Overview of data sources for the Pacific halibut stock assessment and related analyses

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Introduction

This document provides a summary of the data sources available for the Pacific halibut stock assessment, apportionment, harvest policy, management strategy analysis (MSE), and related analyses. It serves as background for the 2013 stock assessment, and also as an ongoing effort to provide transparent documentation and access to the data and processing methods employed. For each data source, a narrative is provided which includes the source, steps taken to filter and analyze the data, and the key quantities available for subsequent analysis. Data sources are described within the categories of: fishery-independent, fishery-dependent, and auxiliary sources of information.

Also provided in this document is a brief synopsis of changes to various data sources and processing explored during 2013, as well as a list of data sources or analyses that are currently not directly used, but are potentially available for future analysis. The latter includes some comment on avenues for additional data collection and/or analysis.

Fishery-independent data

Fishery independent data are generated each year by the IPHC's setline survey, covering most of the range of Pacific halibut habitat from the northern Bering Sea and Aleutian Islands to California, and depths of 20-275 fathoms (Soderlund et al. 2012, Henry et al. 2013). The setline survey generates catch rate information, as well as biological samples from individual fish sampled randomly from the catch including: sex, length, age, maturity, and presence of prior hooking injury. These data are reprocessed each year for use in the stock assessment as new observations become available (Fig. 1).

Survey WPUE (Weight-Per-Unit-Effort)

The catch-rate information from the setline survey serves as the primary source of trend information (along with commercial catch-rates) for the stock assessment. The area-specific setline survey indices of abundance (weight-per-unit-effort, WPUE) are calculated based on the catch in weight relative to the amount of gear deployed at each station. Survey effort for a particular station is standardized to an effective skate (*ES*) that is 1,800 feet long, with 100 hooks (and therefore an 18-foot average spacing), based on the number of skates fished (*S*), the average number of hooks fished per skate (N_h), and the hook-spacing (H_s; Fig. 2) based on the relationship given by Hamley and Skud (1978):

$$ES = S \cdot \left(\frac{N_h}{100}\right) \cdot 1.52 \cdot (1 - e^{-0.06 \cdot H_s})$$

Because the hook spacing is standardized for all recent survey operations, the only variability in this relationship occurs due to changes in the number of hooks (N_h) as a result of missing or extra hooks on a particular skate or skates. The weight of each halibut caught is estimated from the individual length observations via the weight-length relationship (see Auxiliary inputs section below). The sum of the catch weight is divided by the number of effective skates to obtain a station-level WPUE. These observations are then combined within a regulatory area (Fig. 3).

The area-specific WPUE is summarized via a simple arithmetic mean observed value (and SE) of WPUE for all stations (*s*) sampled within a regulatory area (*a*) during each year's (*y*) survey (Fig. 4):

$$\bar{I}_{a,y} = \sum_{s=1}^{Nstation} \frac{WPUE_{s,a,y}}{N_{a,y}}$$

These annual area-specific means are then weighted by the geographic extent of suitable depths occupied by Pacific halibut within each regulatory area (g_a, 0-400 fathoms) relative to the entire coast (Fig. 4). The weighted values are then summed to generate a coast-wide index of abundance:

$$I_y = \sum_{a=1}^{Areas} \bar{I}_{a,y} * \frac{g_a}{\sum_{a=1}^{Areas} g_a}$$

Due to anomalies in survey coverage, a number of calibrated expansions, corrections, and modifications are made to the WPUE for specific areas and years in order to make the coast-wide time-series as consistently representative as possible. By regulatory area these include:

<u>Area 2A</u>: In 1997, Area 2A stations followed a random stratified design instead of the grid-based design used in other areas and year. Therefore, the observed average WPUE values are calculated separately for each stratum, and strata are area-weighted within the regulatory area. In 1998 and 2000, survey catches for 2A are interpolated from adjacent years as there was no survey effort in that area. For all years other than 2011, Area 2A catch rates are expanded based on the ratio of catch rates observed in the additional stations (Puget Sound and outside waters) added in 2011. The 2012 Area 2A observations are also adjusted to the extra stations in Puget Sound fished in 2011, but the outside stations were fished as they had been in 2011, so no additional adjustment is necessary. In 2013, the Area 2A survey was expanded to cover a portion of northern California. An expansion has been developed for historical catch rates based on the survey catches in this area in 2013 (See Webster et al. 2014). In addition, the geographic extent of the 0-400 fathom area in northern California was added to the Area 2A calculations (unlike Puget Sound, for which the area had already been included prior to its initial survey in 2011).

<u>Area 2B</u>: In 1996-1998 and 2000, Area 2B had incomplete sampling coverage. Therefore, the values are scaled via an externally calculated ratio (0.89; Webster and Hare 2012) to the observed catches over the entire sampled area relative to the unsampled area in that year.

<u>Area3A</u>: Prior to 1996, only the western portion of area 3A was surveyed in some years. These values are adjusted by a scalar of 0.81 to reflect the lower catch rates in that region relative to the eastern portion of Area 3A.

Area 4A: In 1999, Area 4A values are scaled by a factor of 0.76 to account for incomplete spatial coverage.

The processing of survey WPUE calculations for the Bering Sea (Areas 4C, 4D, and 4E) is extensive. It consists of several expansions in order to estimate halibut density in large regions that are not covered by the annual setline survey. An expanded setline survey, conducted in 2006, in addition to the annual NMFS Bering Sea bottom trawl survey form the basis for these expansions. The specific methods have been revised for 2013, and are described in a separate summary document in this volume (Webster; 2014).

After these expansions have been applied, the coastwide survey legal-size (above the 32 inch minimum size limit) WPUE index is estimated to have declined by 12% from 2012 to 2013 (Fig. 5). This decline is largely driven by downward trends in areas 3A and 3B, and occurs despite increases in 2C and 4B (Fig. 5).

Sublegal halibut (below the 32-inch minimum size limit) are captured by both the commercial fishery and setline survey. Previous stock assessments have removed the sublegal halibut from the WPUE calculation, in large part to make the index more comparable to the catch rates observed in the commercial fishery. However, there is trend information in the catch of these smaller fish, and the total WPUE for all halibut is most consistent with the age-frequency data available for the survey, which also contains fish of all sizes. The total WPUE index provides a very similar trend to the legal-sized WPUE (Table 1, Figs. 6-7). When the regulatory area contributions are grouped, the declines in Areas 3 and 4 are particularly contrasting with the trend in Area 2 (Fig. 8)

Prior to 1997, survey coverage was sparse enough to preclude even a more complex approach to estimate coastwide catch rates. However, data are available for at least several regulatory areas in a number of earlier years. These data represent only Areas 2B, 2C, and 3A (the geographic 'core' of the stock) for the years 1982-1996, and only Areas 2B and 3A for the years 1977-1981. In 1984, among other changes to the station design and coverage, the setline survey (following the commercial fishery the year before) converted their standard gear to include circle hooks; this had a pronounced effect on observed catch rates (Fig. 9).

Survey age distributions

Otoliths are collected randomly from halibut captured by the setline survey, with sampling rates adjusted annually by regulatory area to achieve a similar number of samples from each area in each year. All otoliths collected during survey activities are read each year by IPHC age-readers. Because the survey catch is sampled randomly at the same rate for all stations within a given regulatory area and year, the raw frequency of ages is an appropriate estimate of the aggregate for the area. Age distributions differ between male and female halibut and among regulatory areas, with older fish comprised of primarily males, and occurring in much greater numbers in the western and northern regulatory areas (Fig. 10).

In order to weight these area-specific distributions, an estimate of the number of halibut in each area is required. This is obtained via calculating the numbers-per-unit-area (NPUE), following identical rules to the calculation of WPUE, and then weighting these values by the same geographic proportions used for WPUE. The relative numbers in each regulatory area then provide a weighting for combining the age-frequency distributions into a coastwide aggregate (Fig. 11). In recent years, the strength of the 1987 year class has been particularly evident in these data. The age frequencies in 2013 do not show any signs of strong incoming cohorts, nor much deviation from the recent observed age-structure.

Ages have been aggregated at age 20 (all ages 20 and older combined) for all data (survey and fishery) collected prior to 2002 when the break-and-bake ageing method was adopted for all halibut age-reading by the IPHC (see section on ageing bias and imprecision below). Most ages read prior to 2002 used surface ageing methods.

During 2013, there were some additional ages (628) determined to be missing from the 2001 sampling that were re-aged using surface aging methods (for comparability with the rest of the year's samples) and added to the IPHC's database. In addition, 3,466 otoliths from 1998 were re-aged using break-and-bake methods in order to provide a comparison of surface ages with break-and-bake ages (see section on ageing bias and imprecision below). These otoliths will also be used to create an improved age distribution for 1998 for use in the 2013 assessment. This distribution will reflect the unbiased and more precise nature of the break-and-bake method. A comparison of the raw age-distributions (not weighted by regulatory area) from the two methods shows reasonable consistency, and does not alter the perception of the particularly dominant 1987 cohort (aged 11 years in 1998; Fig. 12).

As for the catch-rate data, there are some sparse age data available prior to 1997. These age data represent only Areas 2B, 2C, and 3A for the years 1982-1996, and only Areas 2B and 3A for the years 1980-1981. These earlier data do not reveal any particularly strong cohorts, nor do the cohort strengths appear appreciably different for male and female halibut (Fig. 13). However, the persistence of male halibut to older ages at a much higher rate can be clearly observed in the more recent survey data.

Survey weight-at-age

The survey collects individual length observations on all halibut captured, which are then converted to estimated weights via the length-weight relationship (see section below). Age estimates are also available for a random subsample of these lengths.

Ages consist of primarily surface ages prior to 2002, and exclusively break-and-bake ages from 2002 to the present. Prior analyses of weight-at-age attempted to correct for the potential bias of surface ages by converting the weights corresponding to surface ages to the 'true' weight at age given an estimated level of bias (and some assumption of the underlying age structure). Investigation of the data prior to 2002 revealed that many of the surface ages also had corresponding break-and-bake ages that were not being included in the analysis (see summary of ageing bias and precision below). Replacing all surface ages with break-and-bake ages (where available) in the weight-at-age calculations appears to adequately address the differences in the ageing methods for the recent data.

Because the sampling of ages is random within the survey catches for an area each year, the average weight-at-age by area, sex, and year is calculated. Where there are very few individuals in the population of a particular age, the number of survey age samples is also small (the age samples are not length-stratified). This pattern, in combination with incomplete survey sampling for some areas and years, results in a small number of missing weights-at-age within area and year combinations. These are simply interpolated from adjacent years. Because the survey captures few fish younger than age 7 or older than age 25, all fish outside this range are aggregated to these 'minus' and 'plus' groups. Although there has been a very strong trend of declining weight-at-age in recent years, there are marked differences in the magnitude of this decline among regulatory areas (Figs. 14-21). There also appear to be some patterns associated with specific cohorts; e.g., females in Area 2C born in the late-1990s (Fig. 16, upper panel). There do not appear to be consistent or strong trends from 2010-2013 in the area-specific data.

These different trends among areas require appropriate weighting of the areas to create a coastwide time-series that represents the entire stock. The estimates of numbers of fish by regulatory area generated from survey NPUE and geographic area are used to weight the individual regulatory area. At the coastwide level the stronger declines observed in the areas for which the greatest number of halibut are estimated to be present are evident, especially for the years prior to 2010 (Fig. 22).

For input to the stock assessment, a full matrix of weight-at-age by year and sex is required, despite the small number of fish present in the youngest and oldest ages. To complete the matrix, a linear ramp in weight-at-age is applied below age 7. For the plus group (25+), the average age is calculated; this average age is then used to extrapolate the weight-at-age for ages 25-30. This is necessary because the average weight-at-age for all 25+ halibut combined should not be attributed to exactly age 25: the average age must be >25 unless all fish are exactly 25.

Spawning output-at-age

Survey data are also used to define the population-level weight-at-age and spawning output. Unlike the survey index calculation, where interannual sampling variability is logically included, the true population level quantities should be smoother than the raw observations. In previous analyses, these quantities had been smoothed across ages within each year without regard for sample size, which induced significant correlation among ages, and spurious ‘dog-legs’ that extended over several adjacent ages. Reanalysis of these quantities indicated that applying a smoother across years within each age produced results more consistent with those expected for population level values. These summaries most clearly show the population-level decline in weight-at-age observed for both male and female halibut over the recent time-series available from the survey (Fig. 23). Survey observations of weight-at-age might include some bias relative to the population if size-based selectivity is operating on the distribution of lengths within each age. However, the matrix of population-level weight-at-age is most important in the assessment for those ages that are mature, for halibut mainly ages 11 and higher (see Maturity section below) which are less likely to experience significant bias.

Fishery-dependent data

Commercial fishery landings

An annual estimate of total mortality of halibut from all sources is required for all stock assessment and related analyses. Removals can be categorized into five major components: fishery landings, fishery wastage (a combination of sub-legal and legal-sized fish), sport (recreational), personal use or subsistence removals, and bycatch of halibut in fisheries targeting other species (Fig. 24).

Landings of halibut from the directed fishery are documented through the use of commercial fish tickets, reported to the IPHC (Gilroy et al. 2014). From 1981 to the present, these landings are fully delineated by regulatory area (including all of the portions of Area 4; Fig. 25). Prior to 1981, landings are available only in aggregated form for all of Regulatory Area 4. Landings from 1935 to 1980 are not currently included in the IPHC’s database; however previous analysts have left a number of ‘flat files’ which appear to correspond well with tables published in technical reports, and other IPHC documents. Because the raw data are not able to be reprocessed directly, the landings estimates prior to 1981 are more uncertain than those after 1981. Historical landings prior to 1935 were reconstructed within current regulatory areas from summaries by historical statistical areas (Bell et al. 1952). Reported landings of halibut begin in 1888; however, already over one million pounds were being landed per year at that time. The reconstruction by regulatory area of total landings included some use of ratios between Areas 2A and 2B among adjacent years for ambiguous records, therefore the area-specific distributions are therefore more uncertain than the total landings. Several patterns emerge from the longer time series of landings including: the period of substantially reduced fishing in the 1970s in all areas, and the sequential exploitation of Areas 2, 3 and 4 over the entire time series (Table 2, Fig. 26).

Sport (recreational) removals

Sport or recreational removals are reported to the IPHC by the various agencies in charge of managing these fisheries, including Alaska Department of Fish and Game, the Department of Fisheries and Oceans Canada, and the states of Washington, Oregon and California (Williams 2014). The scientific basis for data collection programs, analyses, and the quality of the subsequent estimates vary considerably by year and source. None of the current estimates include mortality of released fish, although analyses are underway for Alaska. It is generally assumed that there was little sport fishing for Pacific halibut prior to the mid-1970s. Sport removals have grown rapidly since that time, with peak harvests estimated at over 10 million pounds annually during the mid-2000s. They have been reduced in recent years as the IPHC has lowered stock-wide mortality (Fig. 27). Among regulatory areas, Area 3A represents over half of the total removals, with Areas 2C, 2B, and 2A each contributing somewhat less (in declining order).

Personal use or subsistence removals

Subsistence harvest estimates are provided to the IPHC by the DFO and NMFS; only those from Alaska are based on an active sampling program (Williams 2014). Estimates are not generated annually in all cases, and therefore some values are applied through intervening years until the next estimate is made available. There are currently no estimates available prior to 1991. The time-series created from these estimates is relatively noisy, but occurs on a scale much smaller (< 2 million pounds) than other critical inputs to the analyses (Fig. 28).

Commercial fishery wastage

‘Wastage’ describes all mortality of halibut that occurs during the directed fishery, but that does not become part of the landed catch. There are three main sources of wastage: 1) fish that are estimated to have been captured by fishing gear that was subsequently lost during fishing operations, 2) fish that are discarded for regulatory reasons (e.g., the vessel’s trip limit or harvester’s IFQ limit have been exceeded), and 3) fish that are captured and discarded because they are below the legal size limit of 32 inches. The methods applied to produce each of these estimates differ due to the amount and quality of information available. For a full description of the improved methods used to calculate wastage for the 2013 assessment see Gilroy and Stewart (2014).

Based on these methods, wastage in the commercial fishery is estimated to have been highest in the early 1980s, subsequently declining (particularly in Area 3A in 1995 when the derby fishery was converted to a quota system), and then increasing from 1995 to 2010 as the size-at-age of halibut declined and more fish at older ages remained below the minimum size limit (Fig. 29, upper panel). The estimates of wastage cannot be delineated within Regulatory Area 4 prior to 1981, but there is very little wastage estimated prior to that time (Fig. 29, lower panel).

Bycatch in non-target fisheries

The estimated bycatch from non-target fisheries by regulatory area is reported to the IPHC by the NMFS and DFO on an annual basis (Williams 2014). These estimates vary greatly in quality and precision depending upon year, fishery, type of estimation method, and many other factors. Bycatch is delineated among Areas 4A, 4B, and 4CDE only from 1990 to the present, during which time it has declined from a peak of over 20 million pounds to a value of approximately 7.9 million pounds in 2013 (Fig. 30, upper panel). Prior to 1991, available bycatch estimates are aggregated for all of Area 4. From the 1960s to 1990s, annual values were variable with a peak in the early 1960s corresponding to the peak of foreign fishing in (currently) Alaska waters, primarily Areas 3A and 3B. There was likely less bycatch prior to the development of the foreign fishery in U.S. waters in the early 1960s; however, bycatch estimates are only available from 1962 to the present (Fig. 30, lower panel).

Summary of total halibut removals

Recent aggregate total removals from all sources reveal that although the directed commercial fishery represents the majority of the anthropogenic mortality, other sources, including bycatch and sport removals, tend to contribute a larger proportion when the total is lower (Fig. 31). Recent total removals from all sources by regulatory area reveal that Area 3A has been the dominant contributor to total mortality throughout the last five decades, that Area 4 has increased in its proportion of the total, and that the other areas have been somewhat consistent (Table 3, Fig. 32).

The full time-series of estimated removals illustrates that all four of the major peaks in the commercial fishery mortality have been of similar magnitude (around 70 million pounds) but that each peak has been larger than the previous with regard to total mortality from all sources (Table 4, Fig. 33). When the removals by source are compared among regulatory areas, there are a number of differing patterns in magnitude and distribution (Figs. 34-36).

Fishery catch-rate and biological data

Directed commercial fishery data is processed similarly to the setline survey data (Fig. 37), with the important exception that there are no sex-specific biological observations available due to the dressing of halibut at sea.

Directed fishery WPUE

Commercial fishery logbook data is collected by port samplers, and reported directly to the IPHC by fishermen. The data that are included in the fishery WPUE analysis are: the regulatory area of fishing (regardless of the port of delivery), the type of fishing gear used (only fixed-hook data are used in Areas 2C, 3A, 3B, 4A, 4B, 4C, 4D; both fixed-hook and snap gear are used in Areas 2A and 2B), the year of fishing (some logbooks are not obtained by port samplers until the following year), the number of skates fished (excluding any gear that was lost), the spacing of the hooks, the number of hooks on each skate, and the pounds of legal-sized halibut captured and landed. Only sets specifically targeting Pacific halibut are included in the analysis and all sets with hook-spacing of less than four feet are assumed to be non-halibut targeting, except in Area 2A.

For each regulatory area and year combination, the sum of the recorded landings is divided by the sum of the effective skates (the calculation of effective skates is identical to that applied to the survey data). Due to the small number of fixed-hook sets in regulatory Areas 2A and 2B, snap gear is included in the calculation for these areas. This is done by dividing the snap gear effort by a factor of 1.35 (Clark 2002). There are too few logs available on an annual basis from Area 4E to include that regulatory area in the WPUE calculations.

The WPUE by regulatory area is combined into a coastwide total by multiplying the area-specific values by the geographic extent of the 0-400 fathom bathymetry in each area (as for survey WPUE). This is consistent with the concept that the commercial WPUE is also a 'survey' of the stock and therefore the estimates are a proxy for density, but diverges from the more common approach of weighting the commercial WPUE from each area by the catch in that area relative to the total. It may be preferable in the future to explore the use of catch- instead of geographic-weighting.

Logbook catch-rates from Areas 2A and 4C were not included in the coastwide total during previous analyses, but were added in 2013 in order to apply a consistent method to all areas, and to include as much of the data as possible. In addition, the geographic extent of each regulatory area was revised slightly to reflect improved bathymetric data and re-analysis by Ray Webster as part of the setline survey standardization analysis. Neither change resulted in a difference to the coastwide time-series that was large enough to detect after rounding the results to an appropriate number of significant digits.

As has been observed over several previous stock assessments, in 2013 there was a change in the 2012 WPUE relative to the dataset available for the 2012 annual stock assessment. Specifically, the final verified record of logbooks available approximately 10-12 months after the end of the annual fishing season (August to September of the following year) have tended to show a lower catch rate than the preliminary data available in November and used in the stock assessment each year. The final 2012 logbook data indicated a 2% decline from 2011 to 2012 in the total WPUE series, as compared to a 0% change in the preliminary data available during November of 2012. Area-specific differences were variable, but generally larger for regulatory areas with few logbook records (e.g., Areas 2A, 4C). These differences reflect the inclusion of logbooks that were not collected by port samplers during the year of fishing (and subsequently mailed in to the IPHC, or collected by port samplers during the 2013 fishing season), as well as logbooks that had been collected but were not available for analysis in 2012 (the fishing season extended until early November; the stock assessment data were finalized the day the fishery closed). A potential contributing factor could be the combination of a decline in WPUE during the fishing season, and a higher probability of logs from later in the season being unavailable at the time of the assessment. Given this pattern, the variance of the terminal year of the WPUE series should be routinely inflated to reflect this additional uncertainty, and the interpretation of small changes tempered by previous trends.

Commercial WPUE series are quite variable among regulatory areas, with Areas 2A, 2B and 2C increasing trends in recent years, and Areas 3A through 4 the greatest declines. Sustained higher catch rates during the 1980s and 1990s are evident in many areas (Table 5, Fig. 38).

Effort data for years prior to 1981 do not currently exist in the IPHC's database. For historical data, as is the case for other sources of information, there exist flat files from previous analysts that include effort and landed catch by regulatory area. These data have been used for other analyses, and date back to 1929. Prior to 1935, records of effort are reported in various technical and other

IPHC reports, and there are a number of differing time-series available. For this summary, total catch and total effort were tabulated from Chapman (1962) for the years 1921-1934, and from Thompson and Bell (1931), although there are differing series in at least Skud (1975) and several others. The oldest historical records do include even earlier years, but have not been included here pending more detailed investigation. It would be preferable to access and process the historical log data directly from data stored in a database with meta-data, but this is not possible at present.

The most dramatic change in the commercial WPUE time series corresponds to the transition from “J” to circle hooks in 1984, although there have been many other changes in the definition of effort over the time series (See synopsis in: Leaman et al. 2012). Changes in catch rates prior to the 1980s also reflect the areas over which fishing was conducted; given the geographic patterns in landings (Fig. 26) it is quite clear that these have shown a strong pattern of moving south to north over much of the time-series. Despite these caveats, it is clear that catch rates were quite low around the time of the formation of the Halibut Commission (in fact, this was the motivation for the original convention), and again in the late 1970s (Table 5, Fig. 39). Additional uncertainty throughout the historical series is reflected by increased CVs (fixed at 0.1) for all years prior to 1996.

Fishery age distributions

Recent fishery ages are created from otoliths collected by port samplers in proportion to the landings in the ports that are annually staffed by the IPHC (Erikson and MacTavish 2013). Because of this method, the raw ages can be directly aggregated within each area and year to estimate the age composition of the catch. Because port samplers also collect individual lengths, the average weight within each area can also be directly estimated via the length-weight relationship. Dividing the total commercial catch for each regulatory area and year by the average fish weight gives an estimate of the number of fish captured. To aggregate the proportions-at-age from each area into a coastwide total, each area is weighted by the numbers of fish in the catch relative to the total number of fish captured over all areas. For the period included in recent stock assessments, the coastwide age distribution displays a very similar pattern to that of the setline survey ages: a very strong 1987 cohort moving through the stock (Fig. 40).

Commercial fishery ages prior to 1991 have been summarized by several previous analysts, in some cases processed originally by one analyst and then subsequently by another (Clark et al. 2000). For this summary, a file produced for the analysis by Clark et al. (2000) was obtained, which included proportions at age by regulatory area from 1935 to 1990. Additional work could be done to verify which of these proportions can and can’t be recreated from the current IPHC database. Weighting of the area-specific proportions followed the method applied to the more recent data, first obtaining an average individual weight (in this case by multiplying the proportions at age by the estimated average weight at age from the historical records), and then dividing the total landings by that weight to get an estimate of the number of fish in the landings by year and area. Again following the survey analysis methodology, the numbers in the landings by area were used to weight the proportions-at-age for a coastwide total.

The resultant fishery age-frequency distributions reveal that halibut in the commercial landings from the 1930s to 1973 (when the current minimum size limit was implemented) have been predominantly age 6 to 14 (Fig. 41). Several strong cohorts can be observed in the data, but none more conspicuous than the 1987 cohort.

Fishery weight-at-age

Both lengths and otoliths are collected by port samplers, and the lengths can be converted into individual weight estimates. No sex information is available from port samples. The average weight of a landed halibut has shown relatively flat trends over Areas 2A, 2B, and 2C, steep declines in Areas 3A and 3B and somewhat less pronounced declines in area 4 (Fig. 42). Several areas showed an increase in average weight in 2013 resulting in an increase at the coastwide level. These observations accurately reflect the fishery landings, but combine the relative influences of weight-at-age, age- and sex-structure, as well as selectivity relative to the underlying population.

Historical observations of average weight are more problematic. Specifically, from 1963-1990 the IPHC did not collect individual lengths from the commercial landings. It was thought at the time that otoliths measurements could be used to adequately estimate the body size of the fish (Southward 1962), and therefore the weight. Subsequent investigation of the relationship between otolith measurements and individual length (Clark 1992) resulted in the resumption of length sampling in 1991. For this reason, the weights-at-age for most of the historical period should be considered much more uncertain than recent observations. In addition, there has yet been no detailed evaluation of surface ageing bias or precision for the period prior to the 1990s (although this work is currently underway at the IPHC). Despite these considerations, there is a clear pattern of increasing fish size in the landings from the 1930s through the 1970s, followed by a subsequent decline to the present (Fig. 43). Also clearly visible is the effect of the implementation of the 32 inch minimum size limit in 1973.

Following the same method applied to the age-composition data (weighting the historical weight-at-age for each regulatory area by the number of fish in the landings for that area), a coastwide weight-at-age can be constructed for the entire time-series. Unfortunately, this series is not sex-specific due to the dressing of fish at sea prior to sampling by port samplers. However, there are similar trends for the best represented ages (8-16) over the historical period. One way to investigate these patterns is to divide the time series of weight-at-age for each age relative to the first year in which we have a coastwide estimate from survey data (1997). Only legal-sized fish from the survey catch are included in these weights-at-age in order to make them comparable to fishery landings. These deviations show very similar temporal patterns, despite expected differences on an absolute scale (Fig. 44).

As a proxy for sex-specific weights-at-age for the time-series, the survey weights-at-age from 1997 were scaled by the time series of annual deviations calculated from the fishery data. This implicitly assumes that male and female halibut have experienced similar trends in size-at-age; recent data that are available by sex support this assumption.

Auxiliary inputs

Several additional sources of information are included in the stock assessment or related analyses and treated as data, even though they represent the products of analyses themselves. These are briefly summarized here but considerable additional background material exists.

Weight-length relationship

The weight-length relationship for Pacific halibut was developed in 1926, re-evaluated in 1991 (Clark), and has been applied as standard practice for al years of IPHC management. The relationship between fork length (L_f), and individual net (headed and gutted) weights (W_n) is given by:

$$W_n = 0.00000692 \cdot L_f{}^{3.24}$$

This relationship reflects the slightly greater than cubic increase in weight with increasing length (Fig. 45).

Maturity schedule

The maturity schedule for Pacific halibut has been investigated several times historically, and maturity-at-age found to be very stable despite long-term changes in length- and weight-at-age (Clark and Hare 2006). Estimates of the age at which 50% of female halibut are sexually mature average 11.6 years among regulatory areas, with very few fish mature at ages less than five and nearly all fish mature by about age-17. The maturity schedule used for stock assessment has not been updated in recent years, and it is represented by a logistic fit that is truncated below age 8 (Fig. 46).

Ageing bias and imprecision

Ages are often treated and referred to as 'data', however they represent estimates of age based (most commonly) on the counting the rings formed annually on otoliths. These estimates are therefore subject to both bias and imprecision depending on the method employed to obtain them. Halibut tend to be relatively easy to age (compared to longer-lived groundfish), and historical estimates of the imprecision of the standard method of 'break-and-bake' ageing showed that the method was very precise (Clark 2004a, b, Clark and Hare 2006). Validation of the method relative to actual age has been performed via analysis of radiocarbon levels observed in known-age otoliths, and the relationship has since been used as the standard for North Pacific groundfish species (Piner and Wischniowski 2004).

Prior to 2002, surface ageing was employed as the primary tool for ageing Pacific halibut, and this method is known to be biased for older individuals and less precise than other methods when applied to many marine species. Previous analyses of the properties of surface ages were based on comparison of an extensive data set of duplicate surface and break-and-bake ages (each otoliths read at least twice) that had been collected opportunistically (Clark 2004b, Clark and Hare 2006). This comparison also included some broken-and-burned ages, which are quite similar, but not identical to those generated by the break-and-bake method. Specifically, as readers found otoliths that were difficult to surface age, they had the option to break-and-bake them, thus the comparisons represented a nonrandom sample biased toward the most difficult ages to read. This work found a modest amount of bias for the surface aging method for ages less than 13-15, but rapidly increasing bias and imprecision with further increases in age.

In order to provide an updated and rigorous test of the properties of surface ageing methods employed by the IPHC, a re-ageing of 4,362 systematically selected otoliths from the setline survey collection from 1998 was conducted. For all of these ages, the original surface age and a break-and-bake age are available for direct comparison without regard to the difficulty of reading. The dataset produced by this effort was analyzed with an updated version of a widely available software program for this purpose that has been simulation tested (Punt et al. 2008) and applied as part of many Pacific coast groundfish stock assessments. Briefly, the program estimates a latent age structure in the sample, and estimates the degree of bias and imprecision (assuming at least one method is unbiased) for each ageing method via the joint probability of possible combinations of individual age reads. Based on the newly available 1998 data set, the degree of imprecision estimate for the break-and-bake method is virtually identical to the one previously estimated by Clark (2004; Fig. 47).

However, the estimated properties of surface ages showed a similar level of imprecision, but notably reduced degree of bias when compared to the previous analysis (Fig. 48). This is consistent with the previous dataset including mainly otoliths that were considered difficult to read, and the updated analysis representing a random sample from an entire year's data. These results indicate a reduced degree of bias is likely for ages above 15 years old, and therefore greater accuracy in weight-at-age and age-frequency distributions calculated from surface ages.

Pacific Decadal Oscillation

Previous research identified a strong correlation between the environmental conditions in the northeast Pacific Ocean, specifically the Pacific Decadal Oscillation (PDO; Mantua et al. 1997) and recruitment of halibut to the commercial fishery during the 1900s. A description of ongoing PDO research as well as access to the time-series of estimates can be found at: http://jisao.washington.edu/pdo/. For Pacific halibut, the positive 'phase' of the PDO (years up to and including 1947 and 1977-2006) and subsequent recruitment of juveniles into the commercial fishery appears to be correlated (Clark et al. 1999, Clark and Hare 2002). Although compelling, that analysis utilized only recruitment estimates prior to the mid-1990s. Pending a fully updated investigation into the correlation between recruitment and the PDO, it may still be of qualitative value to monitor the recent trends in the PDO time series. Inspection of the most recent PDO values indicates that since 2006 annual deviations have been negative (Fig. 49). This represents the longest period of negative annual values observed since the late 1940s.

Conclusions

Despite the heterogeneous nature of the various datasets, there is a considerable quantity of historical data available for Pacific halibut, perhaps more than for any other single groundfish species in the region. The IPHC has the benefit of an extremely long time-series of data collection, a high degree of cooperation from the commercial fleet, and therefore a unique resource for historical fishery and biological patterns in the northeast Pacific Ocean. The data themselves, after accounting for important known changes in fishery and survey activities, are remarkably coherent and potentially highly informative for stock assessment, harvest policy, and Management Strategy Evaluation (MSE) analyses.

Summary of notable changes to data processing made for 2013

This document does not attempt to describe all previous data sources and processing methods used for stock assessment. It is intended to provide an overview of what might be considered current 'best practices'. Some of the more important changes to previously employed methods are outlined here along with the rationale for the changes made.

- Previous analyses have required sex-specific age-composition information from the commercial fishery. These were constructed via the estimation of an age-specific logistic function describing the sex-ratio-at-length from the setline survey data, and then the application of these estimated curves to the commercial fishery length-at-age observations (Clark and Hare 2006). Because it is difficult to propagate uncertainty through these calculations, treatment of fishery age-data may be more appropriately conducted using aggregate age-frequency data for both sexes combined. See future analyses section below.
- As noted above, there is no compelling reason to discard the sublegal catch information when constructing the setline survey WPUE time-series. Use of total WPUE includes all available information and avoids artificially partitioning the survey catch rate data at the legal-size limit.
- Several improvements have been incorporated into the current calculations of commercial fishery wastage. These include use of logbook-reported discards in Area 2A, use of logbook-reported sublegal catches in Area 2B and re-estimating the appropriate filtering of survey catch rates for comparison with commercial catch rates in Areas 2A, 2B (prior to 2006), and 2C, where historically used percentages were consistently biased (Gilroy and Stewart 2013).
- As described above, weighting the area-specific weights-at-age for the survey and fishery observations by the catch of each in numbers is necessary to generate a coastwide aggregate. These changes, as well as the use of smoothing over years (not ages) of weight-at-age observations for the survey data, are now applied. The projection of weight-at-age through the historical time-series using the trends observed in the fishery data is also new for 2013.
- The geographic extent of the bottom areas contained in 0-400 fathom depths have been updated based on more accurate bathymetric areas obtained in 2013.
- Areas 2A and 4C are now included in the coastwide fishery WPUE index.

Data sources for future analysis and potential research projects

This section represents a 'laundry-list' of potential extensions to current efforts, as well as new analyses that could benefit the halibut stock assessment or related analyses in the future. It is not a prioritized list, nor is it to be comprehensive: there are certainly other datasets not listed here but potentially available for analysis. A number of the projects are already underway.

- New approaches are needed for sampling the sex of commercial fish that have been dressed at sea. The IPHC has already begun investigating the potential for genetic sampling to be used on a broad scale.
- Extended analysis of the previously documented relationship between halibut recruitment and the Pacific Decadal Oscillation could inform ongoing harvest policy, MSE, and stock assessment efforts.
- Reevaluation of the historical length-weight relationship to determine whether recent changes in length-at-age are also accompanied by changes in weight-at-length. A pilot study on this topic was begun by IPHC port samplers in 2013.
- A renewed analysis of improved methods for commercial CPUE standardization, with a focus on integrating more of the fishery logbooks. In recent years there have been many improvements in the statistical methods available for CPUE standardization (e.g., Maunder

and Punt 2004). The current approach used is relatively simple, and only includes the fixed-gear logbooks, except for in Areas 2A and 2B where a fixed calibration between gears is applied. Potential collaboration with the University of Washington on this research is under consideration by the IPHC.

- A historical investigation on the factors influencing observed size-at-age, and ageing of additional samples from key periods and areas to support this analysis is ongoing at the IPHC as part of a large collaborative North Pacific Research Board project.
- Historical re-aging efforts will also provide information on the bias and imprecision of historical surface ageing relative to the data that are available from the 1990s onward.
- There is the potential that trawl surveys, accessing juvenile halibut habitat and capturing much younger fish than those observed from longline sampling (fishery or survey), could provide information on recruitment strengths for halibut several years prior to currently available sources of data. The NMFS conducts annual trawl surveys in the Bering Sea (Sadoris and Lauth 2013), and biannual surveys in the Aleutian Islands (Sadoris et al. 2013) and Gulf of Alaska . The NMFS also conducts annual trawl surveys off the U.S. west coast (Keller et al. 2012) which also enumerate halibut catches. The DFO conducts both trawl and longline surveys off the B.C. coast which could be included in an analysis of juvenile or adult habitat.
- The NMFS conducts ichthyoplankton surveys in the southwest Bering Sea that could be investigated with regard to potential correlation of planktonic halibut with the distribution and/or abundance of Pacific halibut spawning biomass.
- Mapping of survey catch rates and biological observations is an ongoing project at the IPHC. This should provide greater ability to evaluate and interpret trends in the survey data in the future.
- The NMFS sablefish longline survey in the Gulf of Alaska, Aleutian Islands and Bering Sea edge conducts fishing operations in depths that overlap and exceed those occupied by the IPHC's setline survey. The IPHC has an ongoing project to evaluate the catch rate information from this survey and explore methods for calibrating and using it to adjusting estimates of deep-water abundance for areas and years where this might be possible.
- Recreational catch-rate and length/age-distribution data are available from Alaska Department of Fish and Game. Although these data do not include samples from all potential recreational removals, they could be investigated as inputs to the stock assessment or for comparison with predicted age distributions.
- Mortality associated with catch-and-release in the recreational fishery has not been included in existing estimates. Analyses have been conducted by ADFG, and future estimates for all areas would be improved by inclusion of this type of mortality.
- There is a vast quantity of archived historical data that is currently inaccessible until organized, keypunched and formatted into the IPHC's database with appropriate meta-data. Information on historical fishery landings, effort, and age samples would provide a much clearer (and more reproducible) perception of the historical period.
- Estimates of migration rates by size, and regulatory area are available from the extensive tagging programs that the IPHC has conducted. These data require careful interpretation, as there are many unknown factors (e.g., reporting rates) that could potentially confound the results. However, they may be useful in both a quantitative and qualitative context for establishing migration rates could be further explored in the context of the stock assessment, harvest policy and MSE analyses.

- Additional efforts could be made to reconstruct estimates of personal use or subsistence harvest prior to 1991.
- Standardizing the setline survey catch rates for use in the stock assessment currently includes only gear-related aspects of the data. Model-based estimators, potentially explicitly spatial, might be explored in order to determine the degree to which the time series may be influenced by spatial and other factors relating to exogenous variables.
- There are length-frequency data available for some portions of the bycatch of Pacific halibut captured in fisheries targeting other species. These data have not been included in the fitting of recent stock assessments, although this could be explored. These data have been used to partition the bycatch into U26, and O26 components for apportionment. Such data could be transformed into predicted ages via an annual age-length key and treated as age data for the stock assessment. However, the values themselves are poorly estimated (high variance and not all contributing sources have length-frequency observations available for appropriate weighting), therefore the accuracy of these values would be suspect. Specifically, the representativeness of the samples relative to the total estimated bycatch would need to be evaluated.

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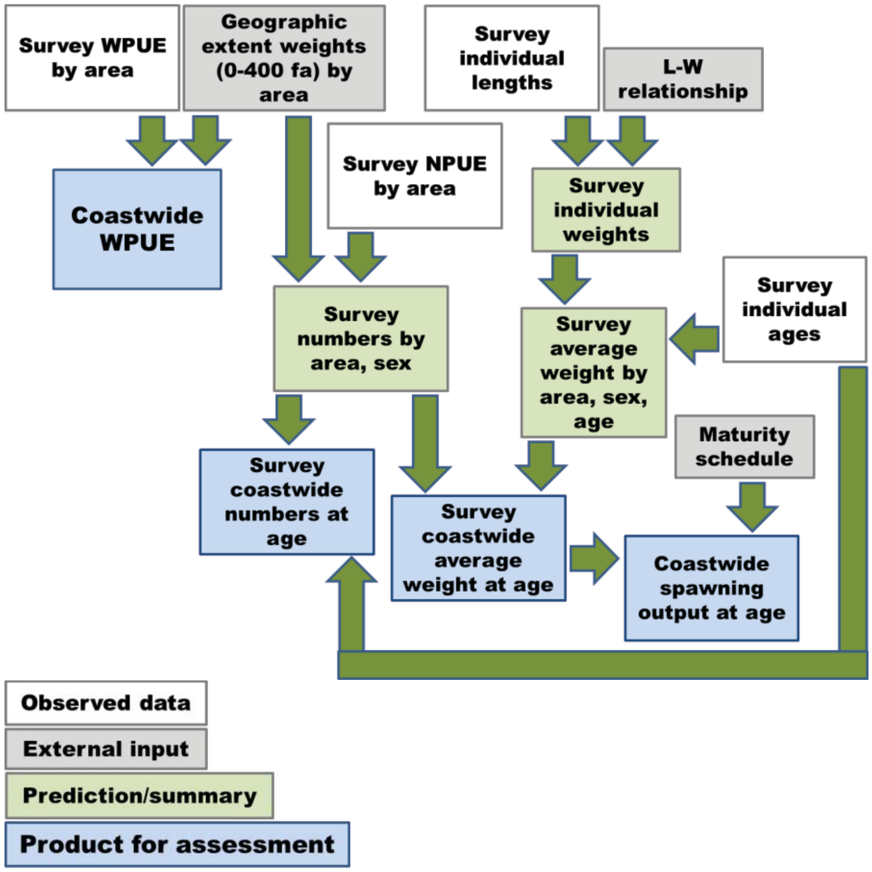

Figure 1. General schematic of the processing of the setline survey data.

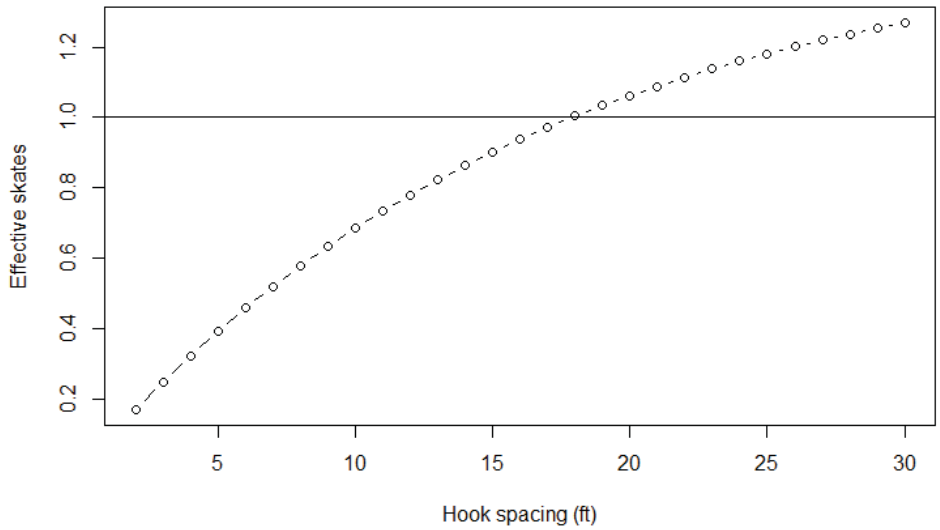

Figure 2. Relationship between hook spacing and the number of effective skates for set line survey and commercial fishery WPUE calculations (From: Hamley and Skud, 1978).

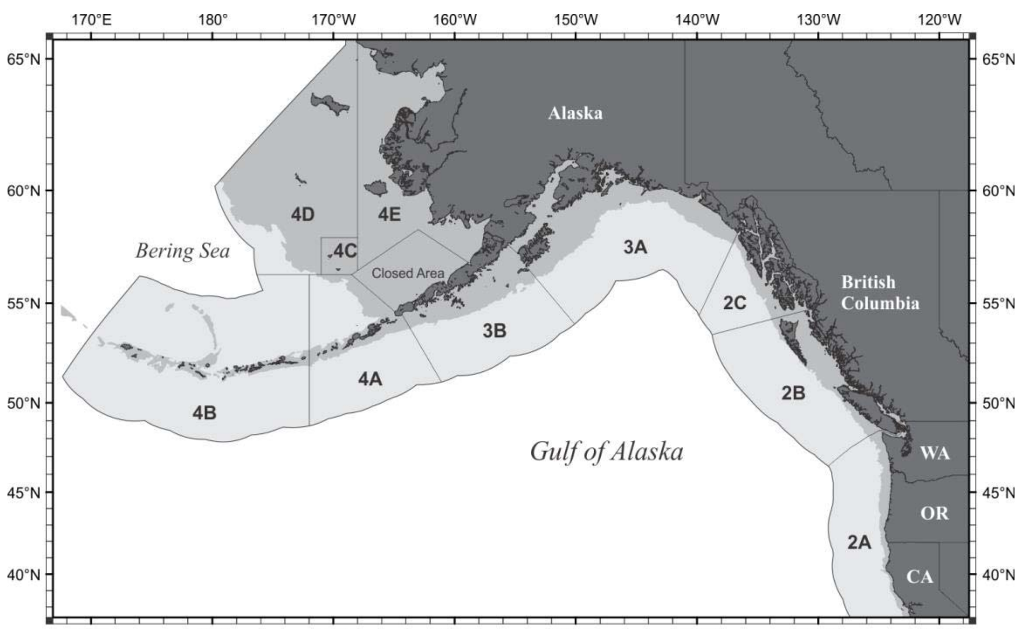

Figure 3. The IPHC's regulatory Areas. Shaded region indicates the Exclusive Economic Zone (EEZ) of the United States and Canada.

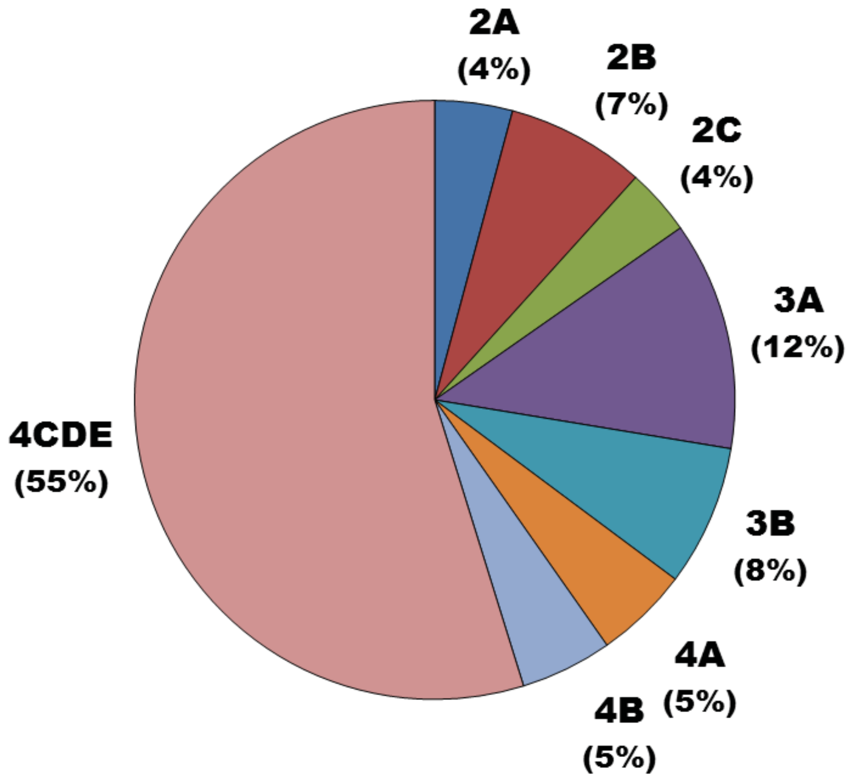

Figure 4. Relative spatial extent of each regulatory Area.

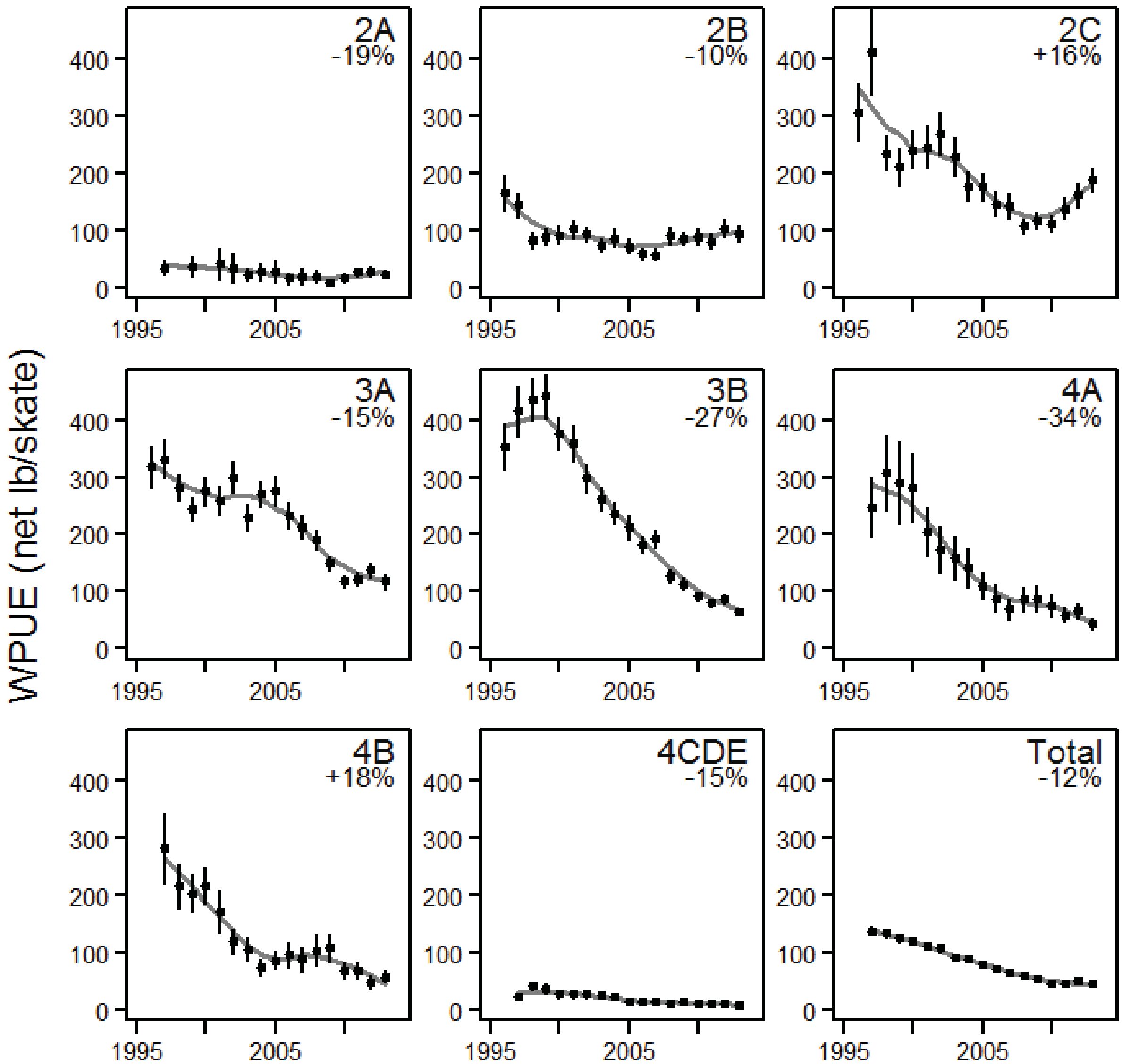

Figure 5. Recent setline survey WPUE for legal-sized fish only by area and year through 2013. Percentages for each area indicate the change from 2012 to 2013; lines represent a smoother for visualization purposes only. Indices include all expansions for incomplete survey coverage.

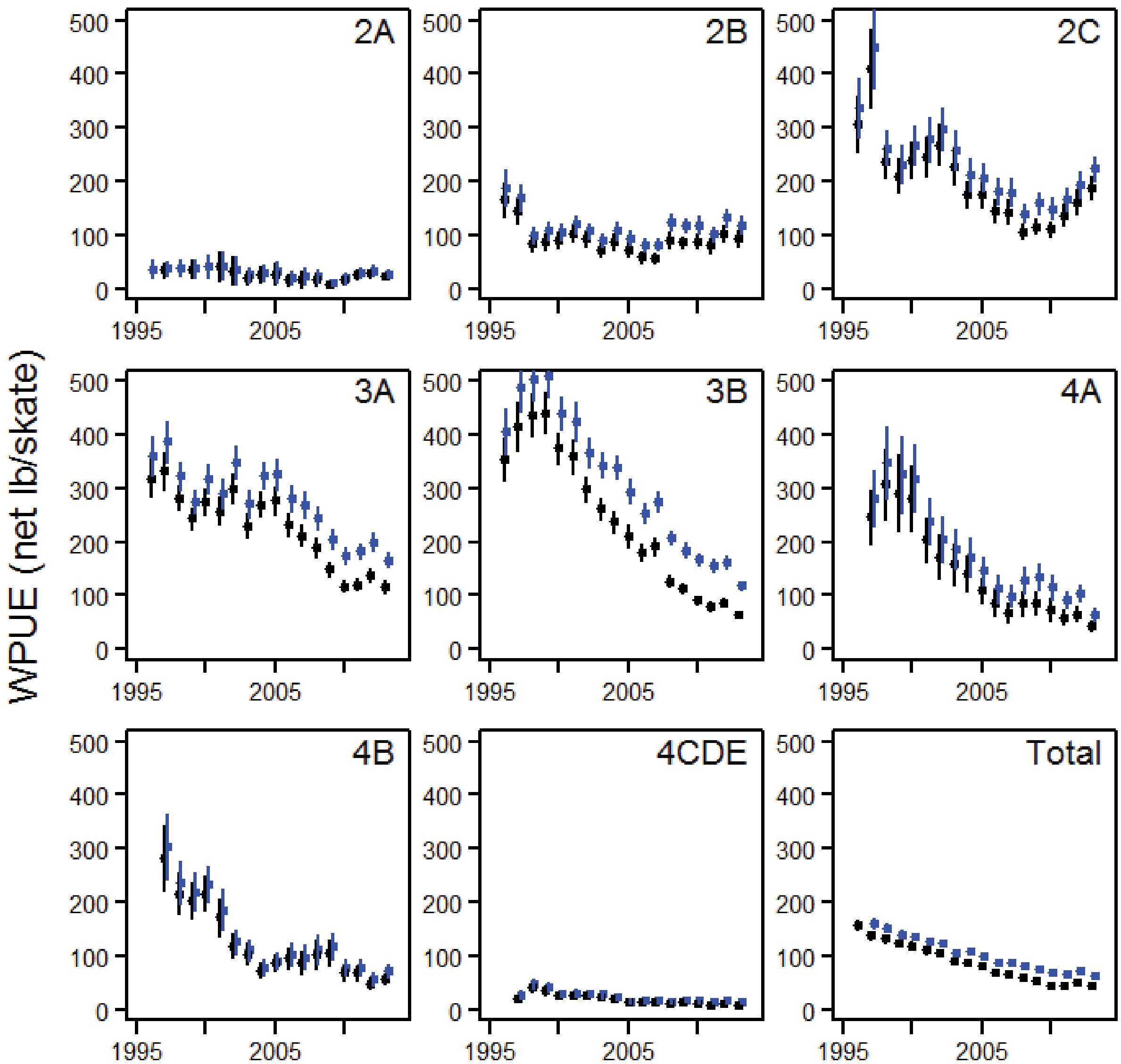

Figure 6. Setline survey total WPUE (blue; slightly larger values) and legal-size WPUE (black) by area and year through 2013. Total WPUE values have been offset slightly on the x-axis to make the points easier to distinguish.

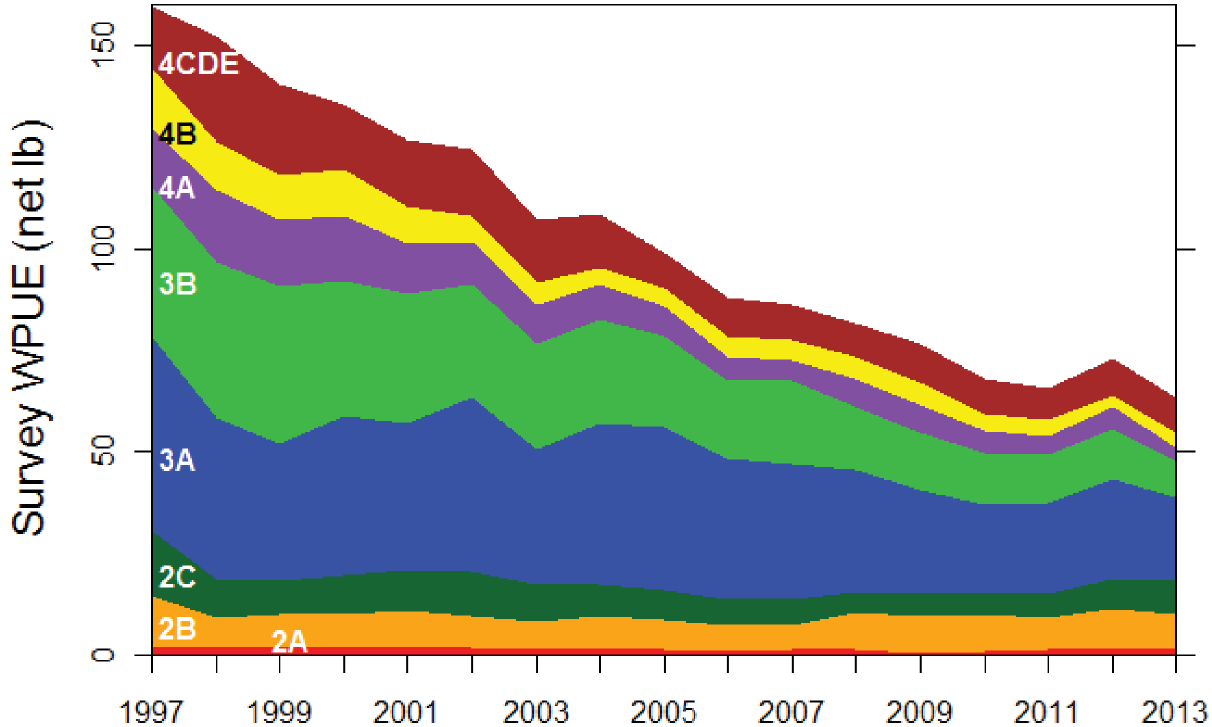

Figure 7. Weighted contributions of the regulatory areas to the coastwide survey total WPUE.

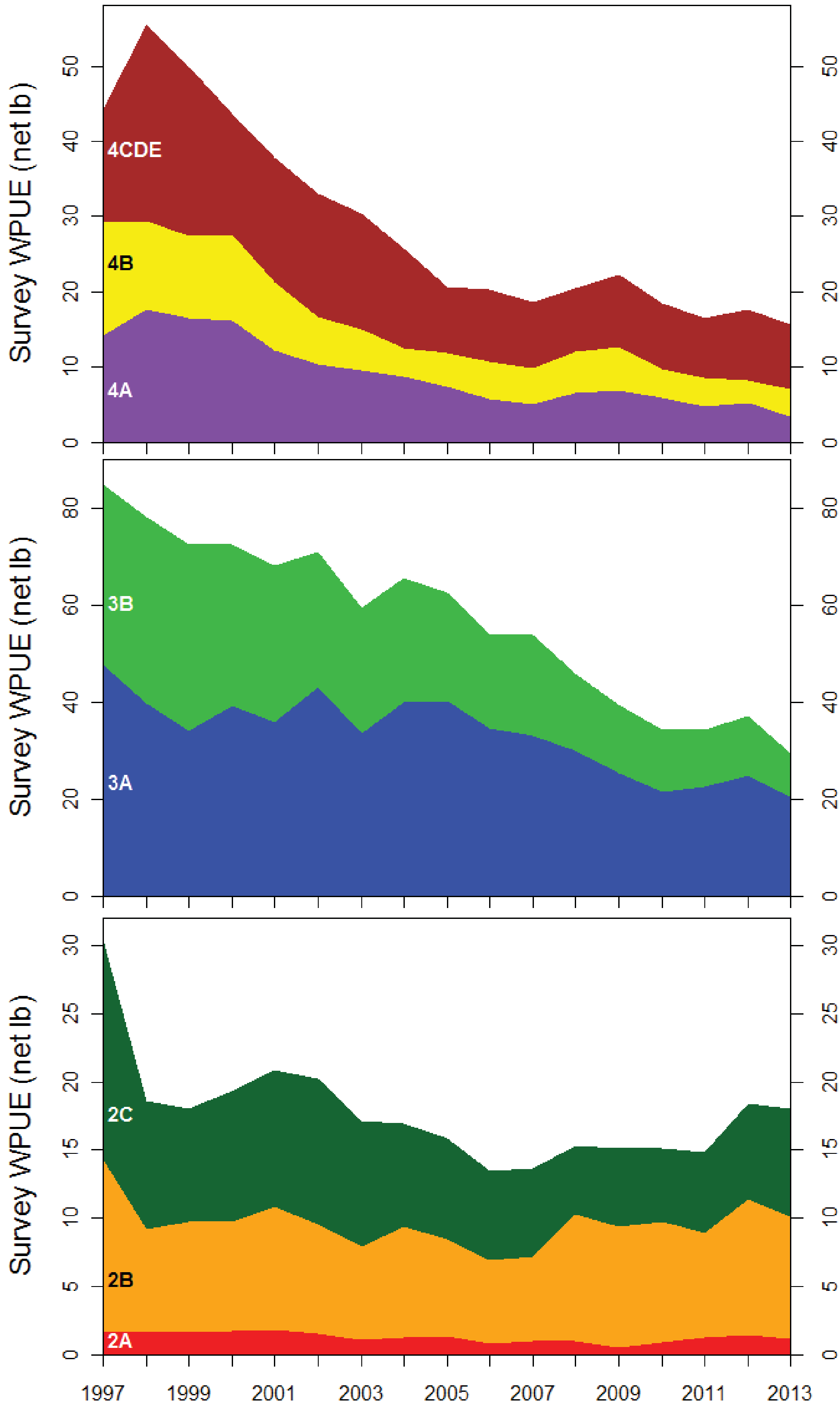

Figure 8. Weighted contributions of the individual regulatory Areas within the survey WPUE for Area 2 (lower panel), Area 3 (middle panel) and Area 4 (upper panel). Note that the y-axes differ among the panels.

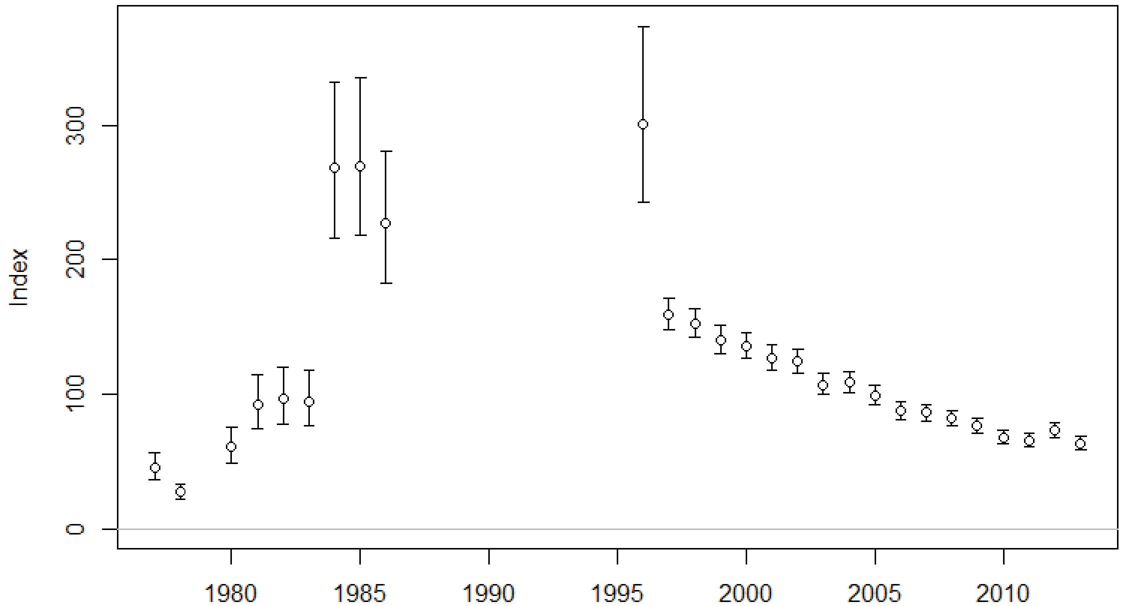

Figure 9. Aggregate setline survey total WPUE. This index contains only regulatory Areas 2B and 3A until 1981, Areas 2B, 2C, and 3A from 1982-1996, and all regulatory Areas from 1997-2013. The increase between 1983 and 1984 coincides with the adoption of circle hooks.

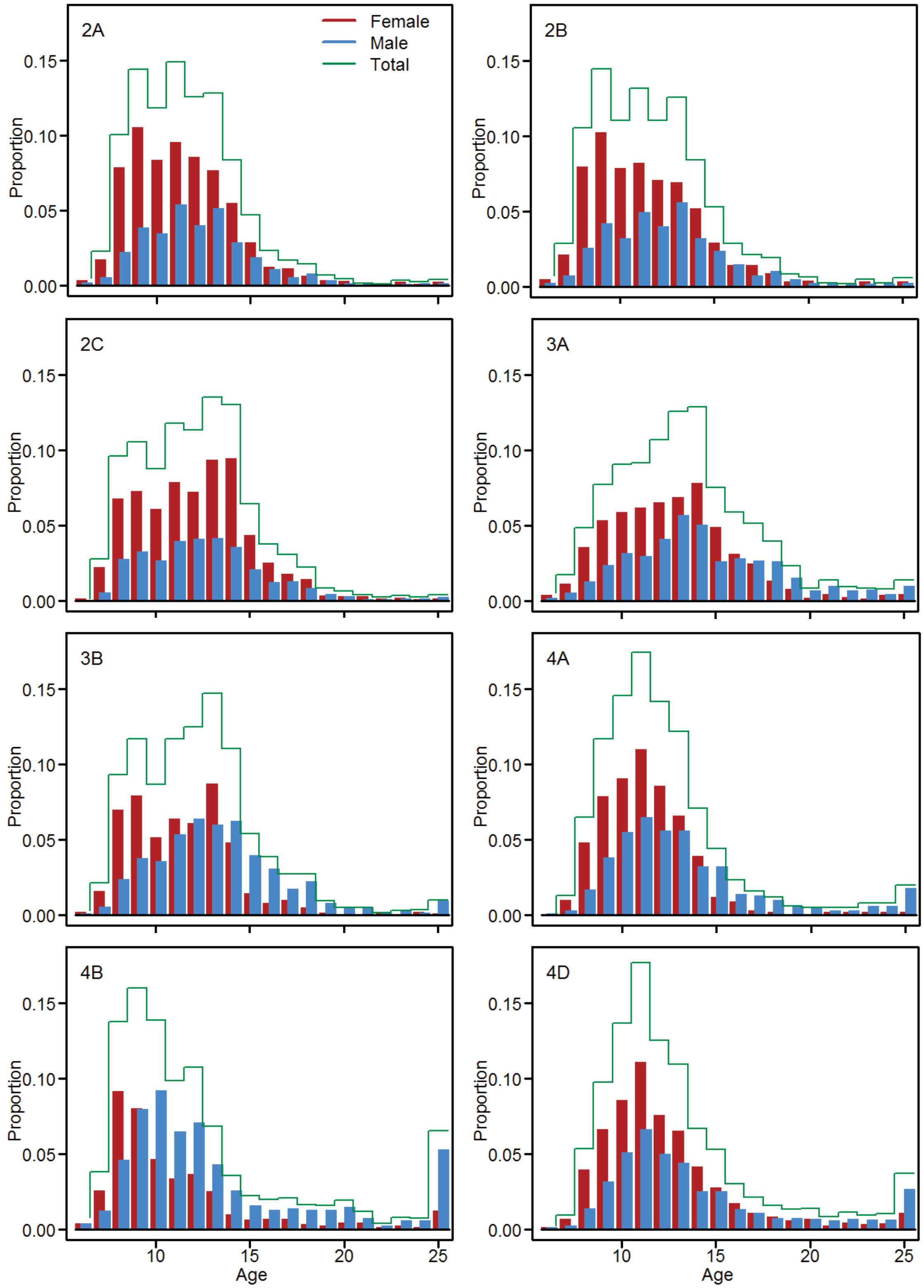

Figure 10. Age distributions from the 2013 setline survey by regulatory Area.

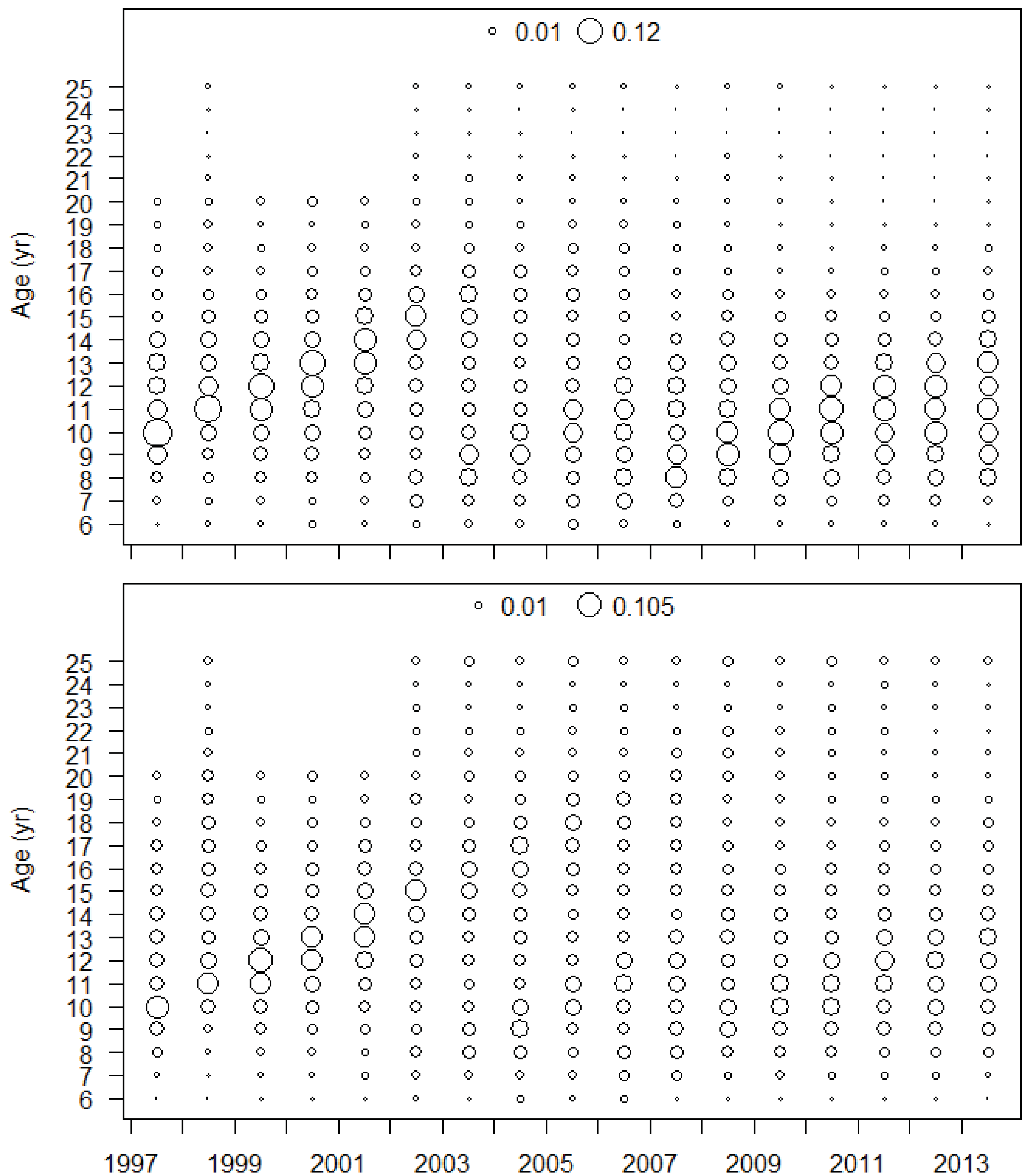

Figure 11. Recent coastwide proportions-at-age for females (upper panel) and males (lower panel) from the setline survey. Proportions sum to 1.0 across both sexes.

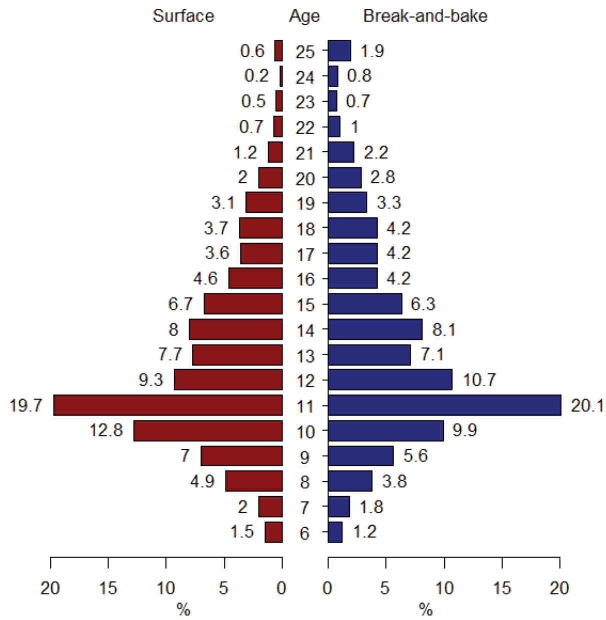

Figure 12. Comparison of raw age-frequency distributions from the 1998 otoliths re-aged in 2013. Age categories 6 and 25 represent aggregates of all ages less and greater than those values.

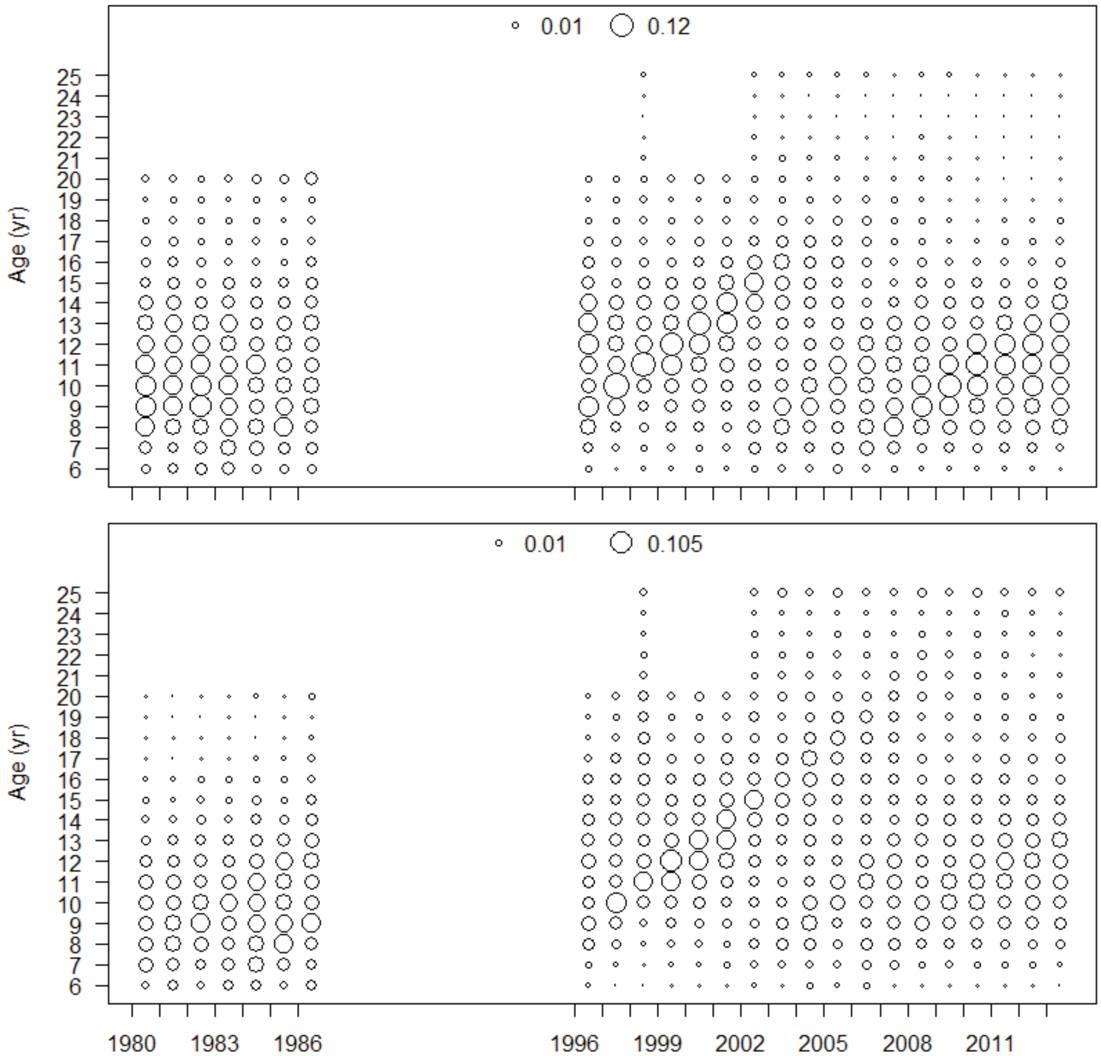

Figure 13. Proportions-at-age for female (upper panel) and male (lower panel) halibut captured by the setline survey. Years prior to 1997 represent reduced and variable spatial coverage.

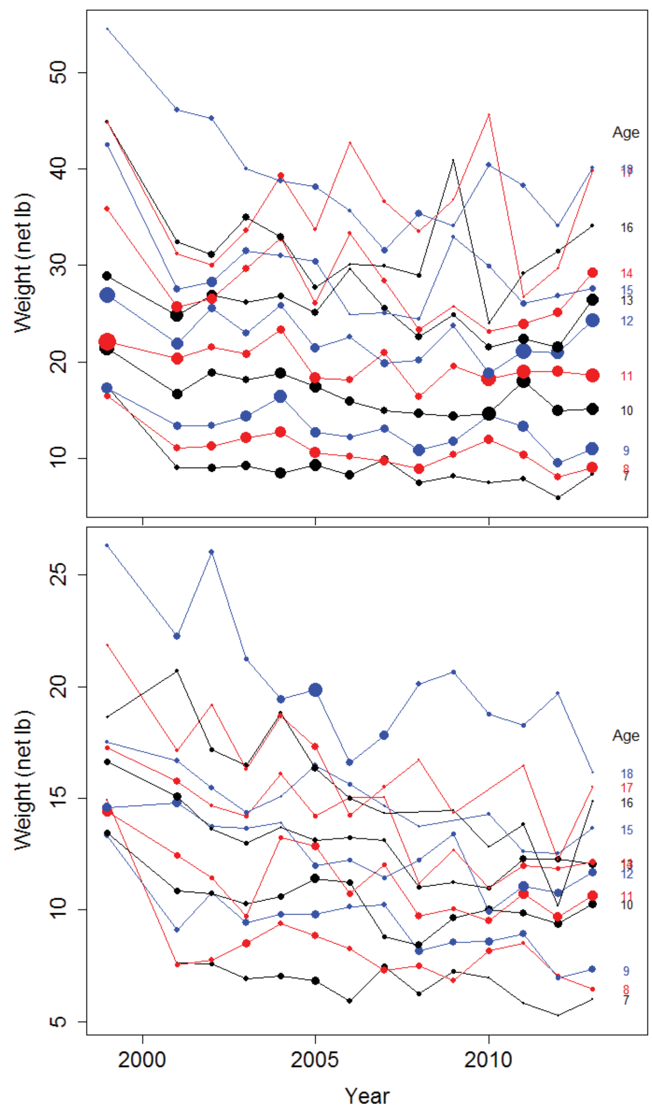

Figure 14. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 2A captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

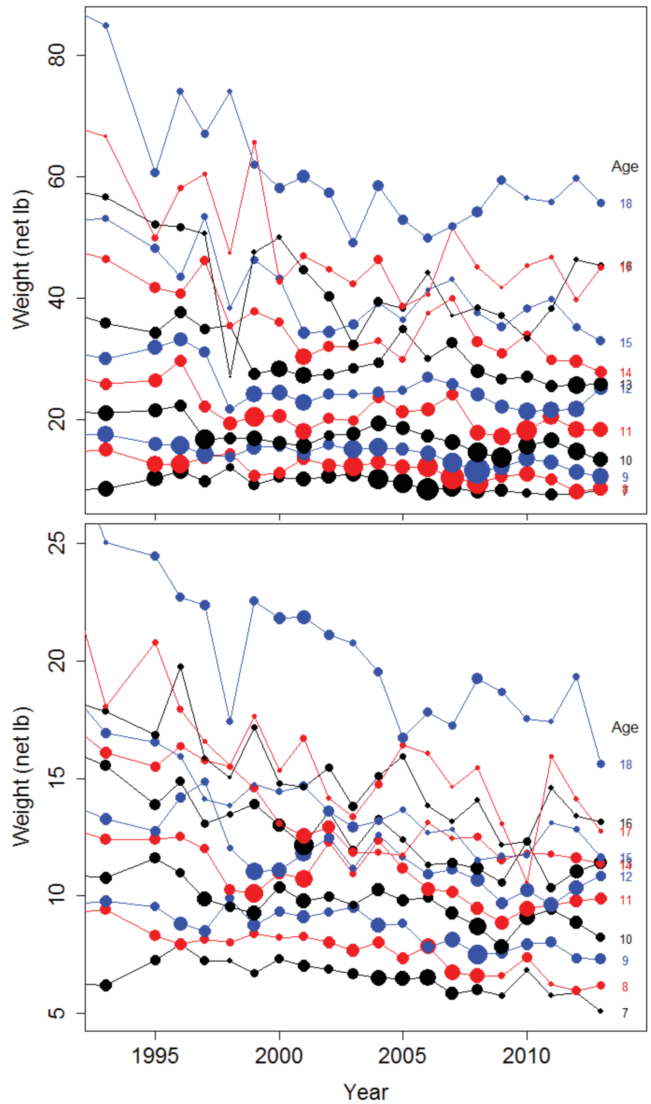

Figure 15. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 2B captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

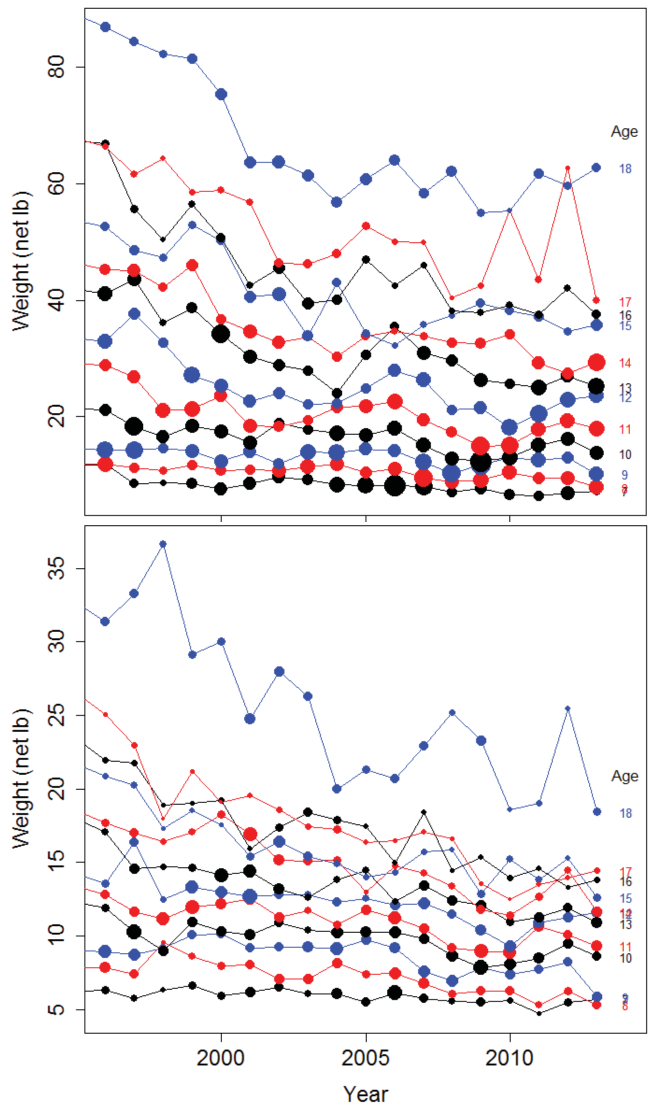

Figure 16. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 2C captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

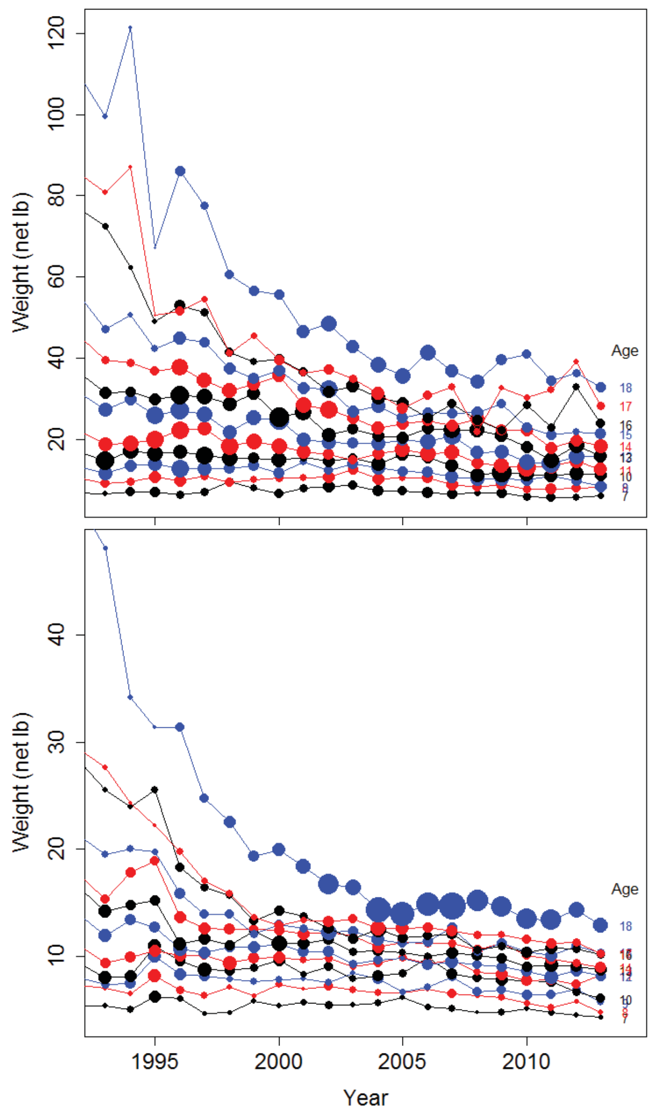

Figure 17. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 3A captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

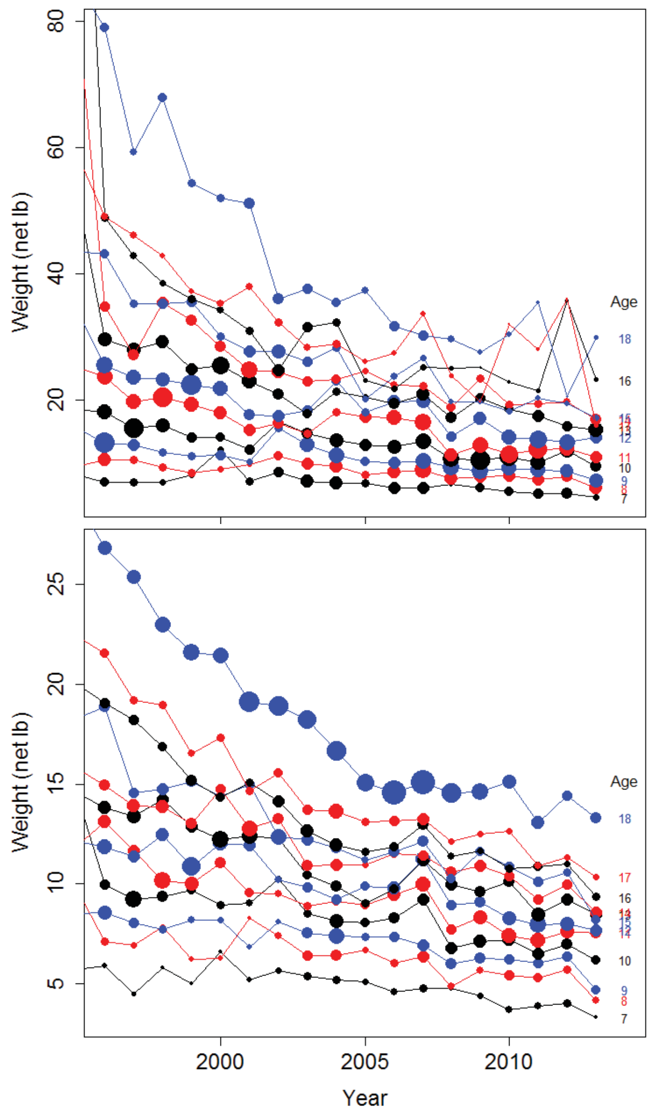

Figure 18. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 3B captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

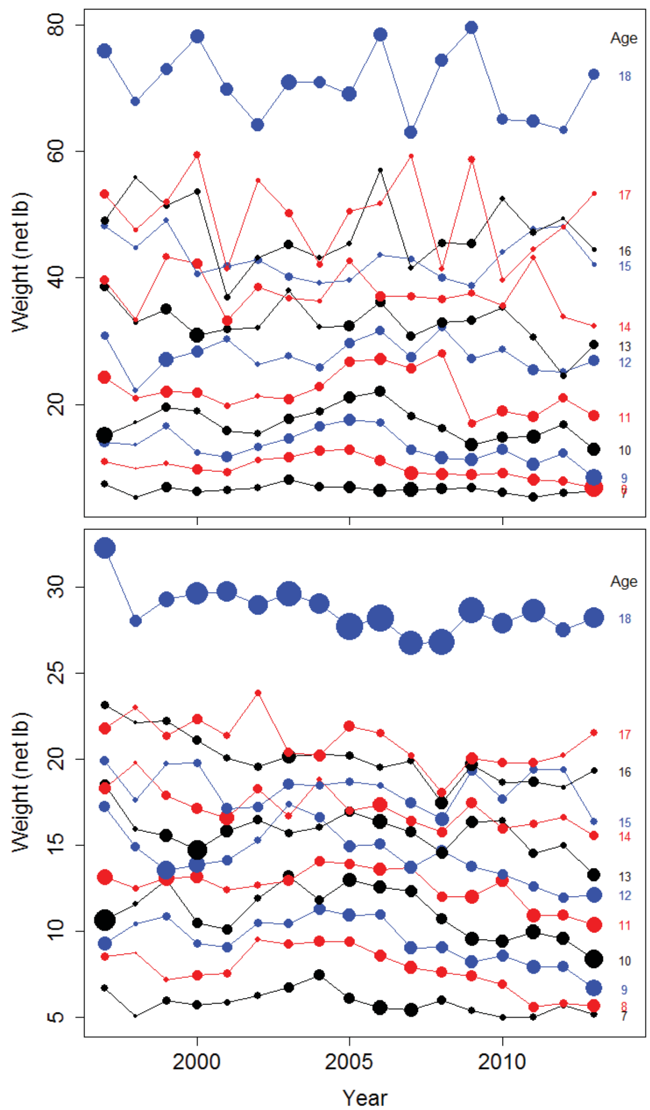

Figure 19. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 4A captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

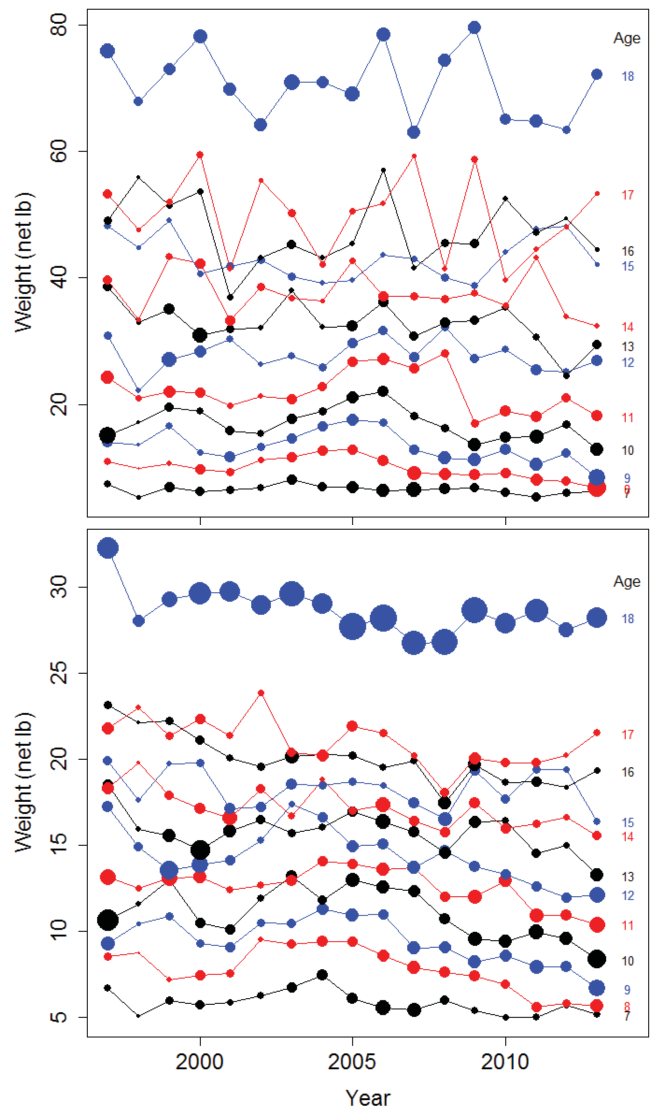

Figure 20. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Area 4B captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

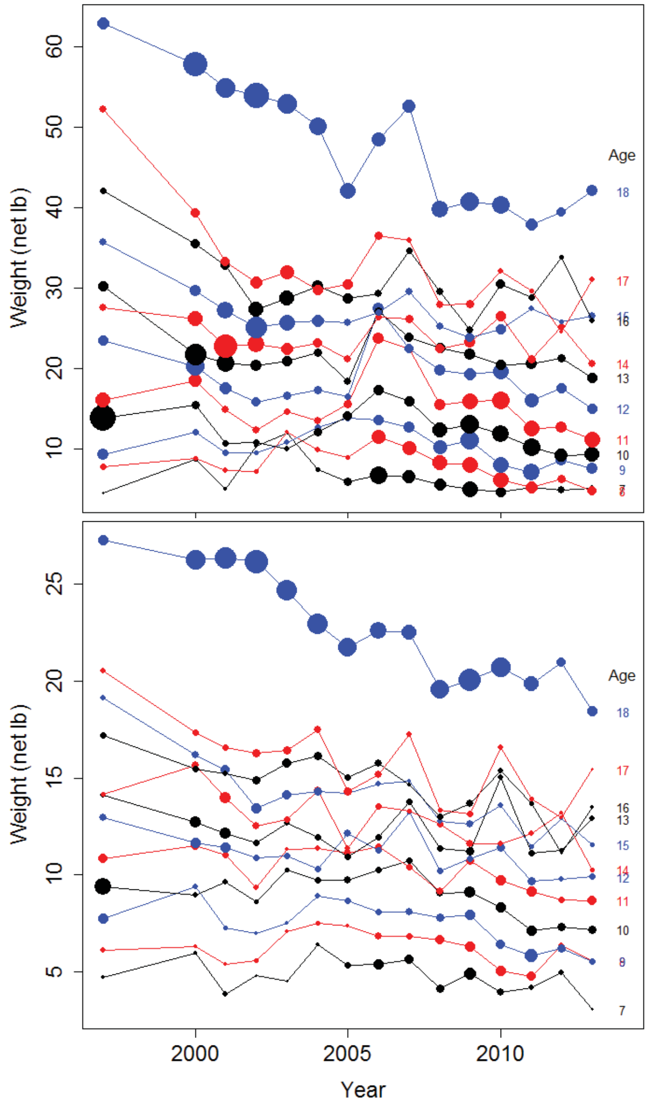

Figure 21. Trends in weight at age for female (upper panel), and male (lower panel) halibut from regulatory Areas 4C, 4D and 4E captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

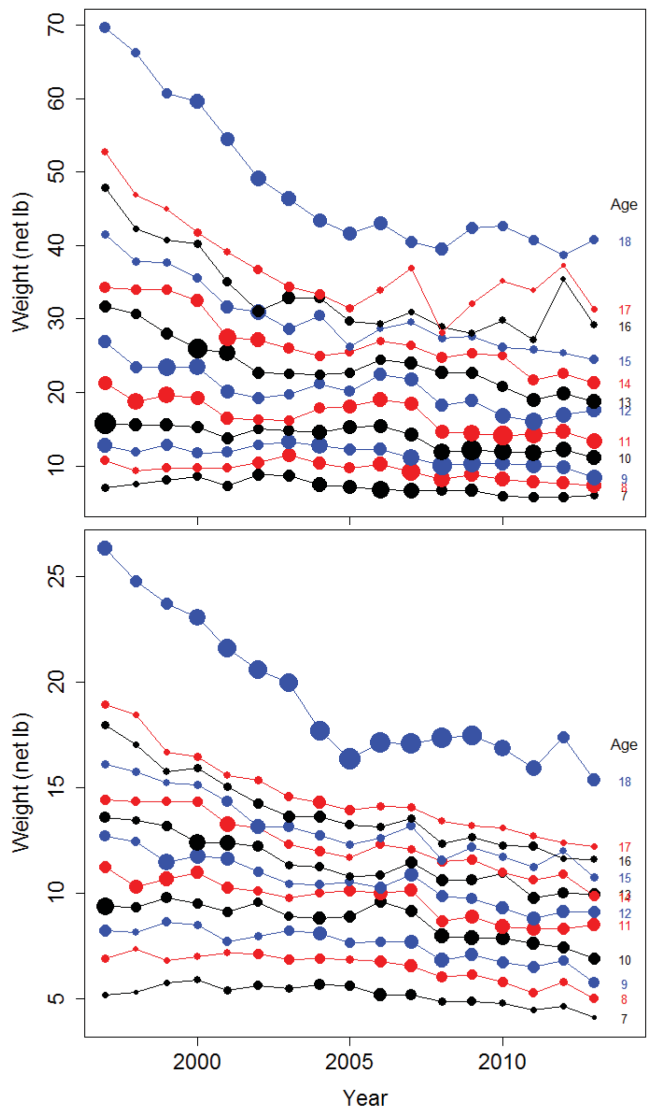

Figure 22. Weighted coastwide trends in weight at age for female (upper panel), and male (lower panel) halibut from all regulatory Areas captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 18 and greater have been aggregated for clarity.

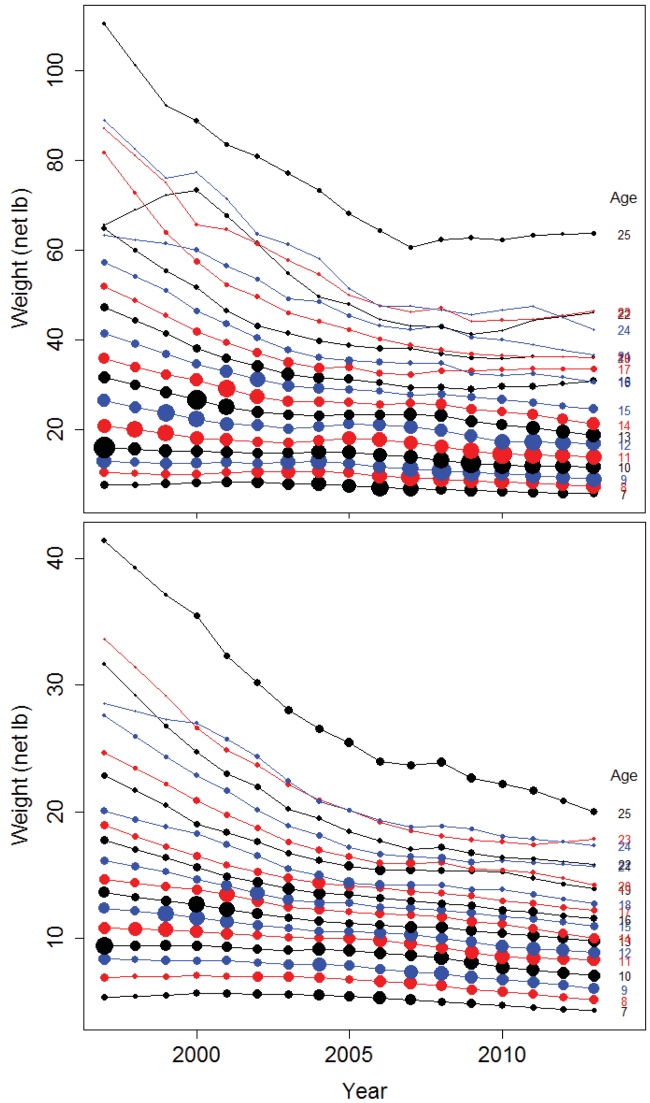

Figure 23. Weighted and smoothed coastwide trends in weight-at-age for female (upper panel), and male (lower panel) halibut from all regulatory Areas captured by the setline survey. The size (area) of the points is proportional to the number of fish contributing to each observation; ages 25 and greater have been aggregated.

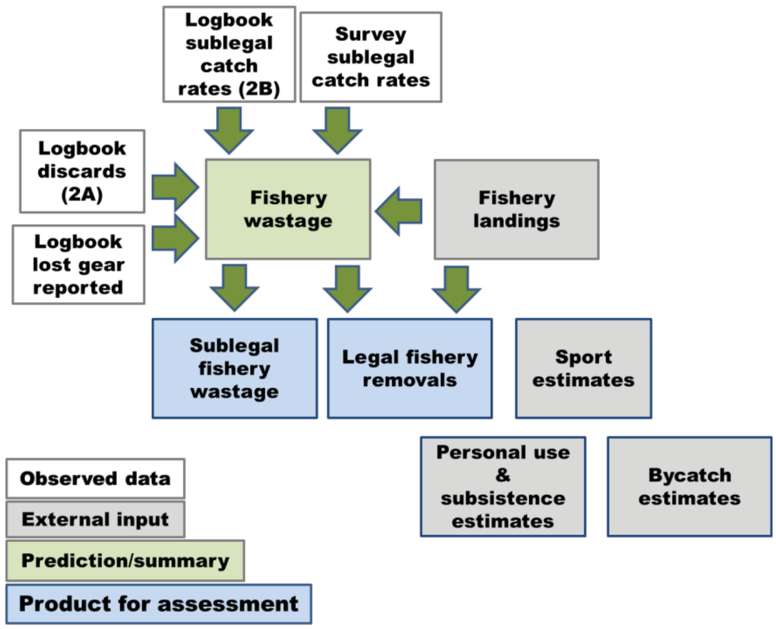

Figure 24. Relationships among estimates halibut mortality by source.

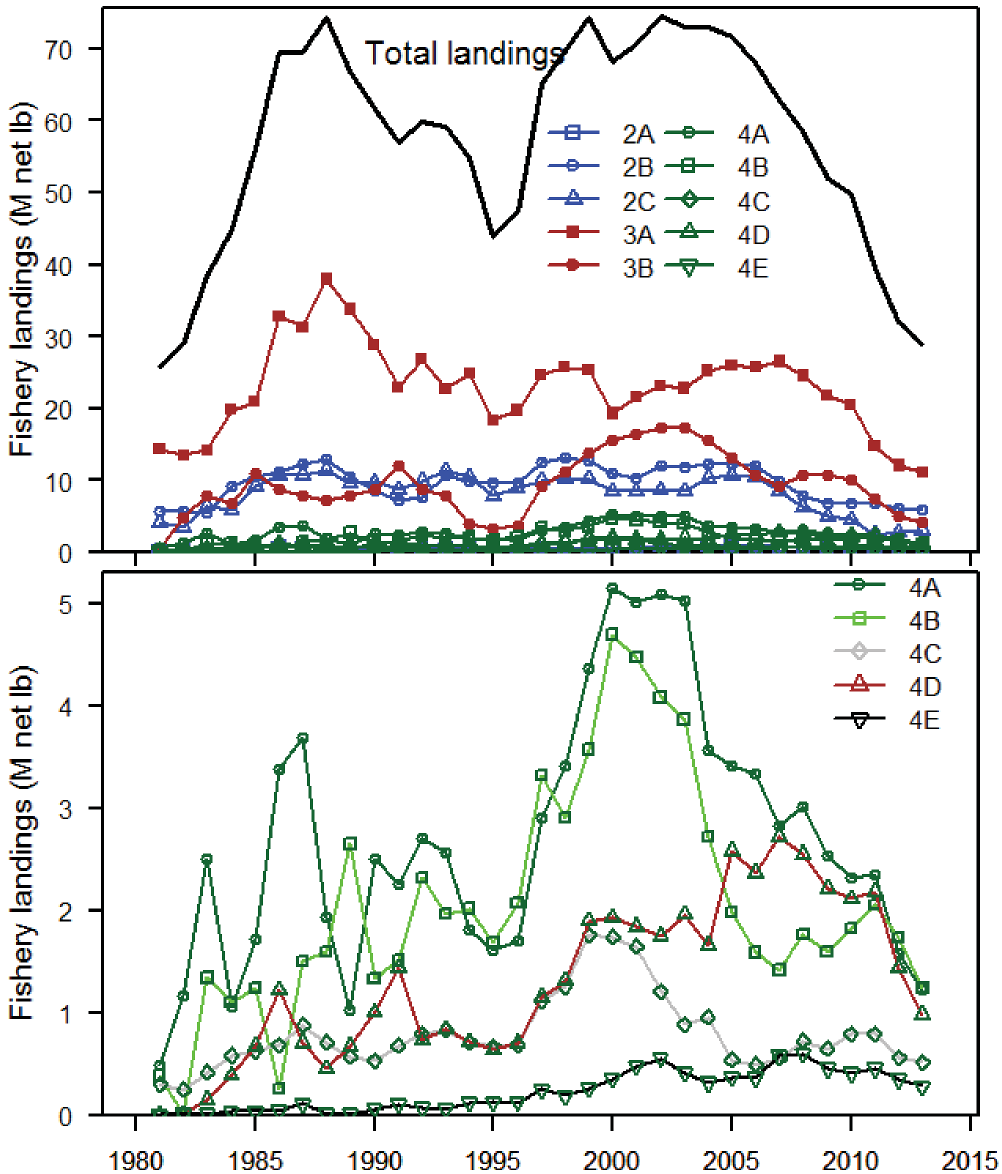

Figure 25. Recent landings of halibut by the directed commercial fishery by regulatory area (upper panel), and within regulatory Areas 4A to 4E for better resolution of the trends (lower panel).

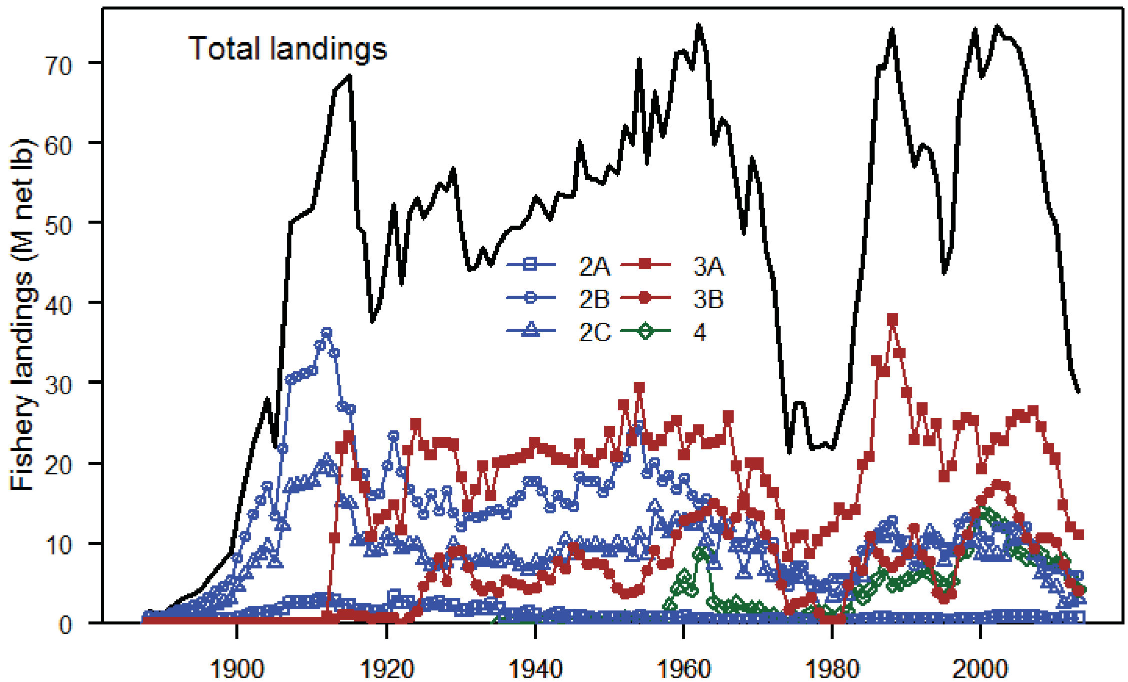

Figure 26. Landings of halibut by the directed commercial fishery by regulatory Area.

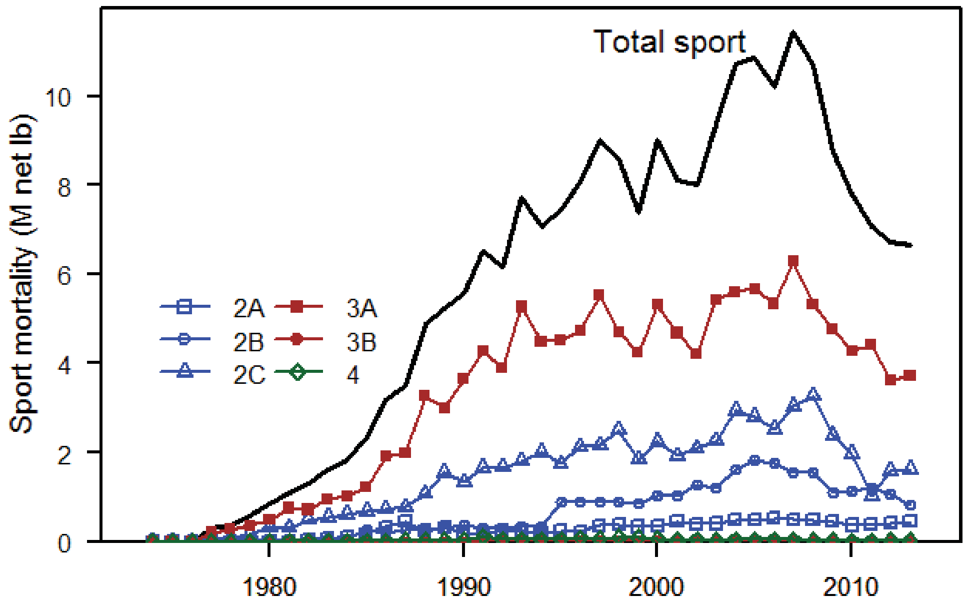

Figure 27. Sport (recreational) removals of halibut by regulatory Area.

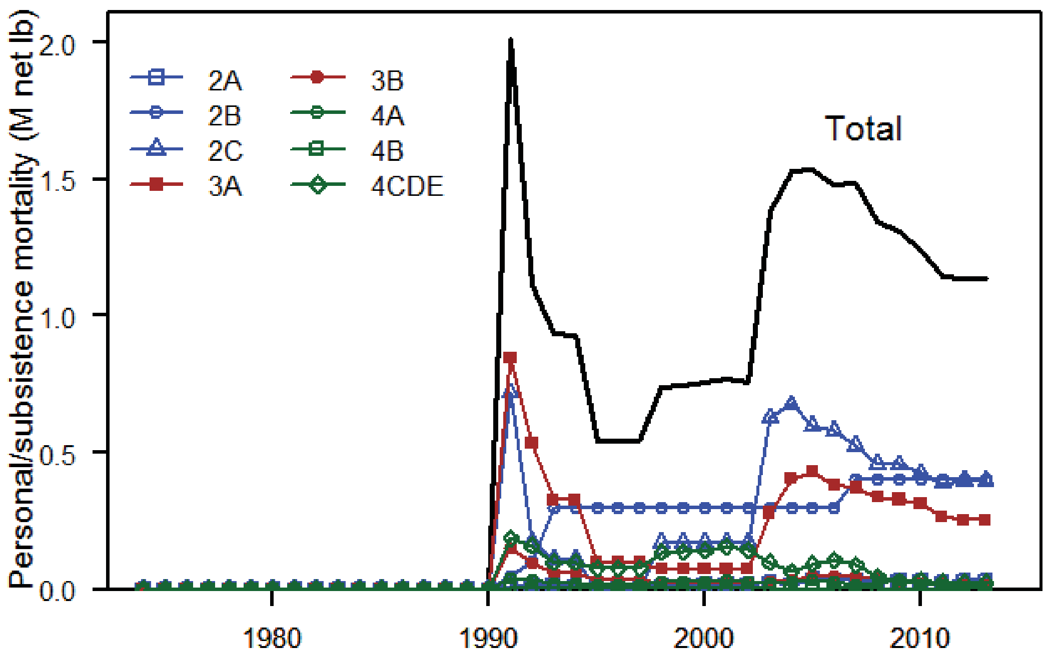

Figure 28. Estimated personal use or subsistence removals by regulatory Area.

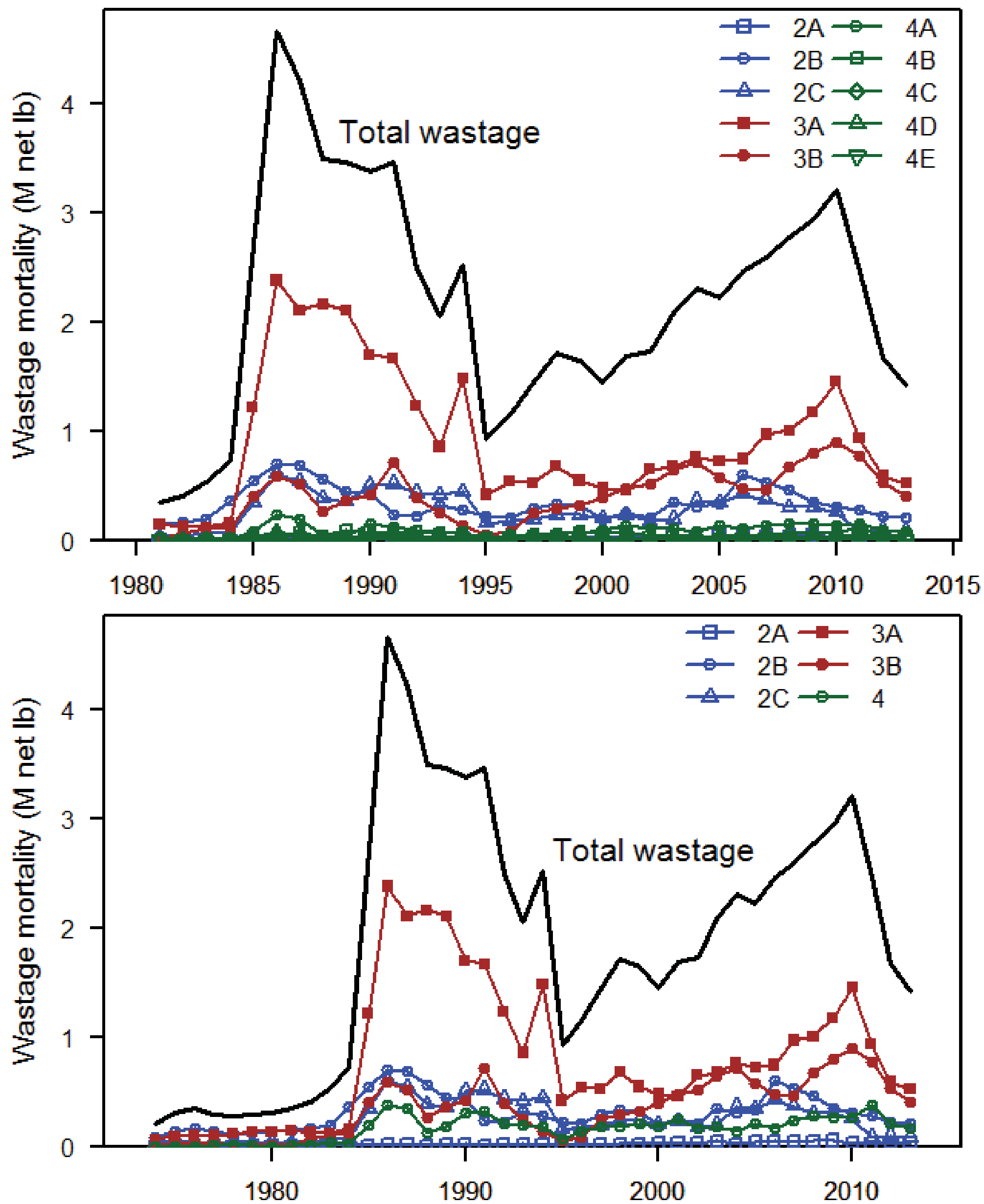

Figure 29. Wastage in the commercial fishery by regulatory Area, 1981-2013 (upper panel), and 1974-2013, with all of Area 4 combined (lower panel).

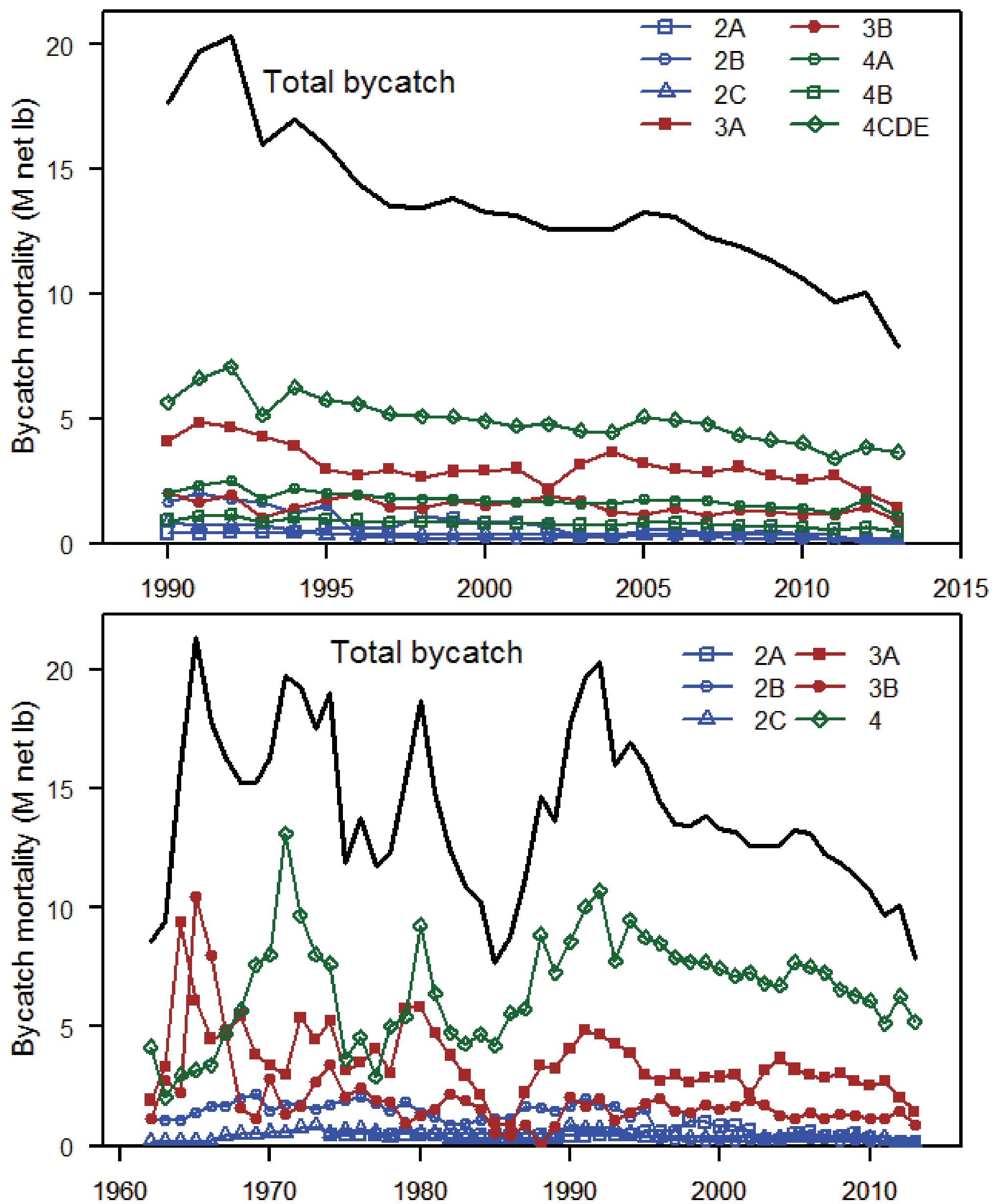

Figure 30. Halibut bycatch estimates by regulatory Area, 1990-2013 (upper panel), and 1962-2012, with all of Area 4 combined (lower panel).

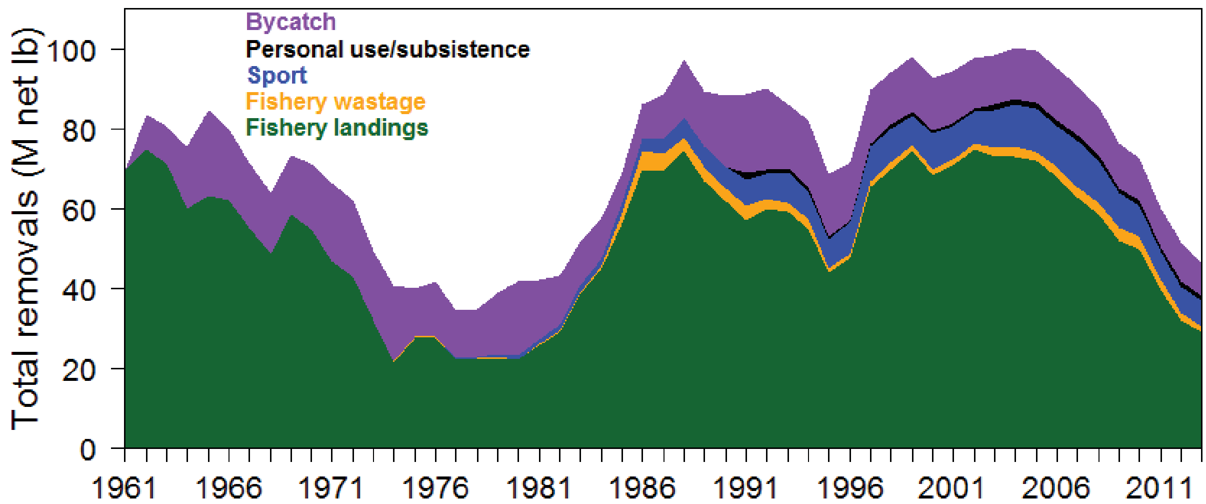

Figure 31. Total removals by source since 1961.

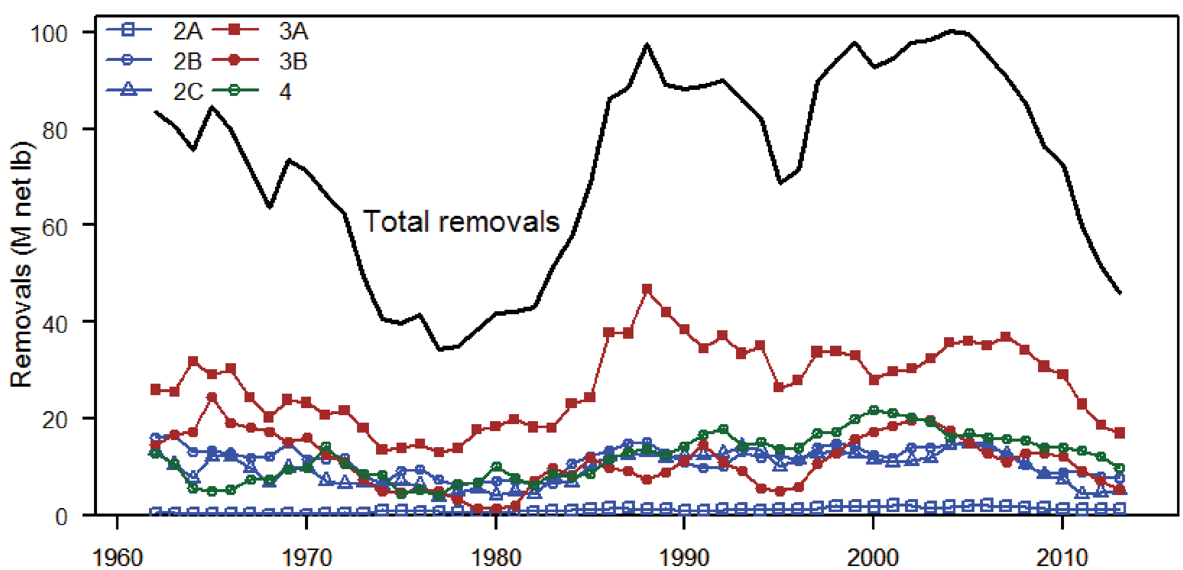

Figure 32. Total removals by regulatory Area since 1962.

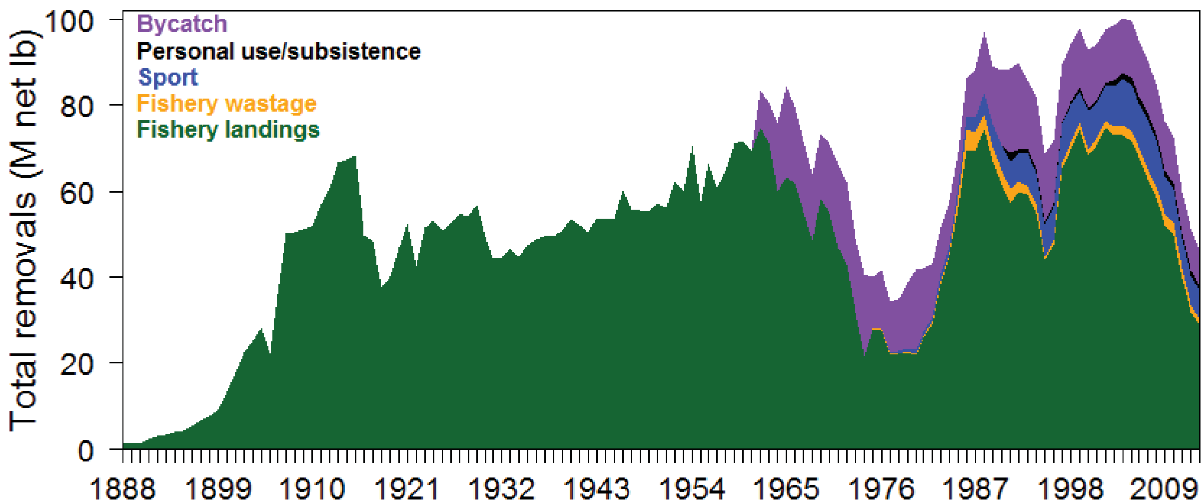

Figure 33. Total estimated removals by source since 1888.

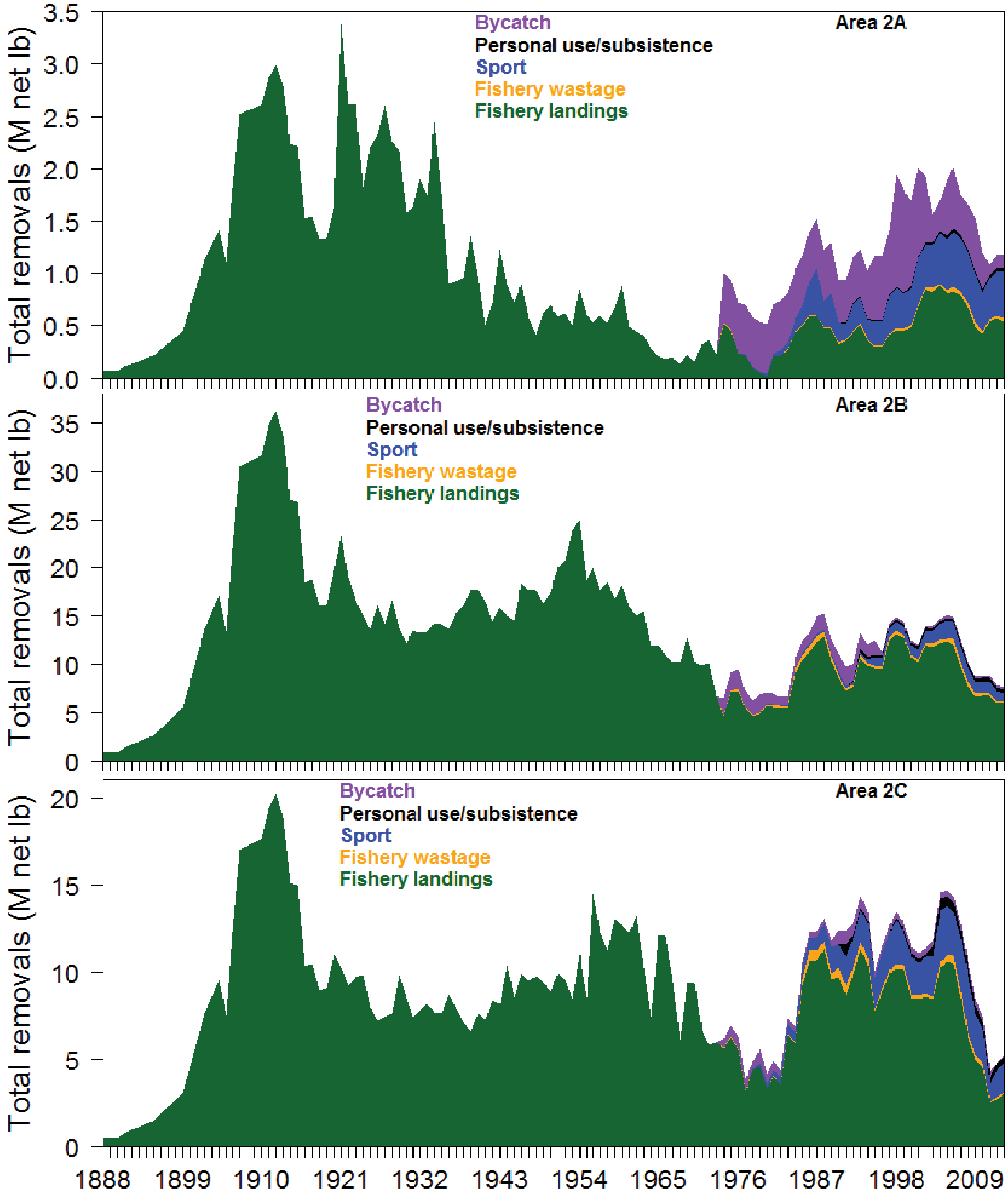

Figure 34. Total estimated removals by source in Areas 2A, 2B, and 2C since 1888. Note that the y axes differ in scale.

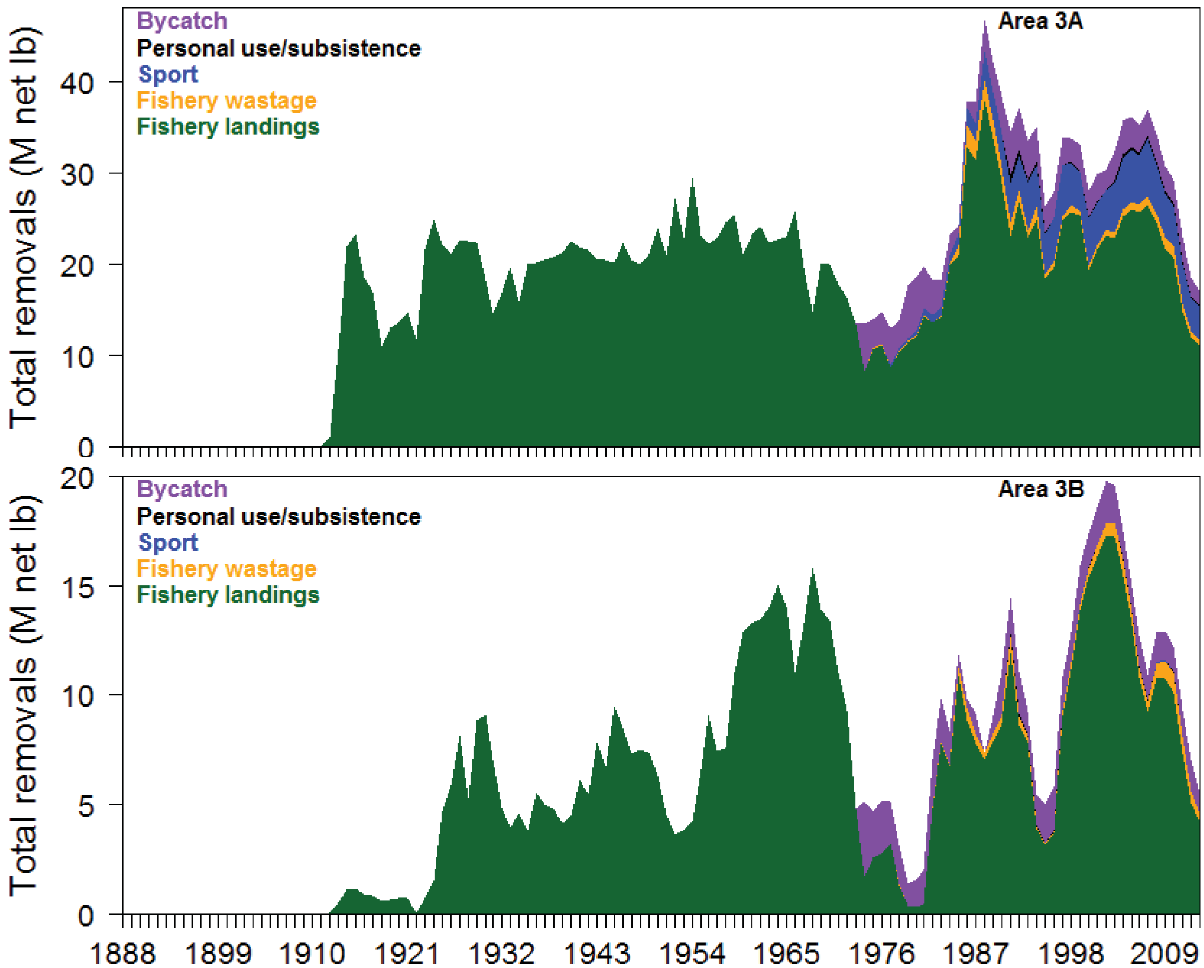

Figure 35. Total estimated removals by source in Areas 3A, and 3B since 1888. Note that the y-axes differ in scale.

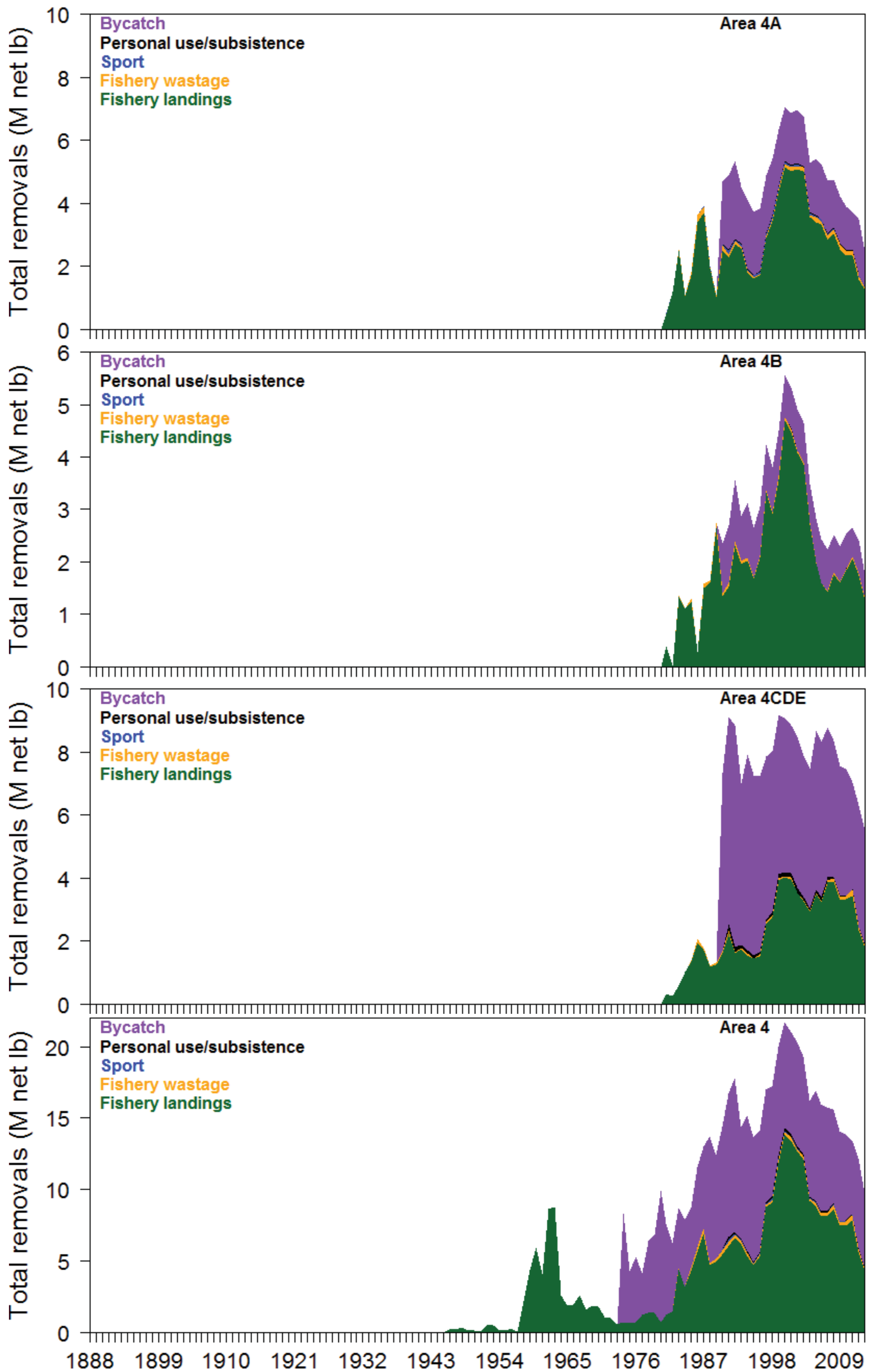

Figure 36. Total estimated removals by source in Areas 4A, 4B, 4CDE, and all of Area 4 combined since 1888. Note that the y-axes differ in scale.

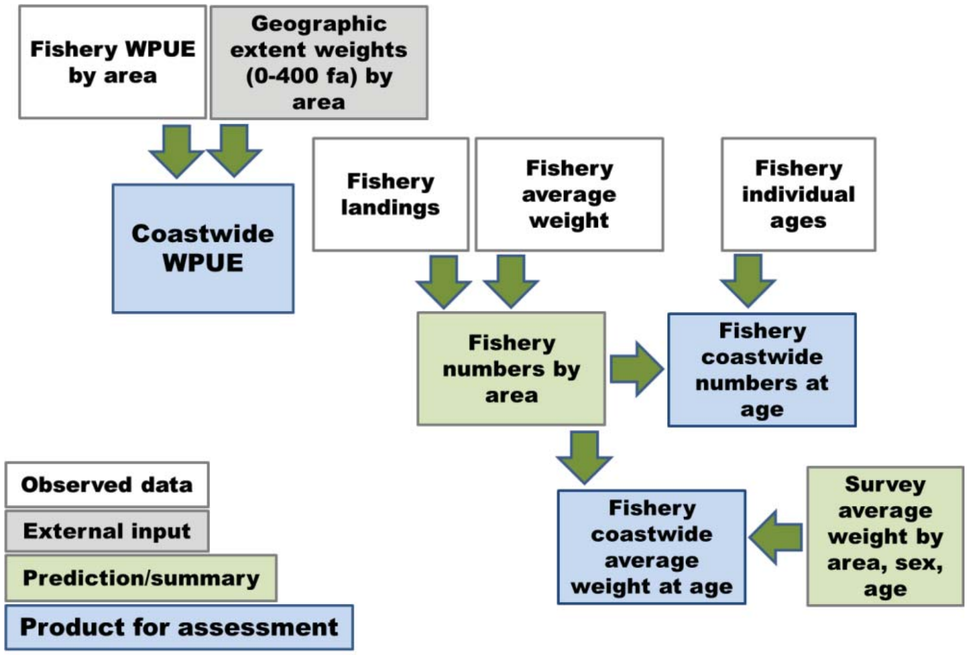

Figure 37. Relationships among fishery-dependent catch-rate and biological data sources.

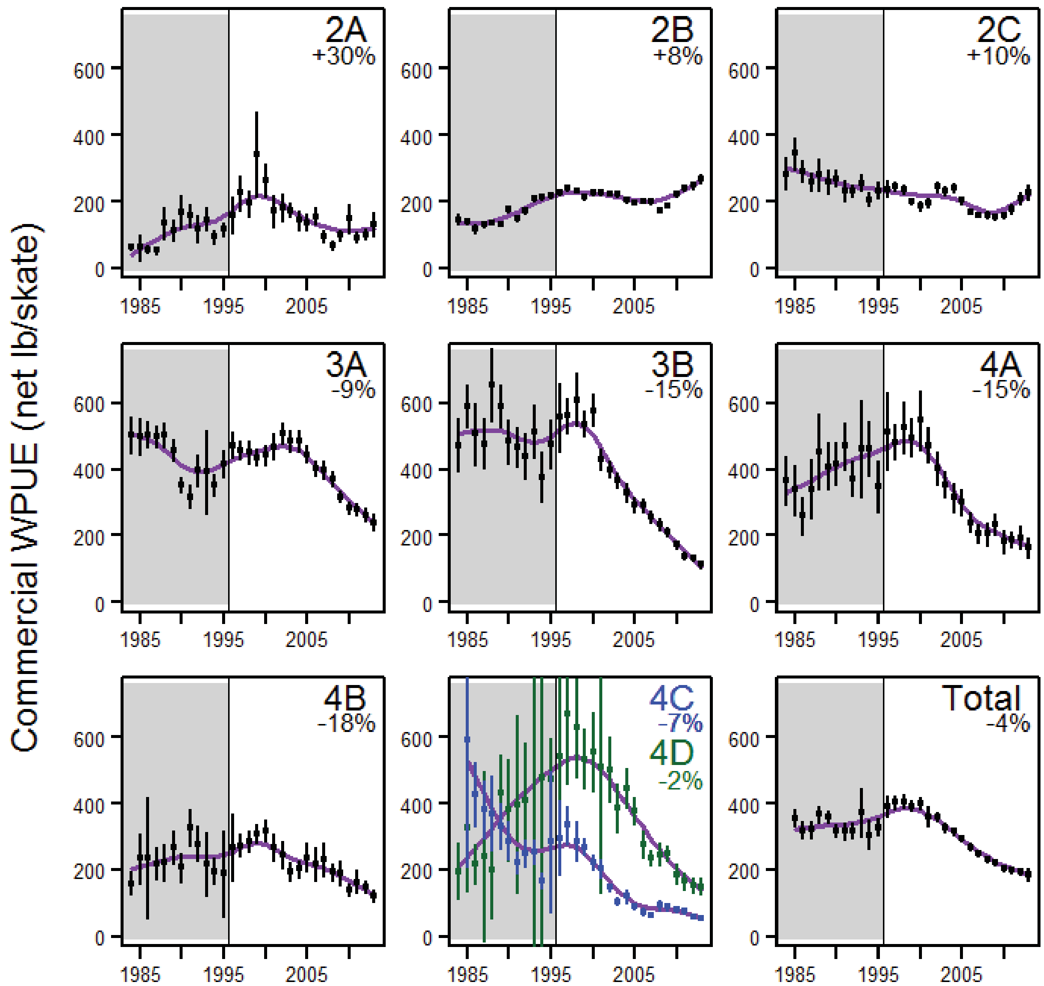

Figure 38. Commercial WPUE summarized by regulatory area and year. Percentages for each Area indicate the change from 2012 to 2013; lines represent a smoother for visualization purposes only.

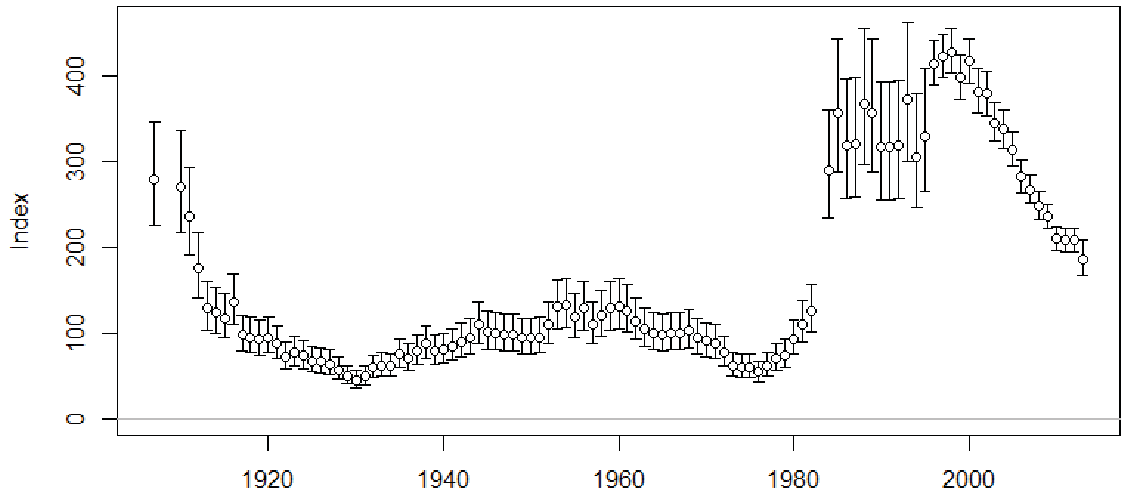

Figure 39. Coastwide commercial WPUE from historical records of effort and catch, as well as more recent direct logbook processing. The large change between 1982 and 1984 coincides with the adoption of circle hooks.

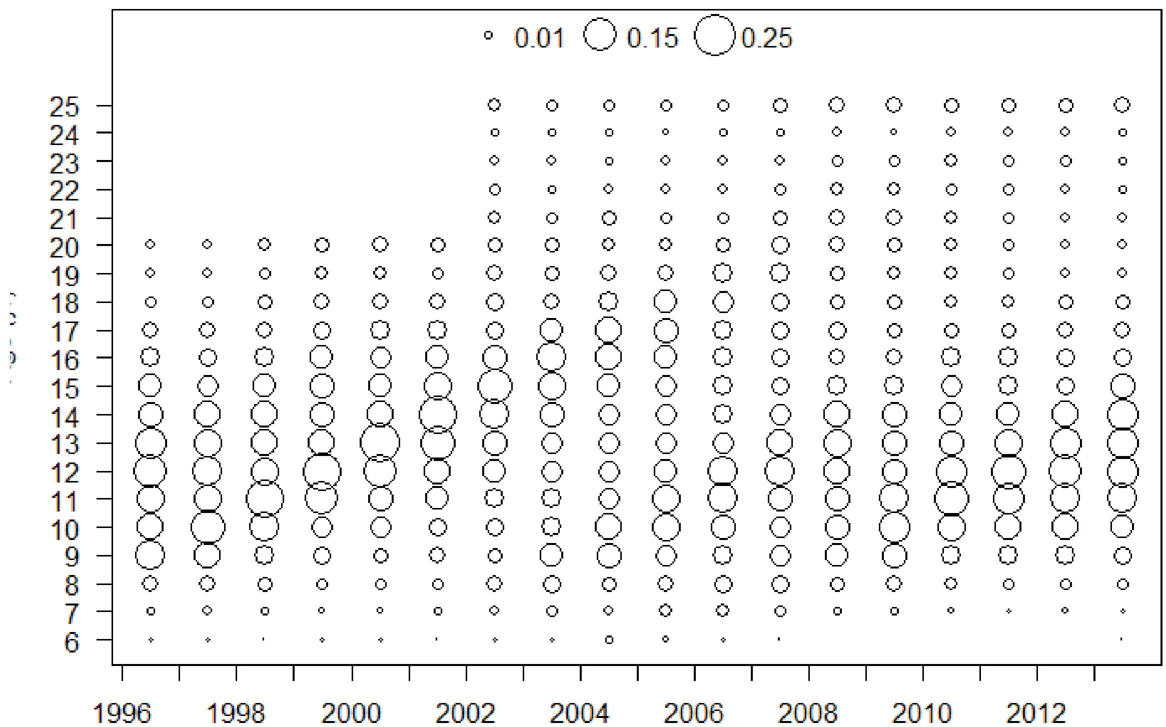

Figure 40. Estimates of recent commercial fishery numbers-at-age.

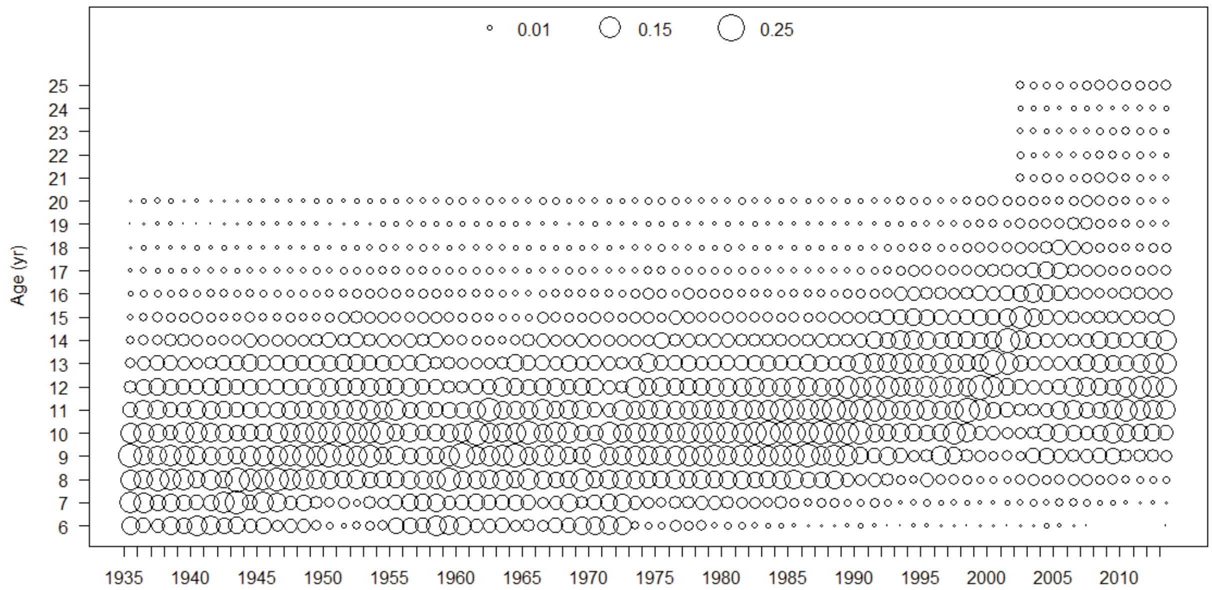

Figure 41. Commercial fishery proportions-at-age from the retained catch (male and female halibut combined). Note that the current 32 inch minimum size limit was implemented in 1973.

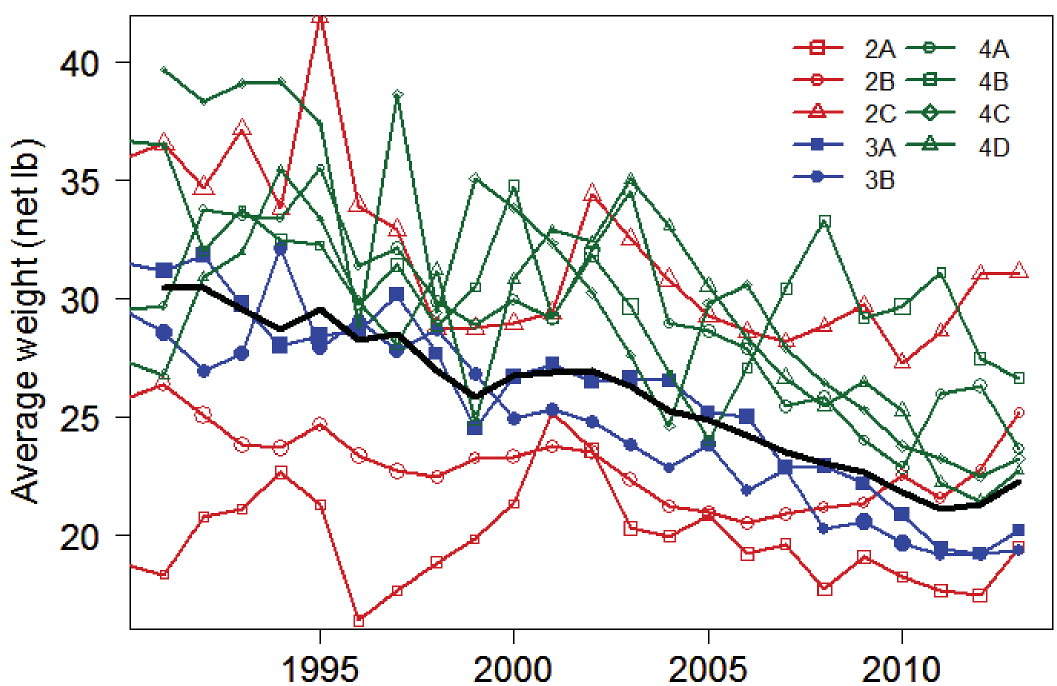

Figure 42. Recent average halibut weight in the directed fishery landings.

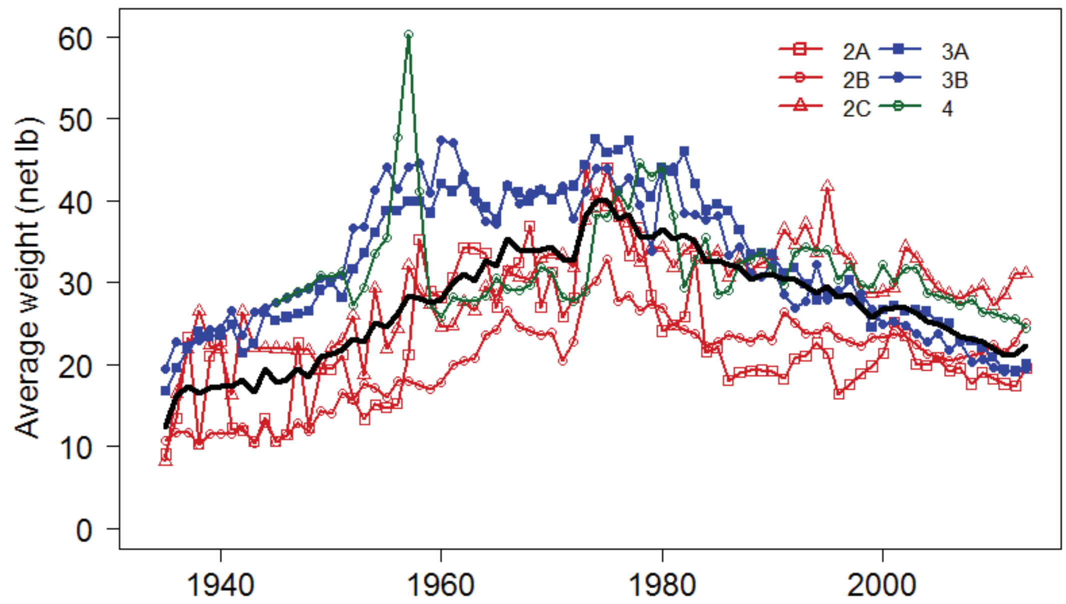

Figure 43. Trends in average individual halibut weight in the commercial fishery landings. The current 32-inch minimum size limit went into effect in 1974.

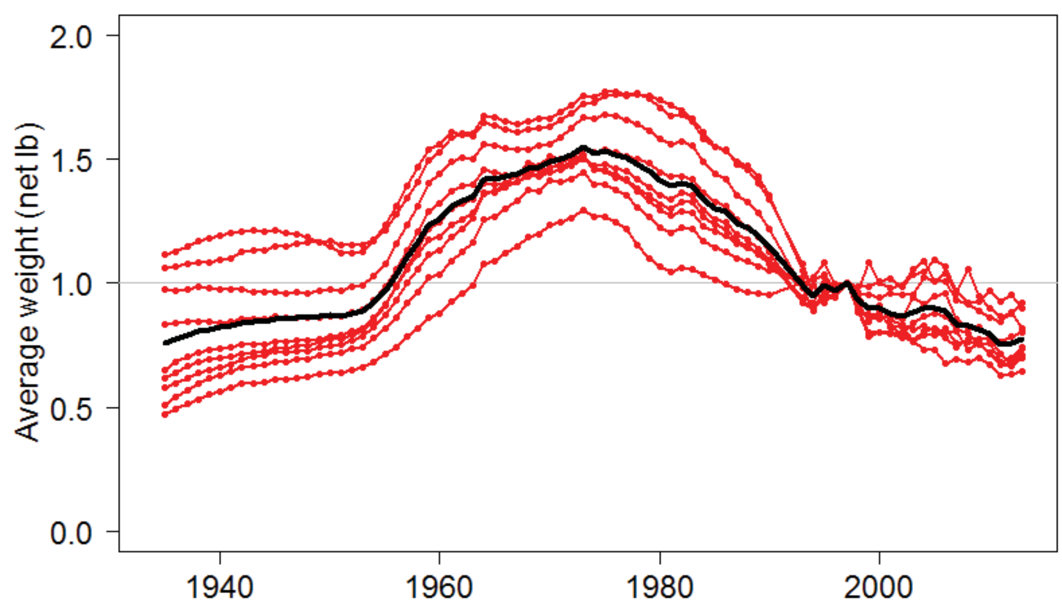

Figure 44. Trends in average individual halibut weight as deviations from 1997 in the commercial fishery landings for halibut aged 8-16 years old (red lines). The black line represents the average trend among the nine ages included. The current 32-inch minimum size limit went into effect in 1974.

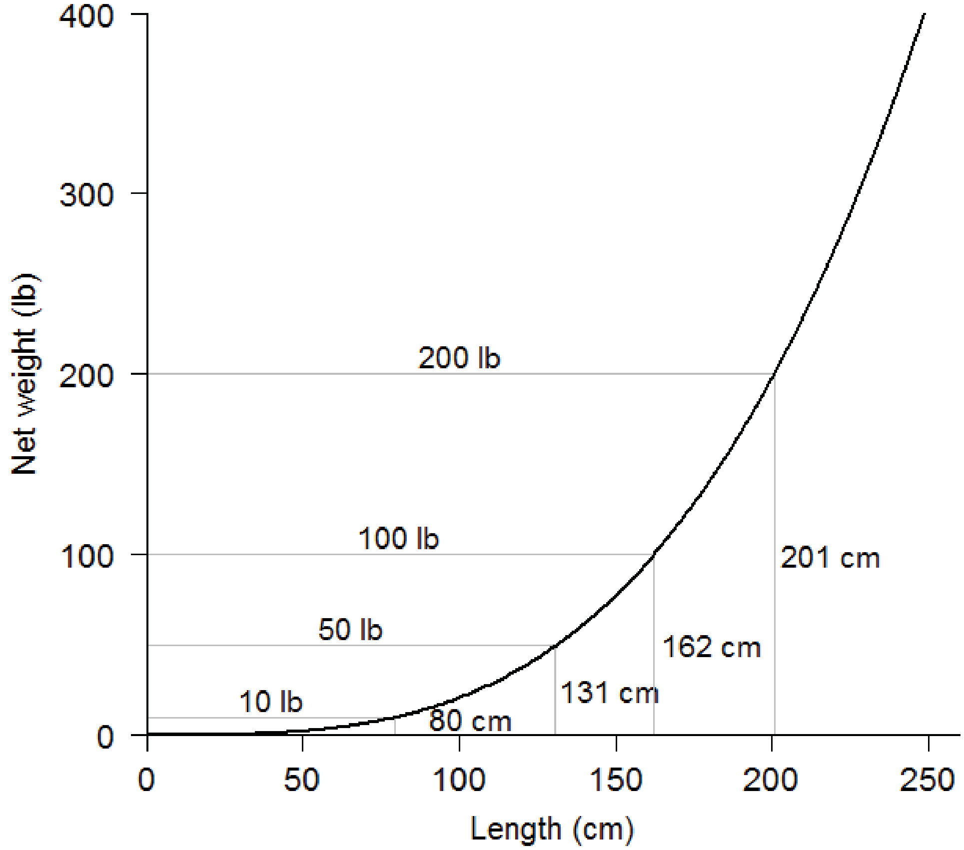

Figure 45. The conversion relationship for length in centimeters to net weight in pounds.

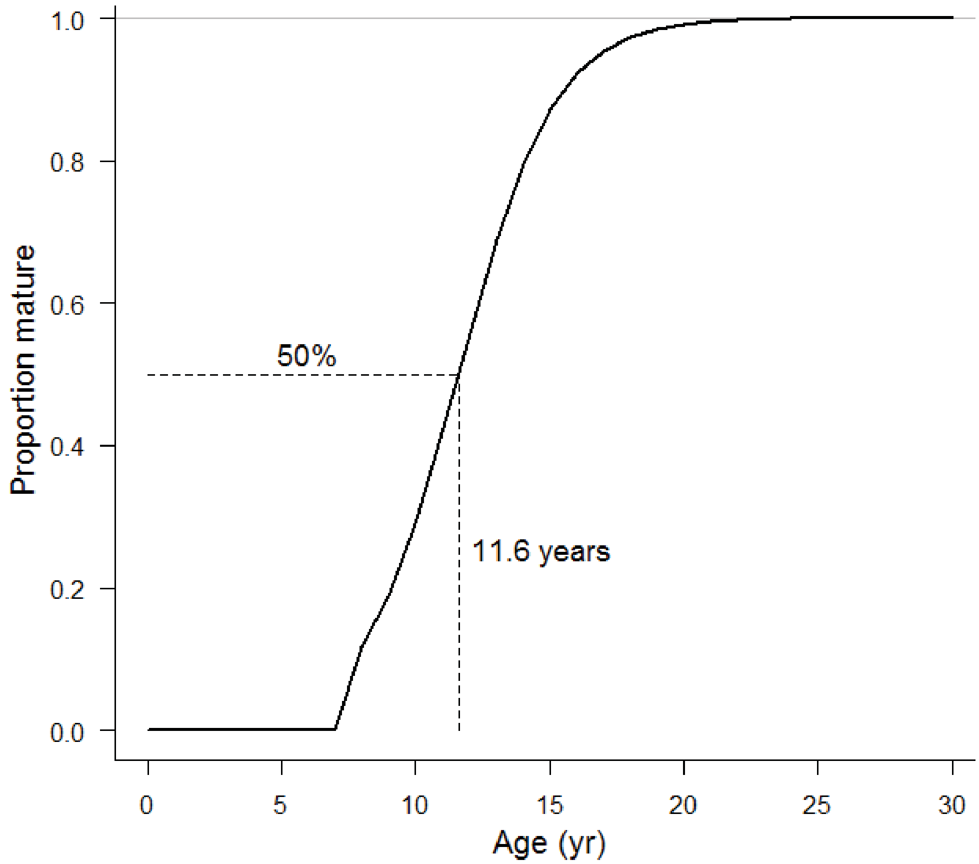

Figure 46. The maturity ogive used in recent halibut assessments. Note that this is a logistic curve, trimmed to be equal to zero below age-8.

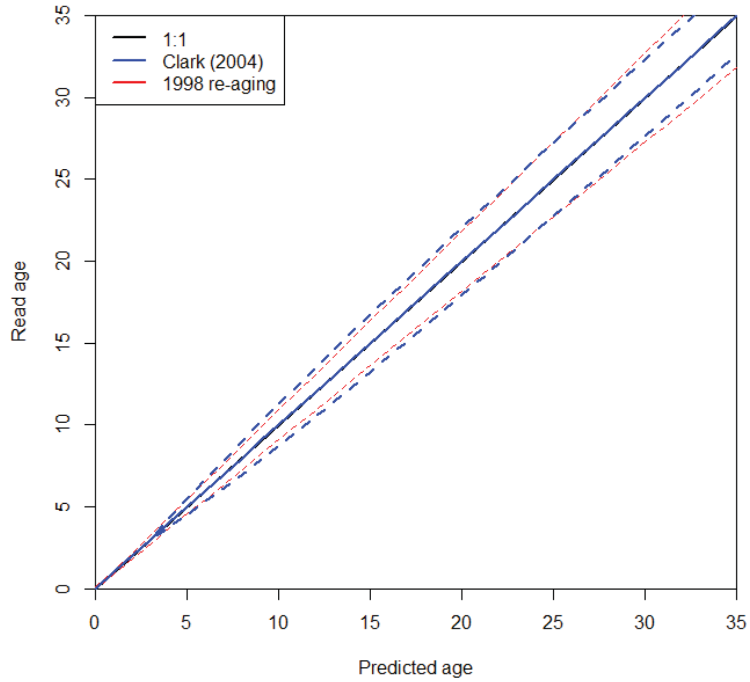

Figure 47. Re-estimated level of imprecision for break-and-bake ages based on the otoliths re-read in 2013, compared with the previously available estimate. Dashed lines indicate 95% prediction intervals for the distribution of individual ages.

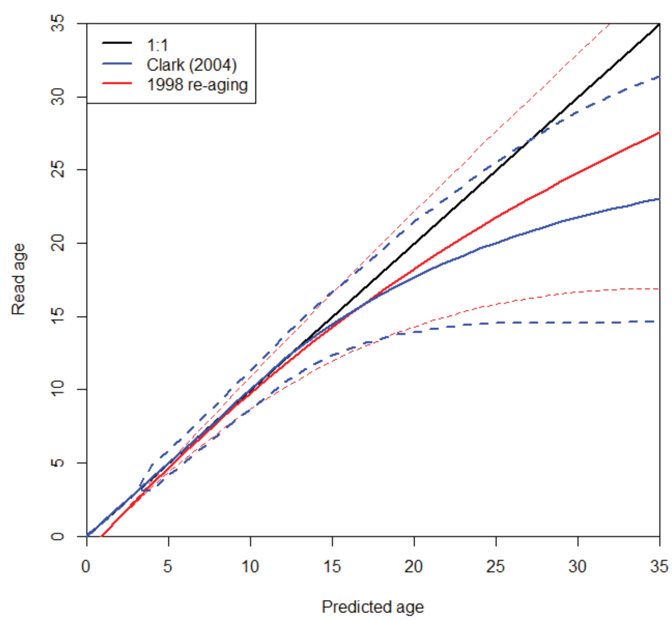

Figure 48. Re-estimated levels of imprecision and bias for surface ages based on the otoliths re-read in 2013, compared with the previously available estimate. Dashed lines indicate 95% prediction intervals for the distribution of individual ages.

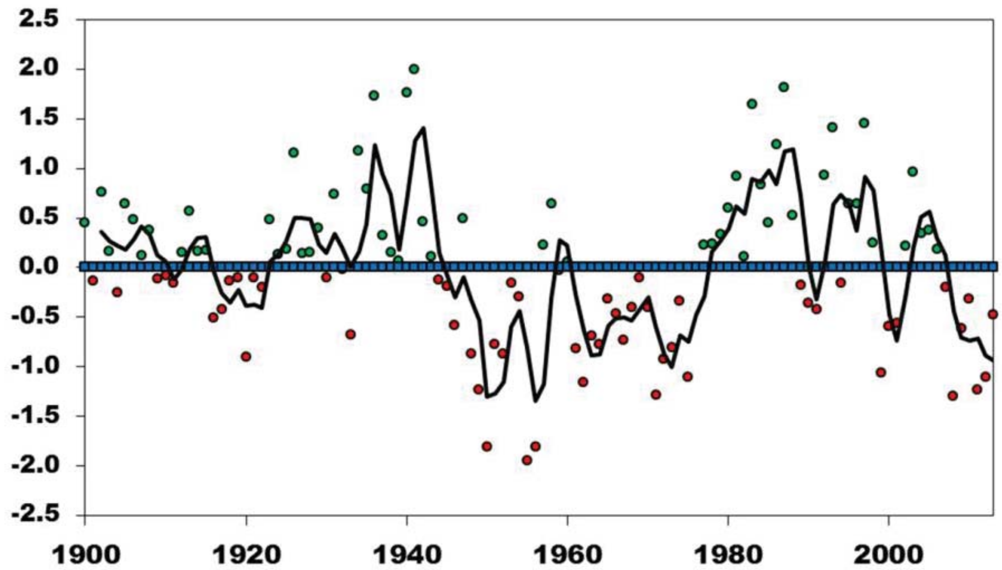

Figure 49. Time series of annual average PDO conditions (deviations from the long-term mean). Monthly means were obtained from (http://jisao.washington.edu/pdo/**).**

Table 1. Time-series of expanded setline survey WPUE by regulatory Area (O32; net lb/skate). Years prior to 1984 are based on surveys conducted with "J" hooks.

Year	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
1977	NA	13.7	NA	58.4	NA	NA	NA	NA	NA
1978	NA	19.1	NA	26.9	NA	NA	NA	NA	NA
1979	NA	NA	NA	41.0	NA	NA	NA	NA	NA
1980	NA	25.5	NA	76.2	NA	NA	NA	NA	NA
1981	NA	16.5	NA	131.4	NA	NA	NA	NA	NA
1982	NA	20.6	113.7	130.3	NA	NA	NA	NA	NA
1983	NA	18.0	142.2	119.0	NA	NA	NA	NA	NA
1984	NA	57.4	259.6	361.2	NA	NA	NA	NA	NA
1985	NA	41.7	260.5	377.5	NA	NA	NA	NA	NA
1986	NA	37.8	282.6	305.1	NA	NA	NA	NA	NA
1987	NA	NA	NA	NA	NA	NA	NA	NA	NA
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	NA	NA	NA	NA	NA	NA	NA	NA	NA
1992	NA	NA	NA	NA	NA	NA	NA	NA	NA
1993	NA	95.7	NA	261.1	NA	NA	NA	NA	NA
1994	NA	NA	NA	255.1	NA	NA	NA	NA	NA
1995	30.0	159.4	NA	300.9	NA	NA	NA	NA	NA
1996	32.6	166.0	307.1	318.1	353.0	NA	NA	NA	NA
1997	35.2	144.3	411.1	331.4	415.4	246.2	281.9	21.9	137.5
1998	36.1	83.4	235.7	281.9	436.1	307.3	216.6	40.7	132.4
1999	37.0	88.2	210.1	243.4	440.6	291.1	203.3	36.3	123.6
2000	39.3	91.9	240.5	274.3	375.2	281.4	216.5	26.4	118.6
2001	41.5	101.8	245.4	257.5	358.9	203.9	171.4	26.5	110.3
2002	33.3	92.6	268.7	299.8	297.8	172.7	119.3	26.6	106.6
2003	22.1	73.1	228.8	229.9	261.8	157.8	104.1	24.7	89.3
2004	27.0	86.3	176.1	270.1	237.0	141.1	73.4	21.1	87.4
2005	28.1	72.2	175.7	276.7	211.3	109.7	86.3	13.2	79.9
2006	16.3	58.9	146.9	232.8	181.6	87.3	95.5	14.2	69.6
2007	18.8	57.6	143.2	212.3	191.8	68.4	87.4	12.9	65.7
2008	18.5	90.2	107.3	189.5	126.3	85.4	103.5	11.1	59.7
2009	8.1	86.6	116.6	149.1	113.6	86.1	106.8	13.0	54.7
2010	16.8	89.2	111.3	117.2	91.5	74.7	68.4	11.1	45.9
2011	26.8	80.2	137.5	120.7	79.9	59.3	68.1	9.3	44.4
2012	28.5	103.9	161.7	137.7	87.2	65.5	48.5	10.8	49.9
2013	23.0	93.6	188.3	116.9	64.0	43.0	57.3	9.1	44.0

Table 2. Time-series of fishery landings by regulatory Area (million lb, net wt.).

Year	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1888	0.07	0.89	0.50	0.00	0.00	NA	NA	NA	NA	1.47
1889	0.07	0.79	0.44	0.00	0.00	NA	NA	NA	NA	1.29
1890	0.07	0.84	0.47	0.00	0.00	NA	NA	NA	NA	1.37
1891	0.11	1.30	0.73	0.00	0.00	NA	NA	NA	NA	2.13
1892	0.14	1.69	0.94	0.00	0.00	NA	NA	NA	NA	2.77
1893	0.16	1.96	1.09	0.00	0.00	NA	NA	NA	NA	3.22
1894	0.19	2.29	1.28	0.00	0.00	NA	NA	NA	NA	3.76
1895	0.21	2.59	1.45	0.00	0.00	NA	NA	NA	NA	4.25
1896	0.27	3.31	1.84	0.00	0.00	NA	NA	NA	NA	5.42
1897	0.33	4.02	2.24	0.00	0.00	NA	NA	NA	NA	6.59
1898	0.39	4.73	2.64	0.00	0.00	NA	NA	NA	NA	7.77
1899	0.45	5.45	3.04	0.00	0.00	NA	NA	NA	NA	8.94
1900	0.68	8.17	4.56	0.00	0.00	NA	NA	NA	NA	13.41
1901	0.90	10.90	6.08	0.00	0.00	NA	NA	NA	NA	17.87
1902	1.13	13.62	7.60	0.00	0.00	NA	NA	NA	NA	22.34
1903	1.27	15.37	8.57	0.00	0.00	NA	NA	NA	NA	25.21
1904	1.41	17.12	9.55	0.00	0.00	NA	NA	NA	NA	28.08
1905	1.11	13.41	7.48	0.00	0.00	NA	NA	NA	NA	22.00
1906	1.81	21.95	12.24	0.00	0.00	NA	NA	NA	NA	36.00
1907	2.52	30.48	17.00	0.00	0.00	NA	NA	NA	NA	50.00
1908	2.55	30.86	17.21	0.00	0.00	NA	NA	NA	NA	50.62
1909	2.58	31.23	17.42	0.00	0.00	NA	NA	NA	NA	51.23
1910	2.61	31.61	17.63	0.00	0.00	NA	NA	NA	NA	51.85
1911	2.87	34.71	19.36	0.00	0.00	NA	NA	NA	NA	56.93
1912	3.00	36.29	20.24	0.86	0.04	NA	NA	NA	NA	60.43
1913	2.79	33.80	18.85	10.58	0.52	NA	NA	NA	NA	66.54
1914	2.24	27.11	15.12	21.87	1.08	NA	NA	NA	NA	67.43
1915	2.22	26.84	14.97	23.31	1.15	NA	NA	NA	NA	68.48
1916	1.53	18.46	10.30	18.56	0.92	NA	NA	NA	NA	49.76
1917	1.55	18.78	10.47	16.96	0.84	NA	NA	NA	NA	48.60
1918	1.32	16.02	8.93	10.88	0.54	NA	NA	NA	NA	37.69
1919	1.34	16.22	9.05	12.90	0.64	NA	NA	NA	NA	40.14
1920	1.62	19.73	11.01	13.59	0.67	NA	NA	NA	NA	46.62
1921	3.39	23.37	10.22	14.75	0.73	NA	NA	NA	NA	52.46
1922	2.61	19.02	9.22	11.63	0.02	NA	NA	NA	NA	42.49
1923	2.62	16.71	9.72	21.60	0.67	NA	NA	NA	NA	51.32
1924	1.82	15.14	9.86	24.82	1.50	NA	NA	NA	NA	53.14
1925	2.20	13.65	7.99	22.16	4.66	NA	NA	NA	NA	50.66
1926	2.32	16.12	7.17	21.01	5.85	NA	NA	NA	NA	52.47
1927	2.62	14.09	7.42	22.62	8.20	NA	NA	NA	NA	54.95
1928	2.27	16.63	7.58	22.54	5.25	NA	NA	NA	NA	54.26
1929	2.18	13.77	9.85	22.27	8.86	NA	NA	NA	NA	56.92
1930	1.58	12.12	8.53	18.19	9.09	NA	NA	NA	NA	49.51
1931	1.63	13.53	7.39	14.61	7.06	NA	NA	NA	NA	44.22
1932	1.90	13.25	7.74	16.71	4.89	NA	NA	NA	NA	44.49
1933	1.75	13.37	8.15	19.67	3.97	NA	NA	NA	NA	46.91
1934	2.45	14.12	7.68	15.88	4.58	NA	NA	NA	NA	44.72
1935	1.77	14.21	7.58	19.96	3.82	0.00	NA	NA	NA	47.34
1936	0.90	13.67	8.75	20.09	5.52	0.00	NA	NA	NA	48.92
1937	0.92	15.29	7.87	20.47	5.00	0.00	NA	NA	NA	49.54
1938	0.95	16.00	7.15	20.66	4.79	0.00	NA	NA	NA	49.55
1939	1.36	17.67	6.56	21.16	4.15	0.00	NA	NA	NA	50.90
1940	0.98	17.81	7.62	22.50	4.48	0.00	NA	NA	NA	53.38

Table 2. Continued.

Year	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1941	0.51	16.53	7.25	21.84	6.10	0.00	NA	NA	NA	52.23
1942	0.72	14.37	8.35	21.50	5.46	0.00	NA	NA	NA	50.39
1943	1.24	15.97	8.15	20.51	7.83	0.00	NA	NA	NA	53.70
1944	0.90	15.07	10.38	20.36	6.73	0.00	NA	NA	NA	53.44
1945	0.73	14.58	8.49	20.07	9.52	0.01	NA	NA	NA	53.40
1946	0.90	18.37	9.90	22.40	8.50	0.20	NA	NA	NA	60.27
1947	0.57	17.67	9.50	20.44	7.33	0.19	NA	NA	NA	55.70
1948	0.41	17.67	9.75	19.93	7.50	0.30	NA	NA	NA	55.56
1949	0.62	16.34	9.45	21.12	7.38	0.12	NA	NA	NA	55.03
1950	0.70	17.46	8.84	23.86	6.30	0.08	NA	NA	NA	57.23
1951	0.59	20.04	9.97	20.86	4.54	0.05	NA	NA	NA	56.05
1952	0.62	20.63	9.56	27.27	3.62	0.56	NA	NA	NA	62.26
1953	0.50	23.80	8.41	22.84	3.81	0.48	NA	NA	NA	59.84
1954	0.85	24.90	11.04	29.46	4.21	0.13	NA	NA	NA	70.58
1955	0.61	18.65	8.54	23.06	6.57	0.09	NA	NA	NA	57.52
1956	0.53	20.06	14.51	22.11	9.12	0.26	NA	NA	NA	66.59
1957	0.60	17.69	12.25	22.85	7.43	0.04	NA	NA	NA	60.85
1958	0.52	18.49	11.20	24.52	7.60	2.18	NA	NA	NA	64.51
1959	0.67	16.83	13.03	25.36	11.00	4.31	NA	NA	NA	71.20
1960	0.89	18.16	12.72	21.05	12.90	5.90	NA	NA	NA	71.61
1961	0.50	16.08	12.29	23.07	13.28	4.07	NA	NA	NA	69.27
1962	0.45	15.03	13.24	24.04	13.48	8.62	NA	NA	NA	74.86
1963	0.41	15.52	10.24	22.31	13.98	8.77	NA	NA	NA	71.24
1964	0.28	11.86	7.43	22.56	15.04	2.62	NA	NA	NA	59.78
1965	0.21	11.97	12.07	22.98	14.07	1.88	NA	NA	NA	63.18
1966	0.18	11.04	12.04	25.77	11.05	1.94	NA	NA	NA	62.02
1967	0.20	10.11	9.41	19.66	13.26	2.58	NA	NA	NA	55.22
1968	0.14	10.15	6.11	14.77	15.83	1.60	NA	NA	NA	48.59
1969	0.23	12.82	9.33	20.08	13.92	1.90	NA	NA	NA	58.27
1970	0.16	10.26	9.37	19.91	13.37	1.78	NA	NA	NA	54.84
1971	0.32	9.85	6.61	17.76	11.04	1.08	NA	NA	NA	46.65
1972	0.37	10.13	5.78	16.30	9.28	1.02	NA	NA	NA	42.88
1973	0.23	6.73	5.98	13.50	4.79	0.52	NA	NA	NA	31.74
1974	0.52	4.62	5.60	8.19	1.67	0.71	NA	NA	NA	21.31
1975	0.46	7.13	6.24	10.60	2.56	0.63	NA	NA	NA	27.62
1976	0.24	7.28	5.53	11.04	2.73	0.72	NA	NA	NA	27.54
1977	0.21	5.43	3.19	8.64	3.19	1.22	NA	NA	NA	21.88
1978	0.10	4.61	4.32	10.30	1.32	1.35	NA	NA	NA	22.00
1979	0.05	4.86	4.53	11.34	0.39	1.37	NA	NA	NA	22.54
1980	0.02	5.65	3.24	11.97	0.28	0.71	NA	NA	NA	21.87
1981	0.20	5.66	4.01	14.23	0.45	NA	0.49	0.39	0.31	25.74
1982	0.21	5.54	3.50	13.52	4.80	NA	1.17	0.01	0.25	29.01
1983	0.27	5.44	6.38	14.13	7.76	NA	2.50	1.34	0.58	38.39
1984	0.43	9.05	5.87	19.77	6.69	NA	1.05	1.10	1.01	44.97
1985	0.49	10.39	9.21	20.84	10.89	NA	1.72	1.24	1.33	56.10
1986	0.58	11.23	10.61	32.80	8.82	NA	3.38	0.26	1.95	69.63
1987	0.59	12.25	10.69	31.31	7.76	NA	3.69	1.50	1.69	69.47
1988	0.49	12.86	11.36	37.91	7.08	NA	1.93	1.59	1.17	74.39
1989	0.47	10.43	9.53	33.74	7.84	NA	1.03	2.65	1.26	66.95
1990	0.33	8.57	9.73	28.85	8.69	NA	2.50	1.33	1.59	61.60
1991	0.36	7.19	8.69	22.93	11.93	NA	2.26	1.51	2.22	57.08
1992	0.44	7.63	9.82	26.78	8.62	NA	2.70	2.32	1.59	59.89
1993	0.50	10.63	11.29	22.74	7.86	NA	2.56	1.96	1.73	59.27

Table 2. Continued.

Year	2A	2B	2C	3A	3B	4	4A	4B	4CDE	Total
1994	0.37	9.91	10.38	24.84	3.86	NA	1.80	2.02	1.55	54.73
1995	0.30	9.62	7.77	18.34	3.13	NA	1.62	1.68	1.44	43.88
1996	0.30	9.55	8.87	19.69	3.66	NA	1.70	2.07	1.51	47.34
1997	0.41	12.42	9.92	24.64	9.06	NA	2.91	3.32	2.52	65.20
1998	0.46	13.17	10.20	25.70	11.16	NA	3.42	2.90	2.75	69.76
1999	0.45	12.71	10.14	25.32	13.84	NA	4.37	3.57	3.92	74.31
2000	0.48	10.81	8.45	19.27	15.41	NA	5.16	4.69	4.02	68.29
2001	0.68	10.29	8.40	21.54	16.34	NA	5.02	4.47	3.97	70.70
2002	0.85	12.07	8.60	23.13	17.31	NA	5.09	4.08	3.52	74.66
2003	0.82	11.79	8.41	22.75	17.22	NA	5.02	3.86	3.26	73.14
2004	0.88	12.16	10.23	25.17	15.46	NA	3.56	2.72	2.92	73.11
2005	0.80	12.33	10.63	26.03	13.17	NA	3.40	1.98	3.48	71.82
2006	0.83	12.01	10.49	25.71	10.79	NA	3.33	1.59	3.23	67.98
2007	0.79	9.77	8.47	26.49	9.25	NA	2.83	1.42	3.85	62.87
2008	0.68	7.76	6.21	24.52	10.75	NA	3.02	1.76	3.88	58.57
2009	0.49	6.64	4.96	21.76	10.78	NA	2.53	1.59	3.31	52.05
2010	0.42	6.73	4.49	20.50	10.11	NA	2.33	1.83	3.32	49.72
2011	0.54	6.69	2.45	14.67	7.32	NA	2.35	2.05	3.43	39.51
2012	0.57	5.98	2.69	12.03	5.05	NA	1.58	1.74	2.34	31.99
2013	0.54	5.92	3.04	11.05	4.12	NA	1.23	1.24	1.78	28.91

Table 3. Time-series of total removals by regulatory Area (million lb, net wt.).

Year	2A	2B	2C	3A	3B	4	Total
1888	0.07	0.89	0.50	0.00	0.00	0.00	1.47
1889	0.07	0.79	0.44	0.00	0.00	0.00	1.29
1890	0.07	0.84	0.47	0.00	0.00	0.00	1.37
1891	0.11	1.30	0.73	0.00	0.00	0.00	2.13
1892	0.14	1.69	0.94	0.00	0.00	0.00	2.77
1893	0.16	1.96	1.09	0.00	0.00	0.00	3.22
1894	0.19	2.29	1.28	0.00	0.00	0.00	3.76
1895	0.21	2.59	1.45	0.00	0.00	0.00	4.25
1896	0.27	3.31	1.84	0.00	0.00	0.00	5.42
1897	0.33	4.02	2.24	0.00	0.00	0.00	6.59
1898	0.39	4.73	2.64	0.00	0.00	0.00	7.77
1899	0.45	5.45	3.04	0.00	0.00	0.00	8.94
1900	0.68	8.17	4.56	0.00	0.00	0.00	13.41
1901	0.90	10.90	6.08	0.00	0.00	0.00	17.87
1902	1.13	13.62	7.60	0.00	0.00	0.00	22.34
1903	1.27	15.37	8.57	0.00	0.00	0.00	25.21
1904	1.41	17.12	9.55	0.00	0.00	0.00	28.08
1905	1.11	13.41	7.48	0.00	0.00	0.00	22.00
1906	1.81	21.95	12.24	0.00	0.00	0.00	36.00
1907	2.52	30.48	17.00	0.00	0.00	0.00	50.00
1908	2.55	30.86	17.21	0.00	0.00	0.00	50.62
1909	2.58	31.23	17.42	0.00	0.00	0.00	51.23
1910	2.61	31.61	17.63	0.00	0.00	0.00	51.85
1911	2.87	34.71	19.36	0.00	0.00	0.00	56.93
1912	3.00	36.29	20.24	0.86	0.04	0.00	60.43
1913	2.79	33.80	18.85	10.58	0.52	0.00	66.54
1914	2.24	27.11	15.12	21.87	1.08	0.00	67.43
1915	2.22	26.84	14.97	23.31	1.15	0.00	68.48
1916	1.53	18.46	10.30	18.56	0.92	0.00	49.76
1917	1.55	18.78	10.47	16.96	0.84	0.00	48.60
1918	1.32	16.02	8.93	10.88	0.54	0.00	37.69
1919	1.34	16.22	9.05	12.90	0.64	0.00	40.14
1920	1.62	19.73	11.01	13.59	0.67	0.00	46.62
1921	3.39	23.37	10.22	14.75	0.73	0.00	52.46
1922	2.61	19.02	9.22	11.63	0.02	0.00	42.50
1923	2.62	16.71	9.72	21.60	0.67	0.00	51.32
1924	1.82	15.14	9.86	24.82	1.50	0.00	53.14
1925	2.20	13.65	7.99	22.16	4.66	0.00	50.66
1926	2.32	16.12	7.17	21.01	5.85	0.00	52.47
1927	2.62	14.09	7.42	22.62	8.20	0.00	54.95
1928	2.27	16.63	7.58	22.54	5.25	0.00	54.26
1929	2.18	13.77	9.85	22.27	8.86	0.00	56.93
1930	1.58	12.12	8.53	18.19	9.09	0.00	49.51
1931	1.63	13.53	7.39	14.61	7.06	0.00	44.22
1932	1.90	13.25	7.74	16.71	4.89	0.00	44.49
1933	1.75	13.37	8.15	19.67	3.97	0.00	46.91
1934	2.45	14.12	7.68	15.88	4.58	0.00	44.72
1935	1.77	14.21	7.58	19.96	3.82	0.00	47.34
1936	0.90	13.67	8.75	20.09	5.52	0.00	48.92
1937	0.92	15.29	7.87	20.47	5.00	0.00	49.54
1938	0.95	16.00	7.15	20.66	4.79	0.00	49.55
1939	1.36	17.67	6.56	21.16	4.15	0.00	50.90
1940	0.98	17.81	7.62	22.50	4.48	0.00	53.38

Table 3. Continued.

Year	2A	2B	2C	3A	3B	4	Total
1941	0.51	16.53	7.25	21.84	6.10	0.00	52.23
1942	0.72	14.37	8.35	21.50	5.46	0.00	50.39
1943	1.24	15.97	8.15	20.51	7.83	0.00	53.70
1944	0.90	15.07	10.38	20.36	6.73	0.00	53.44
1945	0.73	14.58	8.49	20.07	9.52	0.01	53.40
1946	0.90	18.37	9.90	22.40	8.50	0.20	60.27
1947	0.57	17.67	9.50	20.44	7.33	0.19	55.70
1948	0.41	17.67	9.75	19.93	7.50	0.30	55.56
1949	0.62	16.34	9.45	21.12	7.38	0.12	55.03
1950	0.70	17.46	8.84	23.86	6.30	0.08	57.23
1951	0.59	20.04	9.97	20.86	4.54	0.05	56.05
1952	0.62	20.63	9.56	27.27	3.62	0.56	62.26
1953	0.50	23.80	8.41	22.84	3.81	0.48	59.84
1954	0.85	24.90	11.04	29.46	4.21	0.13	70.58
1955	0.61	18.65	8.54	23.06	6.57	0.09	57.52
1956	0.53	20.06	14.51	22.11	9.12	0.26	66.59
1957	0.60	17.69	12.25	22.85	7.43	0.04	60.85
1958	0.52	18.49	11.20	24.52	7.60	2.18	64.51
1959	0.67	16.83	13.03	25.36	11.00	4.31	71.20
1960	0.89	18.16	12.72	21.05	12.90	5.90	71.61
1961	0.50	16.08	12.29	23.07	13.28	4.07	69.27
1962	0.45	16.21	13.45	25.96	14.65	12.76	83.47
1963	0.41	16.60	10.45	25.62	16.77	10.81	80.66
1964	0.28	12.96	7.64	31.93	17.30	5.59	75.70
1965	0.21	13.40	12.27	29.08	24.51	5.06	84.54
1966	0.18	12.70	12.25	30.28	19.03	5.34	79.79
1967	0.20	11.76	9.85	24.29	18.16	7.30	71.56
1968	0.14	12.11	6.63	20.25	17.41	7.28	63.81
1969	0.23	15.00	9.79	23.89	15.09	9.50	73.50
1970	0.16	11.73	9.93	23.30	16.21	9.80	71.13
1971	0.32	11.59	7.15	20.74	12.40	14.18	66.37
1972	0.37	11.88	6.54	21.71	10.98	10.69	62.16
1973	0.23	8.24	6.82	17.95	7.49	8.55	49.27
1974	1.00	6.43	6.17	13.50	5.10	8.33	40.54
1975	0.94	9.18	6.93	13.85	4.65	4.28	39.84
1976	0.72	9.51	6.28	14.64	5.20	5.29	41.63
1977	0.70	7.39	3.87	13.02	5.12	4.14	34.24
1978	0.59	6.20	4.82	13.75	3.17	6.38	34.90
1979	0.54	6.84	5.56	17.62	1.33	6.79	38.68
1980	0.52	7.16	4.12	18.44	1.53	9.95	41.72
1981	0.70	7.01	4.87	19.85	2.02	7.62	42.06
1982	0.74	6.60	4.33	18.16	7.04	6.21	43.08
1983	0.81	6.63	7.30	18.15	9.80	8.72	51.41
1984	1.03	10.55	6.86	23.10	8.30	7.89	57.73
1985	1.17	12.33	10.53	24.26	11.86	8.70	68.86
1986	1.40	13.27	12.25	37.92	9.82	11.56	86.22
1987	1.52	14.85	12.31	37.64	9.14	13.00	88.46
1988	1.22	15.28	13.13	46.69	7.40	13.70	97.42
1989	1.29	12.69	11.75	42.11	9.03	12.43	89.29
1990	0.95	11.07	12.42	38.29	11.15	14.36	88.25
1991	0.94	9.76	12.31	34.55	14.48	16.69	88.73
1992	1.15	9.98	12.83	37.11	11.12	17.78	89.97
1993	1.23	13.24	14.36	33.48	9.24	14.39	85.94

Table 3. Continued.

Year	2A	2B	2C	3A	3B	4	Total
1994	1.02	12.03	13.46	35.04	5.46	15.18	82.19
1995	1.17	12.56	10.02	26.33	5.00	13.67	68.75
1996	1.17	11.24	11.52	27.81	5.76	14.09	71.59
1997	1.41	14.12	12.67	33.74	10.82	16.97	89.72
1998	1.96	14.90	13.46	33.81	12.88	17.23	94.23
1999	1.80	14.38	12.75	33.05	15.93	20.01	97.92
2000	1.69	12.55	11.46	28.02	17.34	21.74	92.80
2001	2.01	12.03	11.07	29.75	18.53	21.04	94.42
2002	1.92	14.08	11.37	30.25	19.79	20.35	97.76
2003	1.56	13.90	11.84	32.32	19.64	19.29	98.54
2004	1.70	14.64	14.57	35.61	17.49	16.23	100.23
2005	1.90	15.15	14.70	36.08	14.93	16.93	99.70
2006	2.01	14.96	14.36	35.15	12.73	15.99	95.20
2007	1.75	12.58	12.76	36.96	10.89	15.74	90.68
2008	1.66	10.29	10.57	34.25	12.85	15.61	85.23
2009	1.54	8.71	8.44	30.74	12.93	14.08	76.43
2010	1.20	8.75	7.48	29.08	12.21	13.89	72.61
2011	1.08	8.83	4.29	23.00	9.30	13.40	59.91
2012	1.18	7.85	4.78	18.52	7.07	12.21	51.61
2013	1.18	7.58	5.15	16.98	5.44	9.68	46.01

Table 4. Time-series of estimated removals by source (million lb, net wt.).

Year	Commercial landings	Commercial wastage	Bycatch	Sport	Personal use	Total
1888	1.47	0.00	0.00	0.00	0.00	1.47
1889	1.29	0.00	0.00	0.00	0.00	1.29
1890	1.37	0.00	0.00	0.00	0.00	1.37
1891	2.13	0.00	0.00	0.00	0.00	2.13
1892	2.77	0.00	0.00	0.00	0.00	2.77
1893	3.22	0.00	0.00	0.00	0.00	3.22
1894	3.76	0.00	0.00	0.00	0.00	3.76
1895	4.25	0.00	0.00	0.00	0.00	4.25
1896	5.42	0.00	0.00	0.00	0.00	5.42
1897	6.59	0.00	0.00	0.00	0.00	6.59
1898	7.77	0.00	0.00	0.00	0.00	7.77
1899	8.94	0.00	0.00	0.00	0.00	8.94
1900	13.41	0.00	0.00	0.00	0.00	13.41
1901	17.87	0.00	0.00	0.00	0.00	17.87
1902	22.34	0.00	0.00	0.00	0.00	22.34
1903	25.21	0.00	0.00	0.00	0.00	25.21
1904	28.08	0.00	0.00	0.00	0.00	28.08
1905	22.00	0.00	0.00	0.00	0.00	22.00
1906	36.00	0.00	0.00	0.00	0.00	36.00
1907	50.00	0.00	0.00	0.00	0.00	50.00
1908	50.62	0.00	0.00	0.00	0.00	50.62
1909	51.23	0.00	0.00	0.00	0.00	51.23
1910	51.85	0.00	0.00	0.00	0.00	51.85
1911	56.93	0.00	0.00	0.00	0.00	56.93
1912	60.43	0.00	0.00	0.00	0.00	60.43
1913	66.54	0.00	0.00	0.00	0.00	66.54
1914	67.43	0.00	0.00	0.00	0.00	67.43
1915	68.48	0.00	0.00	0.00	0.00	68.48
1916	49.76	0.00	0.00	0.00	0.00	49.76
1917	48.60	0.00	0.00	0.00	0.00	48.60
1918	37.69	0.00	0.00	0.00	0.00	37.69
1919	40.14	0.00	0.00	0.00	0.00	40.14
1920	46.62	0.00	0.00	0.00	0.00	46.62
1921	52.46	0.00	0.00	0.00	0.00	52.46
1922	42.49	0.00	0.00	0.00	0.00	42.49
1923	51.32	0.00	0.00	0.00	0.00	51.32
1924	53.14	0.00	0.00	0.00	0.00	53.14
1925	50.66	0.00	0.00	0.00	0.00	50.66
1926	52.47	0.00	0.00	0.00	0.00	52.47
1927	54.95	0.00	0.00	0.00	0.00	54.95
1928	54.26	0.00	0.00	0.00	0.00	54.26
1929	56.92	0.00	0.00	0.00	0.00	56.92
1930	49.51	0.00	0.00	0.00	0.00	49.51
1931	44.22	0.00	0.00	0.00	0.00	44.22
1932	44.49	0.00	0.00	0.00	0.00	44.49
1933	46.91	0.00	0.00	0.00	0.00	46.91
1934	44.72	0.00	0.00	0.00	0.00	44.72
1935	47.34	0.00	0.00	0.00	0.00	47.34
1936	48.92	0.00	0.00	0.00	0.00	48.92
1937	49.54	0.00	0.00	0.00	0.00	49.54
1938	49.55	0.00	0.00	0.00	0.00	49.55
1939	50.90	0.00	0.00	0.00	0.00	50.90

Table 4. Continued.

Year	Commercial landings	Commercial wastage	Bycatch	Sport	Personal use	Total
1940	53.38	0.00	0.00	0.00	0.00	53.38
1941	52.23	0.00	0.00	0.00	0.00	52.23
1942	50.39	0.00	0.00	0.00	0.00	50.39
1943	53.70	0.00	0.00	0.00	0.00	53.70
1944	53.44	0.00	0.00	0.00	0.00	53.44
1945	53.40	0.00	0.00	0.00	0.00	53.40
1946	60.27	0.00	0.00	0.00	0.00	60.27
1947	55.70	0.00	0.00	0.00	0.00	55.70
1948	55.56	0.00	0.00	0.00	0.00	55.56
1949	55.03	0.00	0.00	0.00	0.00	55.03
1950	57.23	0.00	0.00	0.00	0.00	57.23
1951	56.05	0.00	0.00	0.00	0.00	56.05
1952	62.26	0.00	0.00	0.00	0.00	62.26
1953	59.84	0.00	0.00	0.00	0.00	59.84
1954	70.58	0.00	0.00	0.00	0.00	70.58
1955	57.52	0.00	0.00	0.00	0.00	57.52
1956	66.59	0.00	0.00	0.00	0.00	66.59
1957	60.85	0.00	0.00	0.00	0.00	60.85
1958	64.51	0.00	0.00	0.00	0.00	64.51
1959	71.20	0.00	0.00	0.00	0.00	71.20
1960	71.61	0.00	0.00	0.00	0.00	71.61
1961	69.27	0.00	0.00	0.00	0.00	69.27
1962	74.86	0.00	8.61	0.00	0.00	83.47
1963	71.24	0.00	9.42	0.00	0.00	80.66
1964	59.78	0.00	15.91	0.00	0.00	75.70
1965	63.18	0.00	21.36	0.00	0.00	84.54
1966	62.02	0.00	17.77	0.00	0.00	79.79
1967	55.22	0.00	16.34	0.00	0.00	71.56
1968	48.59	0.00	15.22	0.00	0.00	63.81
1969	58.27	0.00	15.23	0.00	0.00	73.50
1970	54.84	0.00	16.29	0.00	0.00	71.13
1971	46.65	0.00	19.72	0.00	0.00	66.37
1972	42.88	0.00	19.28	0.00	0.00	62.16
1973	31.74	0.00	17.53	0.00	0.00	49.27
1974	21.31	0.20	19.03	0.00	0.00	40.54
1975	27.62	0.31	11.91	0.00	0.00	39.84
1976	27.54	0.34	13.75	0.00	0.00	41.63
1977	21.88	0.29	11.78	0.29	0.00	34.24
1978	22.00	0.28	12.24	0.38	0.00	34.90
1979	22.54	0.30	15.28	0.56	0.00	38.68
1980	21.87	0.30	18.70	0.85	0.00	41.72
1981	25.74	0.35	14.86	1.11	0.00	42.06
1982	29.01	0.40	12.37	1.30	0.00	43.08
1983	38.39	0.53	10.88	1.62	0.00	51.41
1984	44.97	0.72	10.19	1.84	0.00	57.73
1985	56.10	2.70	7.70	2.36	0.00	68.86
1986	69.63	4.65	8.76	3.18	0.00	86.22
1987	69.47	4.20	11.28	3.51	0.00	88.46
1988	74.39	3.49	14.66	4.88	0.00	97.42
1989	66.95	3.46	13.65	5.23	0.00	89.29
1990	61.60	3.38	17.68	5.59	0.00	88.25
1991	57.08	3.46	19.67	6.51	2.01	88.74

Table 4. Continued.

Year	Commercial landings	Commercial wastage	Bycatch	Sport	Personal use	Total
1992	59.89	2.50	20.29	6.18	1.11	89.97
1993	59.27	2.05	15.96	7.73	0.93	85.94
1994	54.73	2.51	16.95	7.07	0.93	82.19
1995	43.88	0.93	15.93	7.46	0.54	68.75
1996	47.34	1.15	14.46	8.08	0.54	71.59
1997	65.20	1.45	13.51	9.03	0.54	89.73
1998	69.76	1.72	13.43	8.59	0.74	94.23
1999	74.31	1.65	13.84	7.38	0.75	97.92
2000	68.29	1.45	13.29	9.01	0.76	92.80
2001	70.70	1.69	13.16	8.10	0.77	94.42
2002	74.66	1.72	12.61	8.01	0.76	97.76
2003	73.14	2.08	12.58	9.35	1.38	98.54
2004	73.11	2.31	12.58	10.70	1.53	100.23
2005	71.82	2.22	13.26	10.86	1.54	99.70
2006	67.98	2.46	13.08	10.19	1.48	95.20
2007	62.87	2.59	12.27	11.46	1.49	90.68
2008	58.57	2.76	11.89	10.67	1.34	85.23
2009	52.05	2.94	11.38	8.75	1.31	76.43
2010	49.72	3.21	10.63	7.80	1.24	72.61
2011	39.51	2.46	9.71	7.09	1.14	59.91
2012	31.99	1.67	10.08	6.73	1.14	51.61
2013	28.91	1.41	7.89	6.66	1.14	46.01

Table 5. Time-series of fishery WPUE by regulatory Area (net lb/skate). Years prior to 1984 are based on fishing conducted with "J" hooks.

Year	2A	2B	2C	3A	3B	4A	4B	4C	4D	Total
1907	NA	NA	NA	NA	NA	NA	NA	NA	NA	280
1910	NA	NA	NA	NA	NA	NA	NA	NA	NA	271
1911	NA	NA	NA	NA	NA	NA	NA	NA	NA	237
1912	NA	NA	NA	NA	NA	NA	NA	NA	NA	176
1913	NA	NA	NA	NA	NA	NA	NA	NA	NA	129
1914	NA	NA	NA	NA	NA	NA	NA	NA	NA	124
1915	NA	NA	NA	NA	NA	NA	NA	NA	NA	118
1916	NA	NA	NA	NA	NA	NA	NA	NA	NA	137
1917	NA	NA	NA	NA	NA	NA	NA	NA	NA	98
1918	NA	NA	NA	NA	NA	NA	NA	NA	NA	96
1919	NA	NA	NA	NA	NA	NA	NA	NA	NA	93
1920	NA	NA	NA	NA	NA	NA	NA	NA	NA	96
1921	NA	NA	NA	NA	NA	NA	NA	NA	NA	88
1922	NA	NA	NA	NA	NA	NA	NA	NA	NA	73
1923	NA	NA	NA	NA	NA	NA	NA	NA	NA	78
1924	NA	NA	NA	NA	NA	NA	NA	NA	NA	74
1925	NA	NA	NA	NA	NA	NA	NA	NA	NA	68
1926	NA	NA	NA	NA	NA	NA	NA	NA	NA	67
1927	NA	NA	NA	NA	NA	NA	NA	NA	NA	65
1928	NA	NA	NA	NA	NA	NA	NA	NA	NA	58
1929	NA	NA	NA	NA	NA	NA	NA	NA	NA	51
1930	NA	NA	NA	NA	NA	NA	NA	NA	NA	46
1931	NA	NA	NA	NA	NA	NA	NA	NA	NA	50
1932	NA	NA	NA	NA	NA	NA	NA	NA	NA	60
1933	NA	NA	NA	NA	NA	NA	NA	NA	NA	63
1934	NA	NA	NA	NA	NA	NA	NA	NA	NA	62
1935	NA	NA	NA	NA	NA	NA	NA	NA	NA	76
1936	NA	NA	NA	NA	NA	NA	NA	NA	NA	71
1937	NA	NA	NA	NA	NA	NA	NA	NA	NA	80
1938	NA	NA	NA	NA	NA	NA	NA	NA	NA	88
1939	NA	NA	NA	NA	NA	NA	NA	NA	NA	80
1940	NA	NA	NA	NA	NA	NA	NA	NA	NA	81
1941	NA	NA	NA	NA	NA	NA	NA	NA	NA	85
1942	NA	NA	NA	NA	NA	NA	NA	NA	NA	90
1943	NA	NA	NA	NA	NA	NA	NA	NA	NA	95
1944	NA	NA	NA	NA	NA	NA	NA	NA	NA	110
1945	NA	NA	NA	NA	NA	NA	NA	NA	NA	102
1946	NA	NA	NA	NA	NA	NA	NA	NA	NA	101
1947	NA	NA	NA	NA	NA	NA	NA	NA	NA	99
1948	NA	NA	NA	NA	NA	NA	NA	NA	NA	99
1949	NA	NA	NA	NA	NA	NA	NA	NA	NA	95
1950	NA	NA	NA	NA	NA	NA	NA	NA	NA	95
1951	NA	NA	NA	NA	NA	NA	NA	NA	NA	96
1952	NA	NA	NA	NA	NA	NA	NA	NA	NA	110
1953	NA	NA	NA	NA	NA	NA	NA	NA	NA	131
1954	NA	NA	NA	NA	NA	NA	NA	NA	NA	133
1955	NA	NA	NA	NA	NA	NA	NA	NA	NA	119
1956	NA	NA	NA	NA	NA	NA	NA	NA	NA	129
1957	NA	NA	NA	NA	NA	NA	NA	NA	NA	110
1958	NA	NA	NA	NA	NA	NA	NA	NA	NA	121
1959	NA	NA	NA	NA	NA	NA	NA	NA	NA	129
1960	NA	NA	NA	NA	NA	NA	NA	NA	NA	132

Table 5. Continued.

Year	2A	2B	2C	3A	3B	4A	4B	4C	4D	Total
1961	NA	NA	NA	NA	NA	NA	NA	NA	NA	127
1962	NA	NA	NA	NA	NA	NA	NA	NA	NA	115
1963	NA	NA	NA	NA	NA	NA	NA	NA	NA	105
1964	NA	NA	NA	NA	NA	NA	NA	NA	NA	100
1965	NA	NA	NA	NA	NA	NA	NA	NA	NA	99
1966	NA	NA	NA	NA	NA	NA	NA	NA	NA	100
1967	NA	NA	NA	NA	NA	NA	NA	NA	NA	101
1968	NA	NA	NA	NA	NA	NA	NA	NA	NA	103
1969	NA	NA	NA	NA	NA	NA	NA	NA	NA	95
1970	NA	NA	NA	NA	NA	NA	NA	NA	NA	91
1971	NA	NA	NA	NA	NA	NA	NA	NA	NA	89
1972	NA	NA	NA	NA	NA	NA	NA	NA	NA	78
1973	NA	NA	NA	NA	NA	NA	NA	NA	NA	63
1974	59	64	57	65	57	NA	NA	NA	NA	61
1975	59	68	53	66	68	NA	NA	NA	NA	61
1976	33	53	42	60	65	NA	NA	NA	NA	55
1977	83	61	45	61	73	NA	NA	NA	NA	63
1978	39	63	56	78	53	NA	NA	NA	NA	71
1979	50	48	80	86	37	NA	NA	NA	NA	75
1980	37	65	79	118	113	NA	NA	NA	NA	94
1981	33	67	144	142	160	158	99	110	NA	111
1982	22	69	146	168	203	103	NA	91	NA	127
1983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1984	63	147	284	502	474	366	161	NA	197	291
1985	62	139	345	500	592	337	234	594	330	357
1986	55	118	290	506	506	260	238	427	218	320
1987	53	130	260	498	478	342	220	384	241	321
1988	134	137	281	503	654	453	224	371	201	368
1989	113	133	258	457	590	409	268	333	432	358
1990	168	176	270	354	484	418	209	288	381	318
1991	158	149	233	319	466	471	329	223	399	317
1992	117	171	230	397	440	372	280	249	412	319
1993	147	208	256	393	514	463	218	257	851	373
1994	93	215	207	354	377	463	197	167	480	306
1995	116	219	234	417	476	349	189	286	475	330
1996	159	227	239	473	557	515	269	297	543	392
1997	226	241	246	458	563	483	275	335	671	404
1998	194	232	236	452	611	525	287	287	627	407
1999	342	213	199	437	538	497	310	271	535	392
2000	263	229	187	443	579	548	320	223	556	402
2001	171	227	196	469	431	474	270	203	511	362
2002	181	223	244	508	399	402	245	148	503	359
2003	173	221	233	485	365	355	196	105	388	328
2004	143	203	240	486	328	315	202	120	445	318
2005	137	195	203	446	293	301	238	91	379	296
2006	156	201	170	403	292	241	218	72	280	270
2007	96	198	160	398	257	206	230	65	237	251
2008	69	174	161	370	234	206	193	94	247	232
2009	98	188	155	318	211	234	189	88	249	222
2010	149	222	158	285	173	182	142	82	188	203
2011	92	240	175	280	140	189	165	75	166	198
2012	102	248	207	263	133	194	149	60	155	195
2013	132	269	227	240	113	164	122	55	151	187