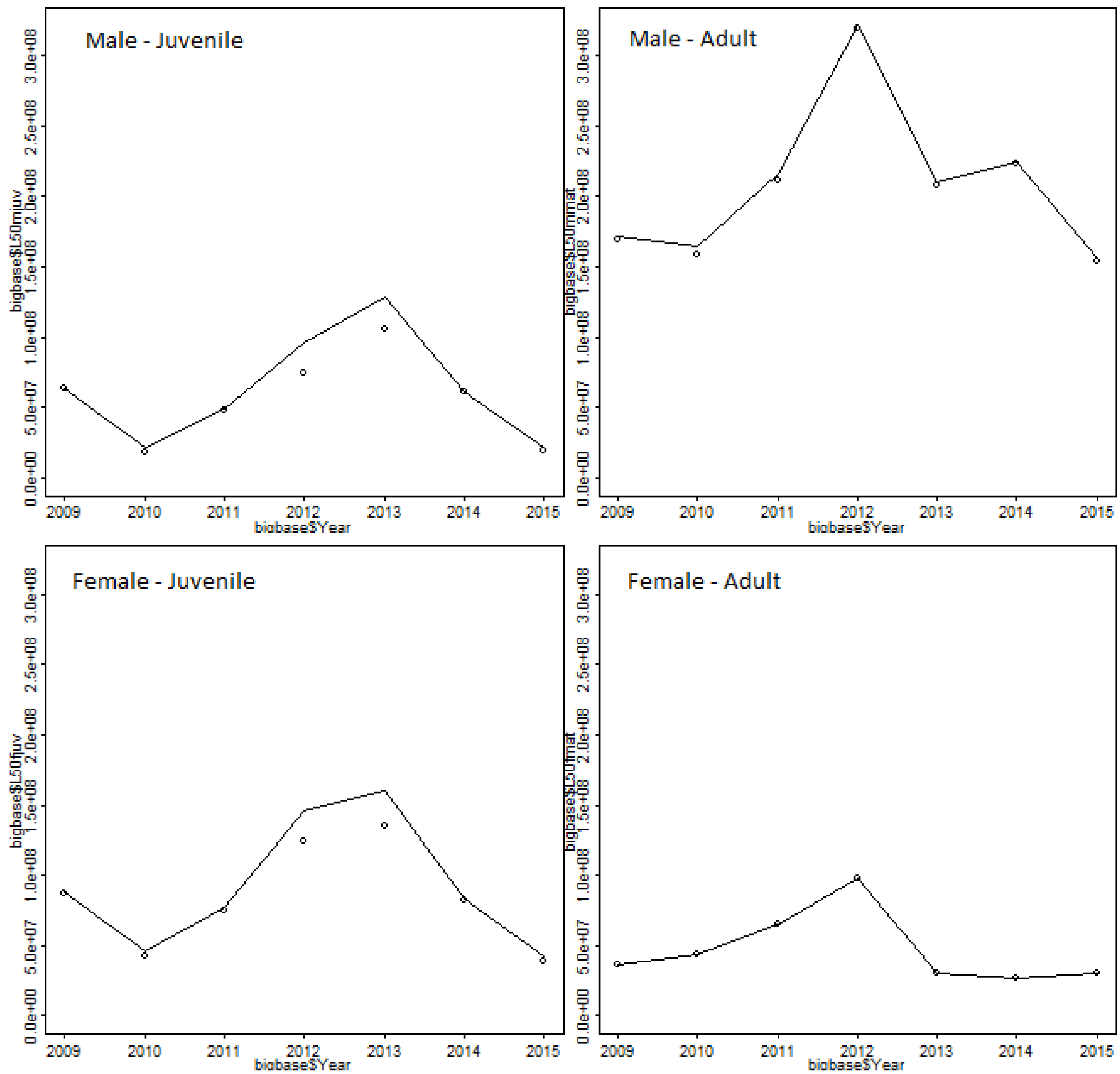



*Figure 14. A comparison of stratified survey abundance of Spiny Dogfish by sex and life stage calculated from sampling by the Bigelow (lines) during 2009–2015, with re-calculated estimates (points) from a randomization that selects fewer samples per strata to mimic the level of sampling done prior to 2008 by the Albatross.*

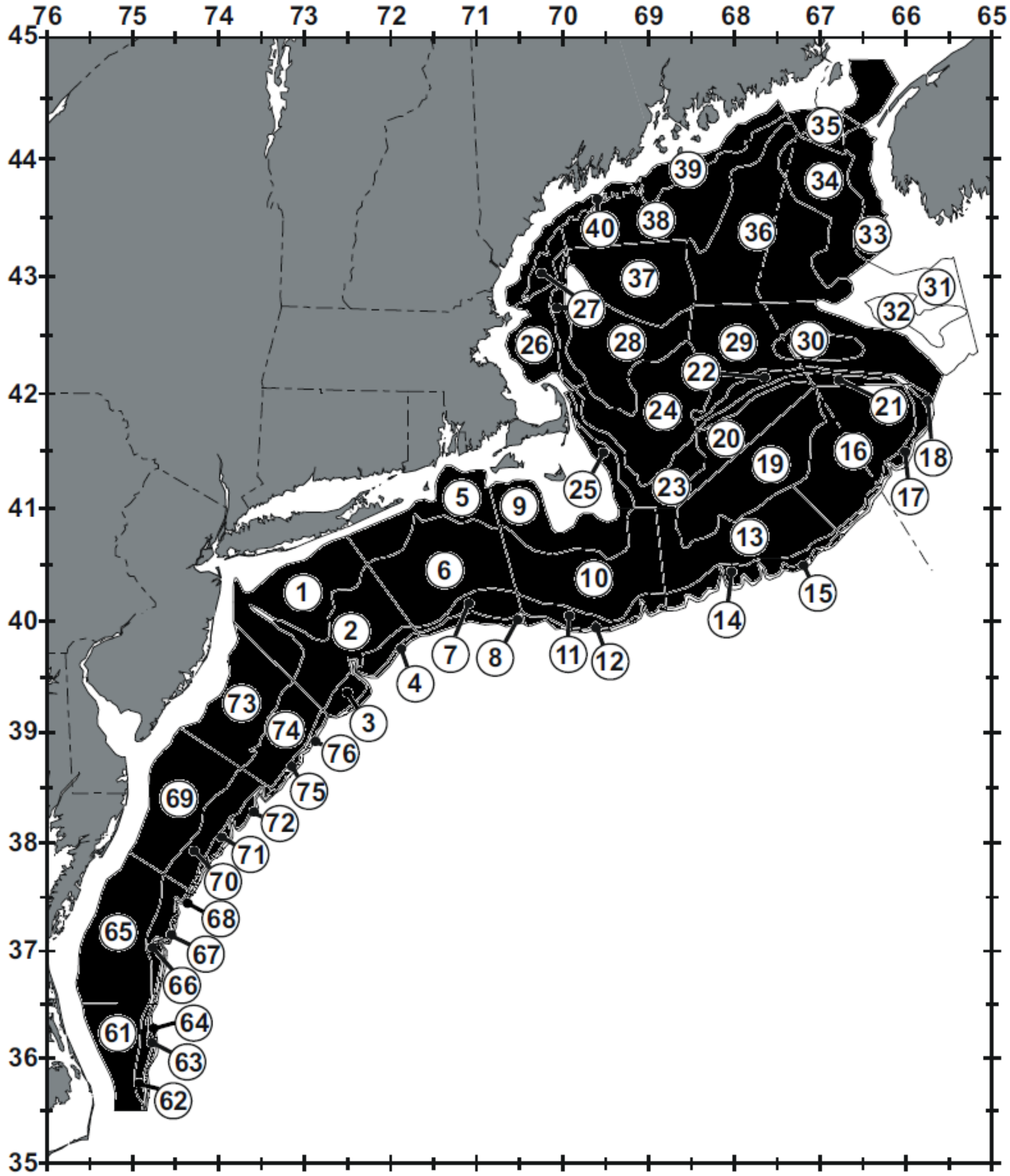



*Figure 15. The offshore strata sampled during the NMFS Spring survey, with those included in the dogfish stock definition coloured black. Re-printed from Figure 2 in NEFSC (2006).*

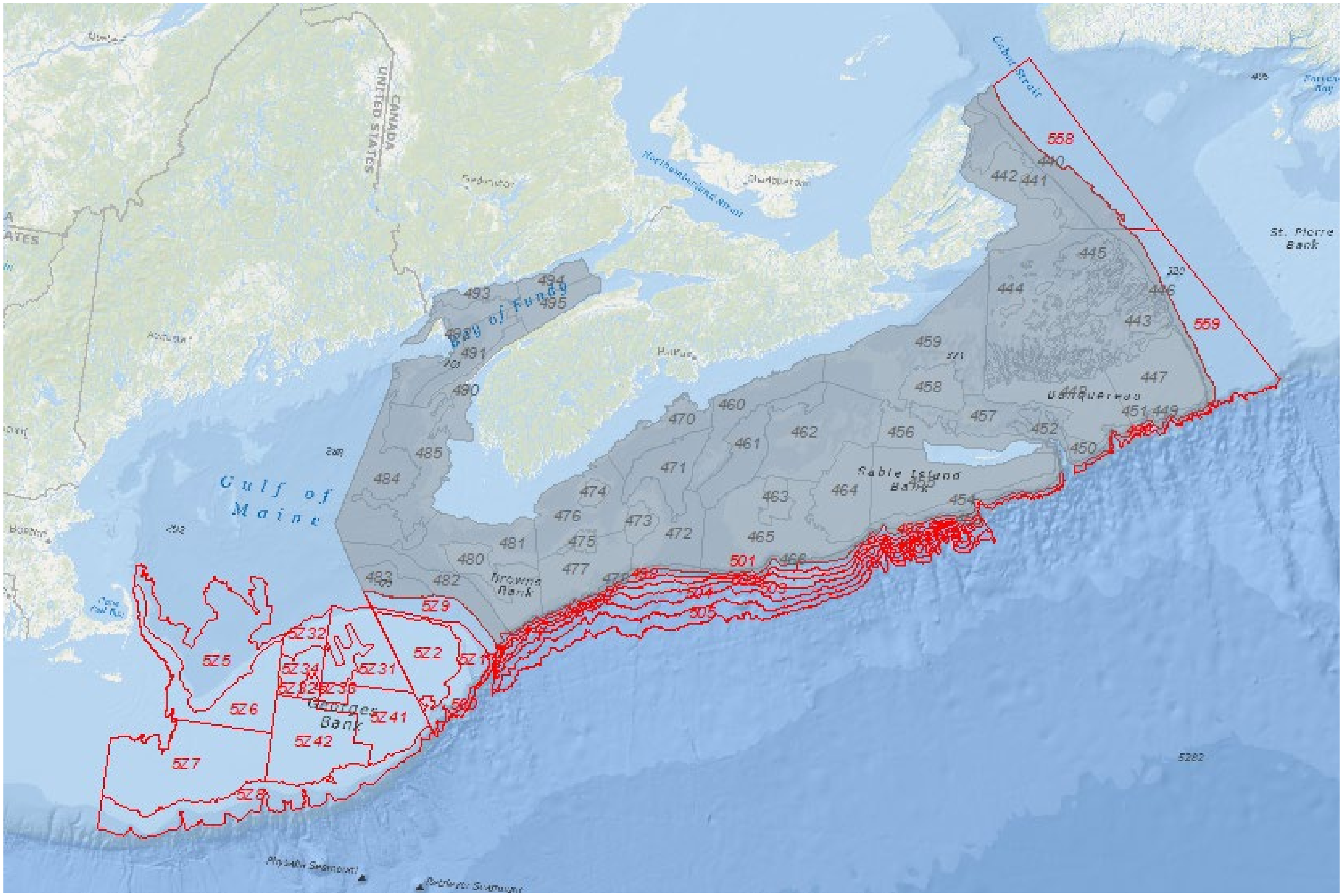



Figure 16. Sampling strata for the Canadian Spring and Summer Research Vessel surveys, with the strata included in the Spiny Dogfish stock definition coloured grey.

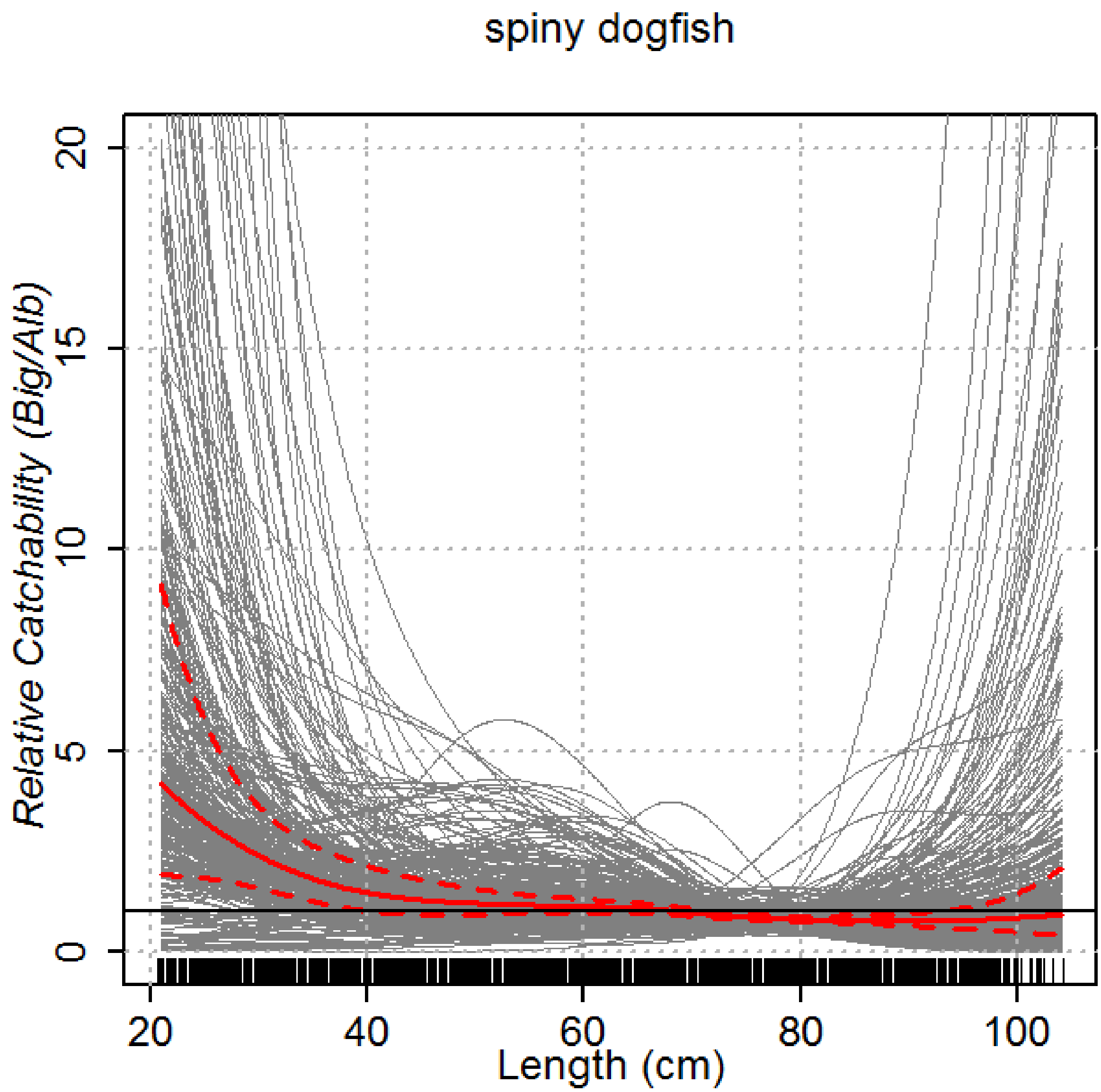



*Figure 17. Estimated mean (red line), 95% Confidence Interval (dashed red lines), and station-specific (grey lines) relative catch efficiency at length for Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model from the Miller (2013) suite of models.*

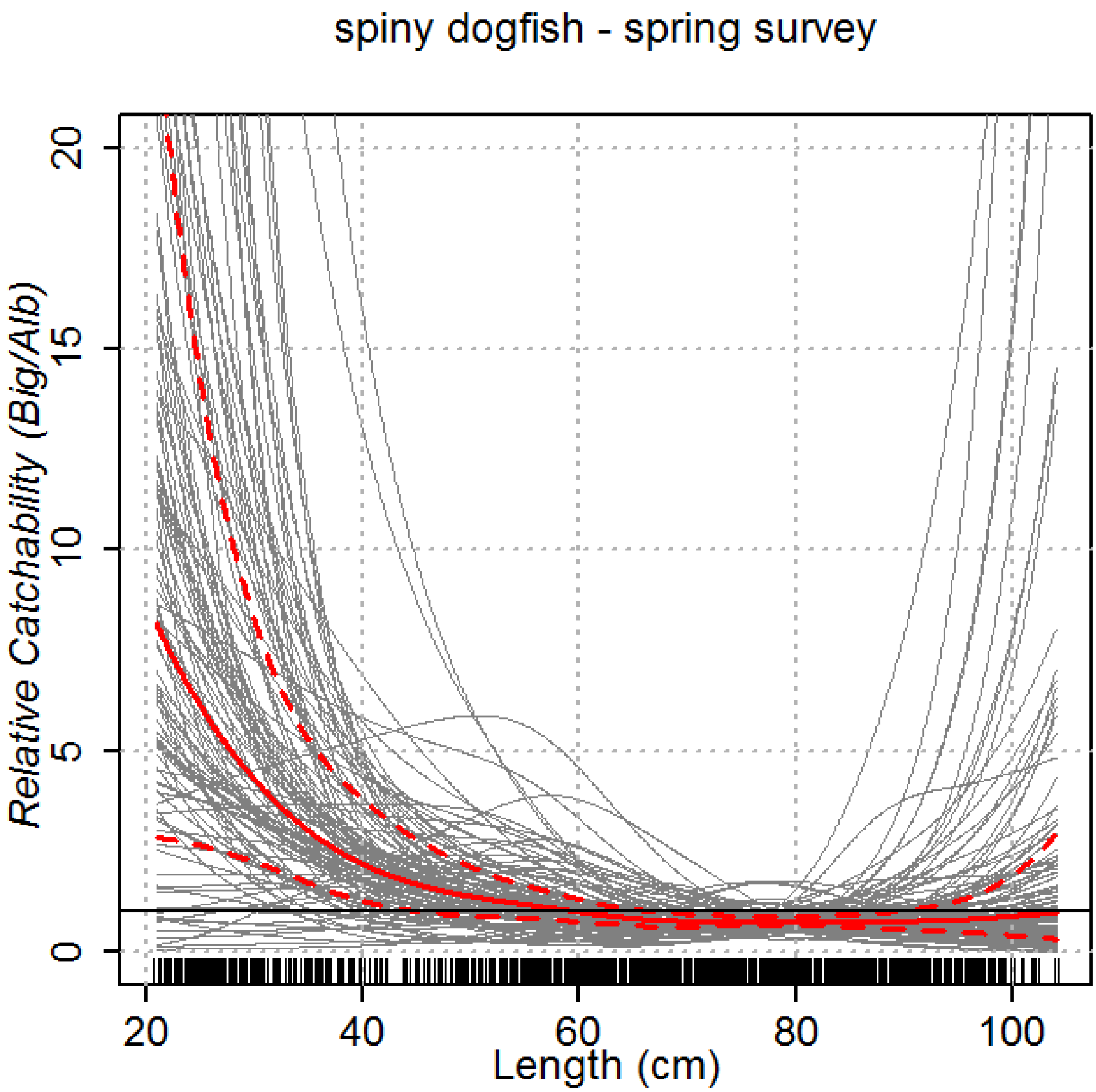



*Figure 18. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data from the Spring survey exclusively.*

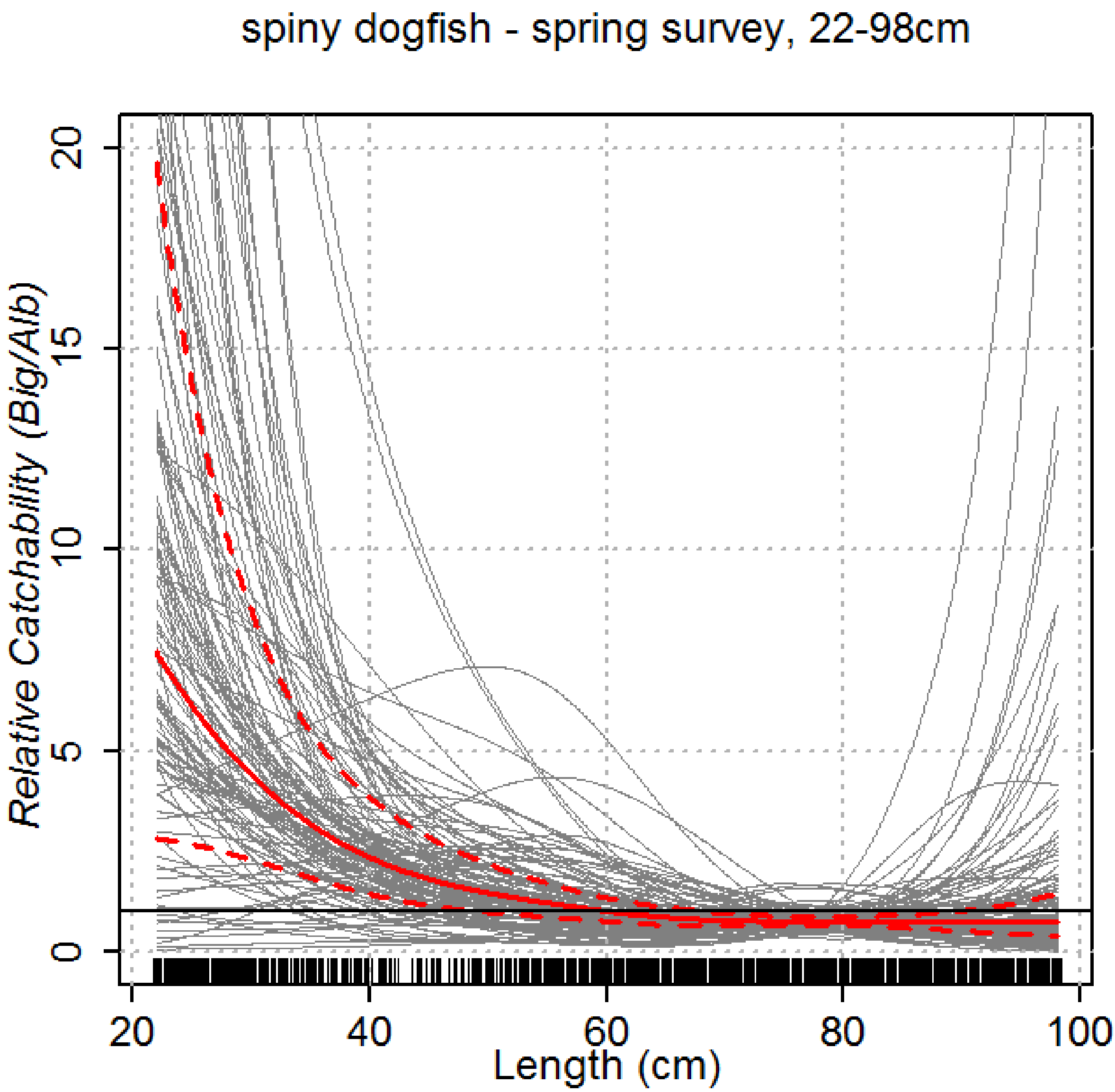



*Figure 19. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

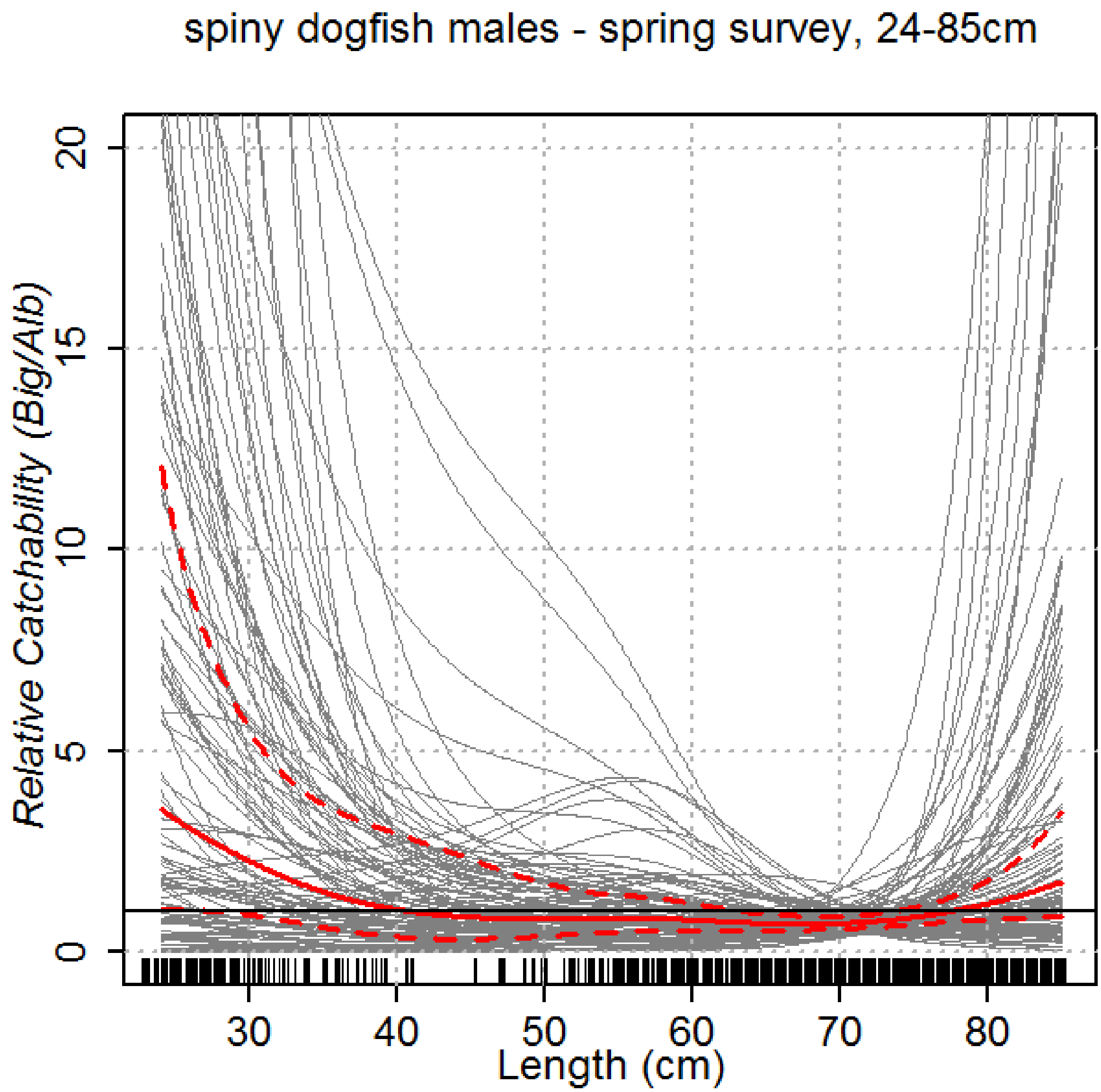



*Figure 20. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for male Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

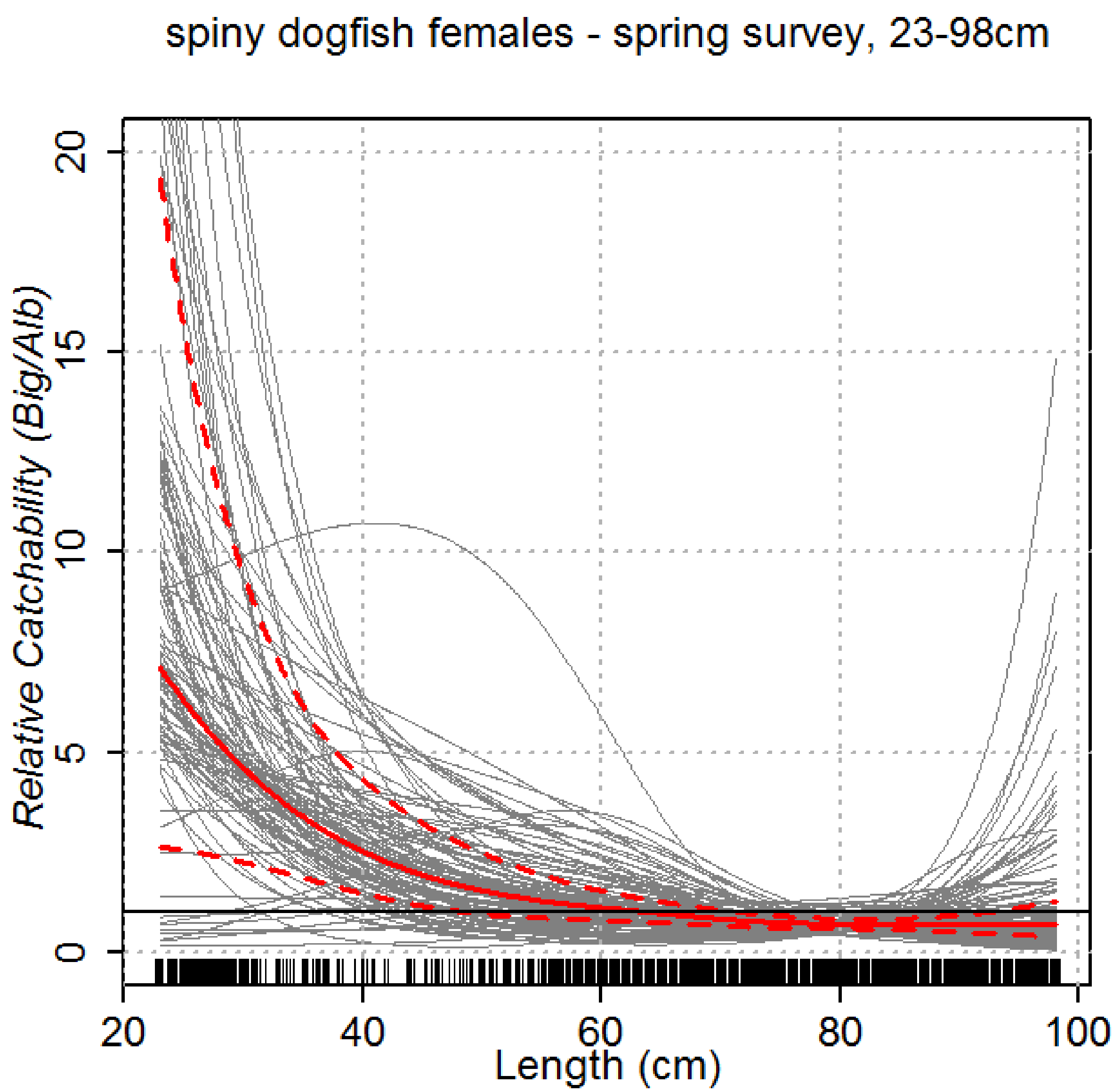



*Figure 21. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for female Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

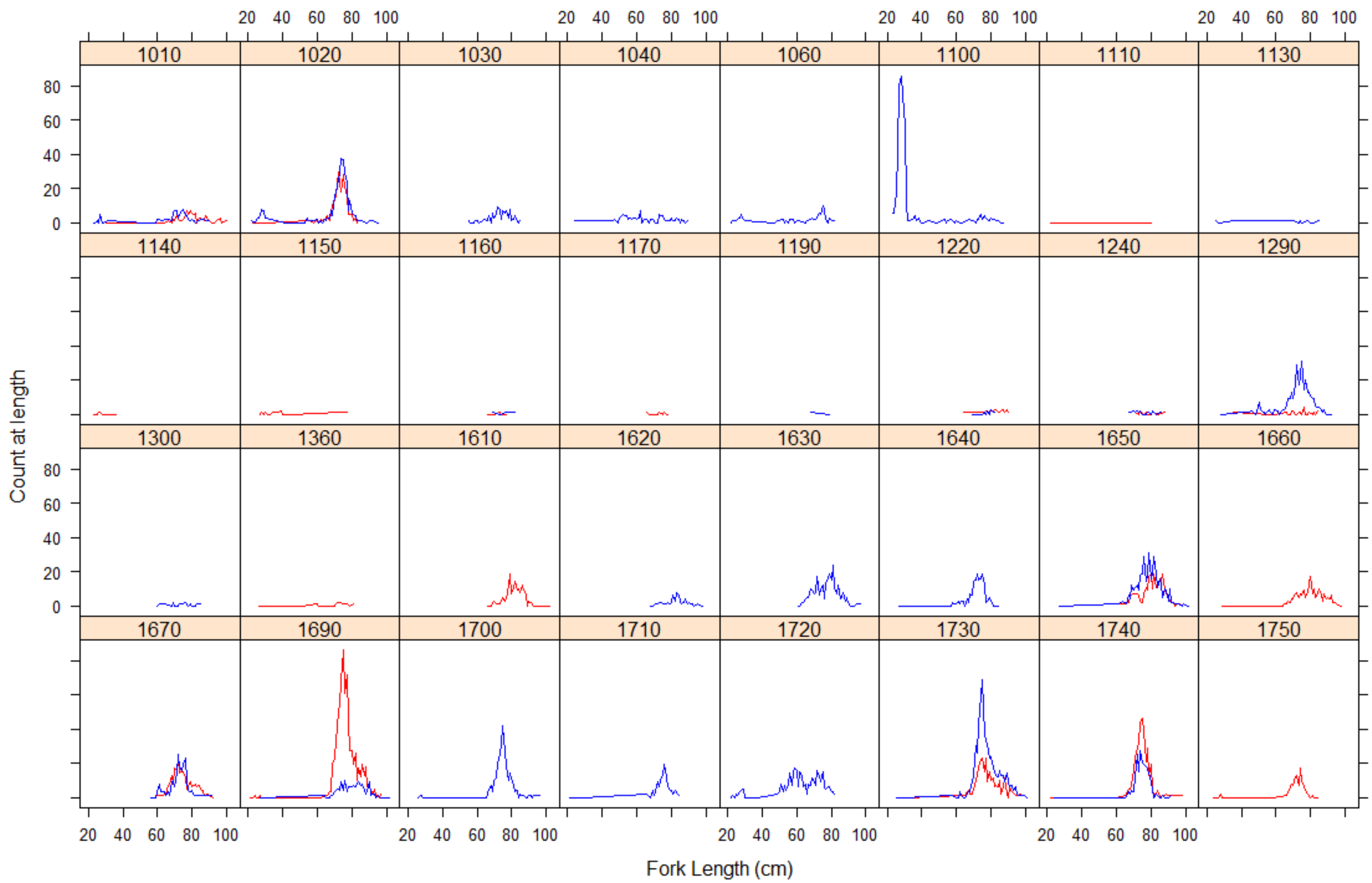



*Figure 22. Total counts at length of Spiny Dogfish from the NMFS Spring survey in strata sampled by the Albatross during the day (blue lines) and night (red lines) during the paired-tow study in 2008.*

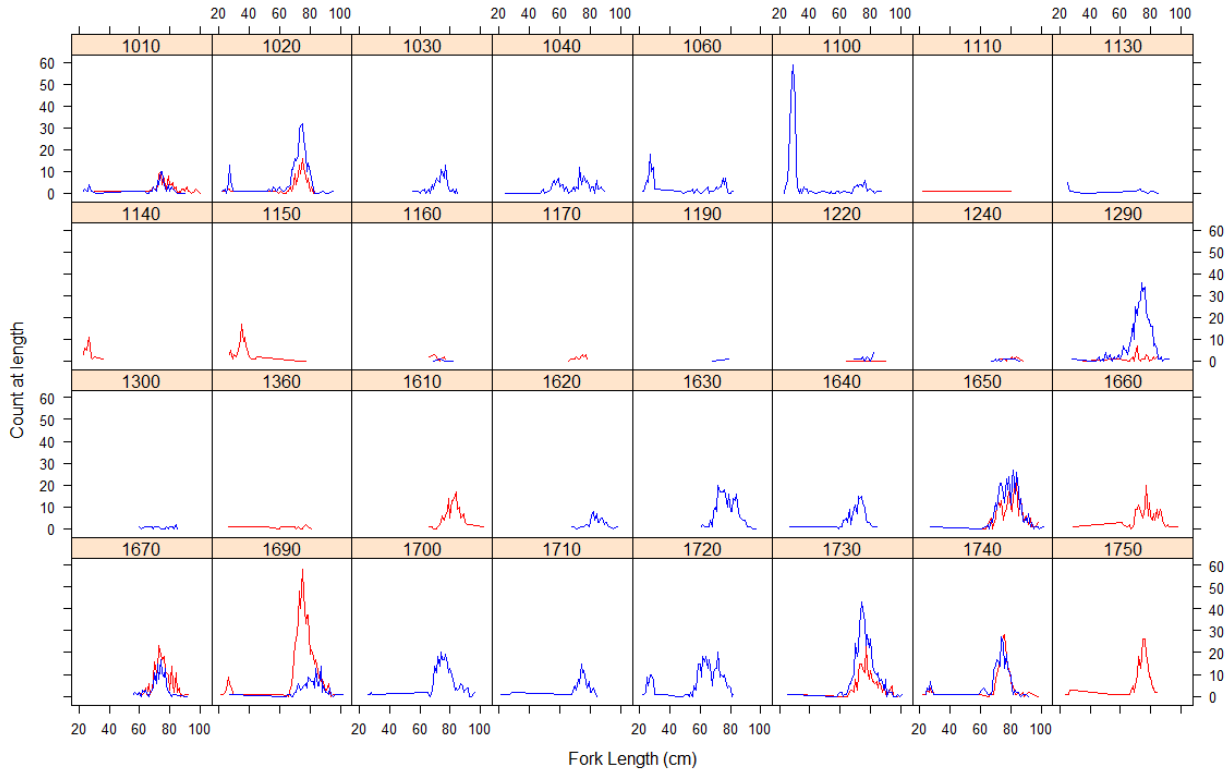



*Figure 23. Total counts at length of Spiny Dogfish from the NMFS Spring survey in strata sampled by the Bigelow during the day (blue lines) and night (red lines) during the paired-tow study in 2008.*

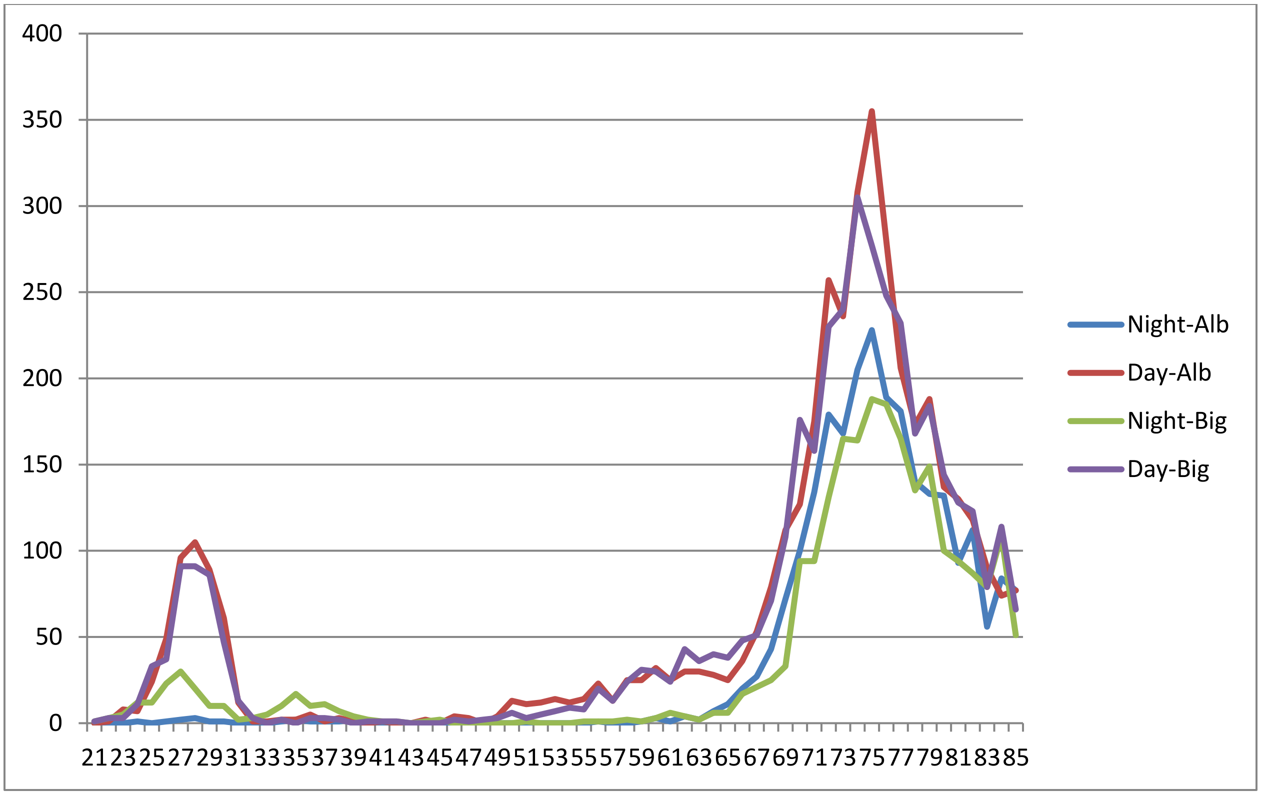



*Figure 24. Total catch at length of Spiny Dogfish by the Albatross (Alb) and Bigelow (Big) during the 2008 calibration study for tows completed during the day and those completed at night.*

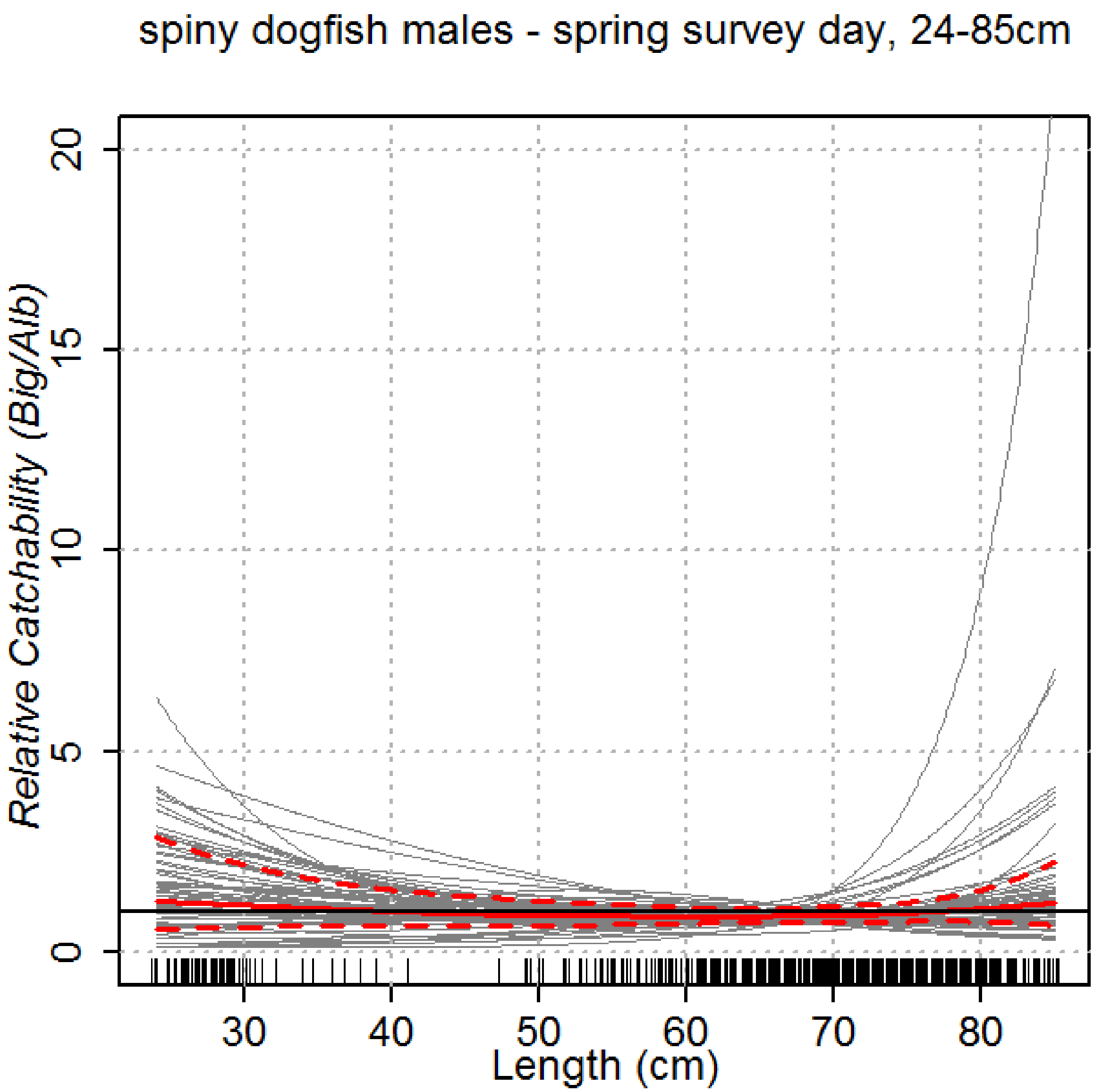



*Figure 25. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for male Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data collected during the day from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

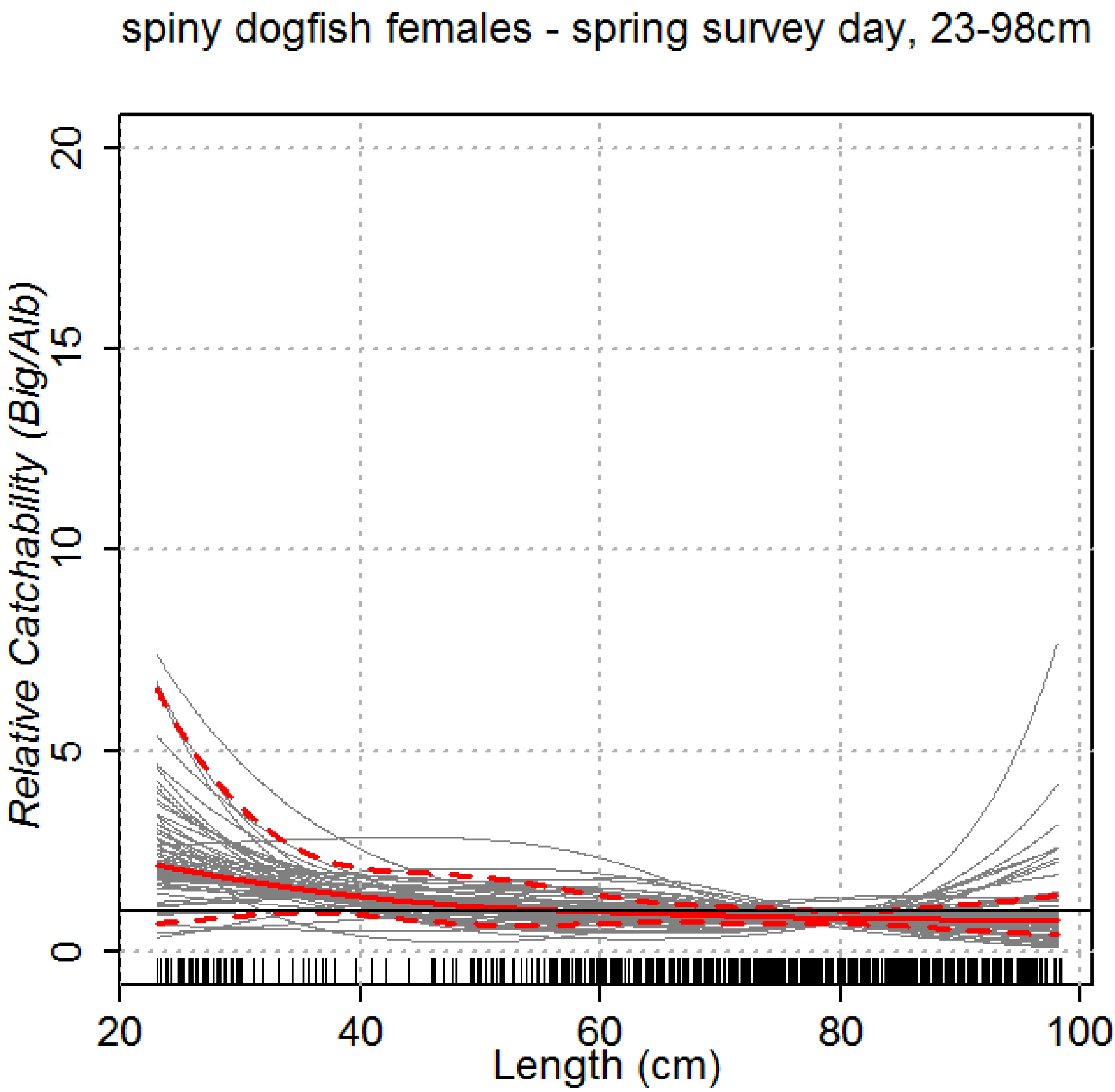



*Figure 26. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for female Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data collected during the day from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

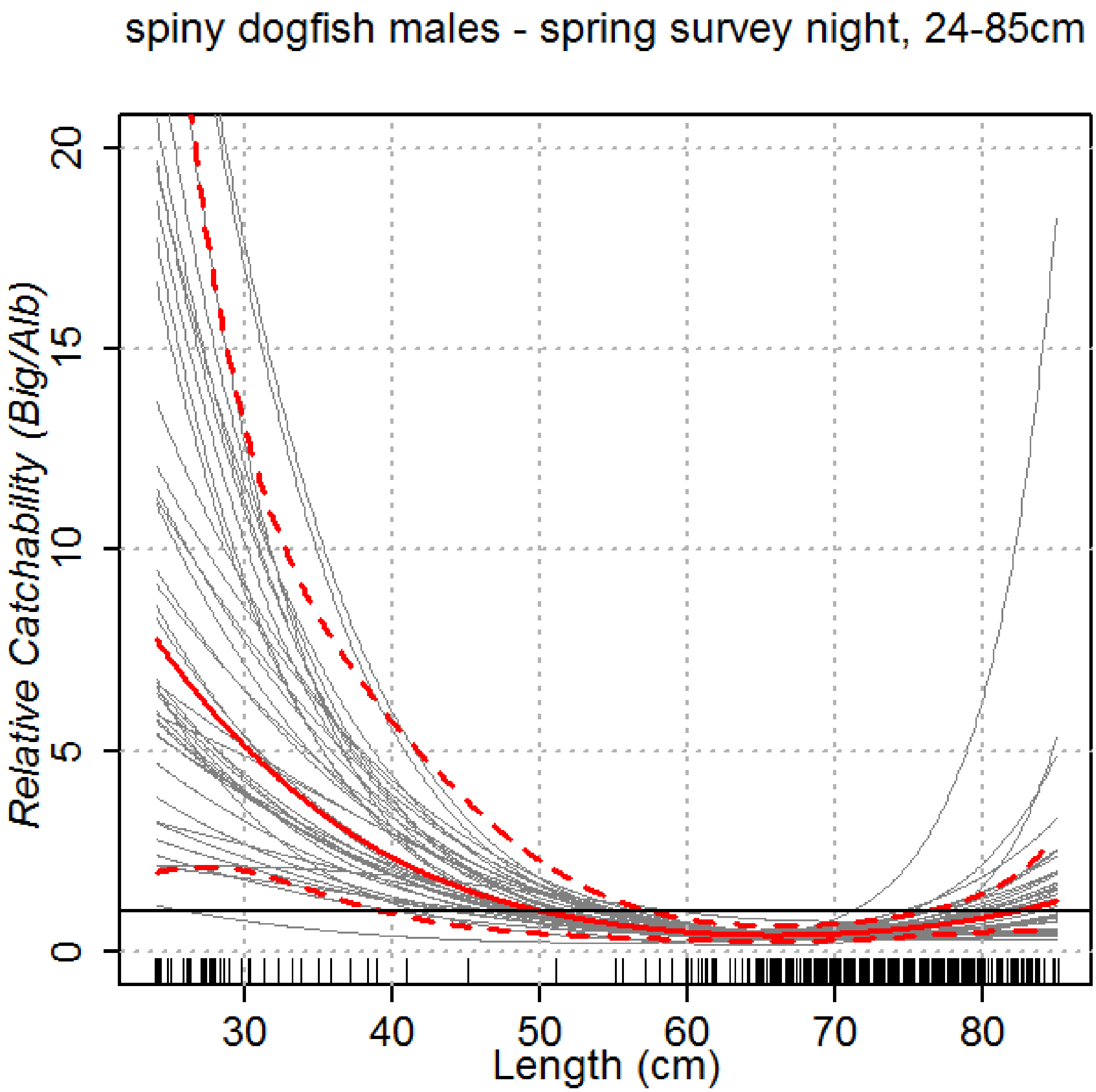



*Figure 27. Estimated mean (red line), 95% Confidence Interval (dashed red lines) and station-specific (grey lines) relative catch efficiency at length for male Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data collected at night from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

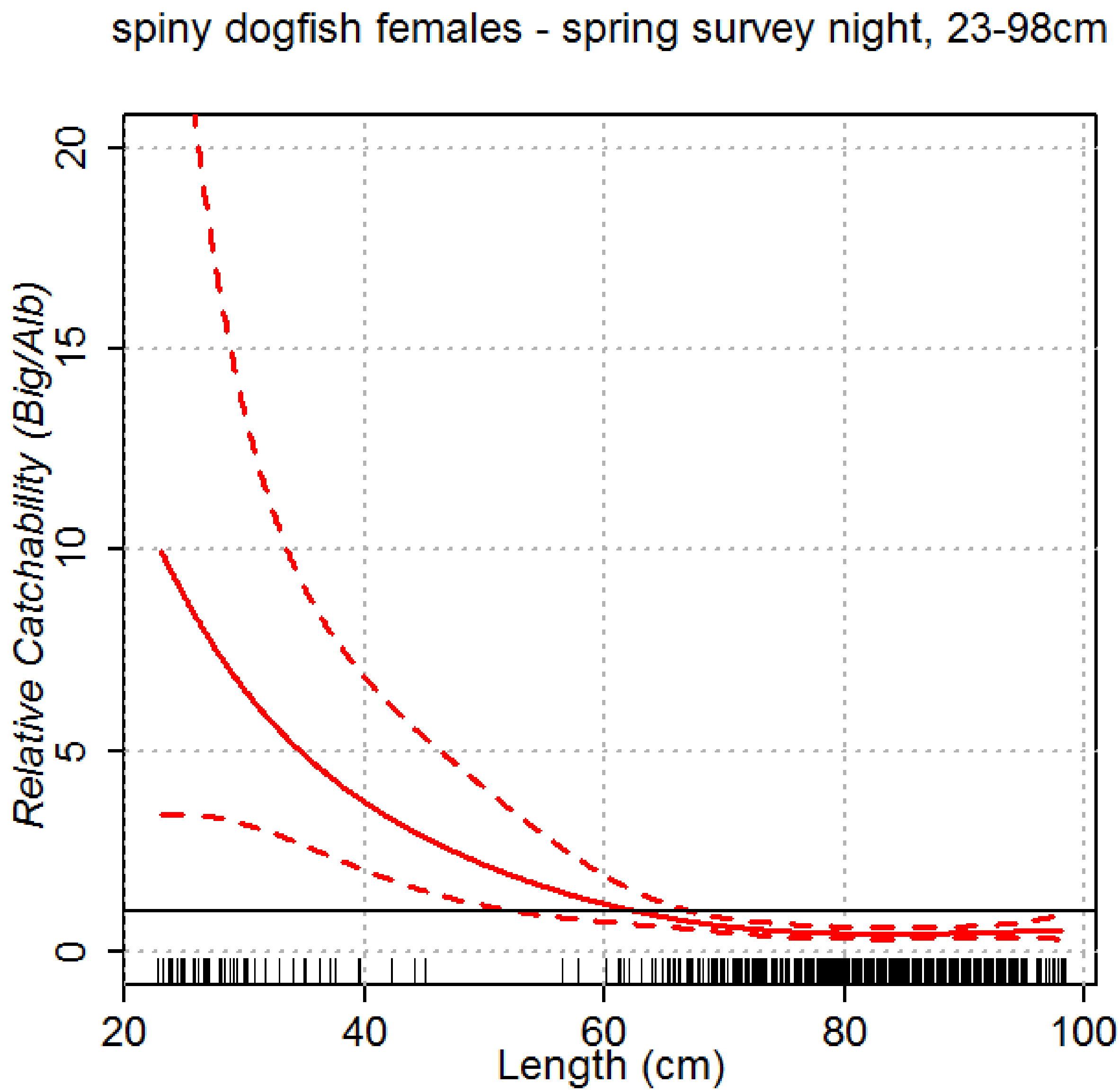



*Figure 28. Estimated mean (red line) and 95% Confidence Interval (dashed red lines) for relative catch efficiency at length for male Spiny Dogfish from the chosen beta-binomial Generalized Linear Mixed Model, using paired-tow data collected at night from the Spring survey exclusively and constraining the length range to sizes with a minimum of 10 fish caught by either vessel.*

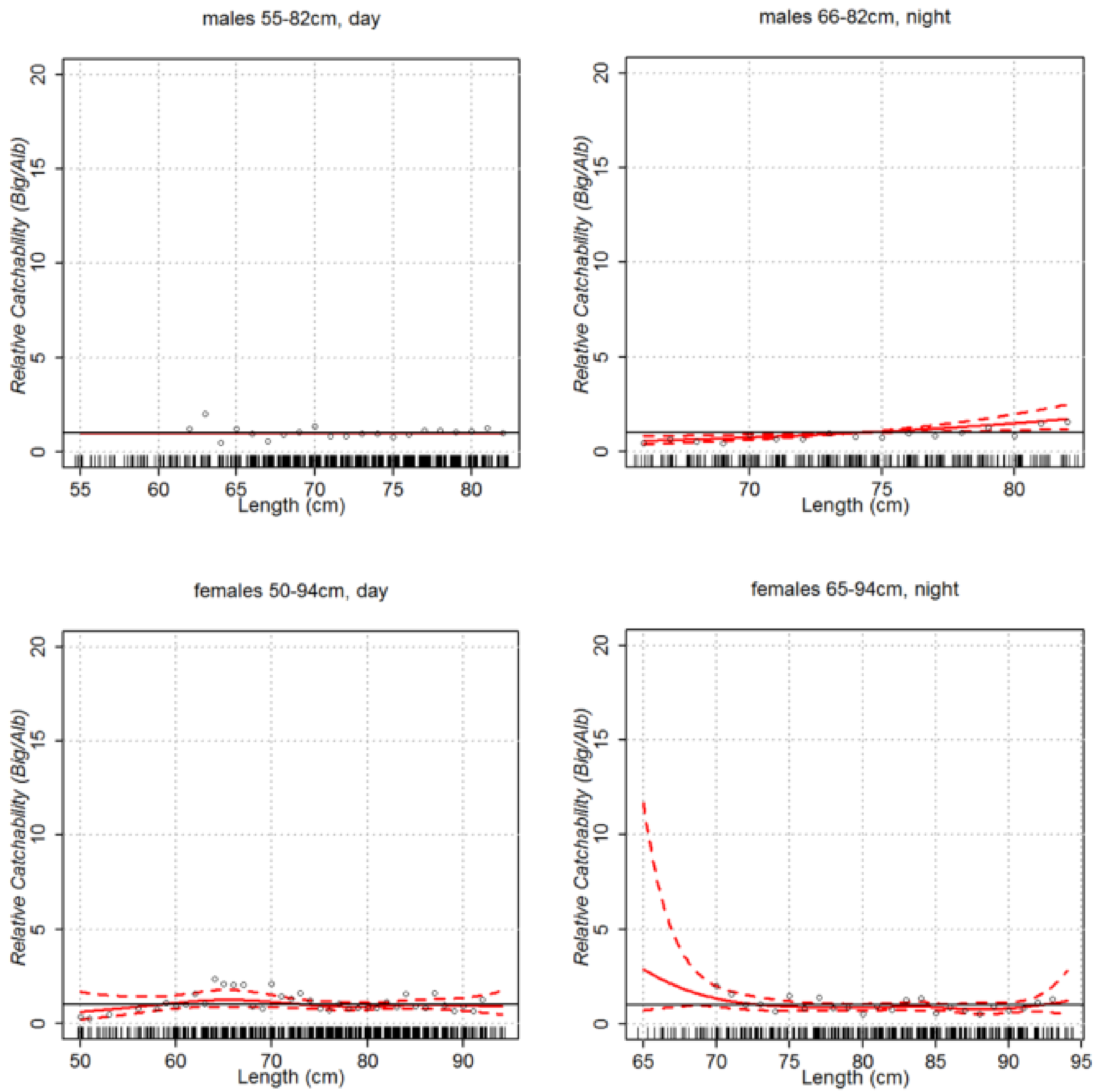



*Figure 29. Relative catchabilities between vessels of adult (demersal) Dogfish by sex and diel period as suggested using Miller et al. (2013) models and model selection protocol.*

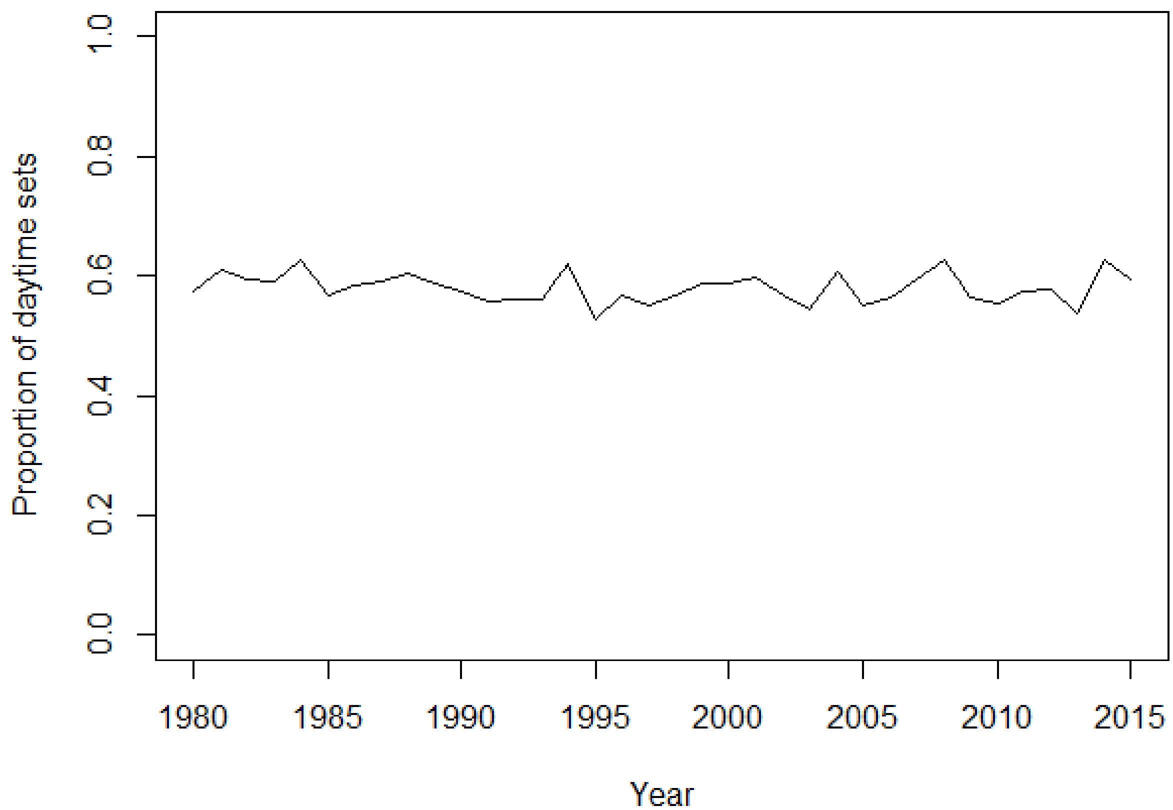



*Figure 30. Annual estimates of the proportion of NMFS Spring survey sets that took place during the day.*

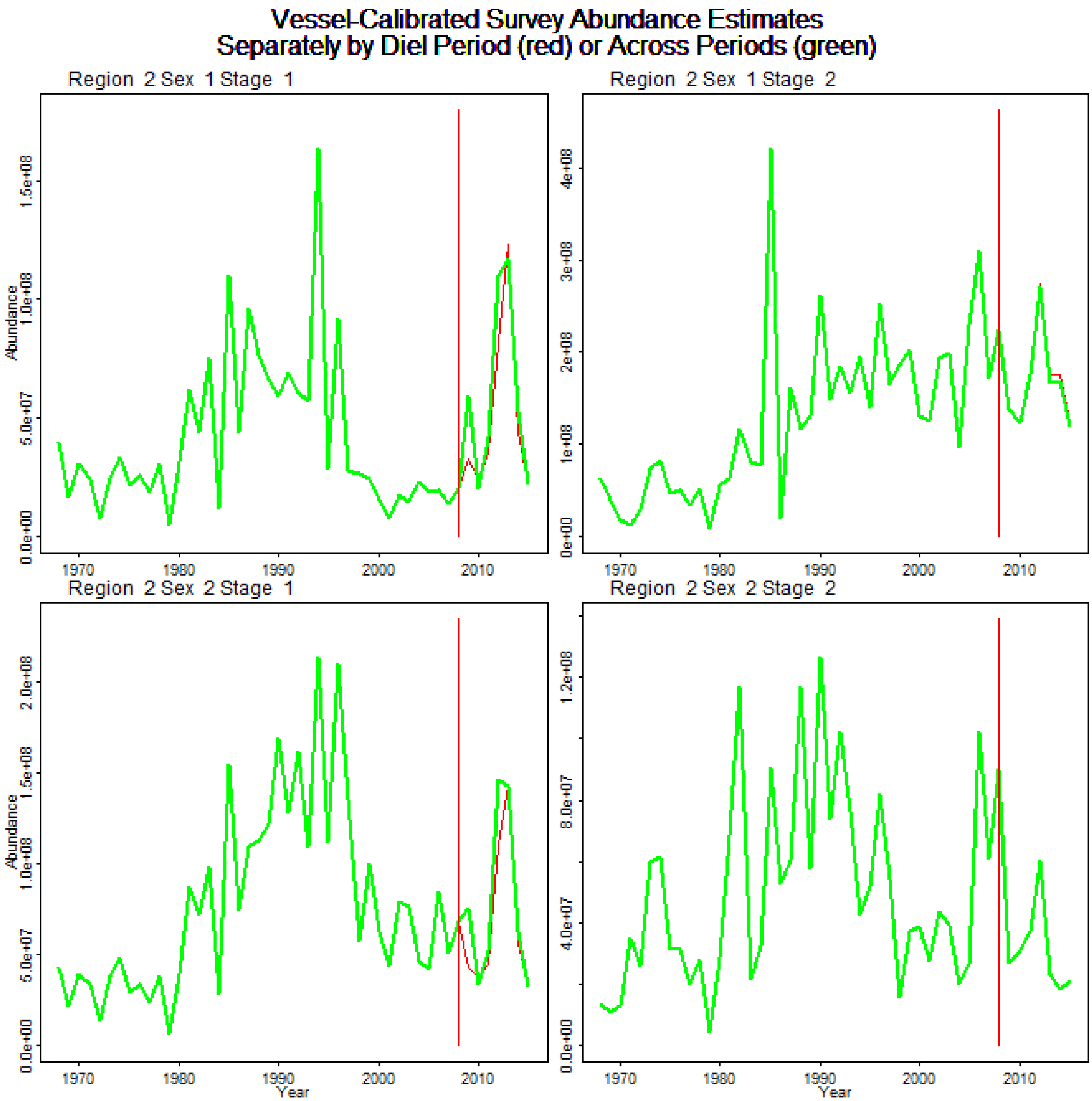



*Figure 31. A comparison of two calibrations for the NMFS Spring survey for 2009–2015 by sex and life stage of Spiny Dogfish. The green line represents total abundance if life stage-specific calibration coefficients are applied, while the red line represents total abundance if calibration coefficients are conditional on life stage and diel period.*

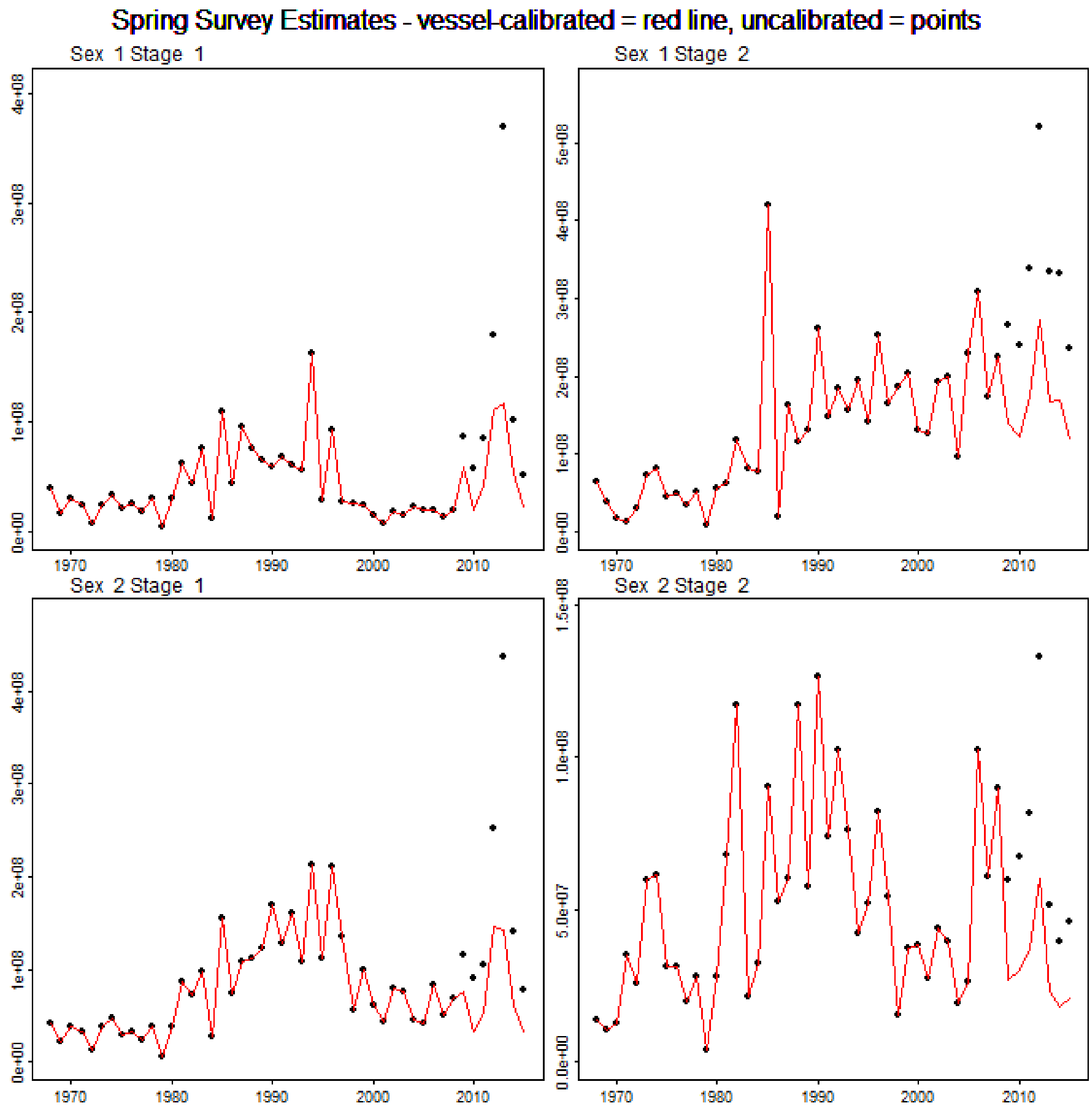
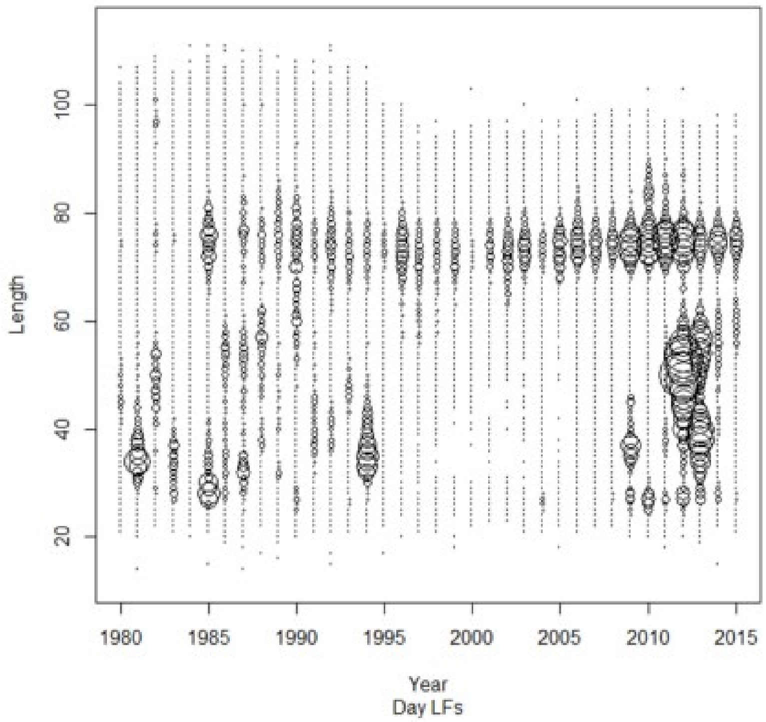



*Figure 32. Comparison of uncalibrated (points) and vessel-calibrated (red line) survey abundances grouped by sex (1 = male, 2 = female) and maturity stage (1 = juveniles, 2 = adults) of Spiny Dogfish. The uncalibrated estimates include 7 instances of calibration between the Delaware and Albatross (1980–1982, 1989–1991,and 1994).*



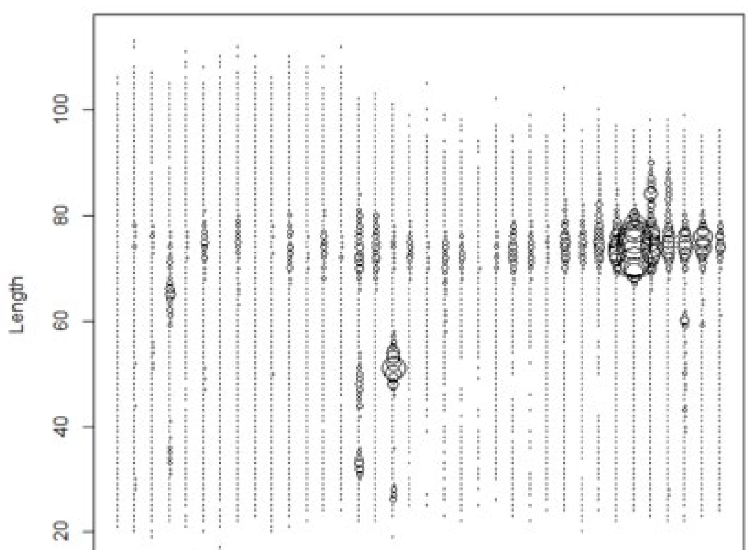




*Figure 33. Spiny Dogfish length composition over time, summed over sets completed during the day and at night. Bubble size is proportional to abundance, with the maximum representing a count of 1817 and the minimum representing approximately 100 fish.*