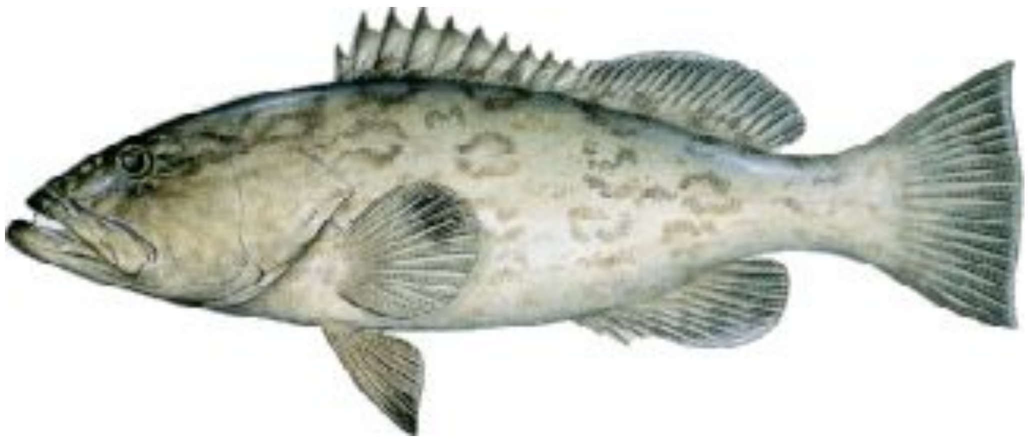
SEDAR 33 UPDATE REPORT Gulf of Mexico Gag Grouper



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1. INTRODUCTION

Gulf of Mexico gag grouper, *Mycteroperca microlepis*, was assessed in 1994 (Schirripa and Goodyear 1994), 1997 (Schirripa and Goodyear 1997), and 2001 (Turner et al. 2001) prior to the Southeast Data, Assessment, Review process. Assessments that have been conducted the SEDAR process include SEDAR 10 (SEDAR 2006), a benchmark assessment that was updated in 2009 (SEDAR 2009), and SEDAR 33, another benchmark assessment was carried out in 2013. This report summarizes the results of the update assessment of SEDAR 33. More specifically, the results from the SEDAR 33 continuity assessment model and an alternative model are presented and compared to the SEDAR 33 model.

During the previous assessment, the Gulf of Mexico Fishery Management Council's (GMFMC) Scientific and Statistical Committee (SSC) chose a model that assumed steepness was equal to 0.855, spawning stock biomass included only females, and a F_{msy} proxy of F_{max}. The ratio of $SSB_{current}$ and SSB_{Fmax} was above 1 indicating that gag grouper were not overfished. Comparing the current fishing mortality ($F_{current}$), calculated as the geometric mean of the fishing mortality between 2010 and 2012, to F_{max} indicated that the stock was not undergoing overfishing.

2. DATA REVIEW AND UPDATE

2.1 Commercial

The primary commercial gears for Gulf of Mexico gag grouper were vertical lines and longline. The data collected from these fleets included landings, discards, catch per unit effort (CPUE), size composition and age composition.

2.1.1 Landings

The commercial landings time-series began in 1963 (**Figure 1**). All commercial landings were converted to gutted weight and partitioned into two fleets: commercial vertical line (1963-2015) and commercial longline (1979-2015) as was done for SEDAR 33 (SEDAR 2013, page 90). The commercial landings time-series used for the update assessment was identical to what was used during SEDAR 33 except for the additional years of data (**Figure 2-Figure 3**).

The majority of commercial landings over time have been from the vertical line fleet **(Figure 1**). The vertical line and longline landings were almost equal in 2015. An individual fishing quota (IFQ) system was implemented in 2010. The quota was greatly reduced in 2011 and corresponded with the lowest landings (**Figure 1, Table 1**). Commercial vertical line landings declined between 2001 and 2011 and have remained low even though the quota has increased (**Figure 2**). Commercial longline landings peaked in 2004, which was followed by a decline until 2011 (**Figure 3**). Commercial longline landings have increased since 2011. Annual total landings have remained below the quota (**Table 1**).

2.1.2 Discards

Data available for the calculation of gag grouper discards from the commercial fishery included vertical line (handline and electric/hydraulic reel) and bottom longline observer data in addition to fisher reported effort data from the coastal logbook program. Complete years of observer data included the years 2007-2015.

The observer and coastal logbook data were stratified by gear (vertical line or longline), size limit (2000-2012: 24 inches or 2013-2015: 22 inches), shallow water grouper season (open, closed) applied to 2007-2009, allocation (0, 1+ pounds) applied to 2010-2015, year, and seasonal depth restriction (20 fathoms or 35 fathoms. Bottom longline vessels were restricted to fishing in depths 35 fathoms or deeper during June-August beginning in 2010. That restriction did not apply to vertical line vessels. Annual discards were calculated as:

Year/stratum-specific discard rate*year/stratum-specific total effort

There were no major changes in the vertical line discard estimates between SEDAR 33 and the update (**Figure 4a**). The vertical line discards peaked at 104,000 gag in 2009 and have declined to ~10,000 gag in 2015. The longline discards were initially very low (less than 500) between 2007 and 2010, peaked at ~6000 in 2011, and have declined since (**Figure 4b)**. The 2012 longline discard estimates differed between SEDAR 33 and the update, where the update estimate was lower. The observer data provided for SEDAR 33 was incomplete, resulted in a higher average discard rate in 2012, and led to a larger discard estimate (5,343 versus 4,029).

2.1.3 Catch-per-unit effort

Eight indices were recommended for use in the SEDAR 33 model. The indices are shown in **Figure 7.** Overall the indices and the associated standard errors used during SEDAR 33 and the update were similar (**Figure 7a, b**).

Data from the National Marine Fisheries Service reef fish logbook program were used during SEDAR 33 to construct standardized CPUE indices of abundance for the populations of gag grouper. The indices used the self-reported catch rate information for the vertical line and the longline fleets from the conception of the logbook program in 1993 through 2009. It is important to note that the terminal year for the commercial handline and commercial longline CPUE indices was 2009 (**Figure 7a, b**). The indices were truncated to account for the unknown influences on catchability due to the IFQ program.

2.1.4 Composition Data

Retained catch length and age composition

The length data for the commercial fleets were obtained from the Trip Interview Program (TIP) and Gulf-FIN databases. All lengths were converted to fork length, separated by fleet, and grouped in 2cm bins. There were no major changes in the length composition data of retained catch for commercial vertical line and commercial longline (**Figure 8a, b**).

The fleet specific annual length composition of retained catch is summarized in **Figure 9.** Shifts towards larger gag grouper exhibited in the retained catch were due to changes in the size limit.

Age samples for the commercial fleets were from the Panama City Laboratory, SEFSC. Age samples were grouped into the same strata as length samples. There were no major changes in the age composition data of retained catch for commercial vertical line and commercial longline (**Figure 10 a,b**). The annual age composition data are shown in **Figure 11**. The apparent cohorts in the commercial vertical line data include 1989, 1993, 1996, 2006, and 2007 (**Figure 11a**). The 1996 and 2006 cohorts were visible in the commercial longline age composition data (**Figure 11b**). The main age classes captured were 3-8 year olds and 4-8 year olds for the vertical line and longline fleets, respectively.

Discard length composition

The commercial discard length data were from the vertical line and longline observer database. All lengths were converted to fork length, separated by fleet, and grouped in 2cm bins.

There were no major changes in the discarded gag grouper length composition data for the commercial vertical line fleet (**Figure 12a**). The gag grouper length composition data for the commercial longline fleet from 2007-2012 had a higher frequency of larger gag than SEDAR33 (**Figure 12b**).

The annual discard length composition data show that some gag grouper above the size limit were discarded by the vertical line and longline fleets (**Figure 13**). The pattern in the size of discards was fairly consistent for the commercial vertical line fleet, with a greater frequency in discards above the size limit in 2011-2013, after the implementation of the IFQ program (**Figure 13a**). The discard length composition data from the longline fleet suggested that since the implementation of the IFQ program a large majority of discarded fish were above the size limit **(Figure 13b**).

2.2 Recreational

The recreational fishery for gag was dominated by three modes private, charter, and headboat. Catch and discards in numbers, estimates of effort, length and weight samples, and catch and effort observations for these modes were available for this assessment. The recreational landings and discard estimates for gag (1981-2015) were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP), the Southeast Region Headboat Survey (SRHS), the Texas Parks and Wildlife Department (TPWD), and the Louisiana Creel Survey (see **Appendix A** for a detailed description of the methods). Length and age composition data were obtained from the MFRSS/MRIP, the Head Boat Survey, the Texas Parks and Wildlife Department database, the Gulf-FIN, and the TIP databases.

2.2.1 Landings

The landings used in the SEDAR 33 assessment model, those provided for the update assessment, and the percent difference are summarized in Table 2**.** The headboat landings were unchanged (Table 2**, Figure 14).**

Changes were evident for the charter fleet (Table 2**, Figure 14**). The updated charter landings were approximately 11-12 percent higher than SEDAR 33 between 1983 and 2003. There was one exception, 1987, when the update charterboat landings were 200% higher than the SEDAR 33 estimates. This large difference is due to a change in the 1987 post-stratified estimates. During 1987 sampling in West Florida (Monroe – Escambia county) was stratified to increase sample size in Monroe county in Wave 1, and in the western panhandle (Escambia to Bay county) in Waves 3-5. Catch and effort estimates were generated for these regions separate from the rest of West Florida, designated with st=90, then aggregated to report the 'state' totals for all of West Florida (st=12). An error was discovered in the previous post-stratified program that failed to correctly convert effort estimates from st=90 to st=12 before being merged with the intercept data. This error was discovered in February 2015 and corrected. The resulting, corrected 1987 post-stratified estimates are included in this SEDAR update for gag. The differences in the charter landings were more variable between 2004 and 2012.

The difference between the update and SEDAR 33 landing estimates for the private fleet (Table 2**, Figure 14**) was more variable from year to year. The greatest difference was a 27% in 2006 and the lowest was

19% in 2012.

It should also be noted that several changes were made when estimating the charter and private landings using the MRIP data and help to explain the differences. A new Access Point Angler Intercept Survey (APAIS) adjustment was applied, an MRIP specific gag to black grouper ratio was used, and a new approach to removing the Monroe County landings was used (see **Appendix A** for a description of the methods).

Historical (1963-1980) recreational landings were estimated using the FHWAR method following the best practices advice (SEDAR 2016). Fractional effort data were developed from FHWAR effort estimates for the GOM (excluding shore fishing). It was assumed that CPUE increased by 2% annually between 1963 and 1980 due to improvements in gear and other factors during the historic period, as was done during SEDAR 33. The 1980 landings were scaled to the mean landings between 1981 and 1989, this was also done for the update estimates.

The update estimates of the historical landings were greater than those used in the SEDAR 33 assessment (Table 3**, Figure 14**).The proportional difference was highest in 1963 and declined as the time-series approached 1980. The estimates used in the SEDAR 33 assessment were rescaled to the values produced for SEDAR 10. This was not done, as best practice methods have been accepted (SEDAR 2016).

2.2.2 Discards

Recreational discards were provided for the headboat, charter, and private fleets. Data from the MRFSS/MRIP and the SHRS were the sources of information for these estimates (see **Appendix A** for a summary of methods).

The update discard estimates for charter, private, and headboat and a comparison of the estimates from SEDAR 33 and the update are shown in **Figure 15.** The private fleet comprised the majority of the recreational discards followed by charter and headboat. The charter discards were variable overtime, but had an increasing trend between 1982 and 1998, which was followed by a variable period, and then declined after 2010 (**Figure 15a**). The update discard estimates for charter were approximately 4% greater than those from SEDAR 33 from 1986 until 2005. After 2005, the differences were more variable and range from a -7% in 2006 to a 25% in 2012. The private discards increased between 1982 and 2008 and declined between 2008 and 2015 (**Figure 15b**). The update discard estimates for the private fleet were consistently greater than the SEDAR 33 estimates. The greatest difference was 22% in 1982 and the smallest difference was 14% in 2002. The headboat discards have been variable over time (**Figure 15c**). The headboat discard estimates provided for the update were generally lower than SEDAR from 1982 until 2007. In 1987 the update estimate was 67% lower than the SEDAR 33 estimate.

2.2.3 Catch-per-unit effort

The MRIP/MRFSS intercept data and SRHS logbook data were used to develop standardized CPUE indices of abundance for the charter, private, and headboat fleets. The resulting indices are compared to the SEDAR 33 indices in **Figure 7c-d**. The updated indices and the associated standard errors were similar to those from SEDAR 33.

2.2.4 Composition data

Retained catch length and age composition

The length data for the recreational fleets were obtained from several sources and include the MFRSS/MRIP, the Head Boat Survey, the Texas Parks and Wildlife Department database, the Gulf FIN database, and the TIP database. Length samples were separated by fleet and the length samples were converted to fork length and grouped in 2cm bins. All lengths were converted to fork length, separated by fleet, and grouped in 2cm bins. Overall, any changes in the length composition data for the recreational fleets were subtle **(Figure 8c-e**).

The annual length composition data of retained catch was strongly influenced by the implementation of size limits in 1990 and 2001 (**Figure 16**).

Age samples for the recreational fleets were from the Panama City Laboratory, SEFSC. Age samples were grouped into the same strata as length samples. There were no major changes in the age composition data of retained catch for recreational fleets **(Figure 10 c-e**).

The age composition data from the headboat and charter fleets are shown in **Figure 17a** and **Figure 17b**. The apparent cohorts in the data of both fleets are 1989, 1993, 1996, 2006, 2007. There is some evidence of a 2009 or 2010 cohort in the headboat data (**Figure 17a**). The main age classes captured by the headboat and charter fleets were 2-6 year olds.

Discard length composition

The Florida Fish and Wildlife Conservation Commission's (FWC) Florida Fish and Wildlife Research Institute (FWRI) has conducted a For-hire Survey Program since 2005. Initially the program focused its sampling effort on headboats and started sampling charter boats in 2009. The discard length composition data collected by this program were used as inputs in the assessment model.

The sample design for this survey does not account for various trip-types offered by vessels selected for observer coverage. Single-day trip-types included half-day (<6 hours from departure to return), ¾-day (defined as 6 to <8 hours through 2012, and 6 to <7 hours after 2012), and full day (9 or more hours through 2012, and 8 or more hours after 2012). Multi-day trips included any trips that were more than 24 hours in duration. To generate weighting factors for different trip types, fishing effort data for the years 2009 through 2013 were used to calculate proportional effort by trip-type. For example, multi-day headboat trips were sampled at a much higher rate (between 20% and 30% of samples, versus approximately 1% of headboat effort) and weighting is necessary to account for this oversampling.

Headboat vessels report fishing effort in logbook trip reports, and effort data from the two study regions in the Gulf of Mexico were provided by the NMFS Southeast Fisheries Science Center in Beaufort, NC. Effort data for charter vessels was collected through the For-Hire Survey component of the Marine Recreational Information Program, a weekly vessel directory telephone survey of charter boat operators (Van Voorhees et al. 2002). Proportional fishing effort was calculated as the total number of trips in the Gulf of Mexico reported for a given trip-type (Nt) divided by the total number of Gulf trips reported (N). To obtain the sample weight (Wt), proportional effort was then divided by the proportion of a given trip type in the sample population (nt/n):

$$Wt = (Nt/N) / (nt/n)$$

where nt is the number of trips of type t in the sample population, and n is the total number of sampled trips. Trip-types with $Wt < 1$ are down weighted to account for oversampling and triptypes with $Wt > 1$ were inflated to account for undersampling.

Data collected in 2014 were not used in this assessment. During this year, funds were only available to sample a sub-set of headboats (9 vessels in Florida) that were participating in the Gulf Headboat Collaborative IFQ Program, a pilot program for a small group of vessels in the Gulf that were allocated a separate fishing quota for Red Snapper and Gag that may be harvested throughout the year (under an exempted fishing permit). Due to a lapse in funding for charter vessels in 2014, there was no sample coverage during the first five months of the year, 16 trips were sampled in June during the Federal recreational season for Red Snapper, and full sample coverage was not resumed until October, 2014.

The length frequency distributions of discarded gag by the headboat and charter fleets were similar to the distributions from SEDAR 33 (**Figure 18**). The subtle differences are due to a minor modification in the weighting factors.

The headboat discard length composition data shows that prior to 2011, the majority of discards were below the size limit **(Figure 19a**). An increasing frequency of discards above the size limit is seen in 2011-2013, which corresponds to years with a shortened gag recreational fishing season. The time-series of charter discard length composition is shorter than headboat and corresponds mainly to years with a shortened fishing season, 2010-2015 (**Figure 19b**). Over time a greater frequency of gag discards have been above the size limit.

2.3 Fishery-independent data

There were three sources of fishery-independent data; the video survey conducted as part of the Southeast Area Monitoring and Assessment Program (SEAMAP), the video survey conducted by the Southeast Fisheries Science Center's Panama City (PC) Laboratory, and an age-0 survey that is a compilation of several studies. The SEAMAP and PC video surveys provided indices of abundance and length composition data. The age-0 survey data provided an index of abundance.

2.3.1 Age-0 Survey

An age-0 gag grouper index was developed for the Gulf of Mexico using three available databases, the FSU Estuarine Gag Survey, the NMFS PC Lab St. Andrew Bay Survey, and the State of Florida FWC Estuarine (FIM) Survey. This was done by calculating the overall mean catch rate for each data set and scaling the data in each dataset to a mean of one. See **Appendix B** for a full description of the methods used to develop this index.

The index remained relatively unchanged with the inclusion of additional years of data (**Figure 7f**). The standard errors associated with the age-0 index for the update were smaller than those from SEDAR 33 (**Figure 7f**). This difference is due a modification of the variance calculation that accounted for the correlation (or lack thereof) between the binomial and lognormal components of these indices.

2.3.2 SEAMAP Video Survey

The primary objective of the SEAMAP reef fish video survey is to provide an index of the relative abundance of fish species associated with natural topographic features (e.g. reefs, banks, and ledges) located on the continental shelf of the Gulf of Mexico. Secondary objectives include quantification of habitat types sampled (video and side-scan), and collection of environmental data throughout the survey. The survey has been executed from 1993-1997, 2002, and 2004-2015 and historically takes place from May – August. Types of data collected on the survey include diversity, abundance (minimum count), fish length, habitat type, habitat coverage, and bottom topography. The size of fish sampled with the video gear is species specific.

The index of abundance was standardized using a delta-lognormal model. The index and associated standard errors remained unchanged with additional years of data **(Figure 7g**).

A difference in the length composition data from the SEAMAP Video Survey was apparent between SEDAR 33 and the update assessment (**Figure 20a**). The SEDAR 33 dataset included lengths collected as part of a project that was not included in the index development and standardization process. As such the sample size was reduced and the length frequency distribution differed.

2.3.3 PC Video Survey

The index of abundance was standardized using a delta-lognormal model. There were no major changes to this index; however, the standard errors associated with the PC-video survey for the update were smaller than those from SEDAR 33 (**Figure 7h**). This difference is due a modification of the variance calculation that accounted for correlation (or lack thereof) between the binomial and lognormal components of these indices.

The PC Video Survey length frequency distribution was similar between the update and SEDAR 33 assessments (**Figure 20b**).

3. CONTINUITY MODEL APPROACH

A length-based, age-structured forward-projecting population model was used to assess the status of the Gulf of Mexico gag grouper. The model was implemented in Stock Synthesis 3 (SS3) as was done for SEDAR 33. The GOM gag grouper population was modeled as a single stock that encompasses all U.S. waters of the GOM. The assessment period starts in 1963 as this represents the first year of detailed commercial landings. The terminal year of the assessment is 2015. Data collection was assumed to be relatively continuous throughout the year; therefore, a seasonal component to the removals and biological predictions was not modeled. The fleet structure in the model included two commercial fleets, vertical line and longline, three recreational fleets, headboat, charter, and private modes, and a red tide fleet. The continuity model configuration was identical to SEDAR 33. The continuity model for this assessment represented gag grouper age classes from age zero through age 20, where age 20 is a plus group.

The data inputs for the continuity model are summarized in **Figure .**

3.1 Life history

The assumptions about the weight-length relationship, the maturity schedule, fecundity, natural mortality, growth, and hermaphroditism were the same as SEDAR 33 (**Table C.1**). Maturity was modeled as an age logistic relationship, where the length at 50% maturity and the slope of the maturity curve were fixed parameters. Fecundity was assumed to be equivalent to spawning biomass (i.e., eggs=aW^b, where a=1 and b=1).

Growth was modeled using a single growth curve for both sexes and was assumed to follow von Bertalanffy growth. The von Bertalanffy relationship in SS3 is defined by three parameters; L_{min} (length at A_{min}), L_{max} (body length at A_{max}), and the von Bertalanffy growth coefficient, K (**Table C.1**).

Gag grouper is a protogynous hermaphrodite, so it begins life as a female and transitions to male at older ages. The assessment model was set-up with two genders and hermaphroditism was modeled using the SS3 hermaphroditism feature. It was assumed that the sex ratio at birth was 99.9% females. Hermaphroditism within SS3 is modeled as the proportion of individuals transitioning at a given age using a scaled cumulative normal distribution. The inflection age represents the age at which 50% of individuals transition to male, the standard deviation controls how quickly the asymptote is reached, and the maximum value represents the asymptotic proportion of transition. The three parameters that describe this relationship were fixed in this assessment (**Table C.1**). The relationship is shown in **Figure 21**.

3.2 Stock-recruitment model

A Beverton-Holt stock-recruitment model was used in this assessment. Two parameters of the stock recruitment relationship were estimated in the model; the log of unexploited equilibrium recruitment (R_0), and an offset parameter for initial equilibrium recruitment relative to virgin recruitment, log(R_1), (**Table A.1**). The steepness (h) parameter, which describes the fraction of unexploited recruits produced at 20% of the equilibrium spawning biomass level, was fixed at 0.855. A sensitivity analysis evaluating several values for the steepness parameter was conducted during SEDAR 33. The SSC agreed that the model run assuming a steepness value of 0.855 was most stable. A fourth parameter representing the standard deviation in recruitment (σ_R) was input as a fixed value of 0.6. This assumption is a carryover from the SEDAR 33 assessment and there was no reason to deviate given that predicted recruitment in the forecast was near the historical mean.

Annual deviations from the stock-recruit function were estimated for an early data-poor period (1963-1983) and a later data-rich period (1984-2015). The central tendency that penalizes the log (recruitment) deviations for deviating from zero was assumed to sum to zero over each of the two estimated periods. Stock synthesis assumes a lognormal error structure for recruitment. Therefore, expected recruitments were bias adjusted. Methot and Taylor (2011) recommend that the full bias adjustment only be applied to data-rich years in the assessment and a few years into the data-rich period. This is done so SS3 will apply the full bias-correction only to those recruitment deviations that have enough data to inform the model about the full range of recruitment variability (Methot 2011). Full bias adjustment was used from 1986 to 2014. Bias adjustment was phased in from no bias adjustment prior to 1984 to full bias adjustment in 1986 linearly. Bias adjustment was phased out over the last two years (2014-2015), decreasing from full bias adjustment to no bias adjustment.

3.3 Initial conditions

The starting year of the model was 1963. Removals of gag grouper were known to have occurred prior to 1963 so equilibrium starting conditions could not be assumed. This requires that the initial conditions be estimated.

3.4 Indices of abundance

Several indices were used in the assessment model. Five indices were fishery-dependent; commercial vertical line, commercial longline, headboat, charter, and private and three were fishery-independent; age-0 survey, SEAMAP video survey, and PC-video survey. The commercial vertical line, commercial longline, and headboat indices were modeled as landings only indices. The charter and private indices were treated as surveys since they include landings and discards (i.e., total catch) in the catch-per-unit effort (CPUE) calculation.

Abundance indices were assumed to have a lognormal error structure with units of standard error of $\log_e$(index). If the variance of the observations was available only as a CV, then the value of standard error was approximated as $\mathrm{sqrt}(\log_e(1+CV^2))$, where CV is the standard error of the observation divided by the mean value of the observation.

3.5 Selectivity

Length-specific selectivity was specified for all fleets and surveys, except the age-0 survey. Selectivity was modeled using the six parameter double normal relationship for the commercial vertical line, headboat, charter, and private fleets and the PC-video survey. The double normal relationship allows for a dome-shaped relationship to be estimated. For the recreational fleets and the PC Video survey, estimation ignored the first and last size bins and allowed SS to decay the small and large fish selectivity according to parameters of ascending width and descending width, respectively. The parameter specifying the width of the plateau was often estimated with high uncertainty for multiple fleets; the shape of the double-normal was not sensitive to changes in this parameter over a wide range of parameter values (-5 to -15). For these fisheries (commercial handline, headboat, and charter), the width of the plateau was fixed at - 9.

Selectivity was modeled using a two parameter logistic function for the commercial longline fleet and the SEAMAP-video survey. Assuming that at least one fleet has an asymptotic selectivity pattern helps to eliminate the estimation of "cryptic biomass" and to stabilize parameter estimation. This assumption meant that at least one of the fisheries sampled from the entire population after a specific size. The recreational indices (specified as surveys in SS) were assumed to have the same selectivity patterns as their respective fleets. Age-specific selectivity was modeled for the age-0 survey, where age-0 was the only age selected for.

Selectivity patterns were assumed to be constant over time for each fishery and survey.

3.6 Retention

Retention curves were used to account for discards that resulted from the implementation of minimum size limits, changes in recreational bag limits and seasons, and the Individual Fishing Quota (IFQ) program. The retention function in SS3 is specified as a four parameter logistic function. The inflection point parameter that describes the size at which 50% of a size class is retained, the standard deviation parameter, the asymptote parameter which describes the maximum proportion retained above a particular size class, and a male offset parameter that was not used. Retention functions changed over time as the size limits changed.

The first minimum size limit for the commercial fleets was implemented in 1990. Prior to 1990, there was no minimum size limit for any of the fleets. In 1990, a minimum size limit of 20 inches (50.8 cm TL) was implemented. The minimum size limit was increased from 20 to 24 inches (60.96 cm TL) in June 2000. In 2012, the minimum size limit was decreased from 24 inches to 22 inches (55.88 cm TL). In 2010, the GMFMC implemented an Individual Fishing Quota (IFQ) program to manage the commercial gag grouper fishery.

Time blocks on the retention curves for the commercial fleets were specified to create separate retentions curves for five time periods: 1963-1989, 1990-2000, 2001-2011, and 2012-2015. For the period of 1963-1989, it was assumed that effective size limit (inflection of retention curve) was 16 inches (40.64 cm TL) and the slope of the retention function was 5. For the time periods 1990-2000, 2001-2011, and 2012-2015 the retention function was fixed to be knife-edged (slope=1) at the size limit (20 and 24 inches TL, respectively). The asymptote was fixed at 1(i.e. all fish above the size limit retained) for 1990-1999 and 2000-2010. The asymptote of the retention function was estimated using a single parameter for 2011-2015. This was done to represent the implementation of the IFQ program.

The recreational fleets for gag grouper are managed using a combination of size limits, bag limits, and seasonal closures. The first management regulations were implemented in 1990. A minimum size limit of 20 inches (50.8 cm TL) and a bag limit of 5 fish per person per day were implemented in 1990. In June

2000, the minimum size limit was increased to 22 inches (55.88 cm TL). In 2005, a seasonal closure (February 15-March16) was implemented in an attempt to reduce fishing pressure on gag grouper during the spawning season. In 2007, the bag limit was decreased from 5 fish per person per day to 2 fish per person per day. In 2009, the seasonal closure was extended an additional month (February 1-March 31). In 2011, the GMFMC closed the gag grouper recreational fishery. It was eventually re-opened for 61 days. The recreational fishery was open for 123 days in 2012 and 156 days in 2013, 2014, and 2015.

Time blocks on the retention curves for each of the recreational fleets were specified to create separate retention curves for four time periods: 1963-1989, 1990-2000, and 2001- 2015. Data on recreational discards from MRFSS/MRIP starts in 1981 and shows that some discarding did occur prior to the implementation of management regulations. For the period of 1963-1989 the slope of the retention function was fixed at 5 and the inflection was estimated. For the time periods 1990- 1999 and 2000-2009, the retention function was assumed to be knife-edged (slope=1) at the size limit with an asymptote of 1. For the 2010-2012 time block, the retention function was assumed to be knife-edged (slope=1) at the size limit but the asymptote was estimated by the model. This was done to account for the reduced recreational season length. Size composition data from observer programs on headboat and charterboat vessels showed that recreational fisherman released legal gag grouper when caught outside of the fishing season during these years.

3.7 Mortality due to red tide

Red tide mortality was modeled as a fishing fleet. The red tide fleet was specified as a bycatch only fleet and therefore did not require catch data. An index of fishing effort was input for this fleet that consisted of a time series of all zeroes and a 1 for 2005, which allowed for red tide mortality only in 2005. A catchability coefficient (q) was estimated to scale fishing effort. No discards were input into the model; instead the model used information from data sources already in the model to scale red tide removals. The selectivity of the red tide fleet was set to 1 for ages 1-31, implying that ages 1-31 were fully vulnerable to red tide mortality. Modeling red tide mortality as a fishing fleet allows for the level of mortality to be estimated by the assessment model rather than input as a fixed parameter. It also allows for the additional mortality to be decoupled from the natural mortality so that the magnitude of gag grouper killed by red tide can be estimated.

4. CONTINUITY MODEL RESULTS

4.1 Trends in SSB, Recruitment and Exploitation Rate

The trends in spawning stock biomass, recruitment, and exploitation rates from the continuity model results were similar to those from the SEDAR 33 assessment (**Figure 22**). Differences in SSB were greatest early and late in the time-series (**Figure 22a**). The estimated unfished condition of the continuity model was marginally larger than the SEDAR 33 model and the percent reduction describing the initial conditions (i.e., the recruitment offset parameter) was less resulting in a larger estimate of SSB in 1963 **(Figure 22a**). The SSB estimates of the two models were most similar between 1985 and 2010. Between 2010 and 2012, the estimates of SSB from the continuity model were less than those from the SEDAR 33 model. This corresponded to higher estimated exploitation rates later in the time-series than what was estimated by the SEDAR 33 model (**Figure 22b**).

The estimated recruitment deviations and age-0 recruits were relatively similar throughout the time series, but deviates between 2007 and 2009. During this time, the estimates of the age-0 recruits from the continuity model were less than those estimated by the SEDAR 33 model (**Figure 22c, d**). Given the selectivity pattern **(Figure 22**), the 2007-2009 recruits should have been first captured by the recreational fleets within 3-5 years. Although the composition data used by the SEDAR 33 and continuity models have evidence of a 2006-2007 cohort the additional years of data (2013-2015) in the continuity model did not support the large predicted recruitment between 2007 and 2009 predicted by the SEDAR 33 assessment model. The selectivity curves for the commercial vertical line and recreational headboat fleets were also less domed, suggesting lower cryptic biomass than what was estimated by the SEDAR 33 model (**Figure 23**).

4.2 Fits to Indices

The fits to the relative indices of abundance are shown in **Figure 24**. Overall, the fits to the indices are similar, although some important deviations are noted. The SEDAR 33 assessment model fit the increasing trend in the last few years of the headboat index (2006-2010) more closely than the continuity model (**Figure 24c).** The SEDAR 33 model also overestimated the index values and predicted a greater increasing trend in the last few years of charter survey, private, and SEAMAP video survey indices of abundance (**Figure 24d, e, g**). The continuity model fit to the SEAMAP-video index is similar to SEDAR 33, but the fits to the headboat, charter, and private relative indices of abundance differ from SEDAR 33. The continuity model fit to the headboat index underestimates the increase in the last few years. It also underestimates the increase in the charter and private indices between 2005 and 2010, but better estimates the decline in these indices in more recent years.

4.3 Red tide mortality

The highest fishing mortality was estimated to happen in 2005 for the SEDAR 33 and continuity models. This high level of mortality is associated with additional mortality due to red tide. Its effect was modeled in terms of a discard fishery and caused a substantial increase in catch in 2005. The estimated red tide mortality expressed as an exploitation rate was 0.397 and 0.39 for the SEDAR 33 and the continuity models, respectively (**Table 4**). This corresponded to removals of ~3.4 million and 3.2 million gag in 2005.

The terms of reference for this update assessment indicate that the potential effects of red tide should be re-evaluated with consideration of past red tide events and those of 2014 and 2015. Sensitivity runs with red tide events in 2005 and 2014 and 2005 and 2015 were completed.

The estimated mortality due to red tide was higher in 2005 when the model allowed for a red tide event in 2014 or 2015 in the model (**Table 4**). The continuous mortality estimate was ~0.99 in 2005 and 2014 and the exploitation rates were 0.493 y^{-1} and 0.563 y^{-1}. This resulted in approximately 5.1 million and 4.2 million gag removals due to red tide in 2005 and 2014, respectively. The continuous mortality estimate was ~0.81 in 2005 and 2015 and the exploitation rates were 0.425 y^{-1} and 0.492 y^{-1}. This resulted in approximately 6.7 million and 10.4 million gag removals due to red tide in 2005 and 2015, respectively.

The fits to the indices improved with the inclusion of red tide in 2014 and in 2015. The root mean square error values were generally lower than those from the continuity model (

Table 5). It was interesting that the fit to truncated indices with terminal years before 2014 improved. This may indicate that the addition of red tide mortality is accounting for unexplained variation in the model.

4.4 Continuity Model Diagnostics

Appendix D includes all model fit comparisons.

4.4.1 Jitter analysis

Model convergence of the update model was evaluated using jitter analysis. The jitter analysis perturbs the initial values so that a broad range of parameter values along the likelihood surface are used as starting values. This ensures that the model converged to a global solution rather than a local minima. Starting values of all estimated parameters were randomly perturbed by 10% and 50 trials were run.

The results indicate that there is trade-off between the ability to fit the index/survey data and fitting the discard data. **Figure 25** shows a comparison of the assessment results from the continuity run and the jitter run with the lowest likelihood. The estimates of SSB, exploitation rates, age-0 recruits, and recruitment deviations were similar for the majority of the time-series. SSB was estimated to decline after 2012 by the jitter run and was less than the SSB estimated by the continuity model for 2013-2015 (**Figure 25a**). This corresponded to an increase in exploitation, which was higher than the estimated exploitation by the continuity model (**Figure 25b**). The jitter run with the largest discard likelihood and the lowest total likelihood, resulted in overestimating the charter discards in the last five years of the time-series **(Figure 26a**). The overestimated points cannot be seen because the observations are overestimated by above 5 million discards; whereas, the observations were between 74,000 in 2014 and 231,000 in 2012. This overestimation was due to a retention function that indicated 1% of gag grouper above the size limit were retained (**Figure 26b**). Although gag grouper above the size limit are discarded this retention relationship seems unlikely.

4.4.2. Retrospective analysis

A retrospective analysis was carried out for the continuity model and a pattern was obvious with each peel of the new data. The estimates of SSB increased with each retrospective peel of a single year of data (**Figure 27).** A pattern was also seen in the estimated age-0 recruits (**Figure 27**). The estimated age-0 recruits in 2007 declined with each retrospective peel. The analysis indicates that with additional years of data the expected recruitment signal loses strength and results in lower estimates of SSB.

A retrospective analysis was conducted to determine whether the recruitment signal in 2007 was the main cause of the retrospective pattern. This was done by reading in the time-series of recruitment deviations estimated by the full continuity model. These values were fixed so that with each retrospective peel the remaining time-series remained unchanged. The retrospective pattern was minimized in SSB (**Figure 28**).

Mohn's ρ is a common statistic used to measure the relative difference between the estimated value from a reduced model and the full model. The ρ value from the continuity model was 0.68, whereas the value from the continuity model with fixed recruitment deviations was 0.06. The simulation results from Hurtado-Ferro et al. (2014) suggest that for retrospective patterns with ρ values greater than 0.2 should be addressed explicitly in the model. Retrospective patterns can be the result of over-parameterization, misspecifying time-variant relationships (e.g., specifying selectivity as time-invariant), etc. These issues should be examined during the next gag grouper benchmark assessment.

4.5. Continuity Projections and Stock Status

The reference points agreed upon by the GMFMC SSC for the SEDAR 33 gag grouper assessment were F_{max} and SSB_{Fmax}, where SSB was defined to include only female biomass. The same definition of SSB and the same reference points were used for this update assessment. **Figure 29** shows the yield-per recruit curves used to determine F_{max} for the continuity model and the retrospective models. The maximum fishing mortality threshold (MFMT) is defined as F_{max} and the minimum stock size threshold (MSST) was defined as $(1\text{-}M)SSB_{Fmax}$. $F_{current}$ was calculated as the geometric mean of the last three years of the assessment (i.e., 2013-2015).

Projections were run to evaluate stock status and provide OFL advice. Projections were run assuming that selectivity, discarding, and retention were the same as the three most recent years (2013-2015). Forecast recruitments are derived from the model estimated Beverton-Holt stock-recruitment relationship, based on the recent time period (i.e., 1984-2015). The catch allocation among fleets used for the projections reflects the average distribution of fishing intensity among fleets.

Comparisons of the current fishing mortality and MFMT indicate the stock is not experiencing overfishing and comparisons of the current SSB and MSST indicate the stock is not overfished (

Table 7). The management advice from the retrospective models provided similar status determinations. Each model was marginally more optimistic with the removal of a single year of data and indicated that the gag grouper population was not experiencing overfishing and was not overfished (

Table 7). The retrospective models also have higher OFL streams than the full continuity model. This result suggests that we have consistently overestimated SSB and the allowable catch in recent years and the stock status may have not been as healthy as we previously estimated.

Table 8 and **Figure 30** compare the SSB and exploitation rate time series to MSST and MFMT for the continuity model. Gag grouper have been overfished for the majority of the time-series (1966-1999, 2002-2003, and 2006-2011). In recent years, the model indicates that the gag grouper population has not been overfished. Similarly, gag have experienced overfishing over the majority of the time-series (1974-2010), but have not been experiencing overfishing since 2010 (**Table 8** an**d Figure 30b**). These stock status outcomes are similar to those from the SEDAR 33 assessment. The SEDAR 33 SSB estimates were more optimistic later in the time-series (i.e., 2007-2012) than the continuity model (**Figure 30a**). The trends in exploitation rates were more similar (**Figure 30b**).

5. ALTERNATIVE MODEL

5.1 Alternative Model Parameterization

The jitter analysis of the continuity model showed a trade-off in the model fit to the relative index of abundance data and discard data. Fleet and time-specific retention functions were used to model size-based discarding in the SEDAR 33 and continuity models. The parameter that specified the asymptote of the retention function was freely estimated in the last time block of the SEDAR 33 and continuity models to account for discarding of gag grouper larger than the size limit. This parameter describes the proportion of captured fish above a certain size that will be retained. Fleets with length composition data from retained and discarded catch can better inform the estimation of the asymptote of the retention function than those with retained catch alone. Length composition data from the retained and discarded components of the catch was available for all fleets except the private recreational fleet. The available length composition data for the private fleet were only from retained catch.

A minor modification was made to the continuity model to increase parsimony of the model while working within the spirit of an update assessment. Given the evidence of discarding gag grouper above the size limit for the headboat and charter fleets, and the lack of discard length composition data from the private fleet, the model was modified so that the retention of the private fleet mirrored headboat retention. This allowed us to retain the assumption that retention was below 100% in the later time block for the private fleet, but the estimation was better informed by data. The decision to mirror the retention of the headboat fleet was based on expert judgement that the private fleet would operate more similarly to the headboat fleet than the charter fleet.

5.2 Alternative Model Results

The estimated SSB, exploitation rates, and recruitment from the continuity and alternative models are compared in **Figure 31**. Unfished SSB and recruitment was estimated to be higher for the alternative model than the continuity and the recruitment offset was estimated to be lower (-1.5 or 22%) for the alternative model than the continuity model (-1.07 or 34%) **(Table A.1**, **Figure 31a, c**). The estimated SSB trends were similar between the models from the mid-1970s until 2011, where the continuity model estimate of SSB continued to increase and the estimated SSB from the alternative model declined (**Figure 31a**). The estimated exploitation rates were similar for the majority of the time-series, but deviated in 2008 - 2015, where the estimated exploitation rate by the alternative model was higher than the estimated exploitation rate of the continuity model (**Figure 31b**). Estimated recruitment was similar for the majority of the time period, but the estimated recruitment from the alternative model was greater between 2000 and 2010 than the estimated recruitment from the continuity model **(Figure 31c**).

The estimated red tide mortality expressed as an exploitation rate was $0.313y^{-1}$ (**Table 4**). This resulted in 3.24 million dead gag grouper. The estimated exploitation rate was lower than the rate estimated by the continuity model, but resulted in a similar magnitude of dead gag grouper (3.21 million estimated by the continuity model).

5.3 Alternative Model Diagnostics

The R.M.S.E values for the individual relative indices of abundance for the alternative model are shown in

Table 9. There was a trade-off in the fit to the relative indices of abundance between the continuity model and the alternative model. The R.M.S.E values were higher for the commercial vertical line, commercial longline, and headboat for the alternative model than the continuity model, indicating poorer fit. The R.M.S.E values were lower for the fishery-independent indices, the charter survey index, and private recreational index for the alternative model than the continuity model, indicating better fit. The commercial vertical line, commercial longline, and headboat indices are truncated at 2009 and 2010. The SEAMAP video, PC video, charter survey, and private recreational indices are continuous through 2015 and exhibit declining trends in recent years **(Figure 24d, e, g, h**). The improved fit to this latter group of indices helps to explain the declining trend in SSB estimated by the alternative model.

A jitter analysis was conducted on the alternative model. The results are shown in

Table 10. The trade-off between the fit to the relative indices of abundance and the discard data is not apparent in these results. In general, the likelihood of the discards is lower than the likelihood of the relative indices of abundance. This is likely due to the poor fit to the commercial vertical line, commercial longline, and headboat indices.

A retrospective analysis was carried out for the alternative model. A retrospective pattern was obvious with each peel of the new data; similar to the retrospective analysis of the continuity model. The estimates of SSB increased with each retrospective peel of a single year of data (**Figure 32**). A pattern was also seen in the estimated age-0 recruits (**Figure 32**). The estimated age-0 recruits in 2007 declined with each retrospective peel similar to the retrospective analysis of the continuity model. The Mohn's rho statistic was 0.46 for the alternative model, which was less than the Mohn's rho statistic for the continuity model, 0.68. Although this is an improvement, the systematic overestimation of SSB with each data peel would lead to a more optimistic view of the gag grouper population and higher OFL streams.

The yield-per recruit curve used to determine F_{max} for the alternative model is shown in **Figure 33**. Comparisons of the current fishing mortality and MFMT indicate the stock is experiencing overfishing and comparisons of the current SSB and MSST indicate the stock is overfished (

Table 7). The annual estimates of SSB and annual exploitation rates from the alternative model relative to MSST and MFMT are shown in **Table 8** and **Figure 33**. These comparisons indicate that gag grouper have been overfished since 1963 and have experienced overfishing over the majority of the time-series.

Given that the stock status of gag grouper from the alternative model was overfished, rebuilding projections were done. The SPR equivalent of F_{max} from the alternative model was $SPR_{29\%}$. Projections were done to determine the OFL advice that would allow the gag population reach $SPR_{29\%}$ in 10 years. Table 12 shows the OFL advice from the rebuilding projection for several time-periods. The shortest time to reach and exceed $SPR_{29\%}$ was 6 years. The OFL advice from this scenario was considerably more restrictive than the other scenarios.

6. CONCLUSIONS

The assessment outcomes of the continuity model were similar to the SEDAR 33 benchmark assessment. Concern was expressed by fishermen after SEDAR 33 that the rapid increase in SSB seemed unreasonable given their catch rates. The increase in SSB in the continuity model was not as rapid as the SEDAR 33 trajectory, but the model predicts more of an increase than would be expected given the declining trends in the relative indices of abundance that continue through 2015. This, in combination with jitter results that illustrate the trade-offs in the data and the retrospective pattern indicate that the utility of management advice resulting from this model should be carefully evaluated.

The alternative model was less optimistic than the continuity model. All things considered, this was a minor modification to the model, but the impact was significant with respect to stock status. The improvement in fit to the fishery-independent indices and the temporally comprehensive fishery-dependent indices (i.e., charter and private) and the degradation in the fit to the commercial vertical line, the commercial longline, and headboat indices shows the sensitivity to the model and ultimately stock status to conflicting data sources. The jitter analysis indicated that the alternative model was more stable than the continuity model; however, the retrospective pattern was still prevalent. The persistence of the retrospective pattern may indicate that the model was over-parameterized (a total of 356 parameters were estimated) or that a time-variant mechanism was misspecified or ignored. These possibilities should be thoroughly examined during the next benchmark assessment of gag grouper.

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8. TABLES

Table 1. Commercial quota and landings statistics for 2010-2015.

Year	Quota (lbs)	Quota (MT)	Landings (lbs)	Landings (MT)	Proportion of quota
2010	1,410,000	639.57	496,826.00	225.3567508	0.35
2011	430,000	195.04	318,663.00	144.5432773	0.74
2012	567,000	257.19	523,138.00	237.2916875	0.92
2013	708,000	321.14	575,335.00	260.9678766	0.81
2014	835,000	378.75	586,377.00	265.9764495	0.70
2015	939,000	425.92	542,774.00	246.1984378	0.58

Table 2. Recreational landings in numbers (1000s) and the percent difference between the SEDAR 33 and update estimates.

	SEDAR33			Update			Percent difference		
Year	Charter	Private	Headboat	Charter	Private	Headboat	Charter	Private	Headboat
1981	22.661	189.478	14.053	25.191	194.856	14.053	11.2	2.8	0
1982	45.221	419.415	23.653	50.268	437.945	23.653	11.2	4.4	0
1983	63.039	886.797	36.322	70.075	876.487	36.322	11.2	-1.2	0
1984	28.372	237.306	17.342	31.539	225.997	17.342	11.2	-4.8	0
1985	153.110	390.541	92.463	170.200	407.950	92.464	11.2	4.5	0
1986	166.348	460.217	42.495	184.915	482.401	42.495	11.2	4.8	0
1987	33.723	376.959	32.156	103.516	356.618	32.156	207	-5.4	0
1988	65.417	548.231	26.336	72.718	574.892	26.336	11.2	4.9	0
1989	36.177	336.110	35.145	40.215	347.591	35.145	11.2	3.4	0
1990	33.086	138.999	19.097	36.897	148.574	19.097	11.5	6.9	0
1991	13.281	261.690	11.453	14.806	264.648	11.453	11.5	1.1	0
1992	45.850	205.026	13.789	51.131	212.763	13.789	11.5	3.8	0
1993	104.800	247.240	19.335	116.870	255.088	19.335	11.5	3.2	0
1994	51.703	226.921	20.561	57.658	241.128	20.561	11.5	6.3	0
1995	111.512	319.024	17.816	124.355	328.863	17.816	11.5	3.1	0
1996	103.589	253.628	16.062	115.515	268.356	16.062	11.5	5.8	0
1997	98.884	304.053	15.623	110.273	322.990	15.623	11.5	6.2	0
1998	152.660	366.230	36.316	170.236	362.697	36.316	11.5	-1.0	0
1999	132.759	421.071	32.117	147.994	443.369	32.117	11.5	5.3	0
2000	162.991	580.242	30.824	181.755	611.784	30.824	11.5	5.4	0
2001	109.513	388.076	14.494	122.124	414.746	14.494	11.5	6.9	0
2002	95.508	448.916	11.615	106.508	478.097	11.615	11.5	6.5	0
2003	100.402	425.942	16.381	111.964	454.765	16.381	11.5	6.8	0
2004	142.853	566.839	24.670	155.956	642.649	24.670	9.2	13.4	0
2005	130.750	386.364	16.784	187.013	403.984	16.784	43.0	4.6	0
2006	87.132	278.707	6.764	92.760	201.746	6.764	6.5	-27.6	0
2007	41.408	248.512	11.141	46.272	249.120	11.141	11.7	0.02	0
2008	94.983	343.288	10.521	87.177	392.243	10.521	-8.2	14.3	0
2009	49.220	164.153	9.483	50.716	191.009	9.483	3.0	16.4	0
2010	58.225	179.584	11.094	60.727	191.079	11.094	4.3	6.4	0
2011	11.026	89.946	5.099	11.422	106.424	5.099	3.6	18.3	0
2012	48.611	83.939	5.253	49.511	99.805	5.253	1.9	18.9	0
2013	-	-	-	24.217	189.218	5.276	-	-	-
2014	-	-	-	11.631	92.031	6.203	-	-	-
2015	-	-	-	15.155	81.434	3.626	-	-	-

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Table 3. Historical recreational landings in numbers (1000s) and the proportional difference between the SEDAR 33 and update estimates.

	SEDAR 33			Update			Proportional difference		
Year	Charter	Private	Headboat	Charter	Private	Headboat	Charter	Private	Headboat
1963	13.694	51.353	3.424	28.879	108.296	7.220	110.9	110.9	110.9
1964	14.791	55.465	3.698	30.289	113.583	7.572	104.8	104.8	104.8
1965	15.975	59.907	3.994	31.743	119.038	7.936	98.7	98.7	98.7
1966	17.254	64.704	4.314	33.414	125.304	8.354	93.7	93.7	93.7
1967	18.636	69.886	4.659	35.139	131.773	8.785	88.6	88.6	88.6
1968	20.129	75.483	5.032	36.920	138.450	9.230	83.4	83.4	83.4
1969	21.397	80.239	5.349	38.758	145.342	9.689	81.1	81.1	81.1
1970	22.730	85.239	5.683	40.655	152.455	10.164	78.9	78.9	78.9
1971	25.541	95.780	6.385	45.302	169.884	11.326	77.4	77.4	77.4
1972	28.692	107.594	7.173	50.120	187.950	12.530	74.7	74.7	74.7
1973	32.221	120.828	8.055	55.112	206.670	13.778	71.0	71.0	71.0
1974	36.173	135.649	9.043	60.284	226.064	15.071	66.7	66.7	66.7
1975	40.588	152.204	10.147	65.640	246.151	16.410	61.7	61.7	61.7
1976	45.608	171.031	11.402	67.200	252.000	16.800	47.3	47.3	47.3
1977	51.232	192.120	12.808	68.796	257.985	17.199	34.3	34.3	34.3
1978	57.597	215.987	14.399	70.429	264.109	17.607	22.3	22.3	22.3
1979	64.742	242.784	16.186	72.100	270.374	18.025	11.4	11.4	11.4
1980	72.362	271.357	18.090	73.809	276.784	18.452	2.0	2.0	2.0

Table 4. Estimates of continuous fishing mortality rate, exploitation rate, and the numbers of dead fish associated with red tide from different model runs.

Model	Continuous F	Exploitation rate	Dead discards (1000s)
SEDAR 33	0.70	0.397	3405.69
Continuity	0.73	0.39	3216.48
Red tide 2005 and 2014	0.986, 0.998	0.493, 0.564	5075.75, 4232.08
Red tide 2005 and 2015	0.805, 0.807	0.425, 0.492	6718.35, 10366.1
Alternative model	0.573	0.313	3243.33

Table 5. The root mean square error estimates for each index for the continuity model and the two red tide mortality sensitivity runs assuming red tide in 2005 and 2014 and 2005 and 2015.

	R.M.S.E			Percent difference from Continuity	
Fleet	Continuity	Red ride 2005 and 2014	Red tide 2005 and 2015	Red ride 2005 and 2014	Red tide 2005 and 2015
CommVL	0.521	0.499	0.515	-4.013	-1.145
CommLL	0.605	0.583	0.599	-3.779	-1.035
Headboat	0.326	0.315	0.33	-3.494	-0.979
Charter	0.587	0.543	0.568	-7.543	-3.216
Private	0.384	0.345	0.364	-10.146	-5.299
Red tide	0.00001	0.002	0.0005	27558.01	6379.76
Age-0	0.664	0.634	0.658	-4.523	-0.897
SEAMAP video	0.694	0.586	0.661	-15.533	-4.730
PC video	0.915	0.834	0.876	-8.8021	-4.211

Table 6. Jitter analysis results from the continuity model.

Label	TOTAL	Catch	Equil_catch	Survey	Discard	Length_comp	Age_comp	Recruitment
21	8487.86	1.9409	0.0552689	97.1865	258.216	6191.65	1783.59	149.613
3	8489.61	1.90761	0.0520804	96.0665	259.108	6190.97	1788.11	147.839
41	8494.68	1.96095	0.0913327	98.346	257.877	6173.27	1796.59	160.942
25	8602.69	1.88597	0.0487037	234.857	91.0678	6259.04	1882.52	128.264
1	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
13	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
14	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
15	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
16	8603.29	1.90892	0.0516596	236.424	90.7715	6258.6	1880.57	129.939
17	8603.29	1.9088	0.0515228	236.447	90.7688	6258.6	1880.61	129.887
19	8603.29	1.90891	0.0516595	236.424	90.7712	6258.6	1880.57	129.939
2	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
22	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
26	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
30	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
34	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
35	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
36	8603.29	1.90892	0.0516596	236.424	90.7713	6258.6	1880.57	129.939
4	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
42	8603.29	1.90892	0.0516595	236.424	90.7715	6258.6	1880.57	129.939
44	8603.29	1.90892	0.0516598	236.424	90.7713	6258.6	1880.57	129.939
45	8603.29	1.90887	0.051658	236.425	90.7686	6258.6	1880.57	129.941
46	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
47	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
5	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
50	8603.29	1.90892	0.0516593	236.424	90.7713	6258.6	1880.57	129.939
6	8603.29	1.90892	0.0516597	236.424	90.7713	6258.6	1880.57	129.939
7	8603.29	1.90892	0.0516597	236.425	90.7714	6258.6	1880.57	129.939
24	8603.3	1.90893	0.0516584	236.433	90.7711	6258.6	1880.57	129.938
23	8603.31	1.90833	0.0517006	236.467	90.7666	6258.58	1880.59	129.931
12	8603.34	1.90749	0.0514436	236.376	90.6676	6257.96	1881.57	129.786
10	8603.36	1.90884	0.0516428	236.479	90.7693	6258.62	1880.58	129.926
18	8603.36	1.90884	0.051643	236.479	90.7693	6258.62	1880.58	129.926
39	8603.36	1.90884	0.0516431	236.479	90.7696	6258.62	1880.58	129.926
40	8603.36	1.90884	0.0516423	236.479	90.7692	6258.62	1880.58	129.925
48	8603.36	1.90886	0.0516442	236.478	90.7694	6258.62	1880.58	129.927
8	8603.36	1.90884	0.0516427	236.479	90.7693	6258.62	1880.58	129.926
9	8609.94	1.93481	0.0744782	237.868	90.9408	6243.77	1891.03	139.25
31	8642.37	2.07782	0.0643443	244.353	139.543	6239.08	1876.29	135.268
32	8642.37	2.07783	0.0643457	244.353	139.544	6239.08	1876.29	135.269
20	8690.89	2.01404	0.0661043	228.04	125.642	6263.49	1922.92	141.787
29	8737.83	2.45318	0.0734619	266.466	129.649	6275.9	1917.26	139.674
43	8928.59	2.77848	0.0719883	188.535	198.636	6528.71	1857.01	145.197

49	8989.16	1.49023	0.0106752	311.89	87.4179	6543.58	1965.99	74.0628
28	9022.3	2.59743	0.0437232	264.694	115.253	6396.06	2114.13	123.798
33	1011960	74418.5	2532.86	845732	1473.32	37953.7	48134.7	1700.98
27	5104360	2122180	2016.86	2745660	17980.2	127444	87700.9	1372.78
37	5109910	3981040	8745	711569	10390.7	206728	190159	1183.03
11	11157200	2725740	5212.12	8093210	19701.2	118294	194478	539.649

Table 7. Management advice table from the continuity model and retrospective models.

		Model			
		Continuity	2014peel	2013peel	Alternative
Criteria	**Definition**				
Base M		0.134	0.134	0.134	0.134
Steepness		0.855	0.855	0.855	0.855
Virgin Recruitment	1000s	5030.8	5262	5561	8958
SSB unfished	Metric tons	24908	25957	27486	43726
	Mortality rate criteria				
Fmsy or proxy	Fmax	0.1964	0.1633	0.167	0.097
MFMT	Fmax	0.1964	0.1630	0.167	0.097
Fcurrent	F (nyr-3)-nyr (geometric mean)	0.0817	0.074	0.069	0.414
Fcurrent/MFMT		0.416	0.455	0.413	4.268
	Biomass criteria				
SSBmsy	SSB at Fmax	7171	8679	8438	12780.3
MSST	(1-M)*SSBmsy	6210.1	7516.0	7307.6	11067.7
SSBcurrent	SSB2015	9688.07	12578.8	12941.4	3505.51
SSBcurrent/MSST	SSB2015	1.56	1.67	1.77	0.32
	Annual yield at MFMT (Metric tons)				
OFL	OFL 2017	2122.93	2256.67	2389.35	84.246
	OFL 2018	1968.94	2076.07	2310.96	106.767
	OFL 2019	1894.62	2025.34	2267.15	155.782
	OFL 2020	1878.04	2008.57	2237.18	219.317
	OFL 2021	1870.46	1999.72	2213.64	282.455

Table 8. Time-series comparison of SSB and MSST and exploitation rate and MFMT for the continuity model.

	SSB	SSB/MSST	F	F/MFMT
1963	7119.27	1.15	0.05	0.28
1964	6838.20	1.10	0.07	0.34
1965	6444.53	1.04	0.08	0.40
1966	5889.07	0.95	0.08	0.40
1967	5049.51	0.81	0.08	0.39
1968	4128.68	0.66	0.09	0.45
1969	3215.77	0.52	0.11	0.54
1970	2375.52	0.38	0.12	0.59
1971	1698.84	0.27	0.13	0.68
1972	1181.25	0.19	0.16	0.84
1973	814.27	0.13	0.17	0.85
1974	598.59	0.10	0.19	0.97
1975	513.41	0.08	0.20	1.03
1976	628.45	0.10	0.18	0.94
1977	1334.46	0.21	0.18	0.91
1978	2981.53	0.48	0.18	0.93
1979	3929.03	0.63	0.22	1.12
1980	4037.26	0.65	0.23	1.15
1981	3872.89	0.62	0.20	1.03
1982	3995.55	0.64	0.26	1.30
1983	3795.96	0.61	0.31	1.58
1984	3673.61	0.59	0.18	0.90
1985	4419.62	0.71	0.29	1.50
1986	4342.13	0.70	0.28	1.42
1987	4170.63	0.67	0.22	1.14
1988	4214.95	0.68	0.25	1.29
1989	4273.78	0.69	0.24	1.23
1990	3954.13	0.64	0.22	1.14
1991	3544.13	0.57	0.24	1.22
1992	3160.24	0.51	0.23	1.16
1993	3620.58	0.58	0.30	1.52
1994	3369.42	0.54	0.25	1.29
1995	3211.74	0.52	0.29	1.48
1996	3152.70	0.51	0.23	1.19
1997	4270.91	0.69	0.23	1.15
1998	4960.09	0.80	0.28	1.41
1999	5093.42	0.82	0.25	1.26
2000	6604.48	1.06	0.30	1.52
2001	6748.16	1.09	0.31	1.57
2002	5942.71	0.96	0.31	1.58

2003	6121.60	0.99	0.28	1.41
2004	6766.58	1.09	0.36	1.82
2005	6227.89	1.00	0.79	4.04
2006	2755.04	0.44	0.35	1.78
2007	2547.31	0.41	0.34	1.74
2008	2349.48	0.38	0.44	2.25
2009	1985.83	0.32	0.22	1.13
2010	3052.82	0.49	0.16	0.84
2011	4698.15	0.76	0.09	0.47
2012	6419.26	1.03	0.11	0.56
2013	7812.83	1.26	0.12	0.61
2014	9139.19	1.47	0.07	0.36
2015	9688.07	1.56	0.06	0.33

Table 9. The root mean square error estimates from the continuity model and the alternative model.

	R.M.S.E	
Fleet	Continuity model	Alternative model
CommVL	0.521	0.532
CommLL	0.605	0.619
Headboat	0.326	0.352
Charter	0.587	0.490
Private	0.384	0.317
Red tide	0.00001	7.51E-06
Age-0	0.664	0.623
SEAMAP video	0.694	0.527
PC video	0.915	0.738

Table 10. Jitter analysis results for the alternative model.

Run	TOTAL	Catch	Equil_catch	Survey	Discard	Length_comp	Age_comp	Recruitment
6	8732.55	2.63	0.08	149.73	146.79	6355.63	1841.50	229.71
42	8586.33	2.80	0.07	163.24	81.52	6262.35	1822.79	248.46
25	8591.94	2.76	0.07	163.87	81.38	6269.29	1823.93	245.57
39	8591.95	2.76	0.07	163.88	81.38	6269.28	1823.92	245.59
16	8591.98	2.76	0.07	163.89	81.37	6269.29	1823.93	245.59
11	8584.90	2.76	0.07	163.89	81.41	6261.77	1824.53	245.39
19	8584.90	2.76	0.07	163.89	81.41	6261.77	1824.53	245.39
23	8584.90	2.76	0.07	163.89	81.41	6261.77	1824.53	245.39
28	8584.90	2.76	0.07	163.89	81.41	6261.77	1824.53	245.39
38	8584.90	2.76	0.07	163.89	81.41	6261.77	1824.53	245.39
14	8584.91	2.76	0.07	163.90	81.41	6261.82	1824.47	245.40
8	8584.94	2.76	0.07	163.91	81.41	6261.79	1824.54	245.38
44	8584.94	2.76	0.07	163.91	81.41	6261.79	1824.54	245.38
13	8584.90	2.76	0.07	163.91	81.41	6261.78	1824.57	245.32
1	8584.93	2.76	0.07	163.92	81.42	6261.80	1824.52	245.37
33	8593.48	2.78	0.09	164.72	81.68	6244.70	1840.09	254.34
22	8593.57	2.78	0.09	164.83	81.57	6243.97	1841.03	254.22
2	8578.23	2.85	0.06	170.87	82.18	6249.64	1822.95	244.61
3	8578.23	2.85	0.06	170.87	82.19	6249.65	1822.93	244.61
5	8578.22	2.85	0.06	170.87	82.19	6249.64	1822.91	244.62
27	8578.22	2.85	0.06	170.87	82.19	6249.64	1822.91	244.62
12	8578.68	2.85	0.07	171.13	82.12	6247.49	1823.70	246.25
29	8578.64	2.86	0.07	171.24	82.16	6247.59	1823.33	246.32
7	8578.63	2.86	0.07	171.25	82.13	6247.36	1823.62	246.27
21	8578.63	2.86	0.07	171.27	82.14	6247.35	1823.62	246.26
31	8578.63	2.86	0.07	171.27	82.14	6247.35	1823.62	246.26
35	8578.63	2.86	0.07	171.27	82.14	6247.35	1823.62	246.26
36	8578.63	2.86	0.07	171.27	82.14	6247.35	1823.62	246.26
9	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.27
10	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.27
15	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.60	246.27
17	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.27
20	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.26
30	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.27
34	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.26
37	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.61	246.27
43	8578.62	2.86	0.07	171.27	82.14	6247.34	1823.60	246.27
32	8578.62	2.86	0.07	171.27	82.14	6247.32	1823.62	246.26
26	8587.18	2.88	0.09	172.15	82.39	6230.05	1839.18	255.37
41	8920.36	2.36	0.01	215.77	92.60	6515.82	1931.46	157.64
45	9420.67	3.45	0.07	236.58	91.14	7029.14	1803.41	251.42
40	9536.88	3.45	0.07	238.77	89.98	7142.50	1802.80	253.85
4	5261830.00	893359.00	5550.55	4130250.00	6631.50	83305.30	141674.00	1042.93

Table 11. Time-series comparison of SSB and MSST and exploitation rate and MFMT for the alternative model.

	SSB	SSB/MSST	F	F/MFMT
1963	8402.89	0.759	0.047	0.488
1964	8064.33	0.729	0.057	0.592
1965	7622.27	0.689	0.067	0.691
1966	7003.73	0.633	0.068	0.704
1967	6012.36	0.543	0.068	0.703
1968	4878.42	0.441	0.078	0.809
1969	3737.36	0.338	0.095	0.976
1970	2683.61	0.242	0.105	1.079
1971	1826.11	0.165	0.123	1.269
1972	1170.93	0.106	0.151	1.556
1973	716.018	0.065	0.160	1.650
1974	438.835	0.040	0.192	1.977
1975	306.695	0.028	0.193	1.994
1976	382.566	0.035	0.169	1.747
1977	1086.93	0.098	0.168	1.734
1978	3023.19	0.273	0.180	1.852
1979	4014.51	0.363	0.223	2.295
1980	4080.86	0.369	0.231	2.386
1981	3924.13	0.355	0.204	2.108
1982	4129.56	0.373	0.267	2.754
1983	3939.46	0.356	0.339	3.494
1984	3763.54	0.340	0.181	1.867
1985	4673.22	0.422	0.302	3.117
1986	4634.14	0.419	0.303	3.121
1987	4393.27	0.397	0.241	2.482
1988	4395.81	0.397	0.286	2.946
1989	4326.83	0.391	0.263	2.716
1990	3942.62	0.356	0.249	2.564
1991	3551.16	0.321	0.302	3.111
1992	3146.16	0.284	0.259	2.673
1993	3632.79	0.328	0.331	3.410
1994	3404.58	0.308	0.299	3.079
1995	3263.01	0.295	0.360	3.716
1996	3188.48	0.288	0.268	2.759
1997	4342.2	0.392	0.264	2.720
1998	5052.89	0.457	0.322	3.318
1999	5184.77	0.468	0.279	2.876
2000	6725.83	0.608	0.331	3.414
2001	6891.56	0.623	0.368	3.797
2002	6095.71	0.551	0.391	4.026

2003	6185.85	0.559		0.347	3.577
2004	6672.47	0.603		0.462	4.761
2005	5786.79	0.523		0.785	8.097
2006	2812.13	0.254		0.403	4.158
2007	2567.61	0.232		0.446	4.597
2008	2335.49	0.211		0.656	6.765
2009	1790.26	0.162		0.352	3.633
2010	2675.53	0.242		0.238	2.459
2011	4208.07	0.380		0.303	3.123
2012	4974.76	0.449		0.315	3.251
2013	5306.76	0.479		0.465	4.797
2014	4396.65	0.397		0.351	3.617
2015	3505.51	0.317		0.433	4.466

Table 12. The OFL advice in metric tons from rebuilding projections for the alternative model.

	Number of years to reach SPR29%				
Year	6	7	8	9	10
2017	17.341	45.733	63.283	79.714	84.246
2018	24.434	61.660	82.975	101.776	106.767
2019	39.723	95.868	125.384	149.644	155.782
2020	60.970	141.996	181.534	211.971	219.317
2021	84.096	190.355	239.008	274.312	282.455
2022	109.731	242.361	299.624	338.834	347.454
2023	139.132	300.967	367.229	410.133	419.104
2024	171.998	365.604	441.265	487.778	497.027
2025	206.867	433.071	517.867	567.548	576.944
2026	242.284	500.279	593.365	645.481	654.850
2027	277.124	564.935	665.112	718.802	727.963

9. FIGURES

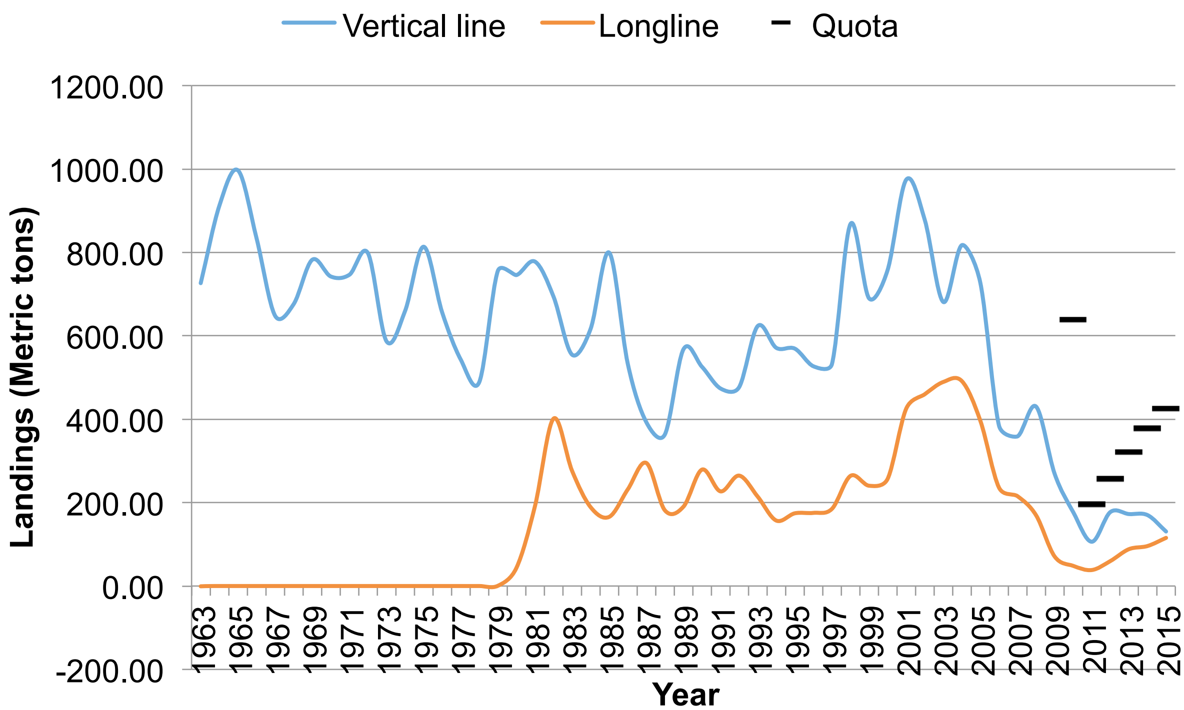


Figure 1. Commercial landings (gutted weight) in metric tons.

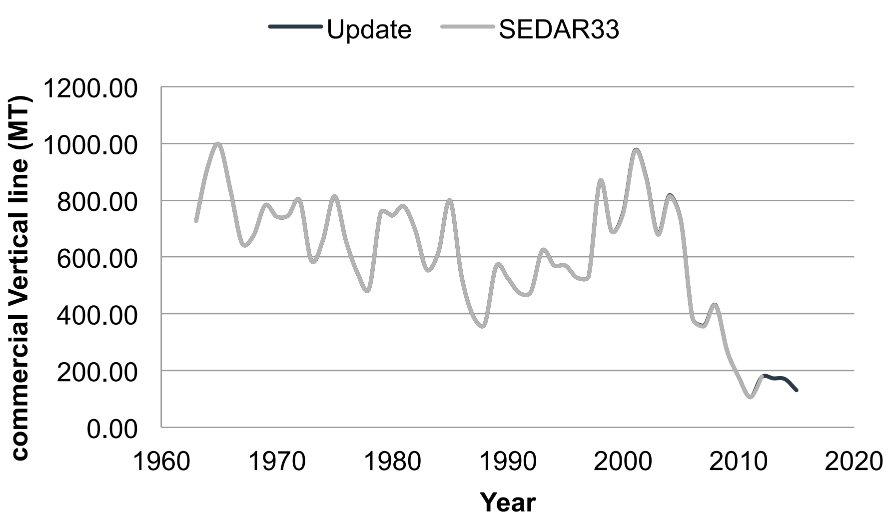


Figure 2. Comparison of the commercial vertical line landings from the update and SEDAR 33 benchmark assessments.

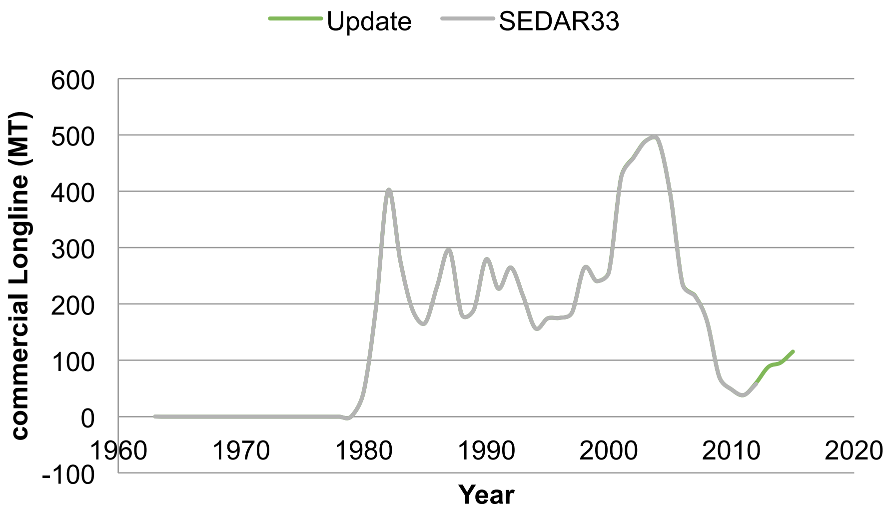


Figure 3. Comparison of the commercial longline landings from the update and SEDAR 33 benchmark assessments.

a) b)

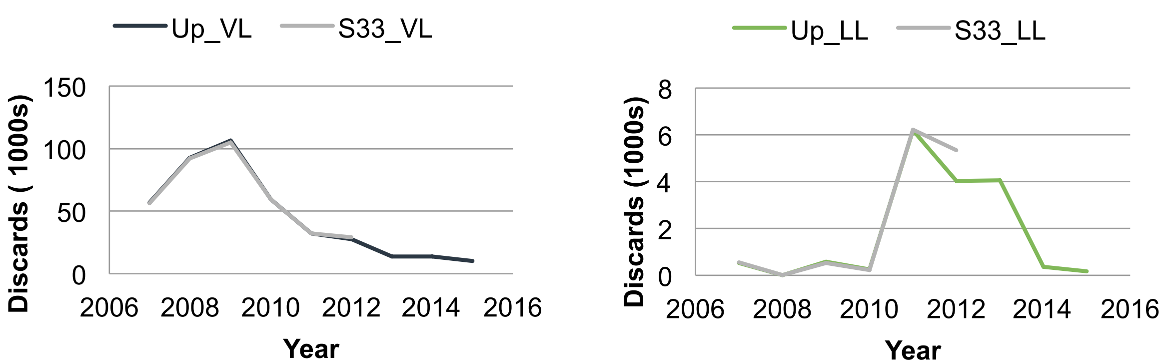


Figure 4. Comparison of the commercial vertical and longline discards from the update and SEDAR 33 benchmark assessments.

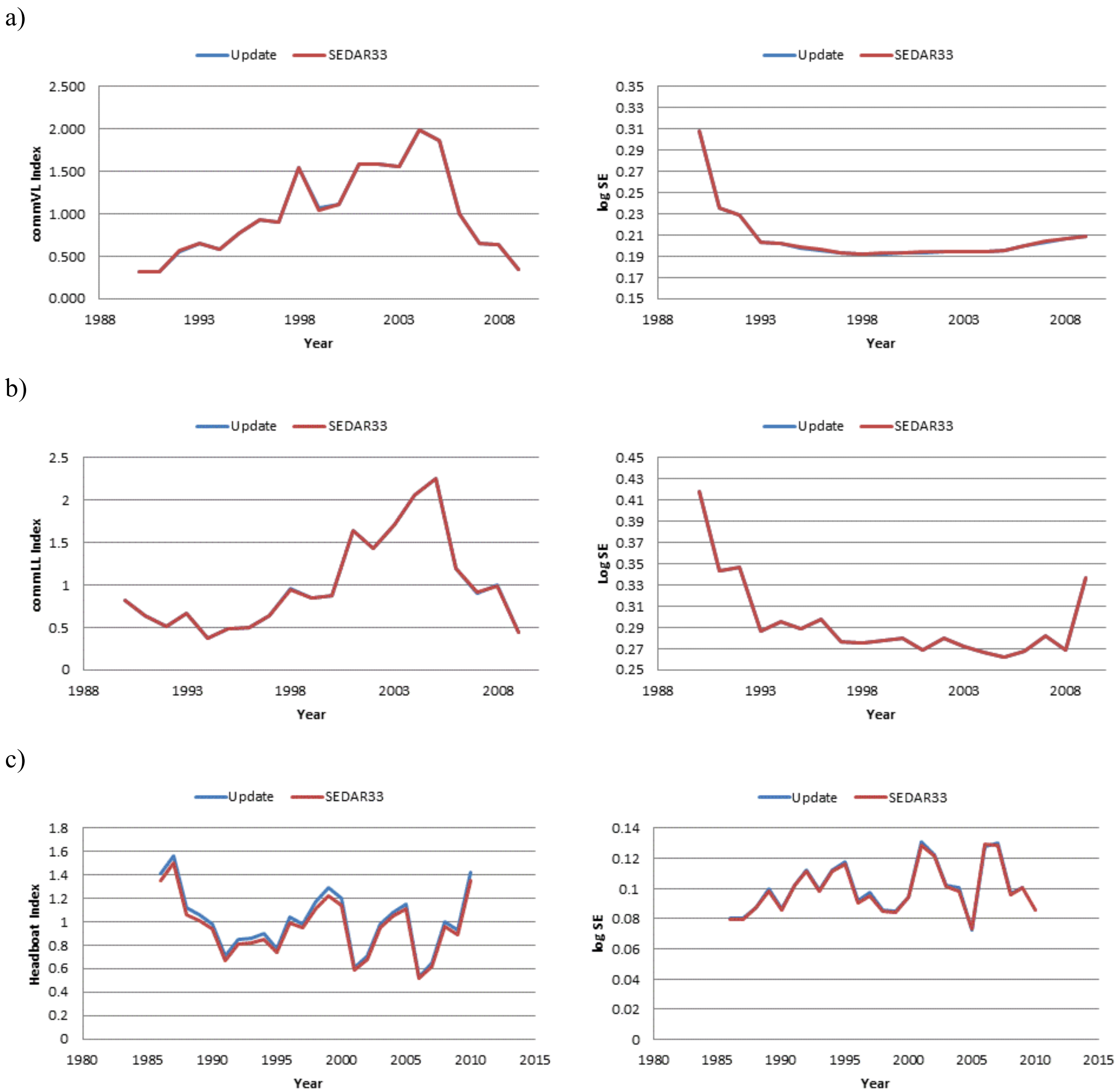
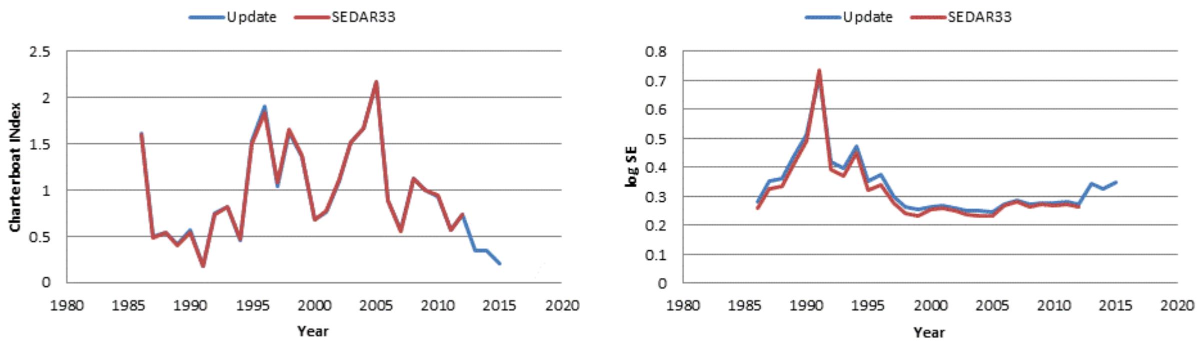


Figure 5. Comparison of the indices and the associated standard errors from SEDAR 33 and the update assessment. a) commercial vertical line, b) commercial longline, c) headboat, d) charterboat, e) private, f) age-0 survey, g) SEAMAP video survey, and h) PC video survey.

d)



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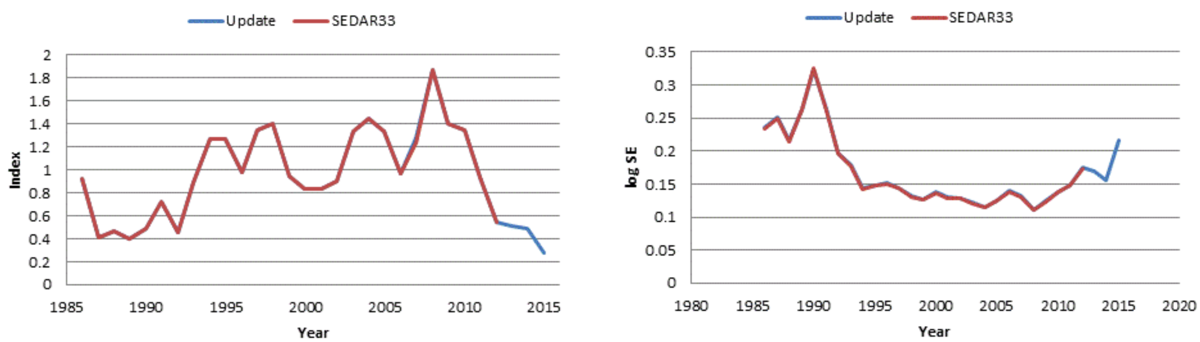

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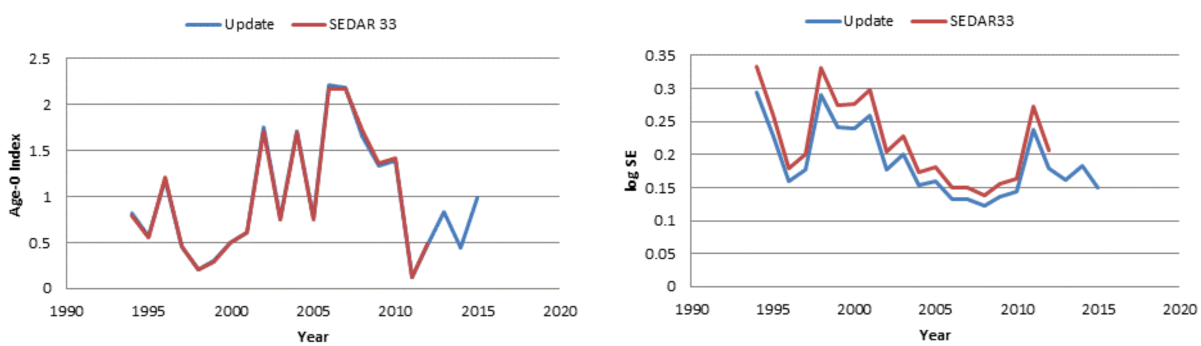
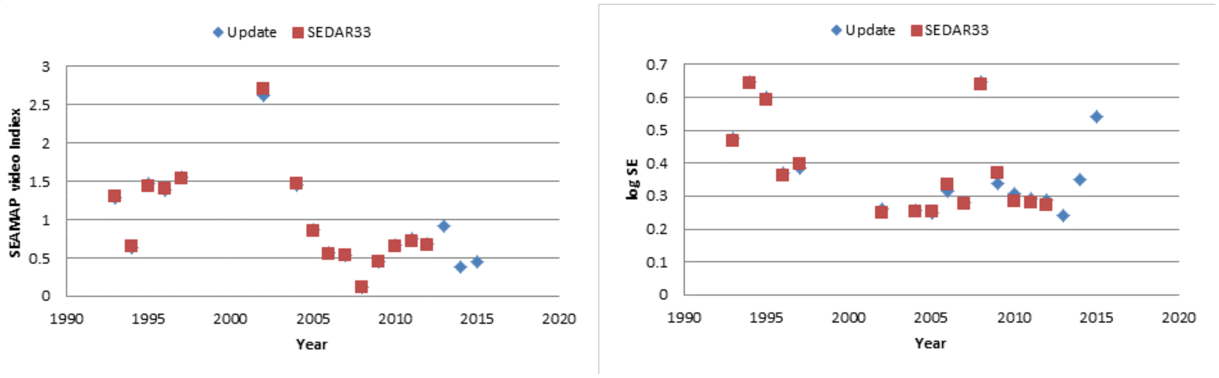


Figure 6. (continued)

g)



h)

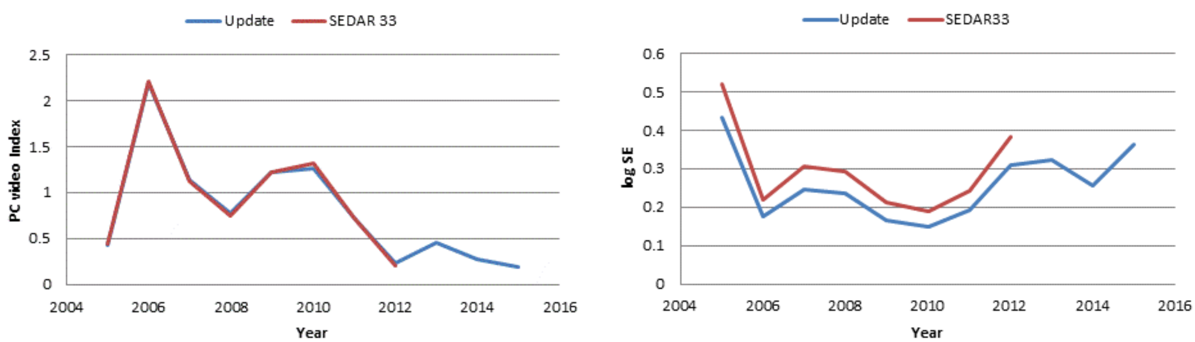


Figure 7. (continued)

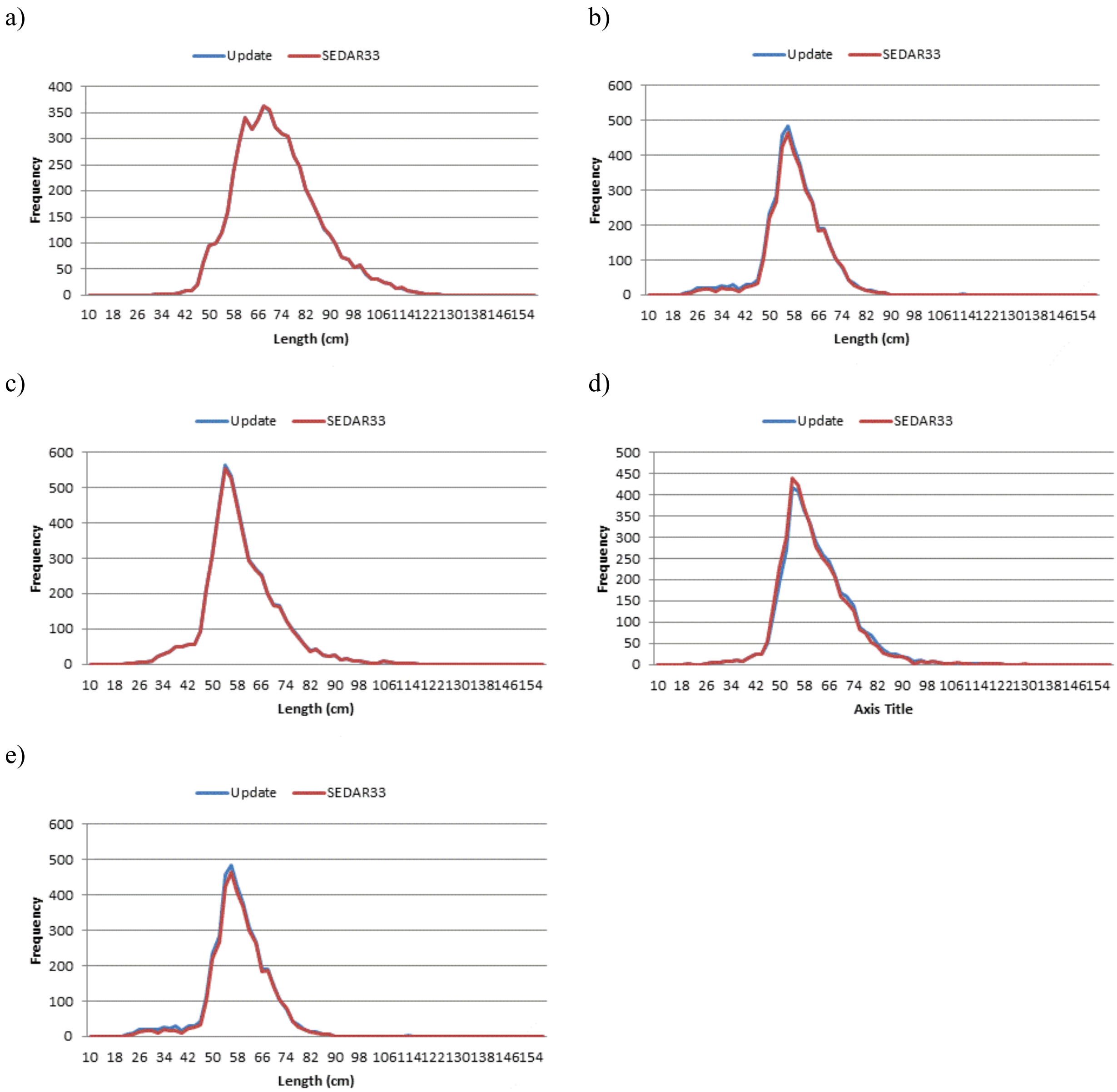
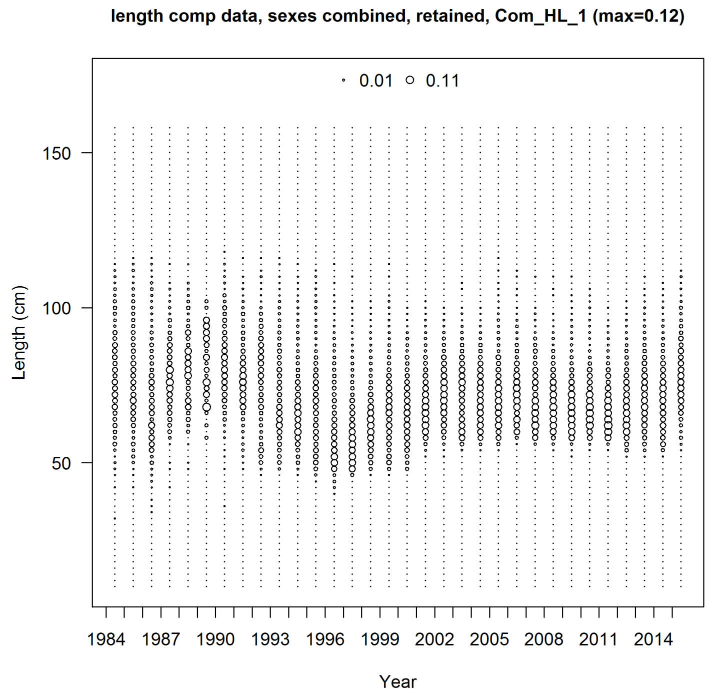


Figure 8. Length composition data of retained catch from the commercial a) vertical line and b) longline, and the recreational c) headboat, d) charter and e) private fleets. The figures do not include data from 2013-2015.

a)



b)

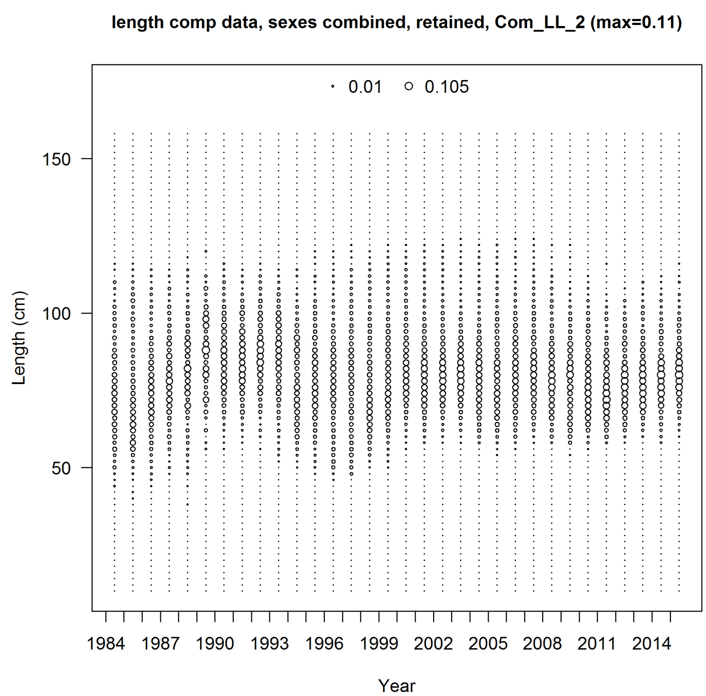


Figure 9. Annual length composition of retained catch for the commercial a) vertical line and b) longline. Size limits were implemented in 1990 (20 inches TL, 49.38 cm FL), 2000 (24 inches TL, 59.24 cm FL), and 2012 (22 inches TL, 54.31 cm FL).

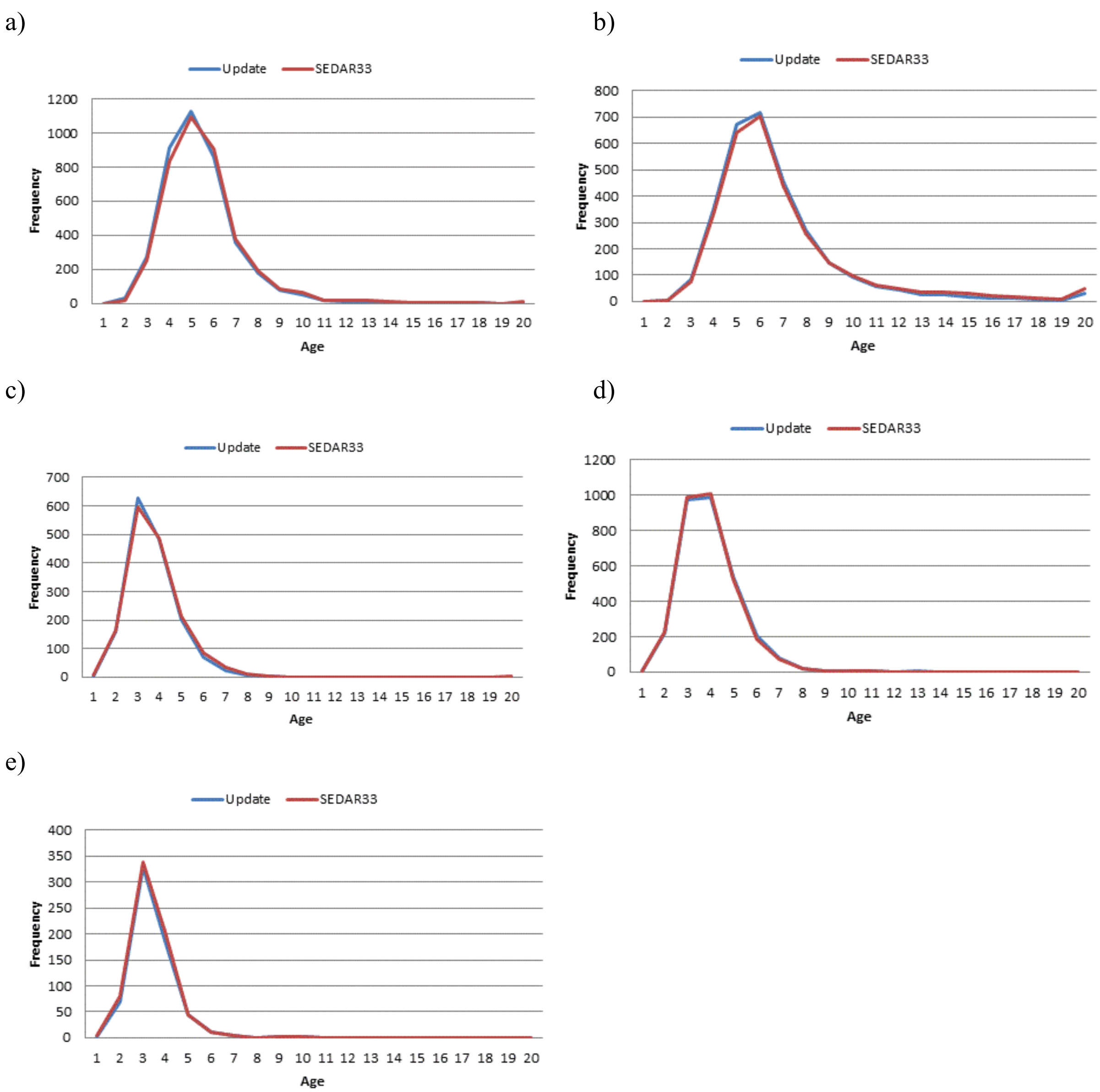
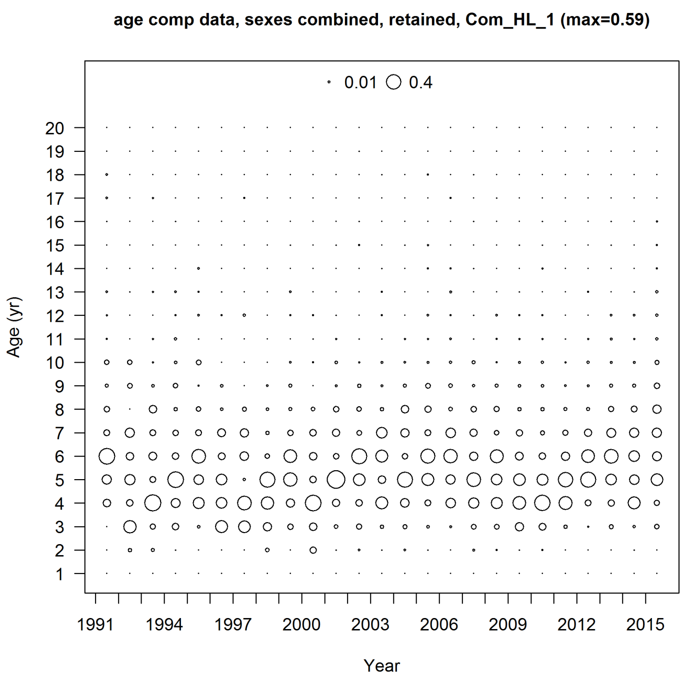


Figure 10. Age composition data of retained catch from the commercial a) vertical line and b) longline, and the recreational c) headboat, d) charter and e) private fleets. The figures do not include data from 2013-2015.

a)



b)

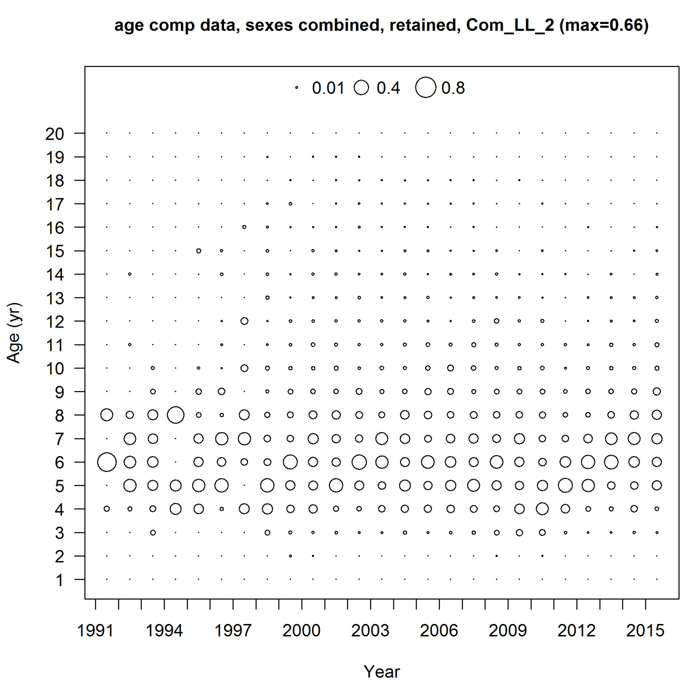
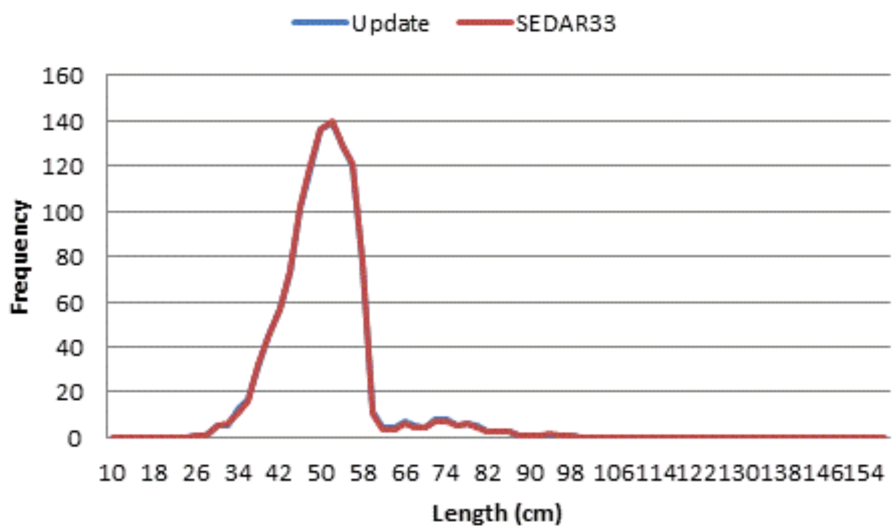


Figure 11. Age composition data from commercial a) vertical line and b) longline retained catch.

a)



b)

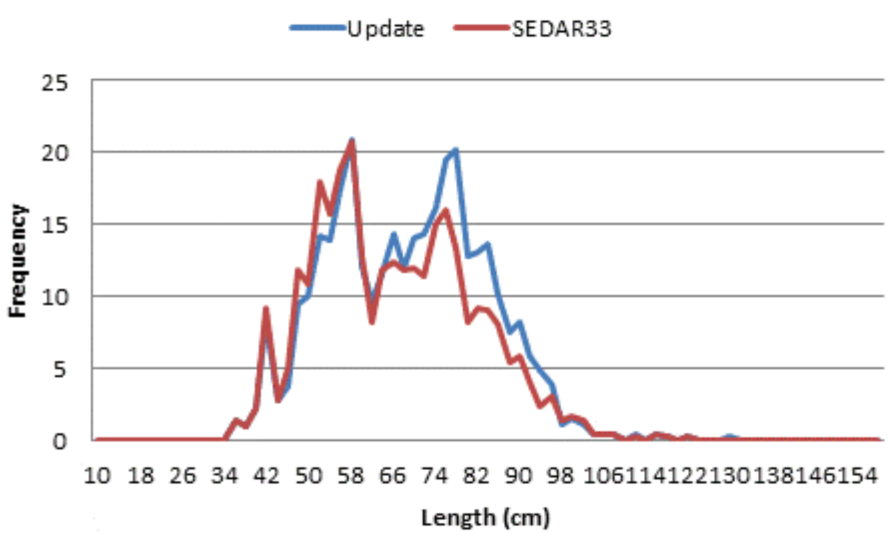
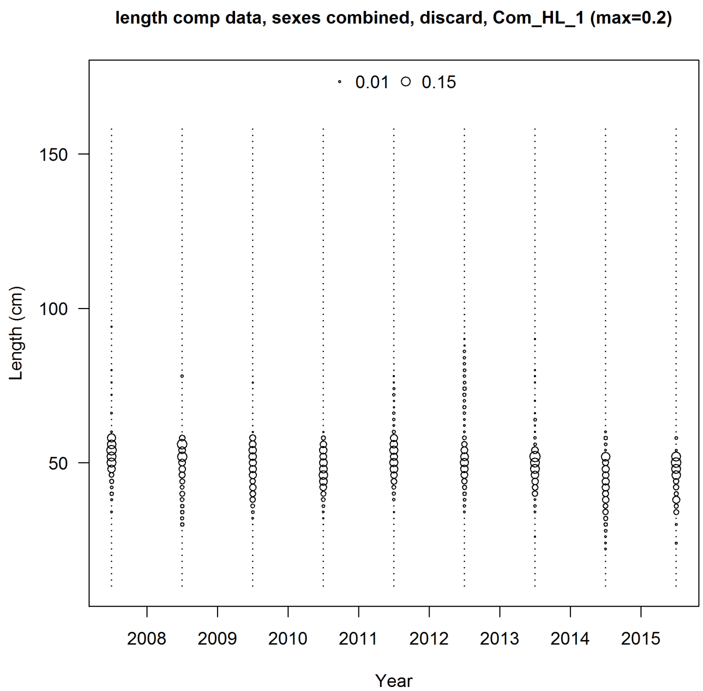


Figure 12. Length composition data of discarded gag grouper from the commercial a) vertical line and b) longline fleets.

a)



b)

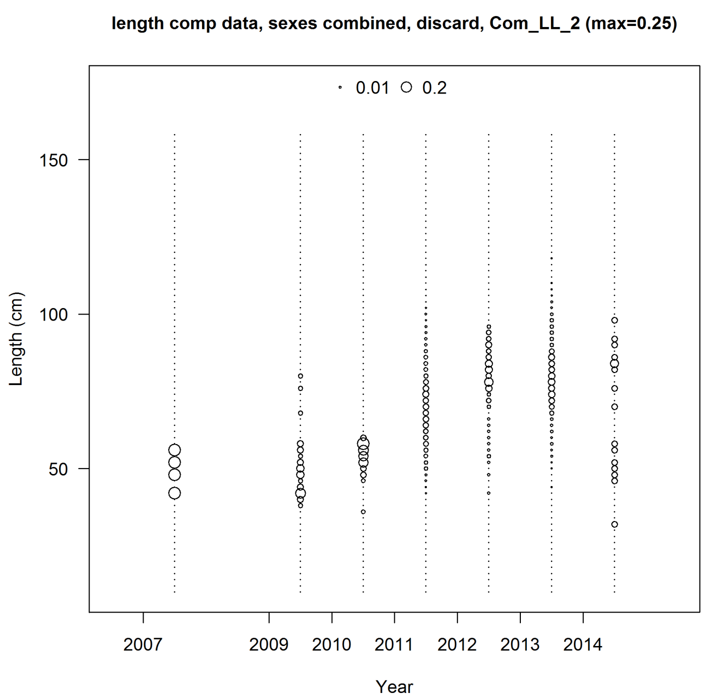
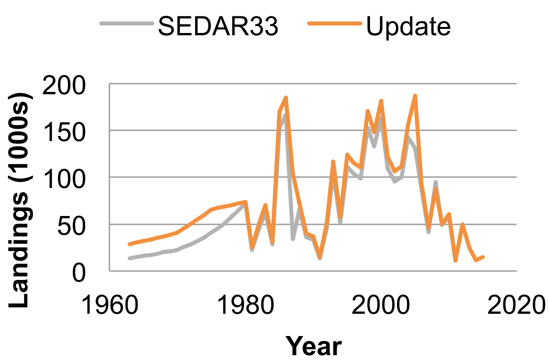
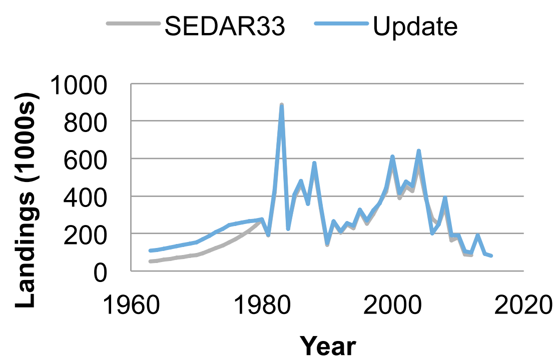


Figure 13. Length composition of discards from the commercial a) vertical line and b) longline fleets. Size limits were implemented in 1990 (20 inches TL, 49.38 cm FL), 2000 (24 inches TL, 59.24 cm FL), and 2012 (22 inches TL, 54.31 cm FL).

a)



b)



c)

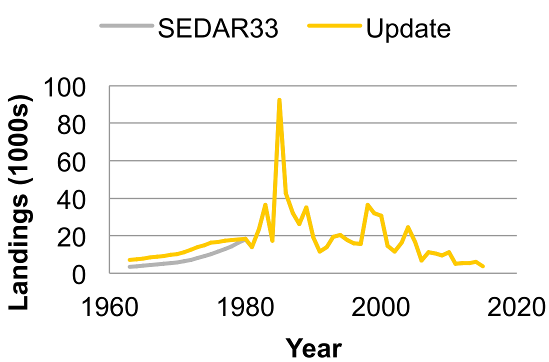


Figure 14. Comparison of landings estimates from SEDAR 33 and the update for the recreational a) charter, b) private, and c) headboat fleets.

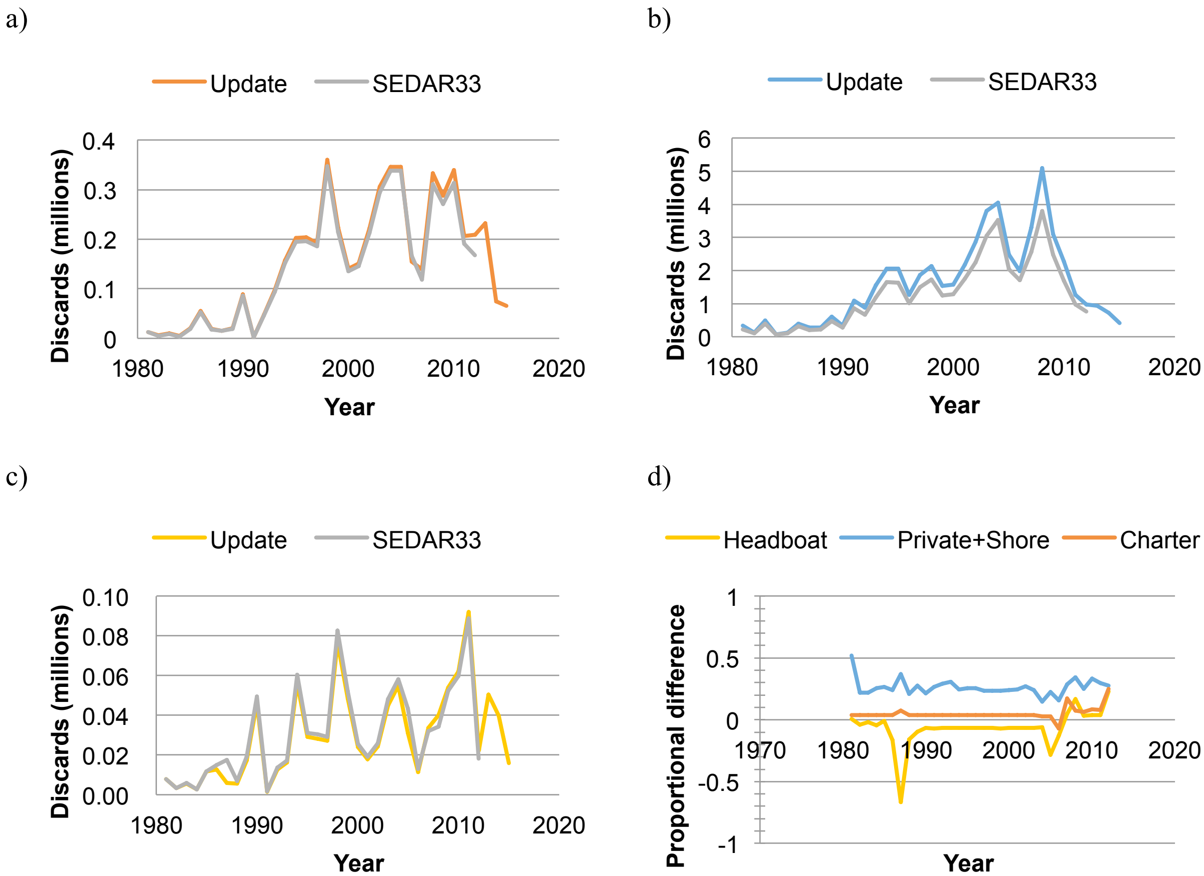
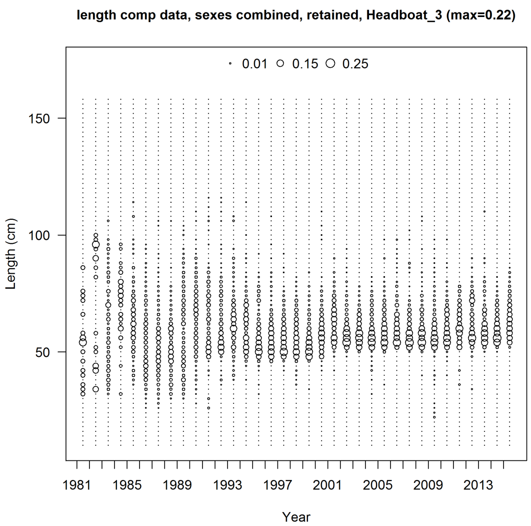
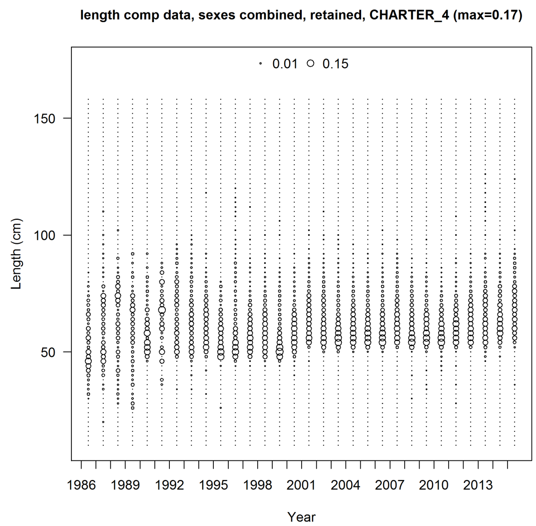


Figure 15. Comparison of recreational discard estimates from the update and SEDAR 33 assessments; a) charter, b) private, c) headboat, and d) the proportional difference.

a)



b)



c)

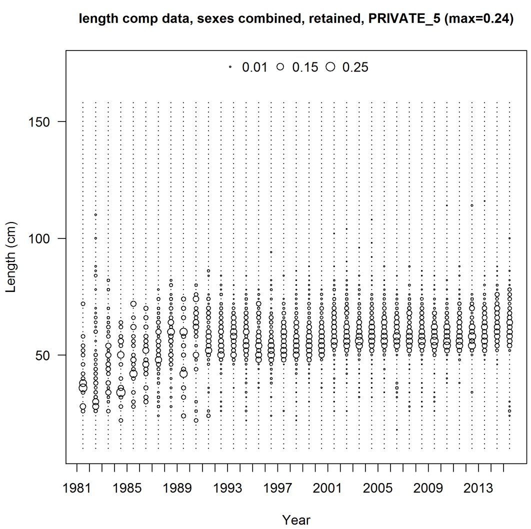
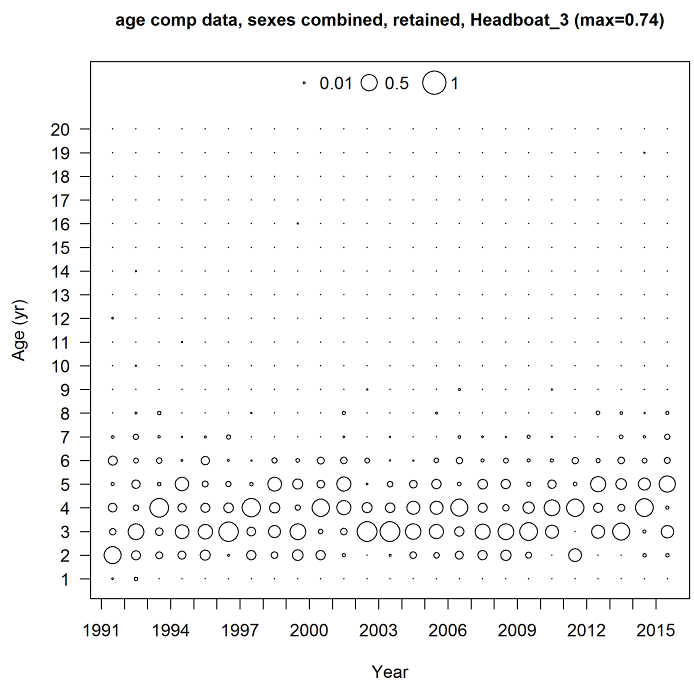


Figure 16. Length composition data of retained catch from the recreational a) headboat, b) charter, and private fleets. Size limits were implemented in 1990 (20 inches TL, 49.38 cm FL) and 2000 (22 inches TL, 54.31 cm FL).

a)



b)

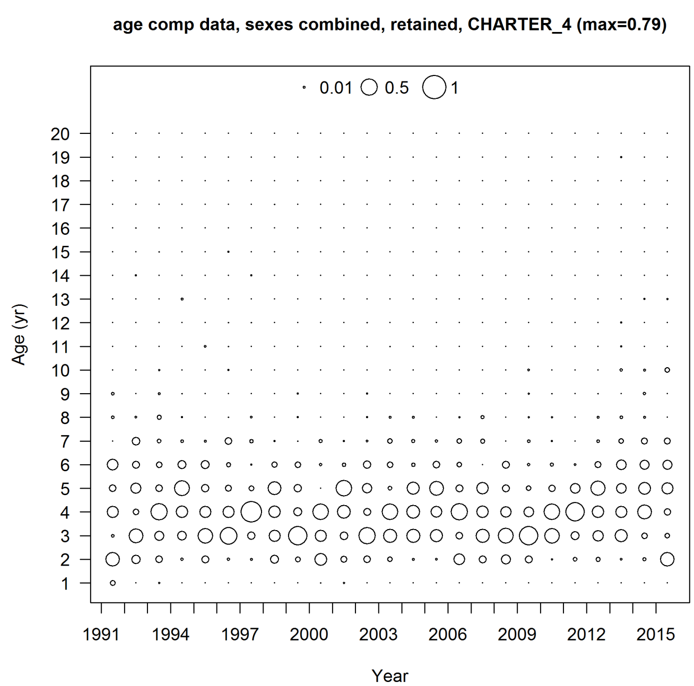
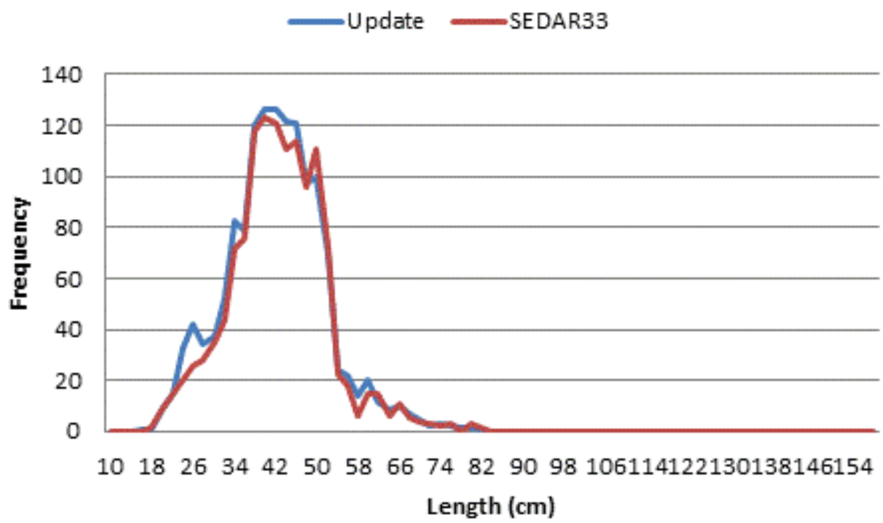


Figure 17. Age composition data for the recreational a) headboat and b) charter fleets.

a)



b)

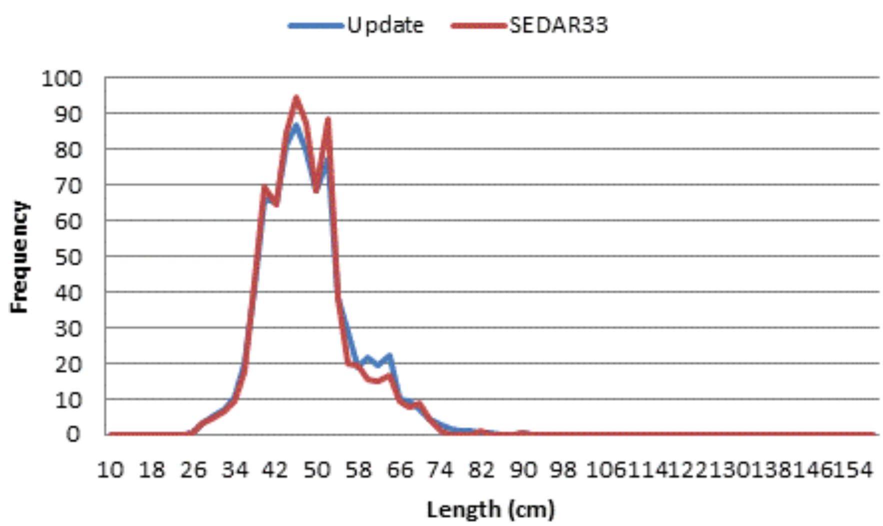
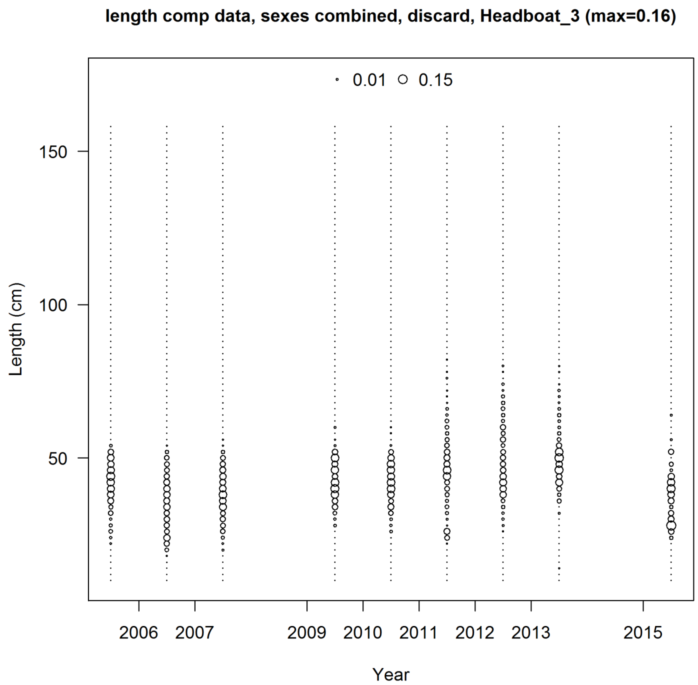


Figure 18. Comparison of the length composition of discarded fish collected by the FWC-FWRI's For-hire Survey for the recreational a) headboat and b) charter fleets.

a)



b)

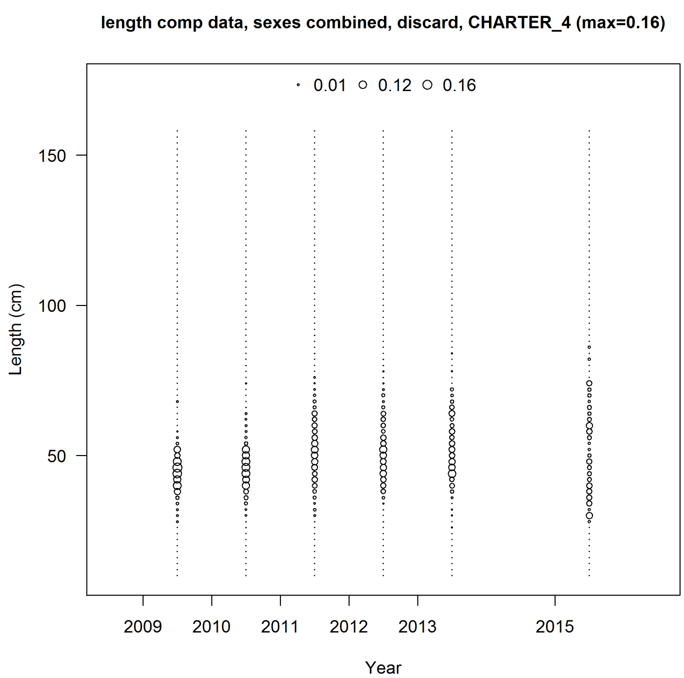


Figure 19 Length composition data of discarded catch from the recreational a) headboat and b) charter fleets. Size limits were implemented in 1990 (20 inches TL, 49.38 cm FL) and 2000 (22 inches TL, 54.31 cm FL).

a) b)

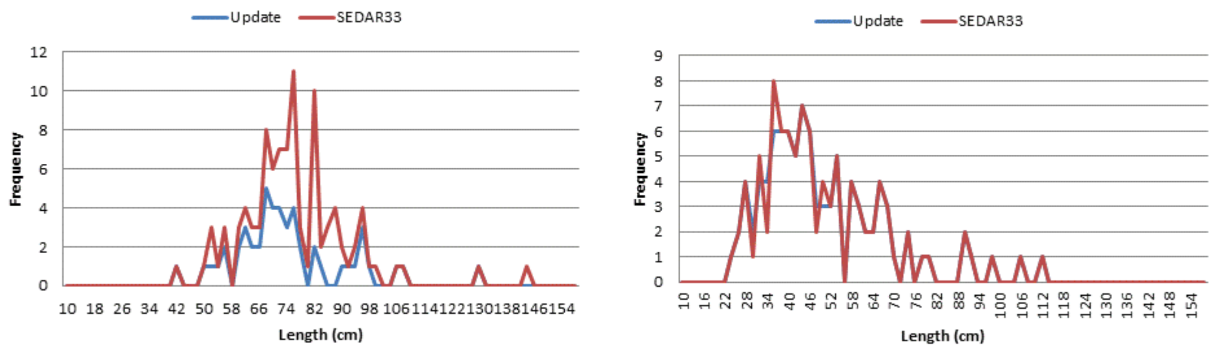


Figure 20. Comparison of length composition of gag observed by the a) SEAMAP video survey and b) PC video survey.

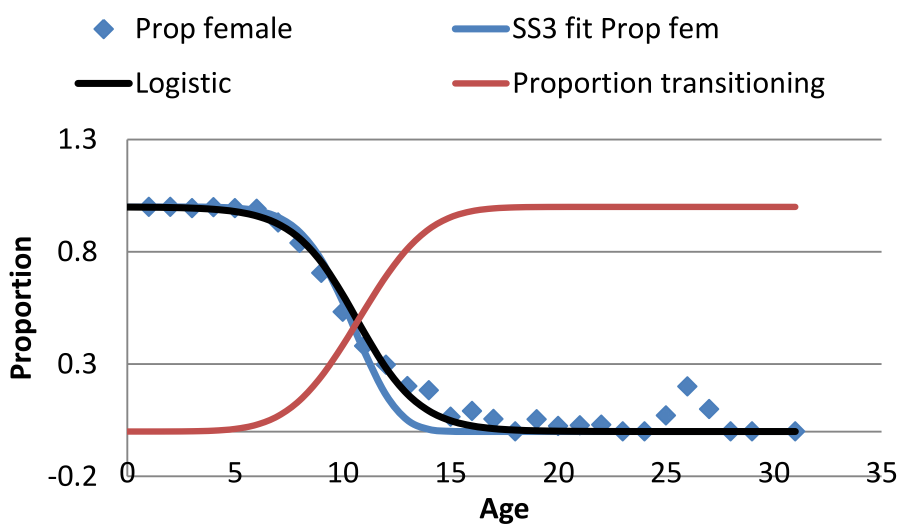


Figure 21. The proportion female estimates and logistic fit describing the observations provided by the PC Laboratory (diamonds and black line), the SS3 expected proportion female (blue line), and the SS3 expected proportion of transition at age (red line).

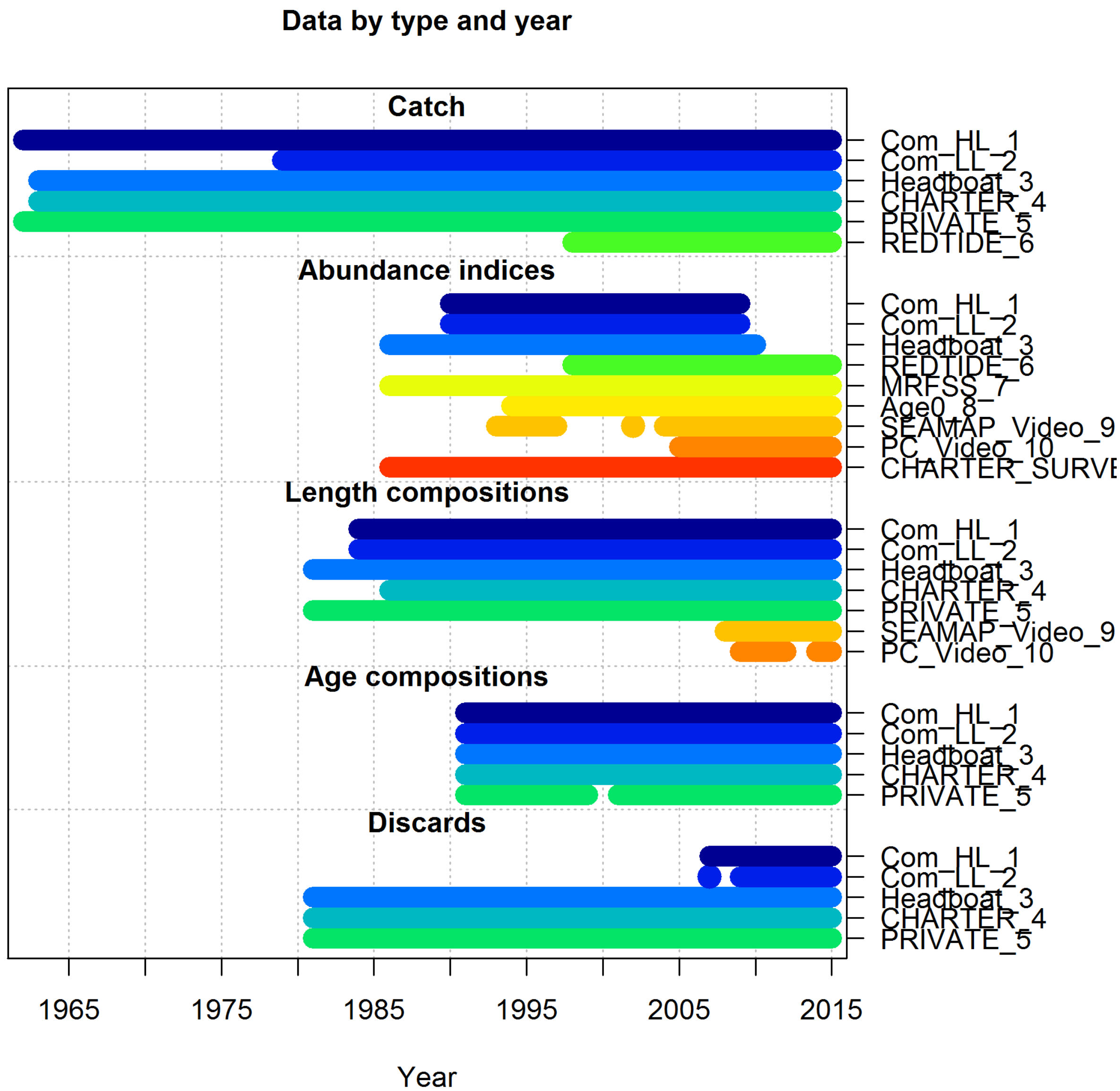


Figure 20. Overview of assessment data inputs.

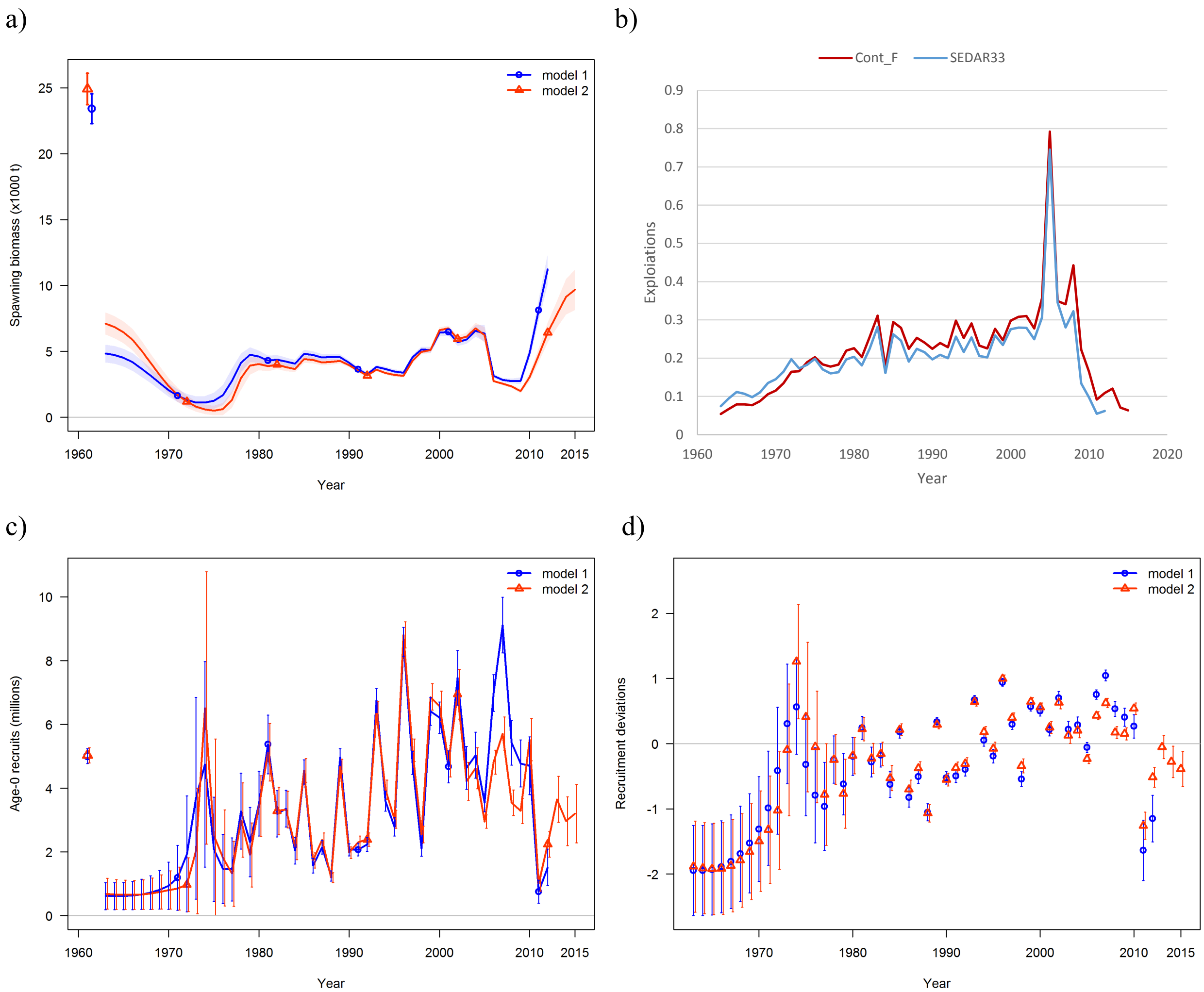


Figure 22. a) Spawning stock biomass (SSB), b) age-0 recruits, c) recruitment deviations, and d) exploitation rate estimates from the SEDAR 33 model (blue lines, model 1) and the continuity model (red lines, model 2).

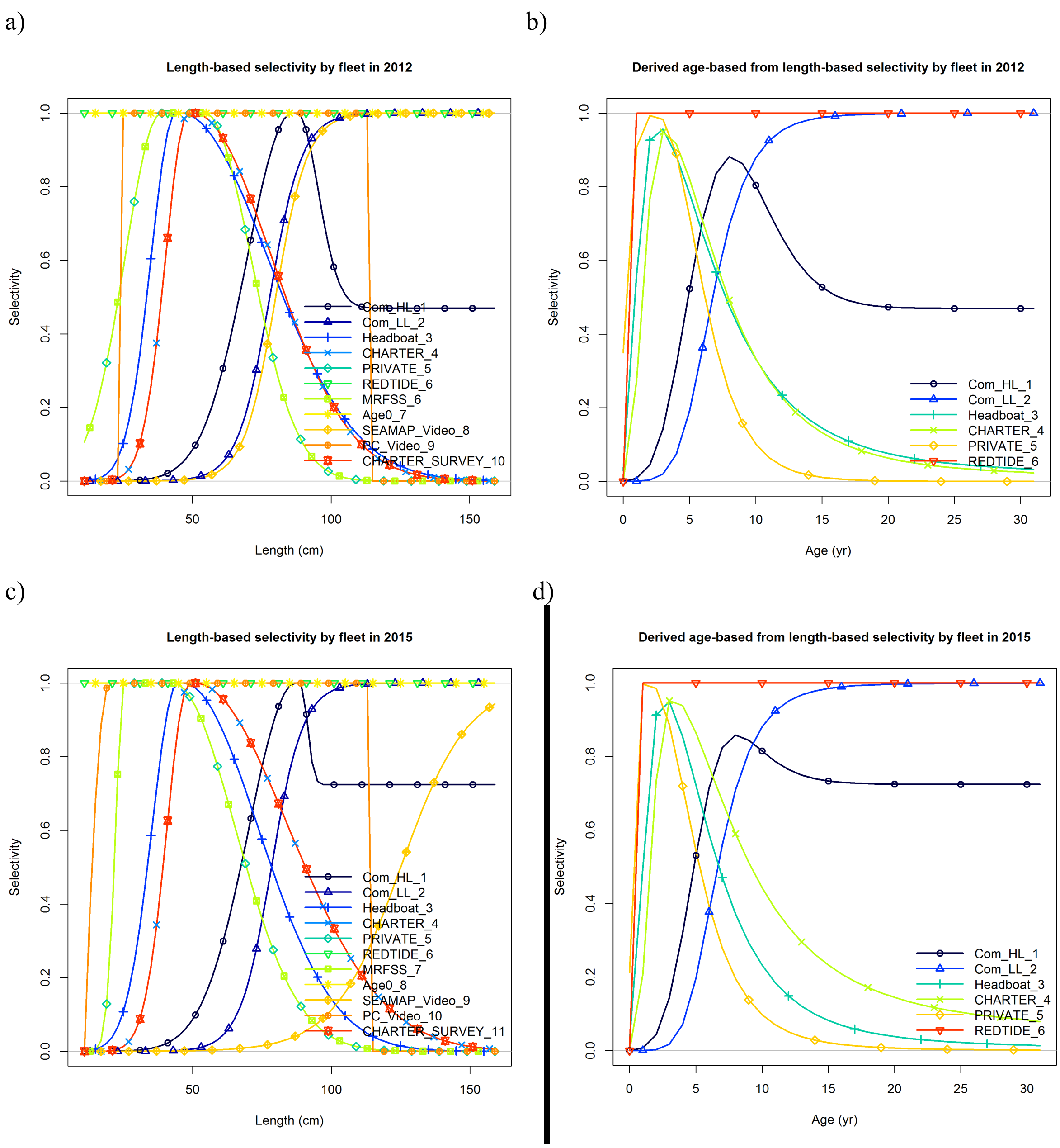


Figure 23. Length and age-based, fleet specific selectivity estimated from the a, b) SEDAR 33 and c, d) continuity models.

Figure 24. Observed indices of abundance the model fits; a) commercial vertical line, b) commercial longline, c) headboat, d) charter, e) private, f) age-0 survey, g) SEAMAP video, and h) PC video.

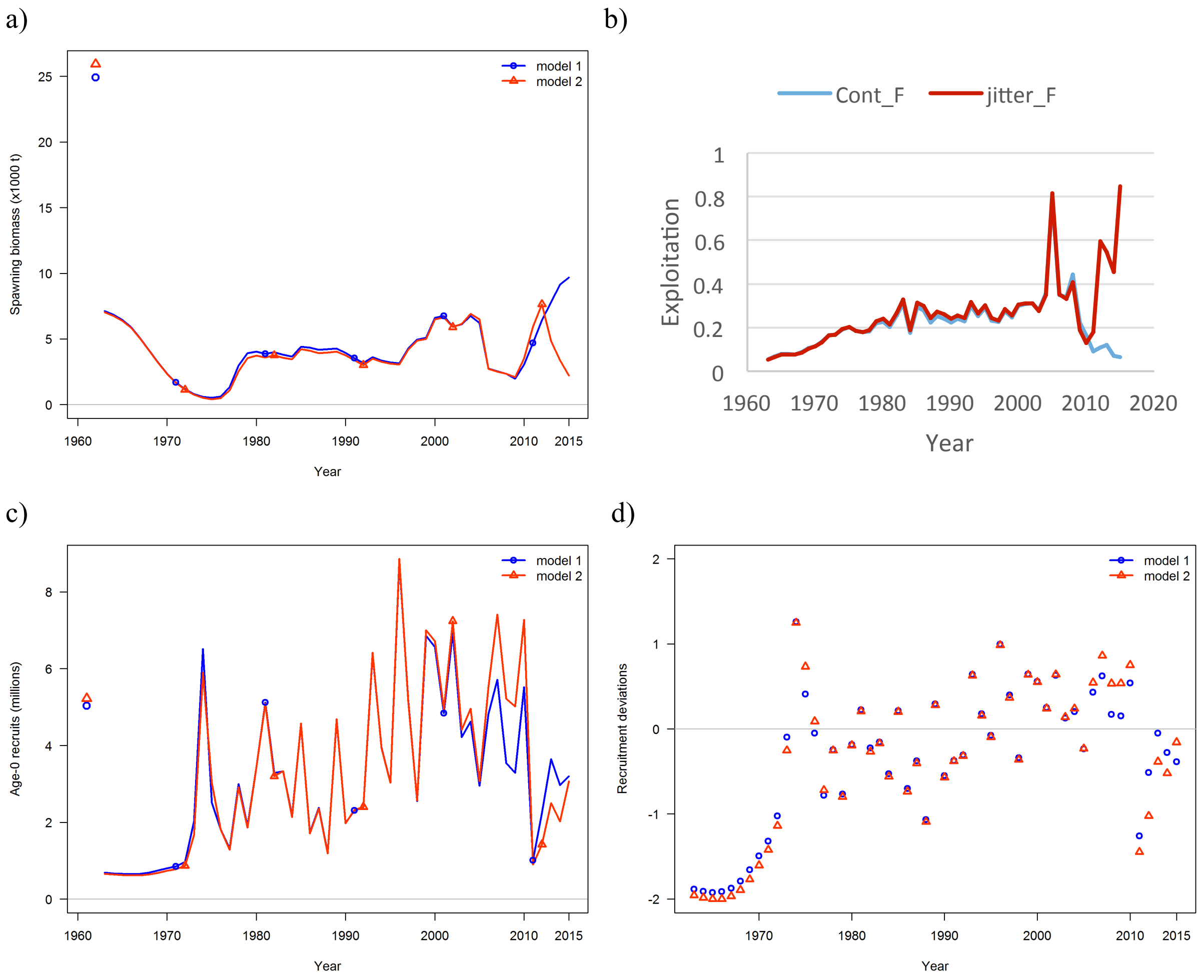
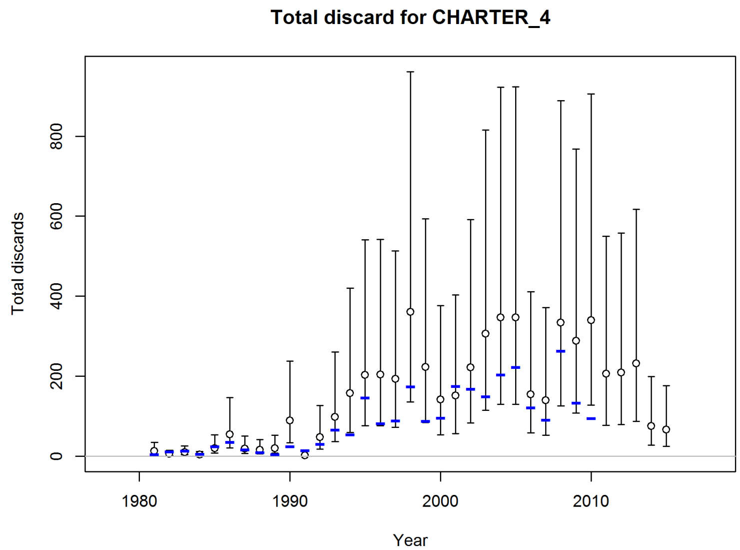


Figure 25. Comparison of the continuity model (blue line, model 1) and the jitter run with the lowest log likelihood (red line, model 2); a) SSB, b) exploitation, c) recruitment, and d) recruitment deviations.

a)



b)

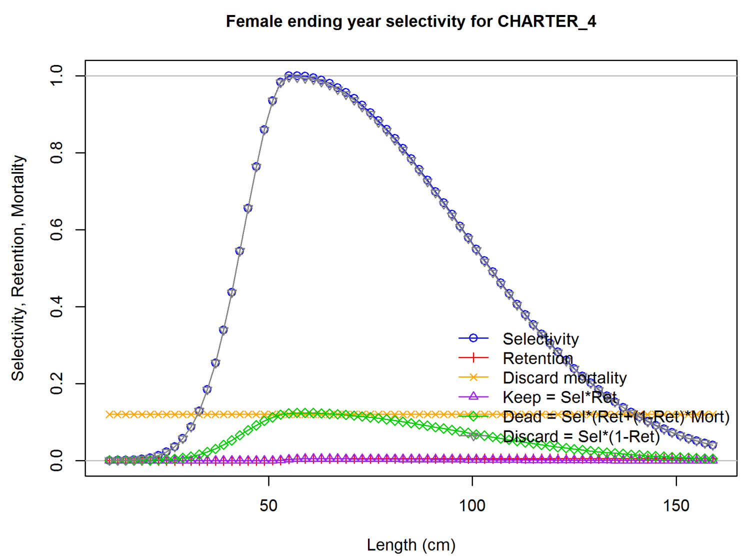
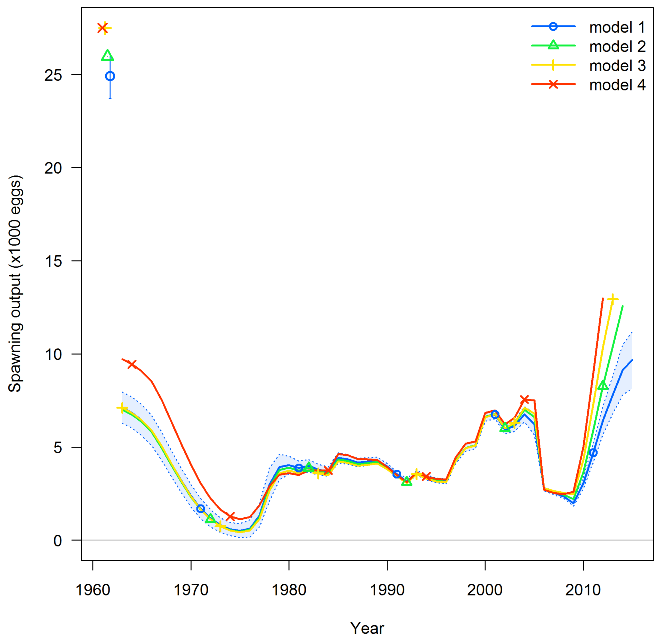


Figure 26. Charterboat discard estimates and the estimated selectivity and retention for the 2011-2015 time block from the jitter run with the lowest log likelihood. The results indicate that less than 1% of gag grouper above the size limit were retained. The discard estimates from 2011 to 2015 were overestimated. The estimated points are not on the plot because they are beyond the y-axis scale.

a)



b)

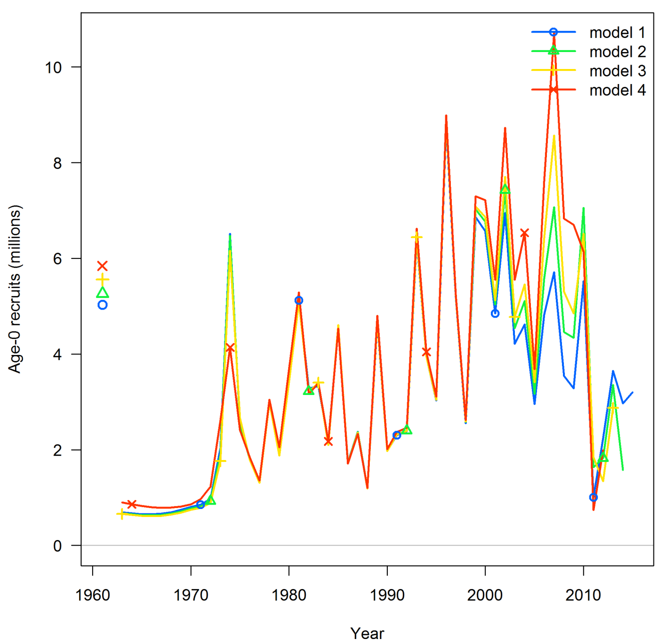
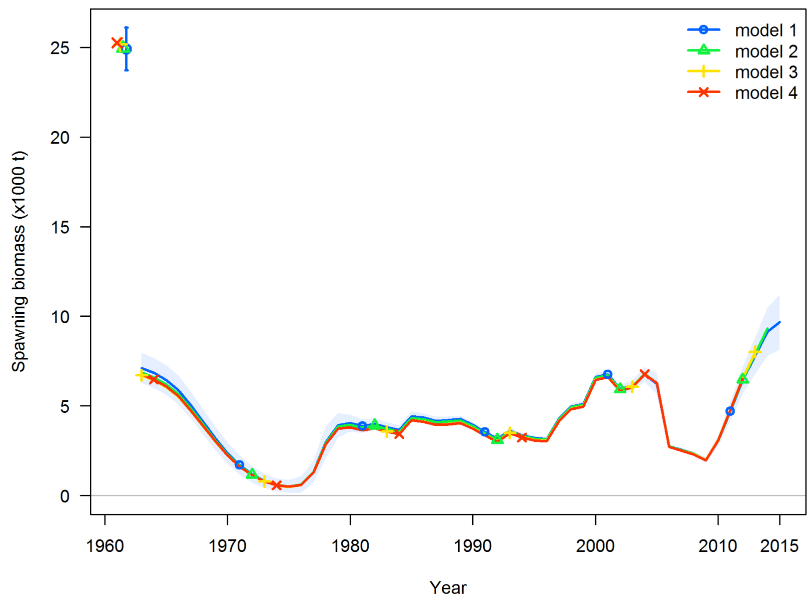


Figure 27. Estimates of a) spawning stock biomass (SSB) and b) age-0 recruits from the retrospective analysis of the continuity model. Model 1 represents the full model through 2015. Each successive model represents the peel of a single year (2014-2011). Symbols in 1960 represent estimates of SBB under unfished conditions.

a)



b)

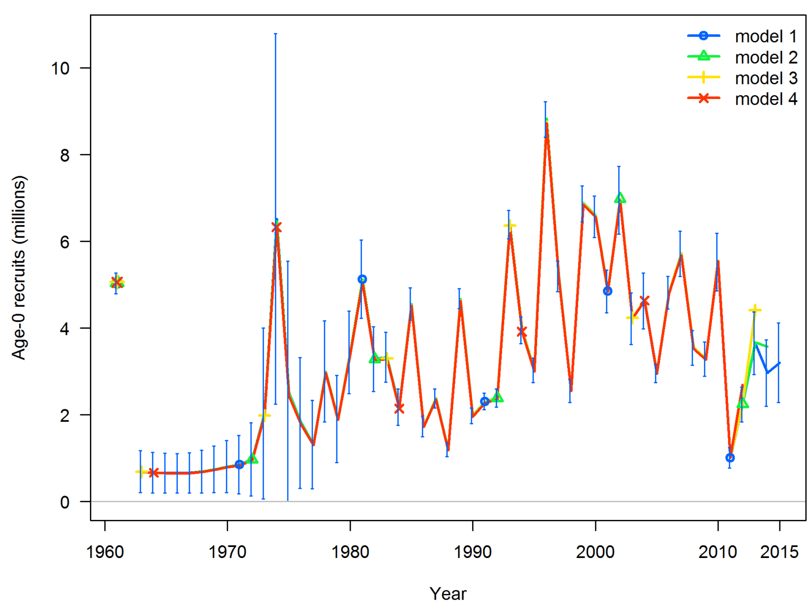
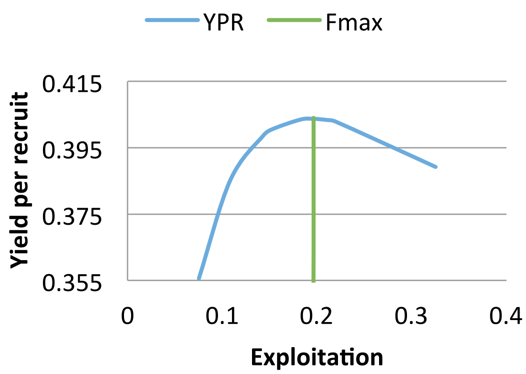
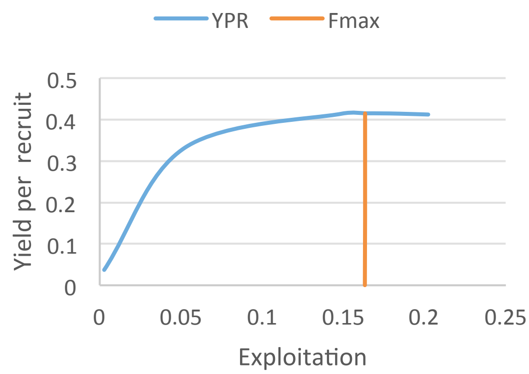


Figure 28. Estimates of a) spawning stock biomass (SSB) and b) age-0 recruits from the retrospective analysis of the continuity model with fixed recruitment deviations from the full model. Model 1 represents the full model through 2015. Each successive model represents the peel of a single year (2014-2011). Symbols in 1960 represent estimates of SBB under unfished conditions.

a)



b)



c)

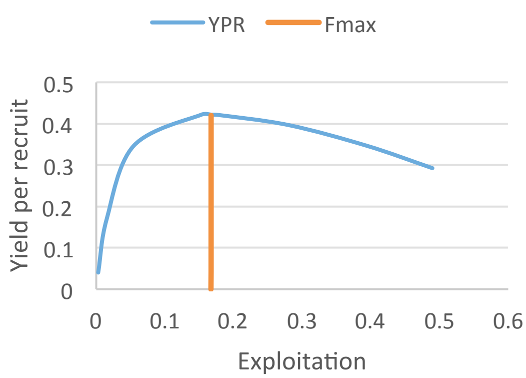
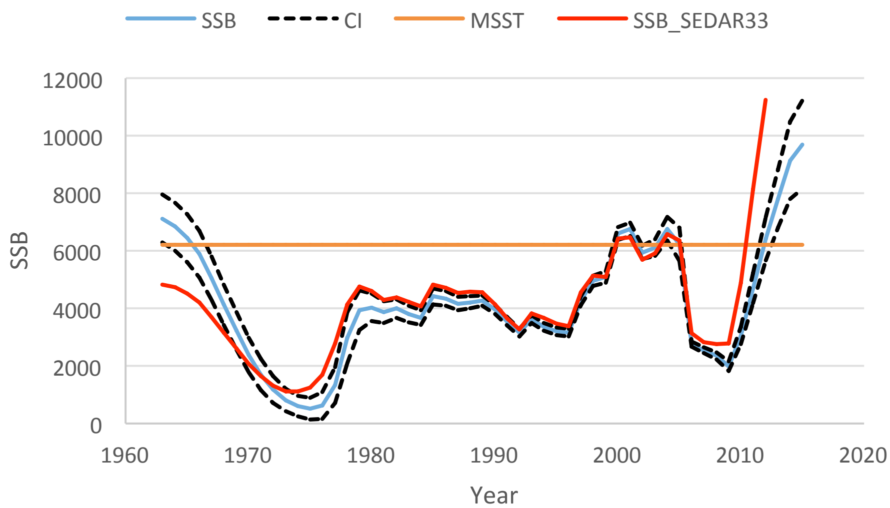


Figure 29. Yield per recruit curves for the a) continuity model and the b) 2014 and c) 2013 retrospective peels.

a)



b)

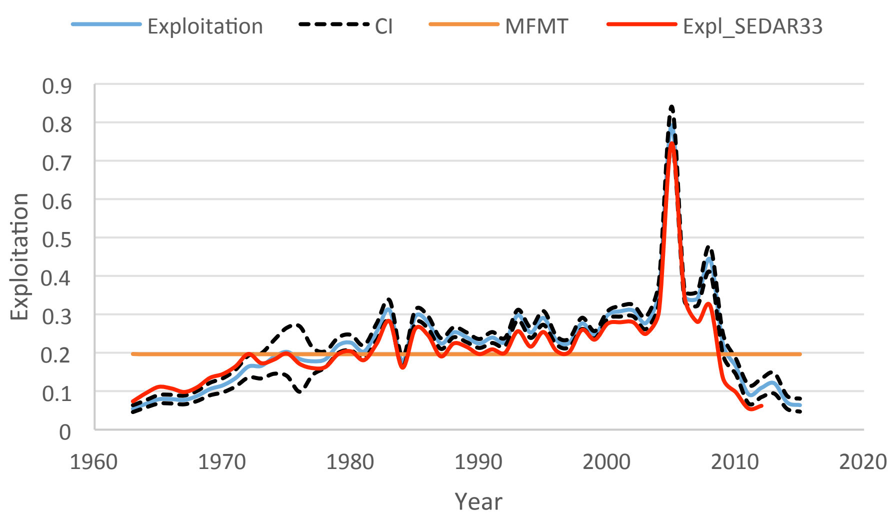


Figure 30. a) SSB time-series compared to MSST and b) Exploitation rate time-series compared to MFMT for the continuity model and the SEDAR 33 assessment model.

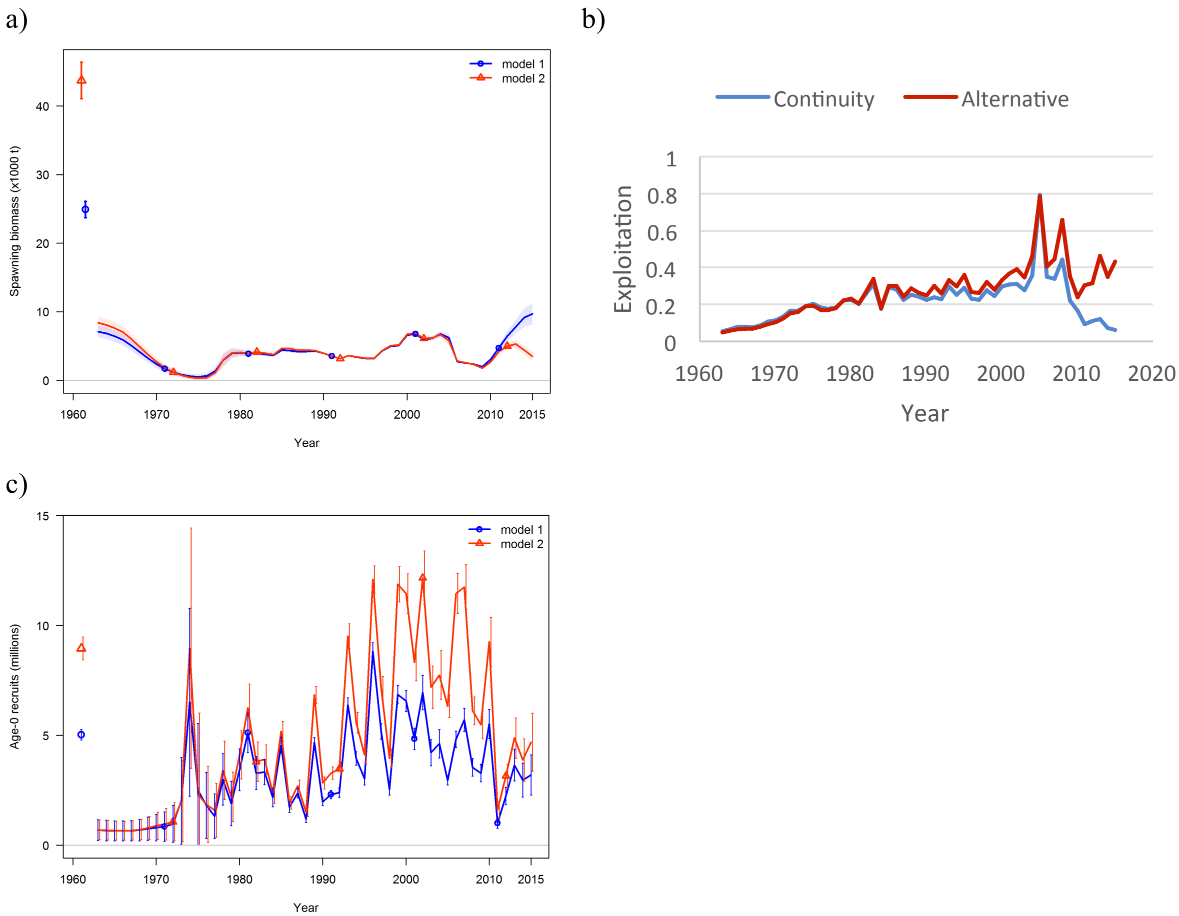


Figure 31.Comparison of a) SSB, b) exploitation, and c) recruitment trajectories from the continuity (model 1, blue line) and alternative (model 2, red line) models.

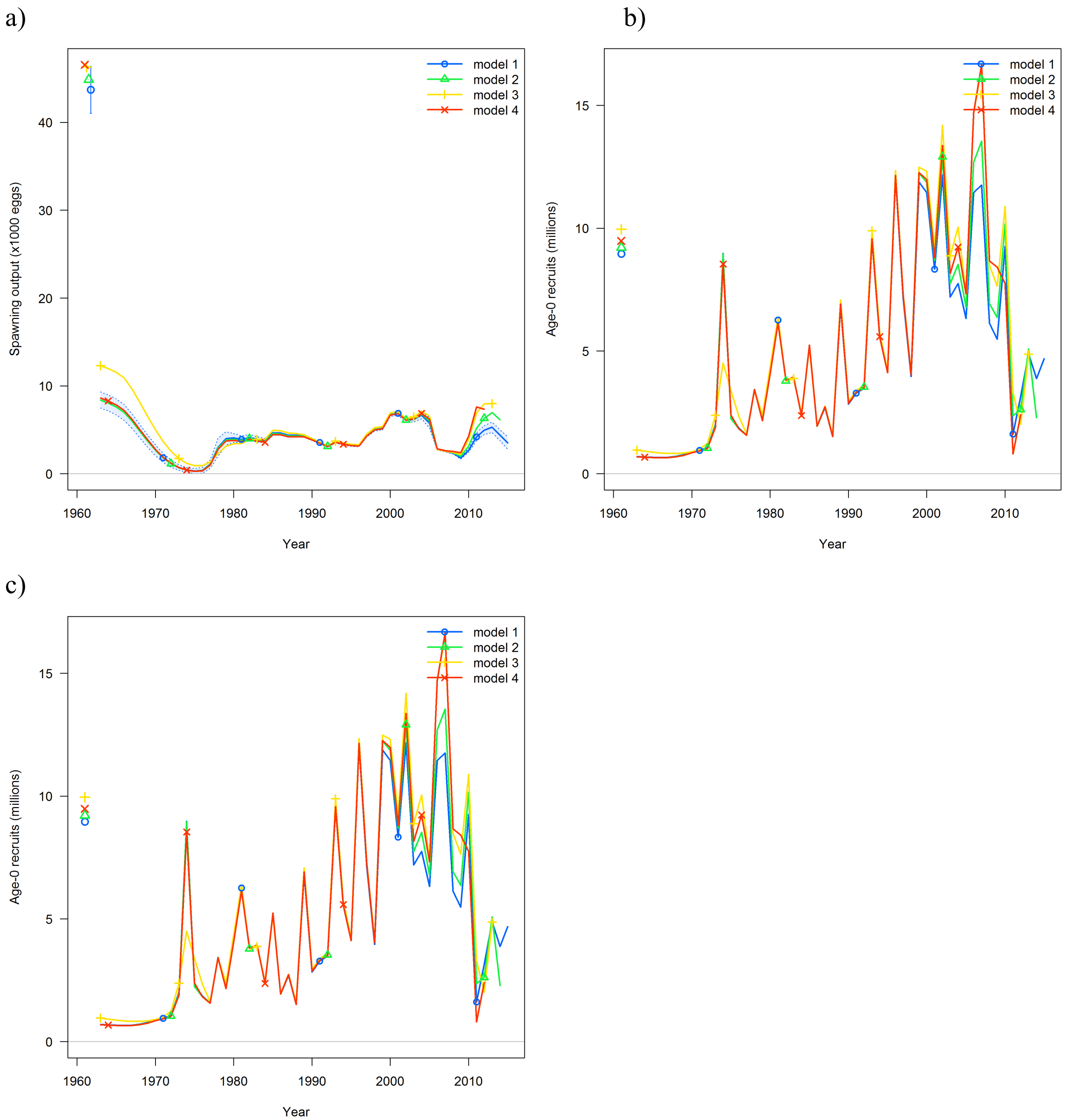


Figure 32. Retrospective analysis results for the alternative model; a) SSB, b) age-0 recruits, c) recruitment deviations.

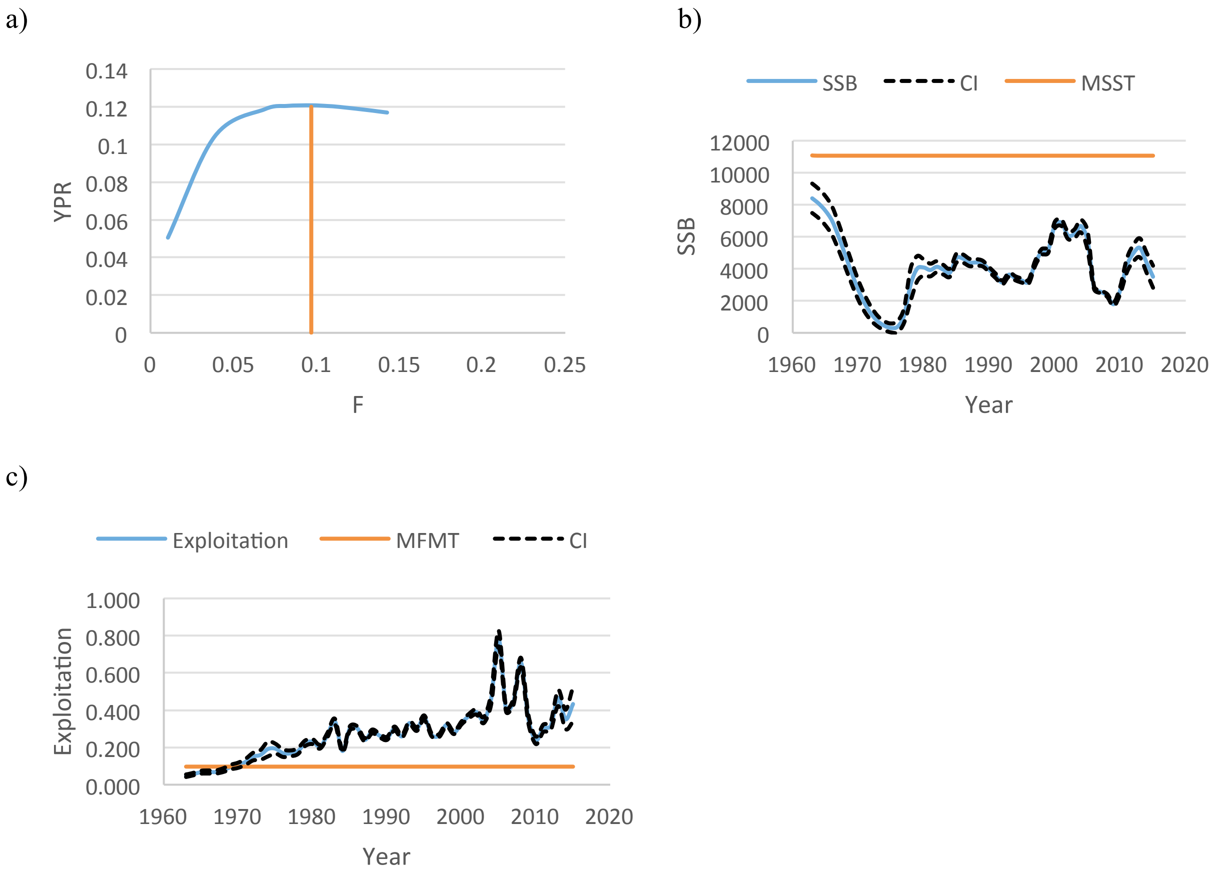


Figure 33. a) Yield per recruit curve, b) SSB time-series compared to MSST and c) exploitation rate time-series compared to MFMT for the alternative model.

APPENDIX A.

RECREATIONAL LANDINGS AND DISCARDS ESTIMATION METHODS

2016 SEDAR Update Gulf of Mexico gag

Recreational Landings

Introduction
The recreational landings for gag were obtained from the following separate sampling programs:

1) Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP)
2) Southeast Region Headboat Survey (SRHS)
3) Texas Parks and Wildlife Department (TPWD)
4) LA Creel Survey

MRFSS/MRIP provides a long time series of estimated catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. MRFSS/MRIP provides estimates for three recreational fishing modes: shore-based fishing (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). When the survey first began in Wave 2 (Mar/Apr), 1981, headboats were included in the for-hire mode, but were excluded after 1985 in the South Atlantic and Gulf of Mexico to avoid overlap with the Southeast Region Headboat Survey (SRHS) conducted by the NMFS Beaufort, NC lab. The MRFSS/MRIP survey covers coastal Gulf of Mexico states from Florida to Louisiana. The state of Texas was included in the survey from 1981-1985, although not all modes and waves were covered.

The Southeast Region Headboat Survey (SRHS) estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. The SRHS began in the South Atlantic in 1972 and Gulf of Mexico in 1986 and extends from the North Carolina\Virginia border to the Texas\Mexico border. Mississippi headboats were added to the survey in 2010. The South Atlantic and Gulf of Mexico Headboat Surveys generally include 70-80 vessels participating in each region annually.

The TPWD Sport-boat Angling Survey was implemented in May 1983 and samples fishing trips made by sport-boat anglers fishing in Texas marine waters. All sampling takes place at recreational boat access sites. The raw data include information on catch, effort and length composition of the catch for sampled boat-trips. These data are used by TPWD to generate recreational catch and effort estimates. The survey is designed to estimate landings and effort by high-use (May 15-November 20) and low-use seasons (November 21-May 14). In SEDAR 16 TPWD seasonal data was disaggregated into months. Since then SEFSC personnel has disaggregated the TPWD seasonal estimates into waves (2 month periods) using the TPWD intercept data. This was done to make the TPWD time series compatible with the MRFSS/MRIP time series. TPWD surveys private and charterboat fishing trips. While TPWD samples all trips (private, charterboat, ocean, bay/pass), most of the sampled trips are associated with private boats fishing in bay/pass, as these trips represent most of the fishing effort. Charterboat trips in ocean waters are the least encountered in the survey.

The Louisiana Department of Wildlife and Fisheries (LDWF) began conducting the Louisiana Creel (LA Creel) survey program for monitoring marine recreational fishery catch and effort on January 1, 2014. Private and charter modes of fishing are sampled. The program is comprised of three separate suverys: a shoreside intercept survey, a private telephone survey, and a for-hire telephone survey. The shoreside survey is used to collect data needed to estimate the mean numbers of fish landed by species for each of five different inshore basins and one offshore area. The private telephone survey samples from a list of people who possess either a LA fishing license or a LA offshore fishing permit and provided a valid telephone number. The for-hire telephone survey samples from a list of Louisiana's registered for-hire captains who provided a valid telephone number. Both telephone surveys are conducted weekly. No information is collected on released fish.

Adjustments and modifications

- The For-Hire Telephone Survey (FHS) was developed to estimate effort in the for-hire mode. Conversion factors have been estimated to calibrate the traditional MRFSS charter boat estimates with the FHS for 1986-1997 in the Gulf of Mexico (SEDAR7-AW-03). To calibrate the MRFSS combined charter boat and headboat mode effort estimates in 1981-1985, conversion factors were estimated using 1986-1990 effort estimates from both modes, in equivalent effort units, an angler trip (SEDAR28-DW-12). These conversion factors are the same as those used in SEDAR 33.

- The Marine Recreational Information Program (MRIP) was developed to generate more accurate recreational catch rates by re-designing the MRFSS sampling protocol to address potential biases including port activity and time of day. Starting in 2013, wave 2, the MRIP Access Point Angler Intercept Survey (APAIS) implemented a revised sampling design. As new MRIP APAIS estimates are available for a portion of the recreational time series that the MRFSS covers, conversion factors between the MRFSS estimates and the MRIP APAIS estimates were developed in order to maintain one consistent time series for the recreational catch estimates. Ratio estimators, based on the ratios of the means, were developed for Gulf of Mexico gag to hind-cast catch and variance estimates by fishing mode. In order to apply the charter boat ratio estimator back in time to 1981, charter boat landings were isolated from the combined charter boat /headboat mode for 1981-1985. The MRFSS to MRIP APAIS calibration process is the same as the original MRFSS to MRIP adjustment that has been used since 2012, which is detailed in SEDAR31-DW25 and SEDAR32-DW02. In SEDAR 33, MRIP estimation adjustment factors were used to maintain a consistent time series of recreational catch. In this update MRIP APAIS adjustment factors, shown in Table 1 below are used to reflect the most current methodologies.

Table 1. Gulf of Mexico gag ratio estimators for adjusting MRFSS numbers and variance estimates (AB1 and B2) to MRIP APAIS numbers and variances for 1981-2003. The variances of the numbers ratio estimators are also shown.

	Numbers Ratio Estimator		Variance Ratio Estimator		Variance of Numbers Ratio Estimator	
MODE	**AB1**	**B2**	**AB1**	**B2**	**AB1**	**B2**
Charter boat	1.162088	1.063766	19.95049	5.565147	0.009203	0.00318739
Private	1.158293	1.191211	6.939433	10.47887	0.002186	0.000555139
Shore	1.282907	1.833671	4.398622	23.9092	0.091118	0.01053995

- Gag grouper (Mycteroperca microlepis) and black grouper (Mycteroperca bonaci) look similar and in parts of the Gulf, Mycteroperca microlepis has traditionally been called black grouper. This issue was investigated and discussed in SEDAR 10 and 33 and it was found that many gag landings were misreported as black grouper landings prior to 1990. The problem was apparently corrected with updated interviewer training, interview supervision, and contractor QA/QC work in the 1990 MRFSS contracts. As was done in the previous assessments, gag catches for this update were adjusted prior to 1990 to correct for this misidentification. The average ratios of gag to the sum of gag and black grouper for 1990 to 2012 were calculated by state and applied to the sum of gag and black grouper landings from 1981 to 1989.

- The MRFSS and the MRIP surveys use different methodologies to estimate landings in weight. To apply a consistent methodology over the entire recreational time series, the Southeast Fisheries Science Center (SEFSC) implemented a method for calculating average weights for the MRIP (and MRIP adjusted) landings. This method is detailed in SEDAR32-DW-02. The length-weight equation from SEDAR 33 (W=1.17E-8*(L^3.02)) was used to convert gag sample lengths into weights, when no weight was recorded. W is whole weight in kilograms and L is fork length in millimeters. This method was used to calculate landings estimates in weight from the MRIP, TPWD, and LA Creel programs.

- In September 2013, after the SEDAR 33 Data Workshop, gag estimates from 1981 to 1990 were updated to use combined gag plus black grouper MRIP adjustment factors, rather than separate gag and black grouper factors originally calculated. Weight estimates were then calculated for the final gag estimates using the SEFSC approach described above. This procedure was followed for this update except that new MRIP APAIS adjustment ratios were used instead.

Table 2. Gulf of Mexico gag and black grouper combined ratio estimators for adjusting MRFSS numbers and variance estimates (AB1 and B2) to MRIP APAIS numbers and variances for 1981-2003. The variances of the numbers ratio estimators are also shown.

	Numbers Ratio Estimator		Variance Ratio Estimator		Variance of Numbers Ratio Estimator	
MODE	**AB1**	**B2**	**AB1**	**B2**	**AB1**	**B2**
Charter boat	1.156663	1.06519	19.83885	5.565203	0.008743	0.003029
Private	1.169833	1.191601	6.967189	10.46233	0.002954	0.000531
Shore	1.282907	1.8422	4.398622	23.8935	0.091118	0.010574

- Following SEDAR 10 and 33 recommendations, Monroe County estimates were excluded from the Gulf of Mexico and included in the South Atlantic stock. Monroe County MRFSS landings from 1981 to 2003 can be post-stratified to separate them from the MRFSS West Florida estimates. Originally, during the first MRIP re-estimation (applied in SEDAR 33), Monroe County landings (2004+) could be estimated separately from the remaining West Florida estimates using domain estimation. The Monroe County domain includes only intercepted trips returning to that county as identified in the intercept survey data. Estimates are then calculated within this domain using standard design-based estimation which incorporates the MRIP design stratification, clustering, and sample weights. However, the new MRIP APAIS calibration does not allow for domain estimation at this time for adjusted estimates from 2004 to 2012. The approach used for this update is to use the annual proportions from the original MRIP domain estimates (panhandle and peninsula over total FLW) and apply those proportions to the new West Florida MRIP APAIS estimates in order to remove Monroe County. This approach was also used in SEDAR 42, Gulf of Mexico red grouper. Traditional MRIP domain estimation is available for estimates 2013+ and is used in this update to exclude Monroe County for that time period.

- Following SEDAR 10 and 33 recommendations, shore mode MRFSS/MRIP gag estimates were included.

- Missing estimates from MRIP 1981, wave 1 have been filled in using the proportion of catch in wave 1 to catch in all other waves for 1982-1984 by fishing mode and area.

- Variances are provided by MRFSS/MRIP for their recreational catch estimates. Variances are adjusted to take into account the variance of the conversion factor when an adjustment to the estimate has been made (FHS and MRIP conversions). However, the variance estimates of the charter and headboat modes in 1981-1985 are missing. This is due to the MRIP calibration procedure, which requires the combined charter/headboat mode to be split in order to apply the MRIP adjustment to the charter mode back to 1981. In addition, variance estimates are not available for weight estimates generated through the SEFSC method described above.

- Headboat landing estimates from 1981-1985 come from the MRFSS/MRIP survey for all states except Texas. Following SEDAR 33 recommendations, headboat landings for Texas 1981 to 1985 were estimated using a 3yr average (1986-1988) from SRHS Texas landings.

- The SRHS was inconsistent in LA in 2002-2006. There were no trip reports collected in LA in 2002. Trip reports from 2001 were used (by the HBS) as a substitute to generate estimates of numbers caught (though there are some minor differences between the resulting estimates for the two years). In 2003, there were only a few trip reports but they were still used to generate the estimates. From 2004 to 2006 there were no trip reports or fish sampled, and no substitutes were used, so there are no estimates or samples from 2004 to 2006 due to funding issues and Hurricane Katrina. However, the MRFSS/MRIP For-Hire Survey included the LA headboats in their charter mode estimates for these years thereby eliminating this hole in the headboat mode estimates.

- Texas data from the MRFSS is only available from 1981-1985 and is sporadic, not covering all modes and waves. For these reasons, Texas boat mode estimates from the MRFSS were not included. Instead, averages from TPWD 1983-1985 by mode and wave were used to fill in theses modes prior to the start of the TPWD survey in May 1983.

- Gag caught by shore mode in the Gulf of Mexico are predominantly from the West coast of Florida, with no shore mode gag caught in any year from 1981 to 2012 in Louisiana and Mississippi. As was done in SEDAR 10 and 33, gag data from Texas shore mode (1984) was excluded.

- LA Creel landings estimates were used for LA 2014 when MRIP estimates are missing.

Recreational Discards

Discarded live fish are reported by the anglers interviewed by the MRIP/MRFSS. Consequently, neither the identity nor the quantities reported are verified. MRFSS/MRIP estimates of live released fish (B2 fish) were adjusted in the same manner as the landings (i.e., using charter boat calibration factors, MRIP adjustment, substitutions, etc. described in section above).

SRHS discards are available from 2004 to the present. In 2013 the SRHS ceased recording the condition of released fish (live vs dead). All releases are recorded as "Estimated alive" starting that year. For consistency, all discards from 2004 to 2012 are categorized as b2 fish (released alive). SRHS discard estimates were not used in SEDAR 33, therefore a proxy method was used to estimate headboat discards in all years (1986-2012). Headboat discard estimates for this update, 1986-2015, were provided using two different proxy methods:

1) MRIP CH proxy method: Apply the yearly Gulf-wide MRFSS charter boat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1986-2015. It was assumed that headboat discards in TX were negligible. This method is consistent with SEDAR 33.
2) SRHS:MRIP CH ratio proxy method (Best Practices approved): Calculate a ratio of the mean ratio of SRHS discard:landings (2004-2015) and MRIP CH discard:landings (2004-2015). Apply this ratio to the yearly MRIP charter boat discard:landings ratio (1986-2015) in order to determine the yearly SRHS discard:landings ratio (1986-2015). This ratio is then applied to the SRHS landings (1986-2015) in order to estimate headboat discards (1986-2015). It was assumed that headboat discards in TX were negligible.

The preferred method was Option 1, to maintain consistency with SEDAR 33.

TPWD and LA Creel surveys do not estimate discards. In SEDAR 33, TPWD discards were assumed to be zero. Similarly, LA discards for 2014 were assumed to be zero in this update.

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APPENDIX B.

Fishery-independent surveys of juvenile gag grouper in the Gulf of Mexico (1994-2015)

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In order to develop abundance indices of age-0 gag grouper in the Gulf of Mexico, three available data bases were combined and subsequently analyzed. In the following sections, each database is briefly outlined along with the survey methodology. Next is presented the statistical approach by which the indices are developed from the combined data. The analyses herein follow those detailed in SEDAR33-AW-06.

1. FSU estuarine gag survey
Gear: 5-m otter trawl towed for 5 minutes at ~2 km/h covering approximately a 150 m transect. Numbers of gag caught are standardized by tow time and estimates of area covered.
Areas covered: St. Andrew Bay, St. Joe Bay, Turkey Point, Big Bend (Keaton Beach, Cedar Key), Crystal River, Anclote Key, Sarasota Bay, Sanibel, primarily in seagrass habitat. The 35 sampling locations in this survey were lumped into 9 sampling regions (Table 1.1 and Figure 1.1) similar to those of Brown et al. (2000).

Index years: 1991-1999, 2003-2009, 2011

Index value based upon: Number of gag per 100-m tow

Noteworthy: Gag is the target species, primarily captured during summer months in the postsettlement juvenile stage. In early years 1991 and 1993, survey efforts were limited to the Turkey Point area, and no sampling was conducted in years 2000, 2001 and 2003. While this is currently one of the longer-term age-0 surveys, the hiatus in sampling during those years resulted in this survey not being recommended during the data workshop for use in the SEDAR 10 assessment (where data was included up to 2005).

Principal contacts: Chris Koenig (koenig@bio.fsu.edu), FSU Marine Lab
Pertinent references: Koenig and Coleman 1998 a & b, Brown et al. 2000.

2. NMFS PC Lab St. Andrew Bay survey
Gear: Weekly sampling, May-November, 16 (50 m) tows taken using 1 m beam trawl (“crab scrape”) at 5 fixed locations pre-determined to be settlement areas. Area covered is precisely measured.

Areas covered: St. Andrew Bay, Florida, principally 1-2 meters depth in conjunction with seagrass habitat

Index years: 1998-2014.

Index value based upon: Catch per meter^2

Noteworthy: Gag, grey snapper, and lane snapper are the target species; fish are primarily sampled soon after settlement into seagrass habitats. This survey has not been used previously as an assessment index for gag.

Principal contacts: Stacey Harter, (Stacey.Harter@noaa.gov) NMFS Panama City
Pertinent references: Harter 2008, 2009, NOAA-FWC 2009

3. State of Florida FWC estuarine (FIM) survey
Gear: 183-m haul seine, a component of the Fishery Independent Monitoring Program (FIM); and 183-m haul seine and 6.1 m otter trawl, components of a polyhaline seagrass survey.

Areas covered: Apalachicola Bay, Cedar Key, Tampa Bay, Charlotte Harbor, in estuarine nearshore habitats (~0.5 m depth).

Index years: 1996-2015

Index value based upon: Catch per haul

Noteworthy: While the FIM survey includes several gear types, the 183-m haul seine catches the most gag juveniles, typically later in the year (about ¾ of a year old) and closer to period of movement to deeper water. Similar sized fish are collected in the 183-m haul seine and 6.1 m otter trawl gears of the recently initiated polyhaline seagrass survey. There was a 2008 expansion to St. Andrew Bay, Big Bend and Apalachicola Bay resulting in increased coverage of seagrass habitats likely to hold juvenile gag. During the SEDAR 10 assessment workshop, issues related to lack of model convergence resulted in this survey not being used in the final model runs.

Principal contacts: Ted Switzer (Ted.Switzer@MyFWC.com), FWC St. Petersburg
Pertinent references: Casey et al. 2005, Ingram et al. 2005, NOAA-FWC 2009

4. Combined index of abundance
4.1 Methodology
In order to develop standardized indices of annual abundance of juvenile gag from Florida estuaries and coastal waters in the Gulf of Mexico, data from the above described surveys were combined. This was accomplished by first calculating the overall mean catch rate for each data set and scaling the data in each dataset to a mean of one. Due to the presence of two gear-types in the FWRI data, each gear type was considered a separate dataset, resulting in four datasets (FWRI trawl, FWRI seine, PCNMFS trawl and FSU trawl); and a database code was assigned to each dataset in order to model for differences between datasets. Next, sampling locations in each dataset were lumped into the 9 sampling regions as described in Section 1 (Table 1.1 and Figure 1.1). Therefore, while the FSU dataset (Section 1) had nine regions sampled, the NMFS PC Lab St. Andrew Bay survey (Section 2) sampled only that region (i.e. St. Andrew Bay, SAR) and the FWC estuarine (FIM) survey (Section 3) had four regions sampled (i.e. Charlotte Harbor, CHR; Cedar Key, CKR; Mid Big Bend, MBB; and Tampa Bay, TBR).

Two indices were developed using data from 1994 through 2015. This was due to sampling limited only to the Turkey Point Region in 1991 and 1993. While employing each of the two different time series, an index was developed that was weighted by the aerial coverage of seagrass in each sampling region (Figure 1.1), and an index was developed that was not weighted.

The weight for each region was based on the seagrass coverage area in each region, between 0 and 6 feet of water depth. This depth range was said to be that in which the majority of juvenile gag are captured (Chris Koenig, personal communication). The area between 0 and 6 feet water depth was estimated in each region using a NOAA bathy model of medium scale (http://www.ngdc.noaa.gov/mgg/coastal/model.html for more details). The seagrass aerial coverage for each region was estimated using a GIS data set based on a compilation of statewide seagrass data from various source agencies and scales. The GIS seagrass data were mapped from sources ranging in date from 1987 to 2007. Not all data in this compilation are mapped from photography; some are the results of field measurements. Some used the Florida Land Use Cover and Forms Classification System (FLUCCS) codes 9113 for discontinuous seagrass and 9116 for continuous seagrass; some defined only presence and absence of seagrass, and some defined varying degrees of seagrass percent cover. In order to merge all of these data sources into one compilation data set, FWRI reclassified the various source data attribute schemes into two categories: "continuous" and "discontinuous" seagrass. In areas where studies overlap, the most recent study where a given area has been interpreted is represented in this data set. The seagrass data was cross-referenced with the bathymetry data to estimate the seagrass coverage area in each region, between 0 and 6 feet of water depth (Figure 1.1).

A delta-lognormal model, as described by Lo et al. (1992) was employed for each index. The GLMMIX and MIXED procedures in SAS were employed to provide yearly index values for both the binomial and lognormal sub-models, respectively. A backward stepwise selection procedure was employed to develop both sub-models. Type 3 analyses were used to test each parameter for inclusion or exclusion into the sub-model. Both variable inclusion and exclusion significance level was set at an $\alpha = 0.05$. The parameters tested for inclusion in each sub-model were categorical variables of year, database code, region code, and season (spring: months 4-5; early summer: months 6-7; late summer: month 8-9; and fall: months 10-11). The fit of each model was evaluated using the fit statistics provided by the GLMMIX macro.

During the SEDAR 33 data workshop and subsequent webinars, much of the discussion centered on which version of the index should be utilized, weighted or unweighted. It was the recommendation of the Indices Working Group that the unweighted index spanning 1994-2012 would be the most appropriate. This was a deviation from an initial recommendation of using an index weighted by seagrass area. The final decision to use the unweighted index centered on the apparent better model fit when compared to the weighted index from the same time span. Also, when region-specific abundance patterns were examined (Figure 4.1), data from the Marco Island Region had a short time series, limited sampling area, and the location of the region was in the southern end of the juvenile gag range. Therefore, these data were not included in the analyses, following previous recommendations.

For this analysis, both the unweighted and weighted indices for years 1994-2015 were developed.

4.2 Unweighted, 1994-2015

Table 4.2.1 summarizes the results of Type 3 analyses for those variables retained in the binomial sub-model. Table 4.2.2 summarizes the results of Type 3 analyses for those variables retained in the lognormal sub-model. Figure 4.2.1 shows the approximate normality of the residual for the lognormal sub-model. Table 4.2.3 and Figure 4.2.2 summarize the unweighted index values for gag in Gulf estuaries of Florida based on all data sets combined from 1994-2015.

4.3 Weighted, 1994-2015

Table 4.3.1 summarizes the results of Type 3 analyses for those variables retained in the binomial sub-model. Table 4.3.2 summarizes the results of Type 3 analyses for those variables retained in the lognormal sub-model. Figure 4.3.1 shows the approximate normality of the residual for the lognormal sub-model. Table 4.3.3 and Figure 4.3.2 summarize the weighted index values for gag in Gulf estuaries of Florida based on all data sets combined from 1994-2015.

Acknowledgments

Many thanks to Chris Koenig, Stacey Harter, and Ted Switzer for coding and providing their respective databases. Also thanks to Gary Fitzhugh for help with summaries of the databases.

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Table 1.1. Sampling location and corresponding region codes for data used in these analyses.

Figure 1.1. Nine sampling regions used in this study. The green areas indicate seagrass coverage between 0 and 6 feet of water depth. Seagrass coverage in acres for each region is listed.

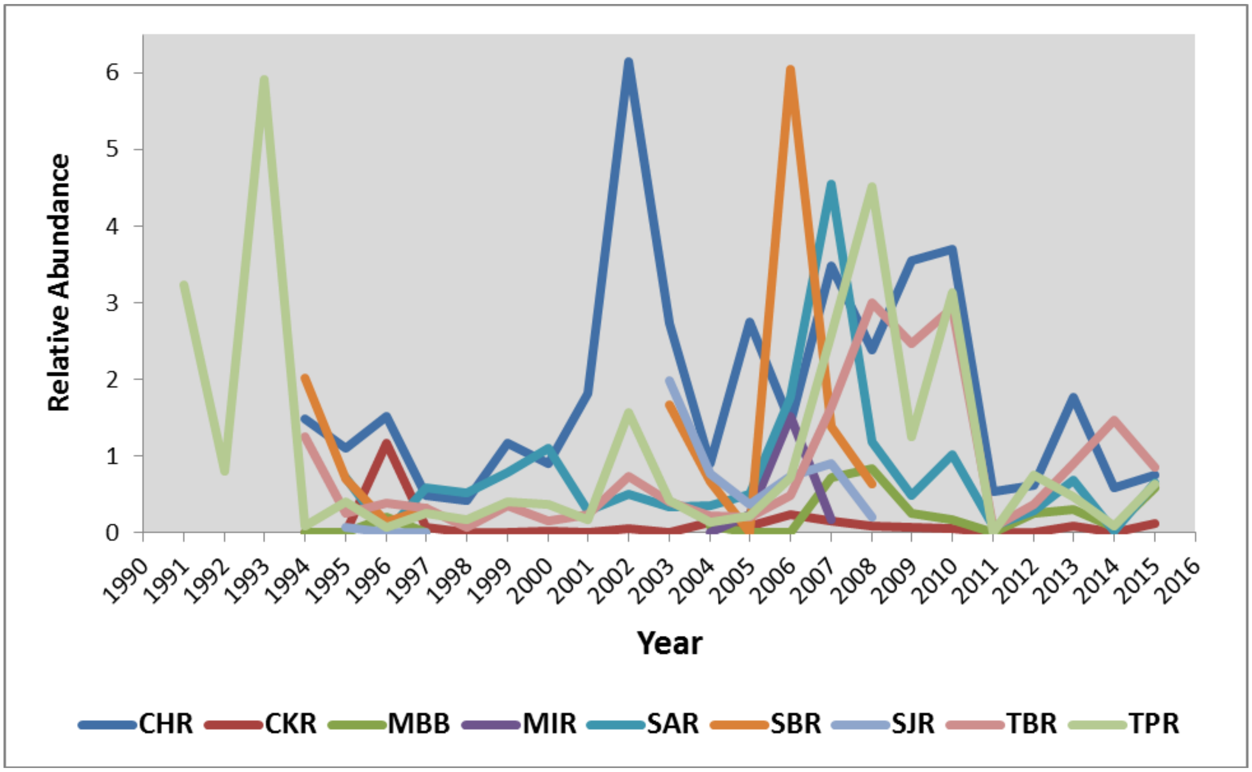


Figure 4.1. Nominal relative catch per region. Region codes described in Table 1.1.

Table 4.2.1. Type 3 tests of fixed effects for binomial sub-model for the unweighted index based on all data sets combined from 1994-2015.

Type 3 Tests of Fixed Effects
Effect
Num
DF
Den
DF Chi-Square F Value Pr > ChiSq Pr > F
year 21 19E3 621.12 29.58 <.0001 <.0001
season 3 19E3 315.08 105.03 <.0001 <.0001
region_code 7 19E3 509.60 72.80 <.0001 <.0001
database_code 3 19E3 655.84 218.61 <.0001 <.0001

Table 4.2.2. Type 3 tests of fixed effects for lognormal sub-model for the unweighted index based on all data sets combined from 1994-2015.

Type 3 Tests of Fixed Effects
Effect
Num
DF
Den
DF F Value Pr > F
year 21 2389 12.07 <.0001
season 3 2389 6.11 0.0004
region_code 7 2389 8.14 <.0001
database_code 3 2389 447.01 <.0001

Figure 4.2.1. QQplot of residuals from the lognormal sub-model for the unweighted index based on all data sets combined from 1994-2015.

Figure 4.2.2. Unweighted abundance indices developed from all data sets combined from 1994-2015.
Table 4.2.3. Unweighted abundance indices developed from all data sets combined from 1994-2015.
Survey Year Nominal Frequency N DL Index Scaled DL Index CV LCL UCL

1994	0.34921	126	0.35225	0.68725	0.22949	0.43685	1.08118
1995	0.50742	337	0.47963	0.93578	0.15276	0.69064	1.26792
1996	0.16134	626	0.17681	0.34496	0.15416	0.25389	0.46869
1997	0.13803	681	0.17236	0.33629	0.15602	0.24661	0.45858
1998	0.06140	570	0.16730	0.32642	0.22472	0.20940	0.50882
1999	0.11203	723	0.30464	0.59436	0.15317	0.43831	0.80597
2000	0.08179	648	0.25745	0.50230	0.17231	0.35677	0.70719
2001	0.05317	583	0.27377	0.53414	0.22290	0.34386	0.82971
2002	0.11000	800	0.75476	1.47257	0.13623	1.12277	1.93134
2003	0.12164	855	0.49248	0.96085	0.13784	0.73028	1.26420
2004	0.11029	807	0.33493	0.65346	0.14837	0.48647	0.87779
2005	0.13341	921	0.37620	0.73398	0.12769	0.56915	0.94656
2006	0.20485	908	1.09459	2.13558	0.10337	1.73768	2.62460
2007	0.24731	837	1.81172	3.53473	0.09251	2.93882	4.25149
2008	0.19331	1376	1.08021	2.10753	0.08591	1.77537	2.50185
2009	0.14632	1237	0.78871	1.53881	0.10105	1.25786	1.88251
2010	0.14361	1142	0.97523	1.90271	0.10577	1.54084	2.34957
2011	0.02864	1327	0.06615	0.12907	0.20658	0.08575	0.19426
2012	0.07030	1138	0.26328	0.51368	0.14701	0.38342	0.68818
2013	0.08555	1239	0.40561	0.79136	0.12892	0.61215	1.02304
2014	0.06499	1231	0.24270	0.47351	0.14720	0.35331	0.63460
2015	0.08932	1142	0.40525	0.79066	0.13198	0.60792	1.02834

Table 4.3.1. Type 3 tests of fixed effects for binomial sub-model for the weighted index based on all data sets combined from 1994-2015.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	21	19E3	384.85	18.33	<.0001	<.0001
season	3	19E3	205.89	68.63	<.0001	<.0001
region_code	7	19E3	987.79	141.11	<.0001	<.0001
database_code	3	19E3	866.12	288.71	<.0001	<.0001

Table 4.3.2. Type 3 tests of fixed effects for lognormal sub-model for the weighted index based on all data sets combined from 1994-2015.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	21	2389	7.55	<.0001
season	3	2389	8.36	<.0001
region_code	7	2389	18.15	<.0001
database_code	3	2389	496.17	<.0001

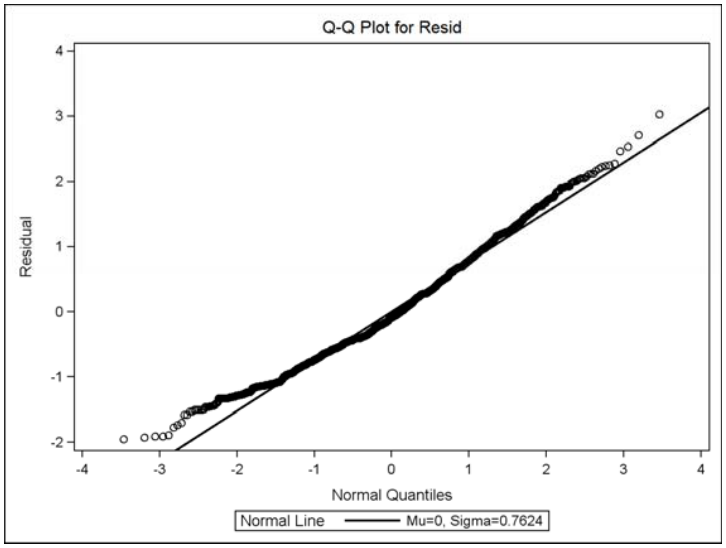


Figure 4.3.1. QQplot of residuals from the lognormal sub-model for the weighted index based on all data sets combined from 1994-2015.

APPENDIX C.

MODEL PARAMETERS

Table C.1. Estimated and fixed parameter values for the SEDAR33, continuity, and alternative models.

	SEDAR 33			Continuity			Alternative model		
Parameter	Value	Stdev	CV	Value	Stdev	CV	Value	Stdev	CV
L_at_Amin	29.145	0.263	0.009	27.959	0.312	0.011	27.759	0.323	0.012
L_at_Amax	132.183	2.533	0.019	132.210	2.439	0.018	135.263	2.933	0.022
VonBert_K	0.102	0.004	0.036	0.107	0.004	0.037	0.102	0.004	0.042
CV_young	0.123	_		0.119	_		0.119	_	
CV_old	0.020	_		0.062	_		0.062	_	
Wtlen_1	0.000	_		0.000	_		0.000	_	
Wtlen_2	3.080	_		3.080	_		3.080	_	
Mat50%_Fem	3.549	_		3.549	_		3.549	_	
Mat_slope_Fem	-2.833	_		-2.833	_		-2.833	_	
Eggs_scalar_Fem	1.000	_		1.000	_		1.000	_	
Eggs_exp_wt_Fem	1.000	_		1.000	_		1.000	_	
Herm_Infl_age	10.745	_		10.745	_		10.745	_	
Herm_stdev	2.528	_		2.528	_		2.528	_	
Herm_asymptote	1.000	_		1.000	_		1.000	_	
RecrDist_GP_1	0.000	_		0.000	_		0.000	_	
RecrDist_Area_1	1.000	_		1.000	_		1.000	_	
RecrDist_Seas_1	-4.000	_		-4.000	_		-4.000	_	
CohortGrowDev	1.000	_		1.000	_		1.000	_	

	SEDAR 33			Continuity			Alternative model		
Parameter	Value	Stdev	CV	Value	Stdev	CV	Value	Stdev	CV
SR_LN(R0)	8.519	0.024	0.003	8.523	0.024	0.003	9.100	0.030	0.003
SR_BH_steep	0.855	_		0.855	_		0.855	_	
SR_sigmaR	0.600	_		0.600	_		0.600	_	
SR_envlink	0.000	_		0.000	_		0.000	_	
SR_R1_offset	-1.254	0.049	-0.039	-1.074	0.052	-0.048	-1.506	0.053	-0.035
SR_autocorr	0.000	_		0.000	_		0.000	_	
Early_RecrDev_1963	-1.946	0.352	-0.181	-1.885	0.357	-0.189	-2.383	0.330	-0.139
Early_RecrDev_1964	-1.946	0.354	-0.182	-1.910	0.357	-0.187	-2.404	0.330	-0.137
Early_RecrDev_1965	-1.930	0.356	-0.185	-1.923	0.358	-0.186	-2.416	0.331	-0.137
Early_RecrDev_1966	-1.888	0.360	-0.191	-1.915	0.360	-0.188	-2.405	0.332	-0.138
Early_RecrDev_1967	-1.809	0.366	-0.202	-1.873	0.362	-0.193	-2.352	0.334	-0.142
Early_RecrDev_1968	-1.690	0.374	-0.221	-1.789	0.366	-0.205	-2.241	0.339	-0.151
Early_RecrDev_1969	-1.527	0.388	-0.254	-1.658	0.375	-0.226	-2.060	0.352	-0.171
Early_RecrDev_1970	-1.309	0.411	-0.314	-1.495	0.393	-0.263	-1.812	0.377	-0.208
Early_RecrDev_1971	-0.989	0.446	-0.452	-1.320	0.420	-0.318	-1.557	0.409	-0.263
Early_RecrDev_1972	-0.415	0.495	-1.195	-1.025	0.460	-0.449	-1.193	0.444	-0.372
Early_RecrDev_1973	0.305	0.469	1.537	-0.096	0.516	-5.393	-0.230	0.500	-2.174
Early_RecrDev_1974	0.563	0.371	0.659	1.260	0.447	0.355	1.647	0.497	0.302
Early_RecrDev_1975	-0.319	0.401	-1.256	0.410	0.585	1.428	0.595	0.686	1.153
Early_RecrDev_1976	-0.792	0.372	-0.470	-0.050	0.436	-8.685	0.185	0.503	2.722
Early_RecrDev_1977	-0.962	0.345	-0.359	-0.779	0.398	-0.511	-0.749	0.406	-0.541
Early_RecrDev_19	-0.243	0.18	-0.760	-0.245	0.196	-0.798	-0.513	0.197	-0.384

78		5							
Early_RecrDev_1979	-0.622	0.240	-0.386	-0.768	0.270	-0.351	-1.051	0.261	-0.248
Early_RecrDev_1980	-0.195	0.148	-0.759	-0.183	0.143	-0.779	-0.434	0.138	-0.319
Early_RecrDev_1981	0.244	0.089	0.367	0.226	0.092	0.407	0.000	0.090	-230.582
Early_RecrDev_1982	-0.280	0.117	-0.419	-0.226	0.118	-0.522	-0.514	0.120	-0.234
Early_RecrDev_1983	-0.178	0.090	-0.508	-0.156	0.092	-0.588	-0.429	0.091	-0.213
Main_RecrDev_1984	-0.625	0.102	-0.164	-0.529	0.099	-0.186	-0.857	0.103	-0.120
Main_RecrDev_1985	0.181	0.048	0.266	0.215	0.047	0.219	-0.108	0.049	-0.449
Main_RecrDev_1986	-0.825	0.075	-0.091	-0.700	0.072	-0.103	-1.049	0.074	-0.071
Main_RecrDev_1987	-0.503	0.055	-0.109	-0.377	0.052	-0.137	-0.696	0.052	-0.075
Main_RecrDev_1988	-1.052	0.067	-0.064	-1.069	0.069	-0.064	-1.278	0.069	-0.054
Main_RecrDev_1989	0.334	0.033	0.099	0.293	0.032	0.110	0.236	0.031	0.133
Main_RecrDev_1990	-0.523	0.049	-0.094	-0.550	0.049	-0.089	-0.612	0.049	-0.080
Main_RecrDev_1991	-0.494	0.051	-0.102	-0.371	0.046	-0.123	-0.431	0.045	-0.105
Main_RecrDev_1992	-0.395	0.051	-0.130	-0.309	0.048	-0.154	-0.329	0.047	-0.143
Main_RecrDev_1993	0.675	0.033	0.049	0.641	0.032	0.050	0.625	0.031	0.050
Main_RecrDev_1994	0.053	0.047	0.885	0.178	0.043	0.243	0.113	0.043	0.385
Main_RecrDev_1995	-0.189	0.054	-0.286	-0.076	0.051	-0.667	-0.174	0.050	-0.290
Main_RecrDev_1996	0.943	0.031	0.033	0.997	0.030	0.030	0.912	0.029	0.032
Main_RecrDev_1997	0.298	0.041	0.137	0.397	0.039	0.097	0.280	0.039	0.138
Main_RecrDev_1998	-0.542	0.059	-0.108	-0.341	0.054	-0.158	-0.354	0.054	-0.153
Main_RecrDev_1999	0.569	0.035	0.061	0.643	0.033	0.051	0.736	0.033	0.045
Main_RecrDev_2000	0.502	0.038	0.076	0.558	0.035	0.064	0.636	0.037	0.057
Main_RecrDev_2001	0.215	0.049	0.230	0.251	0.046	0.184	0.311	0.046	0.148
Main_RecrDev_20	0.703	0.05	0.071	0.630	0.048	0.076	0.719	0.043	0.060

02		0							
Main_RecrDev_2003	0.221	0.064	0.287	0.125	0.061	0.485	0.190	0.058	0.304
Main_RecrDev_2004	0.289	0.061	0.213	0.203	0.058	0.285	0.246	0.059	0.241
Main_RecrDev_2005	-0.059	0.041	-0.698	-0.234	0.035	-0.151	0.078	0.041	0.525
Main_RecrDev_2006	0.755	0.036	0.048	0.430	0.032	0.074	0.906	0.033	0.036
Main_RecrDev_2007	1.048	0.042	0.040	0.623	0.036	0.058	0.970	0.035	0.036
Main_RecrDev_2008	0.536	0.058	0.109	0.171	0.046	0.270	0.360	0.046	0.127
Main_RecrDev_2009	0.406	0.071	0.174	0.152	0.048	0.312	0.378	0.050	0.133
Main_RecrDev_2010	0.266	0.092	0.346	0.539	0.045	0.084	0.714	0.048	0.067
Main_RecrDev_2011	-1.636	0.235	-0.144	-1.259	0.108	-0.086	-1.195	0.108	-0.090
Main_RecrDev_2012	-1.149	0.183	-0.159	-0.515	0.078	-0.152	-0.579	0.075	-0.130
Main_RecrDev_2013				-0.052	0.091	-1.746	-0.159	0.087	-0.547
Main_RecrDev_2014				-0.278	0.122	-0.441	-0.335	0.118	-0.353
Main_RecrDev_2015				-0.388	0.138	-0.357	-0.251	0.139	-0.554

	SEDAR 33			Continuity			Alternative model		
Parameter	Value	Stdev	CV	Value	Stdev	CV	Value	Stdev	CV
InitF_1Com_HL_1	0.088	0.014	0.155	0.036	0.003	0.085	0.028	0.002	0.078
InitF_2Com_LL_2	0.000	_		0.000	_		0.000	_	
InitF_3Headboat_3	0.000	_		0.000	_		0.000	_	
InitF_4CHARTER_4	0.000	_		0.000	_		0.000	_	
InitF_5PRIVATE_5	0.032	0.003	0.084	0.028	0.002	0.075	0.017	0.001	0.058
InitF_6REDTIDE_6	0.000	_		0.000	_		0.000	_	
F_fleet_1_YR_1963_s_1	0.110	0.014	0.131	0.053	0.005	0.101	0.042	0.004	0.096
F_fleet_1_YR_1964_s_1	0.143	0.019	0.133	0.069	0.006	0.087	0.053	0.004	0.080
F_fleet_1_YR_1965_s_1	0.166	0.023	0.137	0.079	0.007	0.091	0.061	0.005	0.083
F_fleet_1_YR_1966_s_1	0.148	0.021	0.142	0.070	0.007	0.094	0.054	0.005	0.086
F_fleet_1_YR_1967_s_1	0.123	0.018	0.145	0.059	0.006	0.098	0.045	0.004	0.089
F_fleet_1_YR_1968_s_1	0.141	0.021	0.150	0.068	0.007	0.102	0.051	0.005	0.092
F_fleet_1_YR_1969_s_1	0.188	0.030	0.158	0.089	0.010	0.108	0.067	0.007	0.097
F_fleet_1_YR_1970_s_1	0.210	0.036	0.170	0.099	0.011	0.114	0.074	0.008	0.103
F_fleet_1_YR_1971_s_1	0.254	0.047	0.184	0.118	0.014	0.122	0.087	0.010	0.109
F_fleet_1_YR_1972_s_1	0.333	0.067	0.202	0.153	0.020	0.130	0.114	0.013	0.115
F_fleet_1_YR_1973_s_1	0.292	0.063	0.217	0.139	0.019	0.139	0.103	0.012	0.121
F_fleet_1_YR_1974_s_1	0.375	0.084	0.224	0.195	0.029	0.150	0.146	0.019	0.128
F_fleet_1_YR_1975_s_1	0.503	0.111	0.221	0.307	0.052	0.168	0.233	0.033	0.142
F_fleet_1_YR_1976_s_1	0.371	0.071	0.192	0.297	0.053	0.177	0.233	0.035	0.151

F_fleet_1_YR_1977_s_1	0.237	0.035	0.146	0.239	0.035	0.145	0.202	0.026	0.129
F_fleet_1_YR_1978_s_1	0.162	0.018	0.109	0.178	0.018	0.102	0.160	0.015	0.095
F_fleet_1_YR_1979_s_1	0.211	0.018	0.086	0.233	0.017	0.075	0.215	0.016	0.075
F_fleet_1_YR_1980_s_1	0.198	0.015	0.075	0.216	0.013	0.059	0.203	0.012	0.060
F_fleet_1_YR_1981_s_1	0.208	0.015	0.071	0.227	0.011	0.050	0.216	0.011	0.050
F_fleet_1_YR_1982_s_1	0.193	0.014	0.070	0.212	0.010	0.049	0.204	0.010	0.049
F_fleet_1_YR_1983_s_1	0.162	0.012	0.072	0.180	0.009	0.049	0.178	0.009	0.049
F_fleet_1_YR_1984_s_1	0.178	0.013	0.072	0.197	0.010	0.049	0.197	0.010	0.049
F_fleet_1_YR_1985_s_1	0.218	0.015	0.070	0.238	0.011	0.047	0.238	0.011	0.048
F_fleet_1_YR_1986_s_1	0.143	0.010	0.070	0.158	0.007	0.046	0.157	0.007	0.046
F_fleet_1_YR_1987_s_1	0.102	0.007	0.068	0.114	0.005	0.044	0.114	0.005	0.043
F_fleet_1_YR_1988_s_1	0.093	0.006	0.066	0.102	0.004	0.041	0.104	0.004	0.041
F_fleet_1_YR_1989_s_1	0.149	0.010	0.065	0.161	0.006	0.039	0.167	0.007	0.039
F_fleet_1_YR_1990_s_1	0.146	0.009	0.064	0.156	0.006	0.039	0.163	0.006	0.039
F_fleet_1_YR_1991_s_1	0.143	0.009	0.064	0.152	0.006	0.039	0.158	0.006	0.038
F_fleet_1_YR_1992_s_1	0.151	0.010	0.065	0.160	0.006	0.039	0.170	0.007	0.039
F_fleet_1_YR_1993_s_1	0.201	0.013	0.065	0.216	0.009	0.040	0.231	0.009	0.040
F_fleet_1_YR_1994_s_1	0.186	0.012	0.064	0.208	0.008	0.040	0.221	0.009	0.040
F_fleet_1_YR_1995_s_1	0.191	0.012	0.064	0.217	0.009	0.040	0.232	0.009	0.040
F_fleet_1_YR_1996_s_1	0.171	0.011	0.064	0.195	0.008	0.041	0.211	0.008	0.040
F_fleet_1_YR_1997_s_1	0.152	0.010	0.064	0.171	0.007	0.040	0.184	0.007	0.039

F_fleet_1_YR_1998_s_1	0.227	0.014	0.062	0.252	0.010	0.039	0.269	0.010	0.038
F_fleet_1_YR_1999_s_1	0.169	0.011	0.064	0.178	0.007	0.038	0.190	0.007	0.037
F_fleet_1_YR_2000_s_1	0.167	0.011	0.063	0.171	0.006	0.036	0.182	0.006	0.036
F_fleet_1_YR_2001_s_1	0.226	0.014	0.062	0.233	0.008	0.036	0.244	0.009	0.035
F_fleet_1_YR_2002_s_1	0.215	0.014	0.063	0.225	0.009	0.038	0.236	0.009	0.036
F_fleet_1_YR_2003_s_1	0.167	0.011	0.066	0.175	0.007	0.042	0.187	0.007	0.040
F_fleet_1_YR_2004_s_1	0.193	0.014	0.071	0.205	0.010	0.050	0.228	0.011	0.050
F_fleet_1_YR_2005_s_1	0.244	0.017	0.068	0.269	0.012	0.046	0.296	0.013	0.045
F_fleet_1_YR_2006_s_1	0.213	0.014	0.065	0.239	0.009	0.038	0.251	0.009	0.035
F_fleet_1_YR_2007_s_1	0.213	0.014	0.068	0.240	0.010	0.040	0.257	0.009	0.037
F_fleet_1_YR_2008_s_1	0.283	0.021	0.073	0.348	0.017	0.049	0.394	0.017	0.043
F_fleet_1_YR_2009_s_1	0.156	0.013	0.082	0.226	0.014	0.064	0.284	0.016	0.056
F_fleet_1_YR_2010_s_1	0.061	0.005	0.083	0.099	0.007	0.070	0.128	0.008	0.064
F_fleet_1_YR_2011_s_1	0.022	0.002	0.082	0.036	0.003	0.072	0.049	0.003	0.066
F_fleet_1_YR_2012_s_1	0.023	0.002	0.081	0.039	0.003	0.074	0.060	0.004	0.067
F_fleet_1_YR_2013_s_1				0.029	0.002	0.079	0.055	0.004	0.074
F_fleet_1_YR_2014_s_1				0.024	0.002	0.084	0.059	0.005	0.093
F_fleet_1_YR_2015_s_1				0.016	0.001	0.089	0.052	0.007	0.129
F_fleet_2_YR_1963_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1964_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1965_s_1	0.000	_		0.000	_		0.000	_	

F_fleet_2_YR_1966_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1967_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1968_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1969_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1970_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1971_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1972_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1973_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1974_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1975_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1976_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1977_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1978_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_2_YR_1979_s_1	0.000	0.000	0.133	0.000	0.000	0.135	0.000	0.000	0.120
F_fleet_2_YR_1980_s_1	0.016	0.002	0.107	0.018	0.002	0.091	0.016	0.001	0.084
F_fleet_2_YR_1981_s_1	0.066	0.006	0.093	0.075	0.005	0.072	0.071	0.005	0.070
F_fleet_2_YR_1982_s_1	0.142	0.012	0.086	0.163	0.010	0.064	0.156	0.010	0.062
F_fleet_2_YR_1983_s_1	0.103	0.009	0.086	0.120	0.007	0.061	0.119	0.007	0.061
F_fleet_2_YR_1984_s_1	0.071	0.006	0.085	0.084	0.005	0.059	0.086	0.005	0.059
F_fleet_2_YR_1985_s_1	0.060	0.005	0.083	0.072	0.004	0.058	0.074	0.004	0.058
F_fleet_2_YR_1986_s_1	0.083	0.007	0.082	0.100	0.006	0.057	0.103	0.006	0.057

F_fleet_2_YR_1987_s_1	0.101	0.008	0.079	0.122	0.007	0.054	0.127	0.007	0.054
F_fleet_2_YR_1988_s_1	0.058	0.004	0.076	0.070	0.004	0.050	0.074	0.004	0.050
F_fleet_2_YR_1989_s_1	0.060	0.004	0.074	0.071	0.003	0.047	0.076	0.004	0.047
F_fleet_2_YR_1990_s_1	0.091	0.007	0.073	0.106	0.005	0.046	0.114	0.005	0.046
F_fleet_2_YR_1991_s_1	0.077	0.006	0.072	0.090	0.004	0.045	0.097	0.004	0.045
F_fleet_2_YR_1992_s_1	0.095	0.007	0.072	0.111	0.005	0.045	0.123	0.005	0.045
F_fleet_2_YR_1993_s_1	0.082	0.006	0.072	0.098	0.005	0.046	0.110	0.005	0.046
F_fleet_2_YR_1994_s_1	0.062	0.004	0.072	0.077	0.004	0.048	0.087	0.004	0.048
F_fleet_2_YR_1995_s_1	0.071	0.005	0.072	0.091	0.004	0.049	0.103	0.005	0.048
F_fleet_2_YR_1996_s_1	0.073	0.005	0.072	0.096	0.005	0.049	0.110	0.005	0.049
F_fleet_2_YR_1997_s_1	0.074	0.005	0.071	0.096	0.005	0.049	0.110	0.005	0.048
F_fleet_2_YR_1998_s_1	0.100	0.007	0.070	0.128	0.006	0.048	0.146	0.007	0.047
F_fleet_2_YR_1999_s_1	0.088	0.006	0.070	0.107	0.005	0.046	0.121	0.005	0.045
F_fleet_2_YR_2000_s_1	0.088	0.006	0.070	0.100	0.004	0.044	0.113	0.005	0.043
F_fleet_2_YR_2001_s_1	0.142	0.010	0.069	0.159	0.007	0.044	0.178	0.008	0.042
F_fleet_2_YR_2002_s_1	0.159	0.011	0.070	0.178	0.008	0.045	0.197	0.008	0.042
F_fleet_2_YR_2003_s_1	0.173	0.012	0.072	0.193	0.009	0.048	0.217	0.010	0.045
F_fleet_2_YR_2004_s_1	0.174	0.013	0.077	0.194	0.011	0.054	0.226	0.012	0.053
F_fleet_2_YR_2005_s_1	0.200	0.015	0.074	0.231	0.012	0.051	0.267	0.013	0.050
F_fleet_2_YR_2006_s_1	0.197	0.014	0.073	0.235	0.011	0.046	0.259	0.011	0.044
F_fleet_2_YR_2007_s_1	0.189	0.015	0.077	0.230	0.011	0.049	0.258	0.012	0.046

F_fleet_2_YR_2008_s_1	0.165	0.014	0.084	0.217	0.013	0.058	0.259	0.014	0.052
F_fleet_2_YR_2009_s_1	0.065	0.006	0.091	0.101	0.007	0.073	0.134	0.009	0.066
F_fleet_2_YR_2010_s_1	0.030	0.003	0.091	0.052	0.004	0.079	0.072	0.005	0.072
F_fleet_2_YR_2011_s_1	0.022	0.003	0.122	0.032	0.003	0.090	0.049	0.004	0.087
F_fleet_2_YR_2012_s_1	0.019	0.002	0.119	0.030	0.003	0.090	0.051	0.004	0.087
F_fleet_2_YR_2013_s_1				0.031	0.003	0.092	0.063	0.006	0.093
F_fleet_2_YR_2014_s_1				0.025	0.002	0.095	0.066	0.007	0.108
F_fleet_2_YR_2015_s_1				0.023	0.002	0.098	0.080	0.011	0.138
F_fleet_3_YR_1963_s_1	0.003	0.000	0.085	0.005	0.000	0.084	0.003	0.000	0.078
F_fleet_3_YR_1964_s_1	0.003	0.000	0.084	0.005	0.000	0.065	0.004	0.000	0.058
F_fleet_3_YR_1965_s_1	0.004	0.000	0.090	0.007	0.000	0.073	0.005	0.000	0.064
F_fleet_3_YR_1966_s_1	0.005	0.001	0.103	0.009	0.001	0.092	0.007	0.001	0.077
F_fleet_3_YR_1967_s_1	0.006	0.001	0.119	0.012	0.001	0.115	0.009	0.001	0.094
F_fleet_3_YR_1968_s_1	0.008	0.001	0.135	0.016	0.002	0.139	0.012	0.001	0.112
F_fleet_3_YR_1969_s_1	0.009	0.001	0.152	0.020	0.003	0.162	0.016	0.002	0.131
F_fleet_3_YR_1970_s_1	0.011	0.002	0.168	0.025	0.004	0.181	0.020	0.003	0.148
F_fleet_3_YR_1971_s_1	0.012	0.002	0.186	0.031	0.006	0.198	0.026	0.004	0.164
F_fleet_3_YR_1972_s_1	0.013	0.003	0.211	0.038	0.008	0.224	0.034	0.007	0.195
F_fleet_3_YR_1973_s_1	0.012	0.003	0.232	0.044	0.012	0.274	0.043	0.011	0.263
F_fleet_3_YR_1974_s_1	0.009	0.002	0.210	0.040	0.013	0.322	0.044	0.015	0.341
F_fleet_3_YR_1975_s_1	0.006	0.001	0.150	0.020	0.004	0.197	0.018	0.003	0.163

F_fleet_3_YR_1976_s_1	0.006	0.001	0.102	0.011	0.002	0.157	0.009	0.001	0.159
F_fleet_3_YR_1977_s_1	0.006	0.001	0.088	0.010	0.001	0.093	0.008	0.001	0.083
F_fleet_3_YR_1978_s_1	0.008	0.001	0.081	0.011	0.001	0.070	0.009	0.001	0.064
F_fleet_3_YR_1979_s_1	0.010	0.001	0.078	0.013	0.001	0.066	0.011	0.001	0.060
F_fleet_3_YR_1980_s_1	0.011	0.001	0.076	0.014	0.001	0.058	0.011	0.001	0.048
F_fleet_3_YR_1981_s_1	0.008	0.001	0.074	0.010	0.001	0.055	0.008	0.000	0.043
F_fleet_3_YR_1982_s_1	0.011	0.001	0.074	0.014	0.001	0.054	0.011	0.000	0.039
F_fleet_3_YR_1983_s_1	0.016	0.001	0.070	0.019	0.001	0.049	0.015	0.001	0.033
F_fleet_3_YR_1984_s_1	0.008	0.001	0.067	0.009	0.000	0.044	0.007	0.000	0.030
F_fleet_3_YR_1985_s_1	0.044	0.003	0.065	0.050	0.002	0.040	0.040	0.001	0.026
F_fleet_3_YR_1986_s_1	0.022	0.001	0.066	0.025	0.001	0.041	0.020	0.001	0.028
F_fleet_3_YR_1987_s_1	0.017	0.001	0.064	0.019	0.001	0.038	0.015	0.000	0.025
F_fleet_3_YR_1988_s_1	0.016	0.001	0.062	0.017	0.001	0.034	0.014	0.000	0.023
F_fleet_3_YR_1989_s_1	0.025	0.002	0.062	0.028	0.001	0.033	0.023	0.001	0.024
F_fleet_3_YR_1990_s_1	0.023	0.001	0.060	0.025	0.001	0.026	0.022	0.001	0.024
F_fleet_3_YR_1991_s_1	0.013	0.001	0.060	0.015	0.000	0.027	0.013	0.000	0.025
F_fleet_3_YR_1992_s_1	0.012	0.001	0.059	0.013	0.000	0.023	0.012	0.000	0.021
F_fleet_3_YR_1993_s_1	0.017	0.001	0.059	0.020	0.000	0.024	0.017	0.000	0.022
F_fleet_3_YR_1994_s_1	0.021	0.001	0.060	0.023	0.001	0.026	0.020	0.000	0.023
F_fleet_3_YR_1995_s_1	0.016	0.001	0.060	0.018	0.000	0.026	0.016	0.000	0.024
F_fleet_3_YR_1996_s_1	0.010	0.001	0.059	0.011	0.000	0.023	0.010	0.000	0.022

F_fleet_3_YR_1997_s_1	0.010	0.001	0.059	0.010	0.000	0.024	0.009	0.000	0.022
F_fleet_3_YR_1998_s_1	0.022	0.001	0.059	0.023	0.001	0.025	0.020	0.000	0.023
F_fleet_3_YR_1999_s_1	0.015	0.001	0.059	0.015	0.000	0.022	0.014	0.000	0.019
F_fleet_3_YR_2000_s_1	0.015	0.001	0.059	0.015	0.000	0.022	0.013	0.000	0.020
F_fleet_3_YR_2001_s_1	0.012	0.001	0.061	0.012	0.000	0.027	0.010	0.000	0.025
F_fleet_3_YR_2002_s_1	0.009	0.001	0.062	0.010	0.000	0.029	0.008	0.000	0.026
F_fleet_3_YR_2003_s_1	0.011	0.001	0.064	0.012	0.000	0.033	0.010	0.000	0.031
F_fleet_3_YR_2004_s_1	0.017	0.001	0.070	0.018	0.001	0.044	0.017	0.001	0.044
F_fleet_3_YR_2005_s_1	0.015	0.001	0.066	0.018	0.001	0.038	0.016	0.001	0.039
F_fleet_3_YR_2006_s_1	0.010	0.001	0.061	0.012	0.000	0.025	0.011	0.000	0.022
F_fleet_3_YR_2007_s_1	0.018	0.001	0.062	0.022	0.001	0.027	0.019	0.000	0.022
F_fleet_3_YR_2008_s_1	0.016	0.001	0.066	0.022	0.001	0.034	0.020	0.001	0.026
F_fleet_3_YR_2009_s_1	0.009	0.001	0.071	0.015	0.001	0.046	0.015	0.001	0.038
F_fleet_3_YR_2010_s_1	0.006	0.000	0.073	0.011	0.001	0.053	0.011	0.001	0.047
F_fleet_3_YR_2011_s_1	0.006	0.001	0.210	0.009	0.001	0.132	0.016	0.001	0.042
F_fleet_3_YR_2012_s_1	0.005	0.001	0.209	0.009	0.001	0.134	0.017	0.001	0.048
F_fleet_3_YR_2013_s_1				0.008	0.001	0.138	0.018	0.001	0.061
F_fleet_3_YR_2014_s_1				0.010	0.001	0.142	0.032	0.003	0.094
F_fleet_3_YR_2015_s_1				0.006	0.001	0.146	0.029	0.004	0.144
F_fleet_4_YR_1963_s_1	0.010	0.001	0.084	0.015	0.001	0.084	0.013	0.001	0.084
F_fleet_4_YR_1964_s_1	0.012	0.001	0.084	0.017	0.001	0.065	0.014	0.001	0.066

F_fleet_4_YR_1965_s_1	0.015	0.001	0.089	0.021	0.002	0.071	0.017	0.001	0.069
F_fleet_4_YR_1966_s_1	0.020	0.002	0.102	0.028	0.002	0.085	0.022	0.002	0.078
F_fleet_4_YR_1967_s_1	0.026	0.003	0.118	0.037	0.004	0.103	0.029	0.003	0.090
F_fleet_4_YR_1968_s_1	0.032	0.004	0.135	0.048	0.006	0.122	0.038	0.004	0.104
F_fleet_4_YR_1969_s_1	0.039	0.006	0.153	0.062	0.009	0.142	0.050	0.006	0.119
F_fleet_4_YR_1970_s_1	0.045	0.008	0.170	0.077	0.012	0.160	0.065	0.009	0.133
F_fleet_4_YR_1971_s_1	0.051	0.010	0.189	0.100	0.018	0.176	0.090	0.013	0.145
F_fleet_4_YR_1972_s_1	0.056	0.012	0.213	0.126	0.025	0.200	0.122	0.020	0.164
F_fleet_4_YR_1973_s_1	0.053	0.012	0.235	0.154	0.038	0.249	0.165	0.036	0.217
F_fleet_4_YR_1974_s_1	0.041	0.009	0.222	0.154	0.047	0.305	0.197	0.059	0.300
F_fleet_4_YR_1975_s_1	0.029	0.005	0.173	0.087	0.019	0.224	0.113	0.023	0.207
F_fleet_4_YR_1976_s_1	0.024	0.003	0.108	0.042	0.007	0.165	0.045	0.008	0.175
F_fleet_4_YR_1977_s_1	0.026	0.002	0.090	0.036	0.003	0.096	0.036	0.004	0.106
F_fleet_4_YR_1978_s_1	0.034	0.003	0.082	0.040	0.003	0.067	0.039	0.003	0.064
F_fleet_4_YR_1979_s_1	0.043	0.003	0.079	0.048	0.003	0.063	0.046	0.003	0.062
F_fleet_4_YR_1980_s_1	0.047	0.004	0.076	0.050	0.003	0.053	0.048	0.002	0.051
F_fleet_4_YR_1981_s_1	0.014	0.001	0.074	0.017	0.001	0.050	0.016	0.001	0.047
F_fleet_4_YR_1982_s_1	0.023	0.002	0.074	0.029	0.001	0.050	0.027	0.001	0.046
F_fleet_4_YR_1983_s_1	0.029	0.002	0.070	0.035	0.002	0.044	0.033	0.001	0.043
F_fleet_4_YR_1984_s_1	0.013	0.001	0.067	0.015	0.001	0.039	0.015	0.001	0.037
F_fleet_4_YR_1985_s_1	0.075	0.005	0.064	0.085	0.003	0.036	0.079	0.003	0.033

F_fleet_4_YR_1986_s_1	0.091	0.006	0.065	0.103	0.004	0.038	0.097	0.003	0.033
F_fleet_4_YR_1987_s_1	0.019	0.001	0.065	0.056	0.002	0.035	0.054	0.002	0.034
F_fleet_4_YR_1988_s_1	0.040	0.002	0.062	0.044	0.001	0.030	0.042	0.001	0.028
F_fleet_4_YR_1989_s_1	0.027	0.002	0.061	0.028	0.001	0.029	0.027	0.001	0.027
F_fleet_4_YR_1990_s_1	0.038	0.002	0.060	0.041	0.001	0.024	0.037	0.001	0.022
F_fleet_4_YR_1991_s_1	0.014	0.001	0.060	0.017	0.000	0.025	0.015	0.000	0.023
F_fleet_4_YR_1992_s_1	0.038	0.002	0.058	0.044	0.001	0.022	0.041	0.001	0.021
F_fleet_4_YR_1993_s_1	0.089	0.005	0.057	0.105	0.002	0.022	0.097	0.002	0.021
F_fleet_4_YR_1994_s_1	0.050	0.003	0.059	0.057	0.001	0.024	0.052	0.001	0.022
F_fleet_4_YR_1995_s_1	0.096	0.006	0.059	0.111	0.003	0.025	0.103	0.002	0.023
F_fleet_4_YR_1996_s_1	0.066	0.004	0.058	0.074	0.002	0.022	0.070	0.001	0.021
F_fleet_4_YR_1997_s_1	0.060	0.004	0.058	0.066	0.001	0.022	0.061	0.001	0.021
F_fleet_4_YR_1998_s_1	0.089	0.005	0.058	0.095	0.002	0.023	0.089	0.002	0.021
F_fleet_4_YR_1999_s_1	0.061	0.004	0.058	0.064	0.001	0.020	0.060	0.001	0.019
F_fleet_4_YR_2000_s_1	0.077	0.004	0.057	0.081	0.002	0.020	0.074	0.001	0.018
F_fleet_4_YR_2001_s_1	0.084	0.005	0.060	0.087	0.002	0.025	0.079	0.002	0.023
F_fleet_4_YR_2002_s_1	0.073	0.004	0.061	0.076	0.002	0.027	0.069	0.002	0.025
F_fleet_4_YR_2003_s_1	0.066	0.004	0.063	0.069	0.002	0.031	0.065	0.002	0.030
F_fleet_4_YR_2004_s_1	0.093	0.006	0.069	0.099	0.004	0.042	0.096	0.004	0.044
F_fleet_4_YR_2005_s_1	0.115	0.008	0.066	0.170	0.006	0.037	0.165	0.006	0.038
F_fleet_4_YR_2006_s_1	0.125	0.007	0.060	0.143	0.003	0.023	0.132	0.003	0.020

F_fleet_4_YR_2007_s_1	0.064	0.004	0.062	0.079	0.002	0.025	0.073	0.002	0.021
F_fleet_4_YR_2008_s_1	0.141	0.009	0.066	0.158	0.005	0.033	0.152	0.004	0.026
F_fleet_4_YR_2009_s_1	0.046	0.003	0.071	0.070	0.003	0.046	0.075	0.003	0.039
F_fleet_4_YR_2010_s_1	0.032	0.002	0.073	0.054	0.003	0.052	0.057	0.003	0.048
F_fleet_4_YR_2011_s_1	0.009	0.001	0.157	0.038	0.009	0.239	0.046	0.009	0.202
F_fleet_4_YR_2012_s_1	0.038	0.006	0.156	0.147	0.036	0.242	0.200	0.041	0.203
F_fleet_4_YR_2013_s_1				0.064	0.016	0.246	0.105	0.022	0.206
F_fleet_4_YR_2014_s_1				0.032	0.008	0.250	0.072	0.016	0.214
F_fleet_4_YR_2015_s_1				0.045	0.011	0.252	0.141	0.033	0.236
F_fleet_5_YR_1963_s_1	0.033	0.003	0.083	0.066	0.006	0.096	0.051	0.004	0.080
F_fleet_5_YR_1964_s_1	0.041	0.003	0.085	0.080	0.006	0.078	0.059	0.003	0.058
F_fleet_5_YR_1965_s_1	0.054	0.005	0.099	0.107	0.010	0.095	0.076	0.005	0.066
F_fleet_5_YR_1966_s_1	0.071	0.008	0.120	0.146	0.018	0.121	0.104	0.009	0.082
F_fleet_5_YR_1967_s_1	0.090	0.013	0.142	0.191	0.028	0.146	0.143	0.015	0.103
F_fleet_5_YR_1968_s_1	0.109	0.018	0.161	0.239	0.040	0.169	0.191	0.024	0.125
F_fleet_5_YR_1969_s_1	0.122	0.022	0.178	0.285	0.053	0.187	0.249	0.036	0.145
F_fleet_5_YR_1970_s_1	0.130	0.025	0.193	0.323	0.064	0.199	0.309	0.050	0.162
F_fleet_5_YR_1971_s_1	0.137	0.029	0.210	0.376	0.079	0.211	0.389	0.068	0.176
F_fleet_5_YR_1972_s_1	0.135	0.032	0.234	0.429	0.102	0.238	0.479	0.100	0.208
F_fleet_5_YR_1973_s_1	0.112	0.028	0.250	0.459	0.132	0.287	0.575	0.158	0.276
F_fleet_5_YR_1974_s_1	0.077	0.017	0.214	0.330	0.108	0.327	0.504	0.167	0.332

F_fleet_5_YR_1975_s_1	0.058	0.007	0.122	0.143	0.028	0.196	0.185	0.030	0.165
F_fleet_5_YR_1976_s_1	0.062	0.006	0.095	0.110	0.014	0.125	0.112	0.015	0.135
F_fleet_5_YR_1977_s_1	0.078	0.007	0.084	0.119	0.010	0.086	0.111	0.008	0.069
F_fleet_5_YR_1978_s_1	0.102	0.009	0.085	0.148	0.013	0.089	0.128	0.008	0.060
F_fleet_5_YR_1979_s_1	0.113	0.009	0.083	0.159	0.013	0.084	0.142	0.008	0.054
F_fleet_5_YR_1980_s_1	0.125	0.010	0.079	0.167	0.013	0.076	0.149	0.007	0.048
F_fleet_5_YR_1981_s_1	0.077	0.006	0.079	0.104	0.008	0.079	0.097	0.004	0.045
F_fleet_5_YR_1982_s_1	0.132	0.010	0.075	0.180	0.014	0.077	0.171	0.007	0.041
F_fleet_5_YR_1983_s_1	0.283	0.018	0.065	0.352	0.023	0.065	0.321	0.011	0.033
F_fleet_5_YR_1984_s_1	0.079	0.005	0.066	0.093	0.006	0.064	0.084	0.003	0.031
F_fleet_5_YR_1985_s_1	0.142	0.009	0.065	0.184	0.011	0.061	0.158	0.004	0.028
F_fleet_5_YR_1986_s_1	0.167	0.012	0.069	0.217	0.016	0.073	0.200	0.006	0.032
F_fleet_5_YR_1987_s_1	0.154	0.010	0.063	0.173	0.010	0.060	0.153	0.004	0.027
F_fleet_5_YR_1988_s_1	0.251	0.015	0.061	0.321	0.020	0.063	0.285	0.007	0.026
F_fleet_5_YR_1989_s_1	0.186	0.013	0.069	0.241	0.016	0.066	0.207	0.006	0.029
F_fleet_5_YR_1990_s_1	0.175	0.011	0.061	0.242	0.014	0.058	0.171	0.005	0.027
F_fleet_5_YR_1991_s_1	0.308	0.018	0.058	0.419	0.023	0.055	0.306	0.008	0.027
F_fleet_5_YR_1992_s_1	0.178	0.010	0.057	0.242	0.013	0.052	0.185	0.004	0.022
F_fleet_5_YR_1993_s_1	0.219	0.013	0.058	0.314	0.017	0.056	0.229	0.005	0.024
F_fleet_5_YR_1994_s_1	0.238	0.014	0.060	0.329	0.018	0.056	0.236	0.006	0.025
F_fleet_5_YR_1995_s_1	0.302	0.018	0.059	0.387	0.021	0.053	0.291	0.007	0.026

F_fleet_5_YR_1996_s_1	0.171	0.010	0.059	0.219	0.011	0.052	0.170	0.004	0.022
F_fleet_5_YR_1997_s_1	0.198	0.012	0.059	0.252	0.014	0.055	0.187	0.004	0.023
F_fleet_5_YR_1998_s_1	0.232	0.014	0.059	0.268	0.014	0.054	0.200	0.005	0.025
F_fleet_5_YR_1999_s_1	0.202	0.012	0.057	0.244	0.013	0.051	0.186	0.004	0.021
F_fleet_5_YR_2000_s_1	0.278	0.015	0.056	0.363	0.020	0.054	0.262	0.005	0.021
F_fleet_5_YR_2001_s_1	0.318	0.020	0.061	0.452	0.028	0.063	0.296	0.008	0.029
F_fleet_5_YR_2002_s_1	0.359	0.022	0.061	0.500	0.031	0.062	0.341	0.010	0.029
F_fleet_5_YR_2003_s_1	0.297	0.019	0.065	0.405	0.026	0.064	0.287	0.010	0.033
F_fleet_5_YR_2004_s_1	0.398	0.029	0.072	0.596	0.043	0.072	0.431	0.020	0.047
F_fleet_5_YR_2005_s_1	0.385	0.027	0.071	0.536	0.036	0.068	0.390	0.016	0.042
F_fleet_5_YR_2006_s_1	0.461	0.028	0.062	0.458	0.028	0.061	0.314	0.008	0.025
F_fleet_5_YR_2007_s_1	0.442	0.028	0.063	0.627	0.038	0.061	0.431	0.011	0.025
F_fleet_5_YR_2008_s_1	0.597	0.040	0.067	1.024	0.065	0.064	0.743	0.021	0.028
F_fleet_5_YR_2009_s_1	0.168	0.013	0.075	0.361	0.026	0.071	0.297	0.012	0.041
F_fleet_5_YR_2010_s_1	0.106	0.008	0.078	0.234	0.018	0.076	0.188	0.010	0.051
F_fleet_5_YR_2011_s_1	0.197	0.074	0.376	0.314	0.085	0.271	0.325	0.012	0.038
F_fleet_5_YR_2012_s_1	0.176	0.067	0.382	0.278	0.077	0.277	0.314	0.013	0.043
F_fleet_4_YR_2013_s_1				0.478	0.136	0.285	0.649	0.036	0.055
F_fleet_4_YR_2014_s_1				0.257	0.076	0.295	0.476	0.041	0.086
F_fleet_4_YR_2015_s_1				0.267	0.081	0.302	0.672	0.092	0.137
F_fleet_6_YR_1963_s_1	0.000	_		0.000	_		0.000	_	

F_fleet_6_YR_1964_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1965_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1966_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1967_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1968_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1969_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1970_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1971_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1972_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1973_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1974_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1975_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1976_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1977_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1978_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1979_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1980_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1981_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1982_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1983_s_1	0.000	_	0.000	_	0.000	_
F_fleet_6_YR_1984_s_1	0.000	_	0.000	_	0.000	_

F_fleet_6_YR_1985_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1986_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1987_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1988_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1989_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1990_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1991_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1992_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1993_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1994_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1995_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1996_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1997_s_1	0.000	_		0.000	_		0.000	_	
F_fleet_6_YR_1998_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_1999_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2000_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2001_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2002_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2003_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2004_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2005_s_1	0.706	0.062	0.088	0.729	0.062	0.084	0.573	0.071	0.124

F_fleet_6_YR_2006_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2007_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2008_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2009_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2010_s_1	0.000	0.000	0.090	0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2011_s_1	0.000	_		0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2012_s_1	0.000	_		0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2013_s_1				0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2014_s_1				0.000	0.000	0.087	0.000	0.000	0.127
F_fleet_6_YR_2015_s_1				0.000	0.000	0.087	0.000	0.000	0.127
LnQ_base_6_REDTIDE_6	0.349	0.089	0.254	0.316	0.085	0.269	0.556	0.124	0.224

	SEDAR 33			Continuity			Alternative model		
Parameter	Value	Stdev	CV	Value	Stdev	CV	Value	Stdev	CV
SizeSel_1P_1_Com_HL_1	85.880	0.703	0.008	87.027	0.802	0.009	86.412	0.705	0.008
SizeSel_1P_2_Com_HL_1	-9.000	_		-9.000	_		-9.000	_	
SizeSel_1P_3_Com_HL_1	6.260	0.037	0.006	6.332	0.042	0.007	6.207	0.035	0.006
SizeSel_1P_4_Com_HL_1	4.706	0.620	0.132	2.357	1.156	0.490	2.746	0.947	0.345
SizeSel_1P_5_Com_HL_1	-14.205	18.860	-1.328	-8.728	3.273	-0.375	-12.934	35.201	-2.722
SizeSel_1P_6_Com_HL_1	-0.121	0.239	-1.974	0.965	0.198	0.205	1.103	0.223	0.202
Retain_1P_1_Com_HL_1	40.640	_		40.640	_		40.640	_	
Retain_1P_2_Com_HL_1	5.000	_		5.000	_		5.000	_	
Retain_1P_3_Com_HL_1	1.000	_		1.000	_		1.000	_	
Retain_1P_4_Com_HL_1	0.000	_		0.000	_		0.000	_	
DiscMort_1P_1_Com_HL_1	-10.000	_		-10.000	_		-10.000	_	
DiscMort_1P_2_Com_HL_1	1.000	_		1.000	_		1.000	_	
DiscMort_1P_3_Com_HL_1	0.250	_		0.250	_		0.250	_	
DiscMort_1P_4_Com_HL_1	0.000	_		0.000	_		0.000	_	
SizeSel_2P_1_Com_LL_2	77.853	0.439	0.006	78.384	0.416	0.005	78.873	0.402	0.005
SizeSel_2P_2_Com_LL_2	17.077	0.338	0.020	16.714	0.314	0.019	16.263	0.289	0.018
Retain_2P_1_Com_LL_2	40.640	_		40.640	_		40.640	_	

Retain_2P_2_Com_LL_2	5.000	_		5.000	_		5.000	_	
Retain_2P_3_Com_LL_2	1.000	_		1.000	_		1.000	_	
Retain_2P_4_Com_LL_2	0.000	_		0.000	_		0.000	_	
DiscMort_2P_1_Com_LL_2	-10.000	_		-10.000	_		-10.000	_	
DiscMort_2P_2_Com_LL_2	1.000	_		1.000	_		1.000	_	
DiscMort_2P_3_Com_LL_2	0.250	_		0.250	_		0.250	_	
DiscMort_2P_4_Com_LL_2	0.000	_		0.000	_		0.000	_	
SizeSel_3P_1_Headboat_3	43.852	0.822	0.019	44.595	0.723	0.016	49.314	0.760	0.015
SizeSel_3P_2_Headboat_3	-9.000	_		-9.000	_		-9.000	_	
SizeSel_3P_3_Headboat_3	5.047	0.089	0.018	5.149	0.076	0.015	5.380	0.068	0.013
SizeSel_3P_4_Headboat_3	7.581	0.070	0.009	7.288	0.056	0.008	7.304	0.068	0.009
SizeSel_3P_5_Headboat_3	-999.000	_		-999.000	_		-999.000	_	
SizeSel_3P_6_Headboat_3	-999.000	_		-999.000	_		-999.000	_	
Retain_3P_1_Headboat_3	40.771	0.789	0.019	41.827	0.759	0.018	37.167	0.774	0.021
Retain_3P_2_Headboat_3	5.000	_		5.000	_		5.000	_	
Retain_3P_3_Headboat_3	1.000	_		1.000	_		1.000	_	
Retain_3P_4_Headboat_3	0.000	_		0.000	_		0.000	_	
DiscMort_3P_1_Headboat_3	-10.000	_		-10.000	_		-10.000	_	
DiscMort_3P_2_Headboat_3	1.000	_		1.000	_		1.000	_	
DiscMort_3P_3_Headboat_3	0.120	_		0.120	_		0.120	_	
DiscMort_3P_4_Headboat_3	0.000	_		0.000	_		0.000	_	

SizeSel_4P_1_CHARTER_4	48.430	0.966	0.020	48.820	0.924	0.019	51.959	1.289	0.025
SizeSel_4P_2_CHARTER_4	-9.000	_		-9.000	_		-9.000	_	
SizeSel_4P_3_CHARTER_4	4.892	0.160	0.033	4.874	0.143	0.029	5.063	0.158	0.031
SizeSel_4P_4_CHARTER_4	7.373	0.073	0.010	7.738	0.082	0.011	7.955	0.122	0.015
SizeSel_4P_5_CHARTER_4	-999.000	_		-999.000	_		-999.000	_	
SizeSel_4P_6_CHARTER_4	-999.000	_		-999.000	_		-999.000	_	
Retain_4P_1_CHARTER_4	39.826	1.067	0.027	38.766	1.088	0.028	38.238	1.035	0.027
Retain_4P_2_CHARTER_4	5.000	_		5.000	_		5.000	_	
Retain_4P_3_CHARTER_4	1.000	_		1.000	_		1.000	_	
Retain_4P_4_CHARTER_4	0.000	_		0.000	_		0.000	_	
DiscMort_4P_1_CHARTER_4	-10.000	_		-10.000	_		-10.000	_	
DiscMort_4P_2_CHARTER_4	1.000	_		1.000	_		1.000	_	
DiscMort_4P_3_CHARTER_4	0.120	_		0.120	_		0.120	_	
DiscMort_4P_4_CHARTER_4	0.000	_		0.000	_		0.000	_	
SizeSel_5P_1_PRIVATE_5	38.718	1.897	0.049	25.376	2.863	0.113	44.631	1.520	0.034
SizeSel_5P_2_PRIVATE_5	-2.000	_		-2.000	_		-2.000	_	
SizeSel_5P_3_PRIVATE_5	5.837	0.325	0.056	2.988	1.331	0.446	5.709	0.199	0.035
SizeSel_5P_4_PRIVATE_5	6.299	0.132	0.021	6.921	0.111	0.016	6.295	0.125	0.020
SizeSel_5P_5_PRIVATE_5	-999.000	_		-999.000	_		-999.000	_	
SizeSel_5P_6_PRIVATE_5	-999.000	_		-999.000	_		-999.000	_	
Retain_5P_1_PRIVATE_5	33.743	1.272	0.038	36.218	1.241	0.034			

Retain_5P_2_PRIVATE_5	5.000	_		5.000	_				
Retain_5P_3_PRIVATE_5	1.000	_		1.000	_				
Retain_5P_4_PRIVATE_5	0.000	_		0.000	_				
DiscMort_5P_1_PRIVATE_5	-10.000	_		-10.000	_				
DiscMort_5P_2_PRIVATE_5	1.000	_		1.000	_				
DiscMort_5P_3_PRIVATE_5	0.120	_		0.120	_				
DiscMort_5P_4_PRIVATE_5	0.000	_		0.000	_				
SizeSel_9P_1_SEAMAP_Video_8	79.978	3.236	0.040	124.979	0.683	0.005	87.547	10.132	0.116
SizeSel_9P_2_SEAMAP_Video_8	16.800	1.912	0.114	35.573	2.603	0.073	23.428	4.062	0.173
SizeSel_10P_1_PC_Video_9	25.000	0.763	0.031	20.044	1.365	0.068	112.818	2.160	0.019
SizeSel_10P_2_PC_Video_9	0.661	0.012	0.018	0.758	1.424	1.879	-8.671	83.764	-9.661
SizeSel_10P_3_PC_Video_9	-0.986	103.05	-104.558	8.485	85.46	10.071	9.386	1.145	0.122
SizeSel_10P_4_PC_Video_9	-2.875	323.09	-112.385	-2.584	124.3	-48.116	-5.574	54.077	-9.702
SizeSel_10P_5_PC_Video_9	-15.000	_		-15.000	_		-15.000	_	
SizeSel_10P_6_PC_Video_9	-15.000	_		-15.000	_		-15.000	_	
AgeSel_3P_1_Headboat_3	0.100	_		0.100	_		0.100	_	
AgeSel_3P_2_Headboat_3	31.000	_		31.000	_		31.000	_	
AgeSel_5P_1_PRIVATE_5	0.100	_		0.100	_		0.100	_	
AgeSel_5P_2_PRIVATE_5	31.000	_		31.000	_		31.000	_	
AgeSel_8P_1_Age0_7	0.100	_		0.100	_		0.100	_	

AgeSel_8P_2_Age0_7	0.900	_		0.900	_		0.900	_	
Retain_1P_1_Com_HL_1_BLK1repl_1990	49.380	_		49.380	_		49.380	_	
Retain_1P_1_Com_HL_1_BLK1repl_2001	59.240	_		59.240	_		59.240	_	
Retain_1P_1_Com_HL_1_BLK1repl_2012	54.310	_		54.310	_		54.310	_	
Retain_1P_2_Com_HL_1_BLK1repl_1990	1.000	_		1.000	_		1.000	_	
Retain_1P_2_Com_HL_1_BLK1repl_2001	1.000	_		1.000	_		1.000	_	
Retain_1P_2_Com_HL_1_BLK1repl_2012	1.000	_		1.000	_		1.000	_	
Retain_1P_3_Com_HL_1_BLK4repl_2011	0.968	0.005	0.005	0.986	0.002	0.002	0.982	0.002	0.002
Retain_2P_1_Com_LL_2_BLK1repl_1990	49.380	_		49.380	_		49.380	_	
Retain_2P_1_Com_LL_2_BLK1repl_2001	59.240	_		59.240	_		59.240	_	
Retain_2P_1_Com_LL_2_BLK1repl_2012	54.310	_		54.310	_		54.310	_	
Retain_2P_2_Com_LL_2_BLK1repl_1990	1.000	_		1.000	_		1.000	_	
Retain_2P_2_Com_LL_2_BLK1repl_2001	1.000	_		1.000	_		1.000	_	
Retain_2P_2_Com_LL_2_BLK1repl_2012	1.000	_		1.000	_		1.000	_	
Retain_2P_3_Com_LL_2_BLK4repl_2011	0.665	0.053	0.080	0.776	0.026	0.033	0.748	0.028	0.037
Retain_3P_1_Headboat_3_BLK2repl_1990	49.380	_		49.380	_		49.380	_	

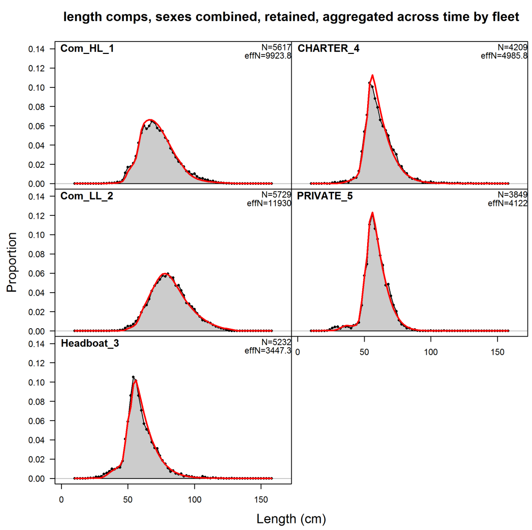
Retain_3P_1_Headboat_3_BLK2repl_2001	54.310	_		54.310	_		54.310	_	
Retain_3P_2_Headboat_3_BLK2repl_1990	1.000	_		1.000	_		1.000	_	
Retain_3P_2_Headboat_3_BLK2repl_2001	1.000	_		1.000	_		1.000	_	
Retain_3P_3_Headboat_3_BLK4repl_2011	0.392	0.076	0.194	0.455	0.051	0.111	0.267	0.017	0.065
Retain_4P_1_CHARTER_4_BLK2repl_1990	49.380	_		49.380	_		49.380	_	
Retain_4P_1_CHARTER_4_BLK2repl_2001	54.310	_		54.310	_		54.310	_	
Retain_4P_2_CHARTER_4_BLK2repl_1990	1.000	_		1.000	_		1.000	_	
Retain_4P_2_CHARTER_4_BLK2repl_2001	1.000	_		1.000	_		1.000	_	
Retain_4P_3_CHARTER_4_BLK4repl_2011	0.495	0.066	0.133	0.210	0.047	0.225	0.190	0.037	0.192
Retain_5P_1_PRIVATE_5_BLK2repl_1990	49.380	_		49.380	_				
Retain_5P_1_PRIVATE_5_BLK2repl_2001	54.310	_		54.310	_				
Retain_5P_2_PRIVATE_5_BLK2repl_1990	1.000	_		1.000	_				
Retain_5P_2_PRIVATE_5_BLK2repl_2001	1.000	_		1.000	_				
Retain_5P_3_PRIVATE_5_BLK4repl_2011	0.207	0.077	0.370	0.342	0.092	0.270			

APPENDIX D.

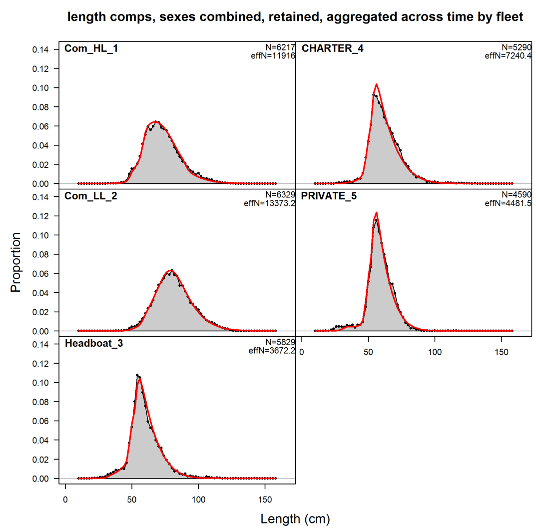
Model diagnostics

FigureD.1 Model fits to the length composition data of retained catch; a) SEDAR 33, b) continuity, and c) alternative.

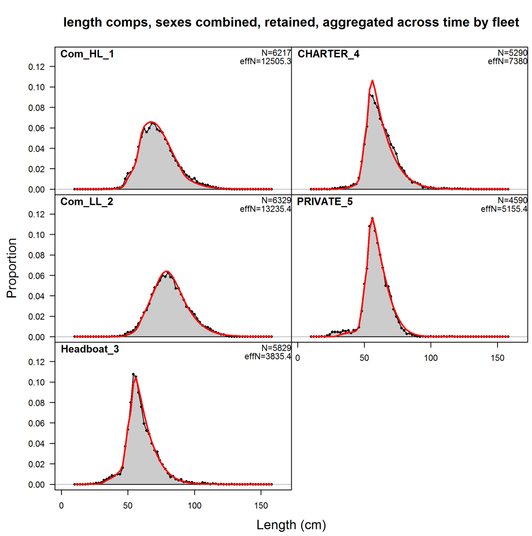
a)



b)

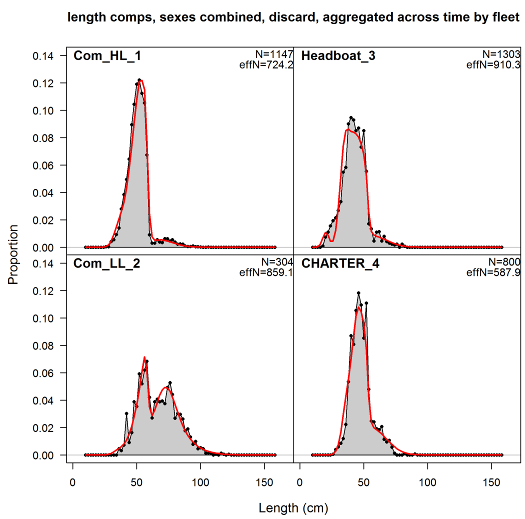


c)

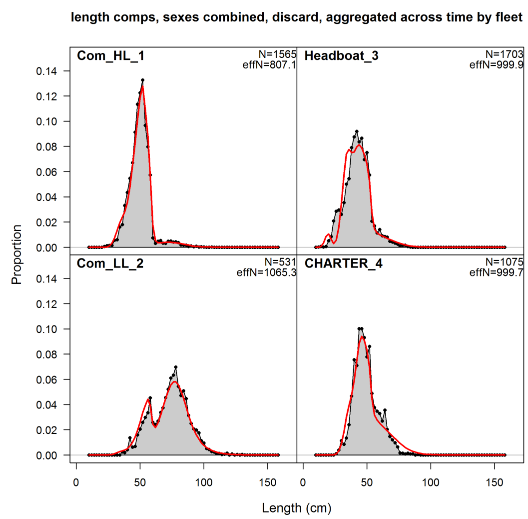


FigureD.2 Model fits to the length composition data of discards; a) SEDAR 33, b) continuity, and c) alternative.

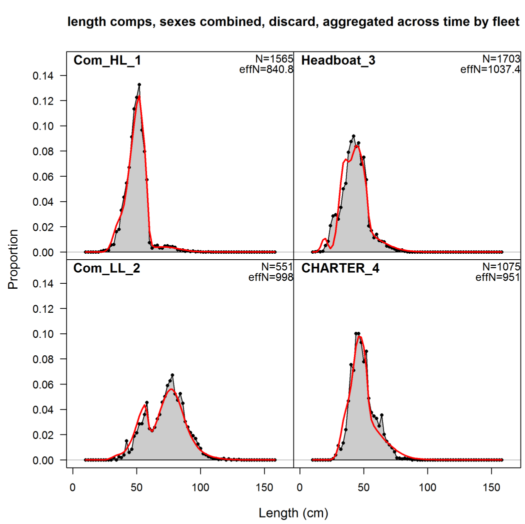
a)



b)

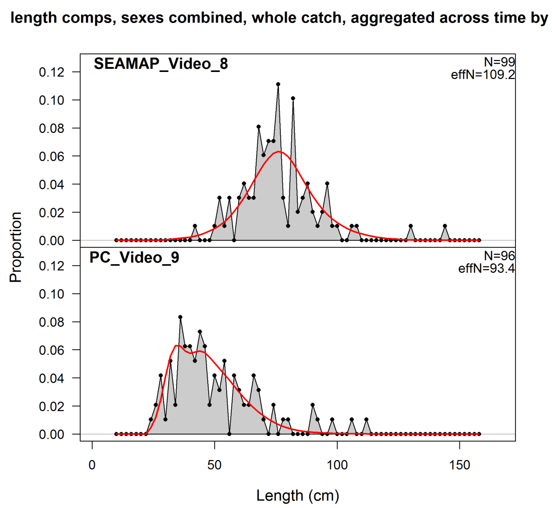


c)

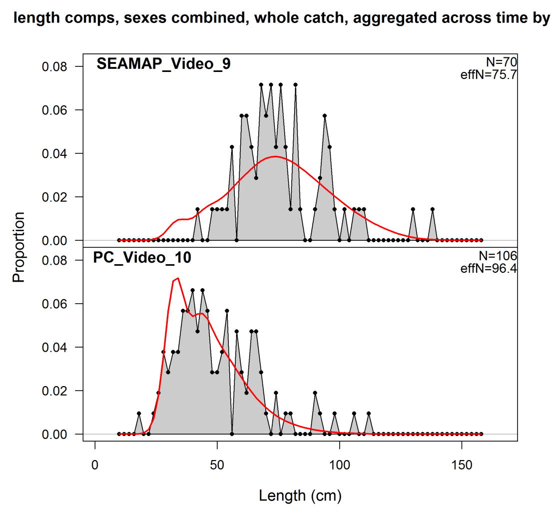


FigureD.3 Model fits to the length composition data from fishery-independent indices; a) SEDAR 33, b) continuity, and c) alternative.

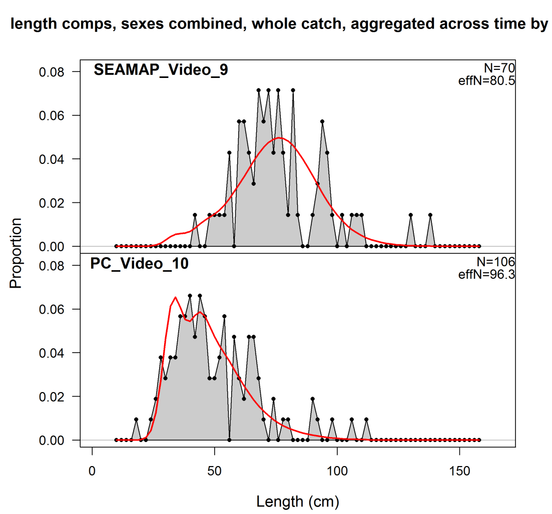
a)



b)

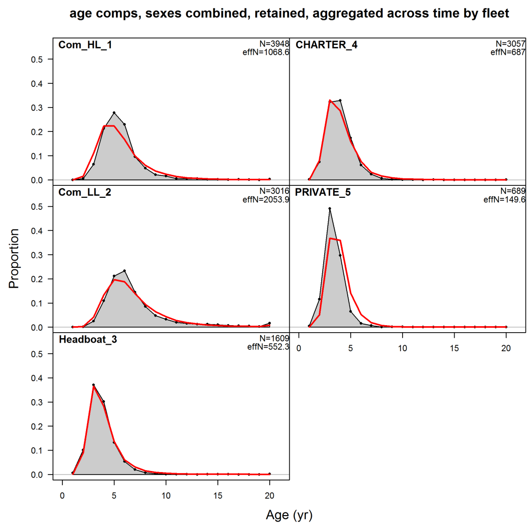


c)

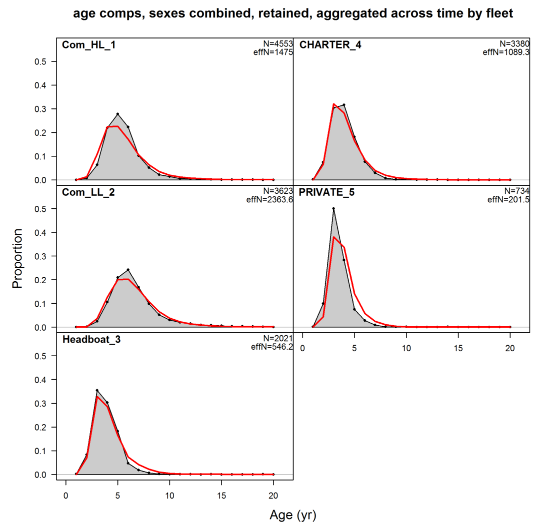


FigureD.4 Model fits to the age composition data; a) SEDAR 33, b) continuity, and c) alternative.

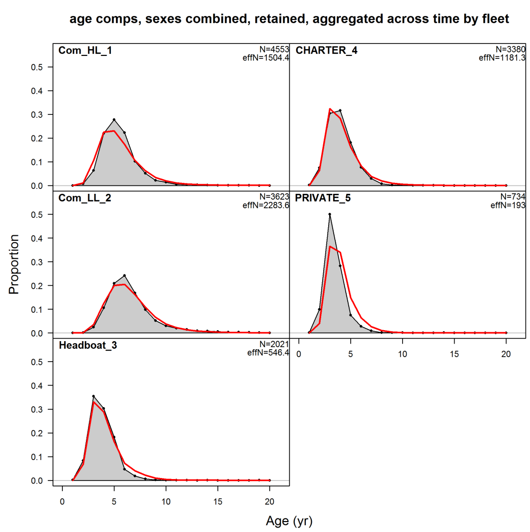
a)



b)

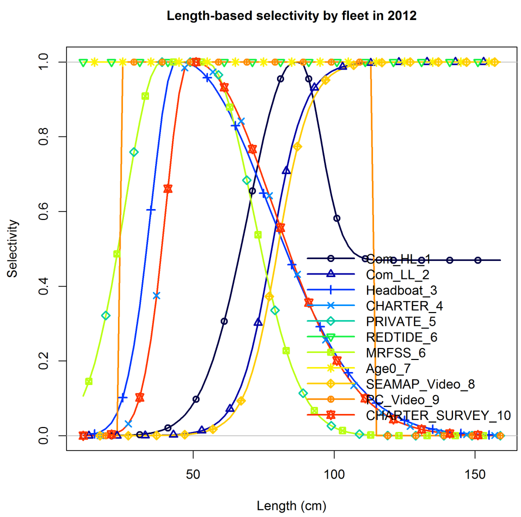


c)

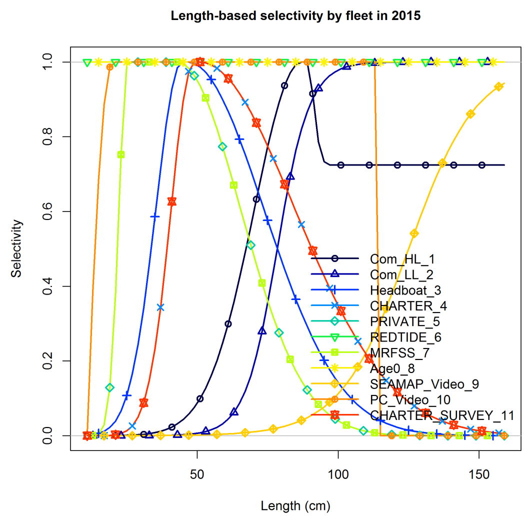


FigureD.5 Estimated length-based selectivity; a) SEDAR 33, b) continuity, and c) alternative.

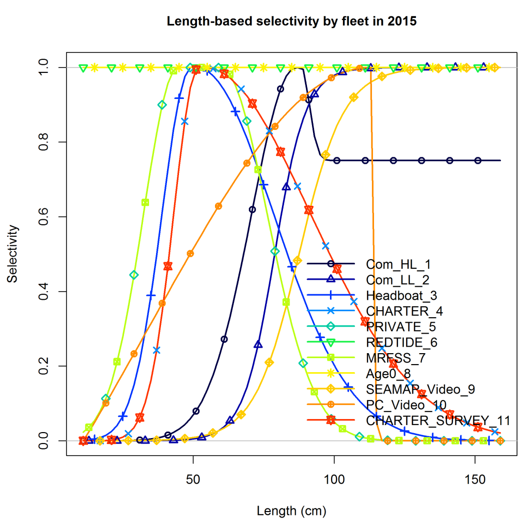
a)



b)

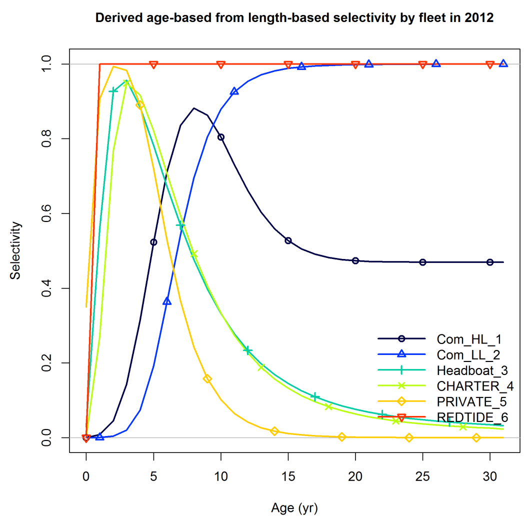


c)

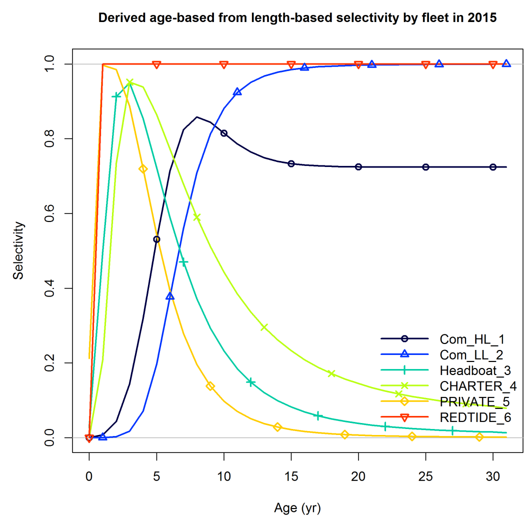


FigureD.6 Derived age-based selectivity; a) SEDAR 33, b) continuity, and c) alternative.

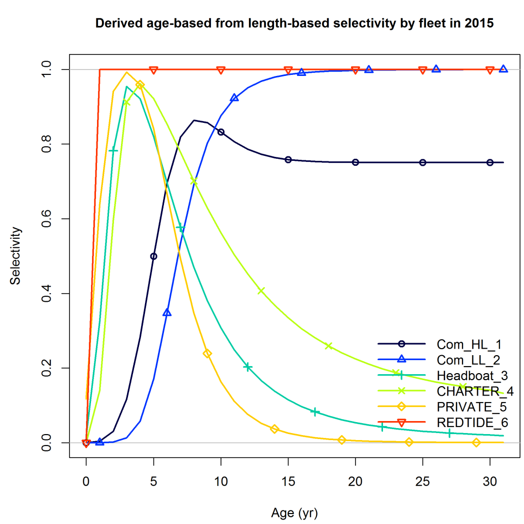
a)



b)

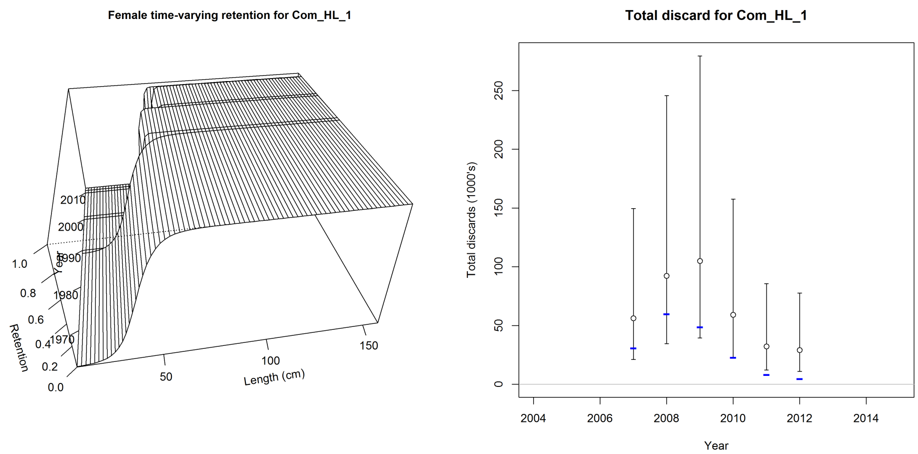


c)

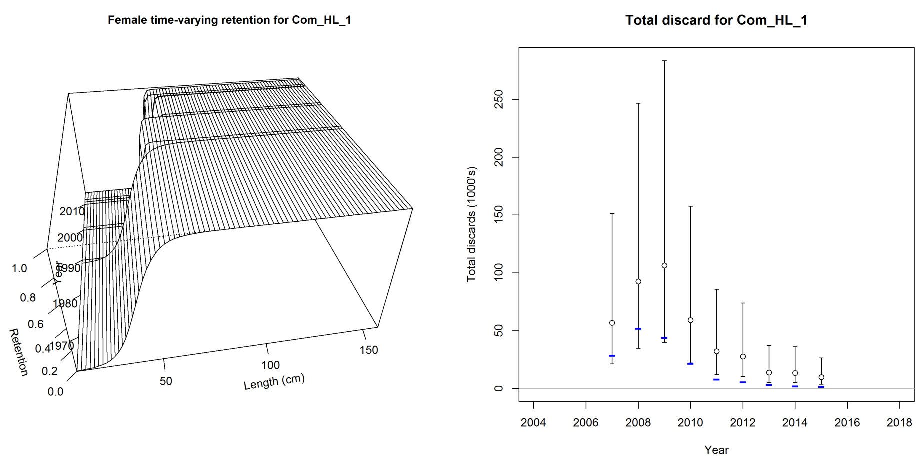


FigureD.7 Estimated retention and model fit to the commercial vertical line discards; a) SEDAR 33, b) continuity, and c) alternative.

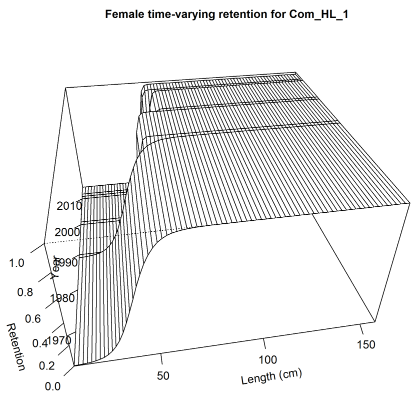
a)

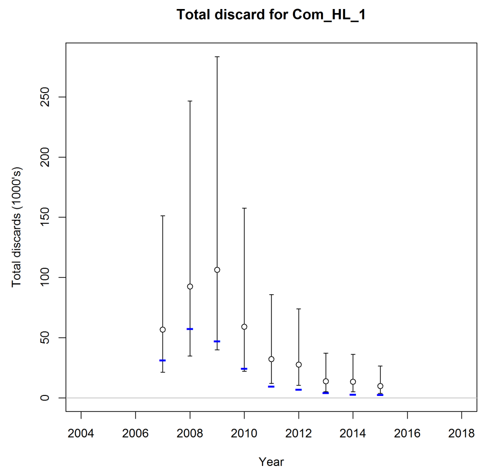


b)



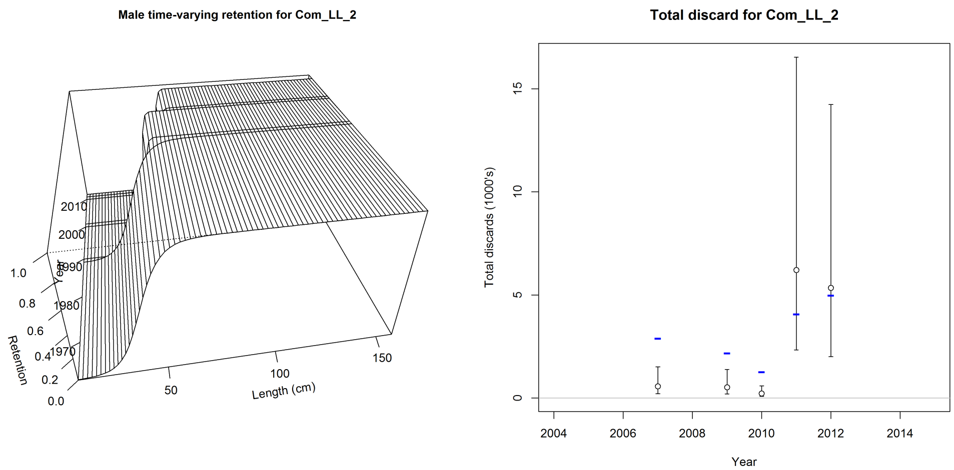
c)


Female time-varying retention for Com_HL_1
Retention
0.0
0.2
0.4
0.6
0.8
1.0
Year
1970
1980
1990
2000
2010
Length (cm)
50
100
150

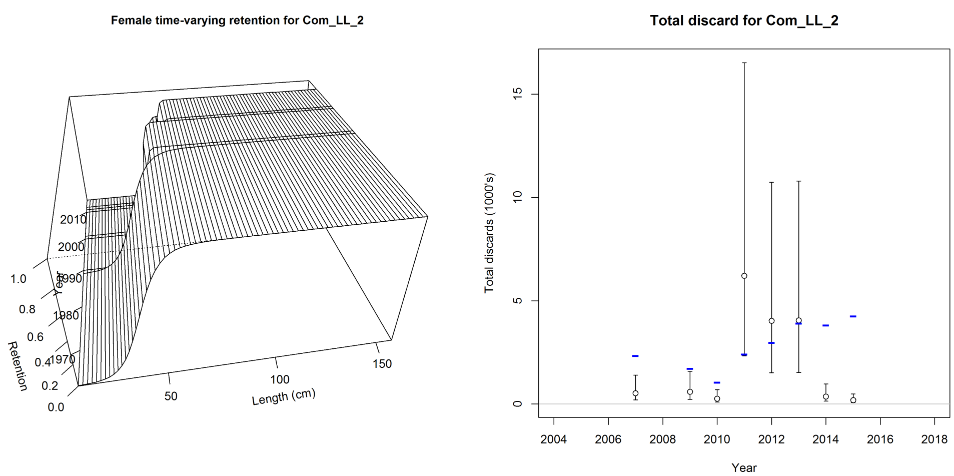

Total discard for Com_HL_1
Total discards (1000's)
0
50
100
150
200
250
Year
2004
2006
2008
2010
2012
2014
2016
2018

FigureD.8 Estimated retention and model fit to the commercial longline discards; a) SEDAR 33, b) continuity, and c) alternative.

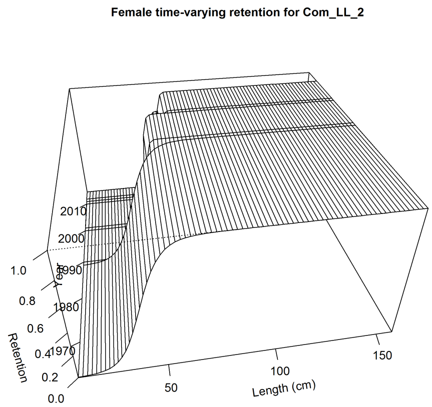
a)

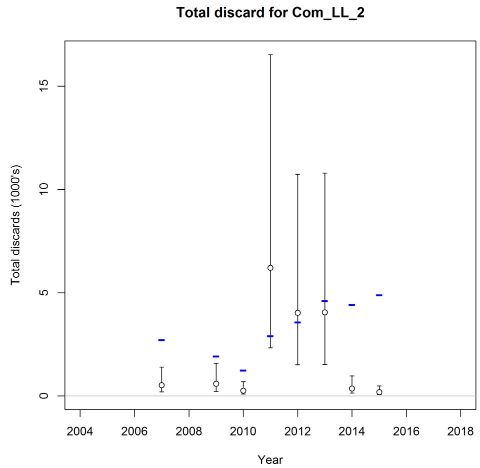


b)



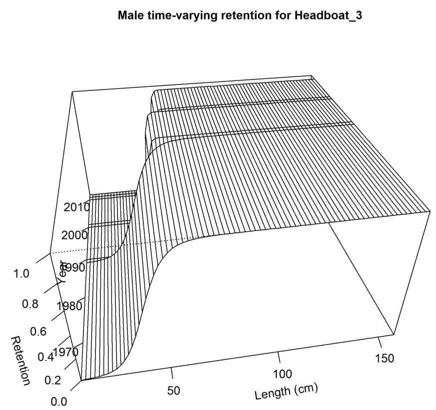
c)

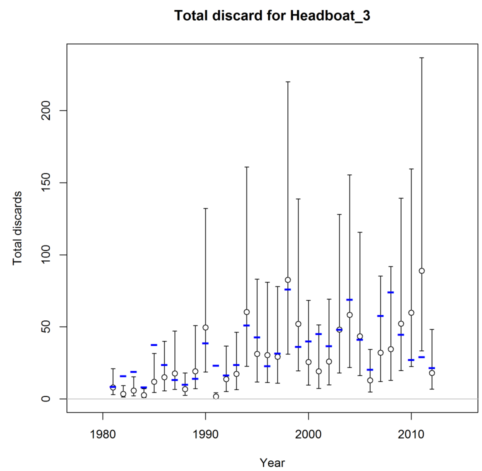

Female time-varying retention for Com_LL_2
Retention
Year
Length (cm)
0.0
0.2
0.4
0.6
0.8
1.0
1970
1980
1990
2000
2010
50
100
150


Total discard for Com_LL_2
Total discards (1000's)
Year
0
5
10
15
2004
2006
2008
2010
2012
2014
2016
2018

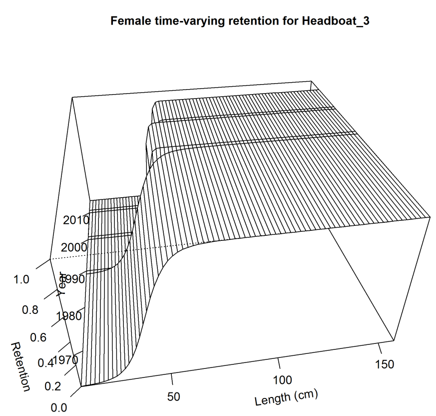
FigureD.9 Estimated retention and model fit to the headboat discards; a) SEDAR 33, b) continuity, and c) alternative.

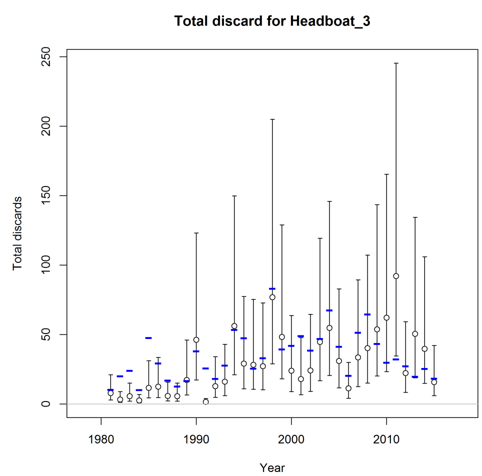
a)



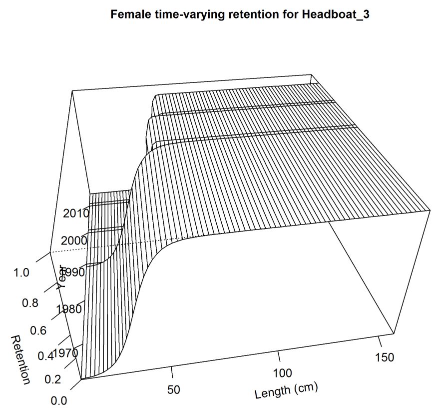


b)

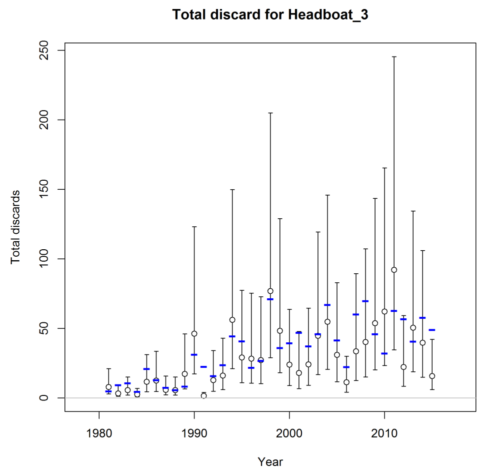




c)



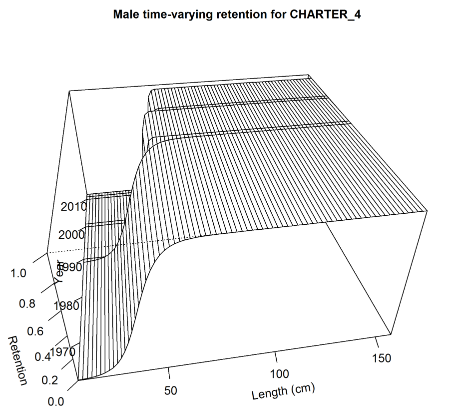
Female time-varying retention for Headboat_3
Retention
Year
Length (cm)

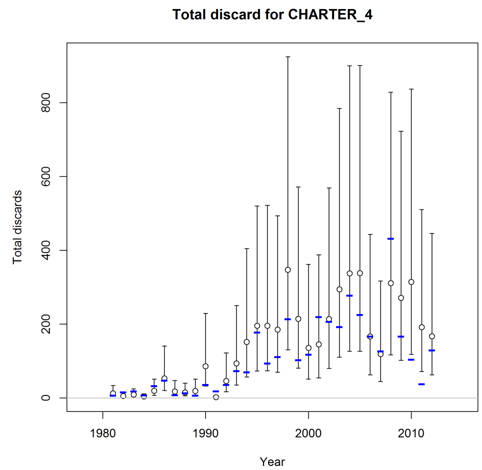


Total discard for Headboat_3
Total discards
Year

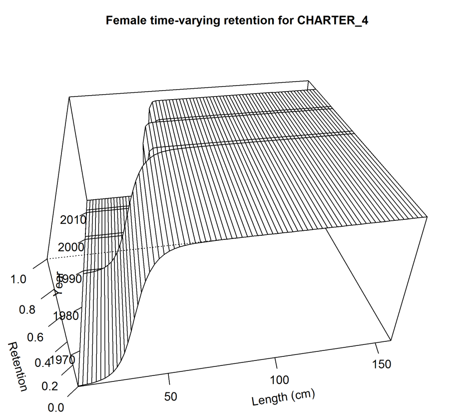
FigureD.10 Estimated retention and model fit to the charter discards; a) SEDAR 33, b) continuity, and c) alternative.

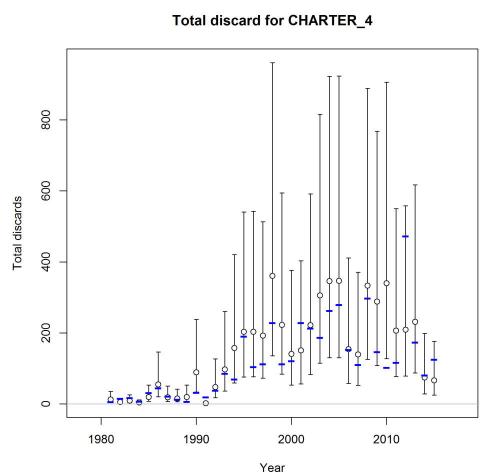
a)



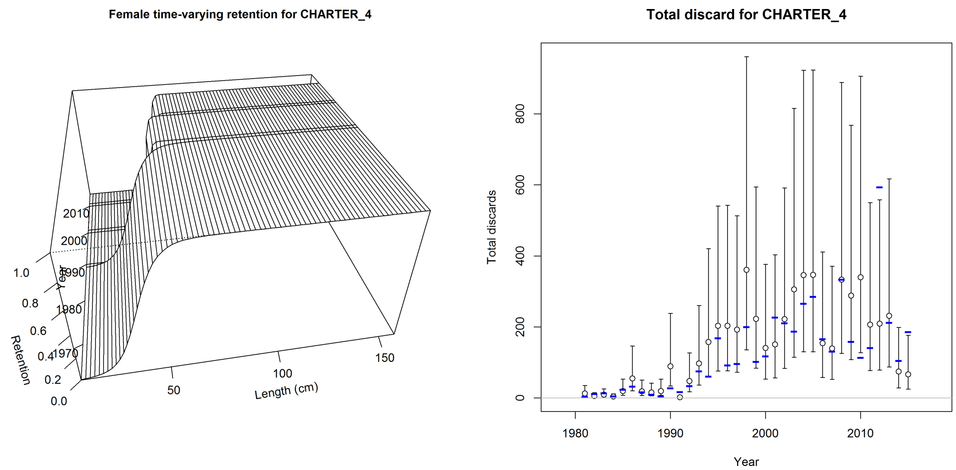


b)





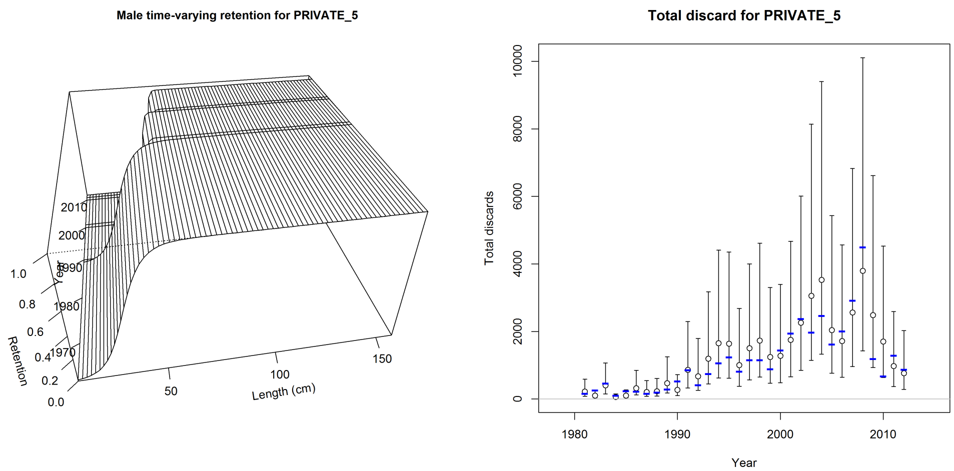
c)



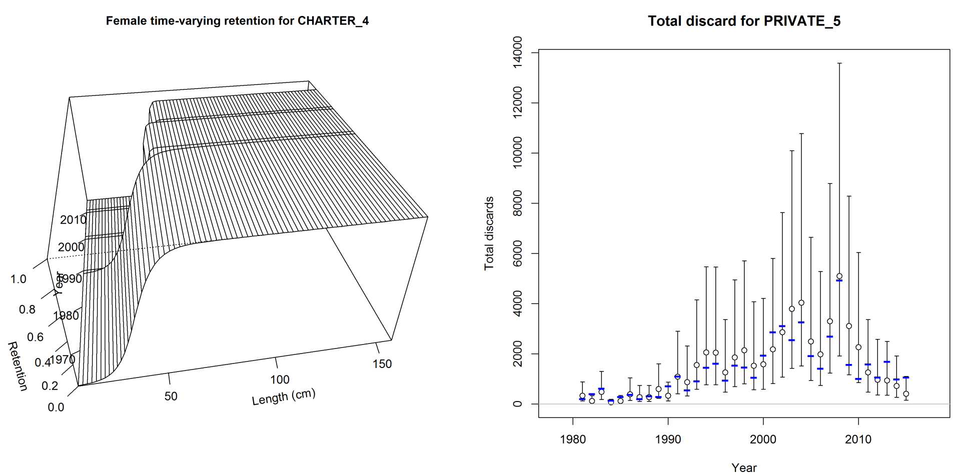
Female time-varying retention for CHARTER_4
Retention
0.0
0.2
0.4
0.6
0.8
1.0
Year
1970
1980
1990
2000
2010
50
100
150
Length (cm)
Total discard for CHARTER_4
Total discards
0
200
400
600
800
1980
1990
2000
2010
Year

FigureD.11 Estimated retention and model fit to the private discards; a) SEDAR 33, b) continuity, and c) alternative.

a)



b)



c)

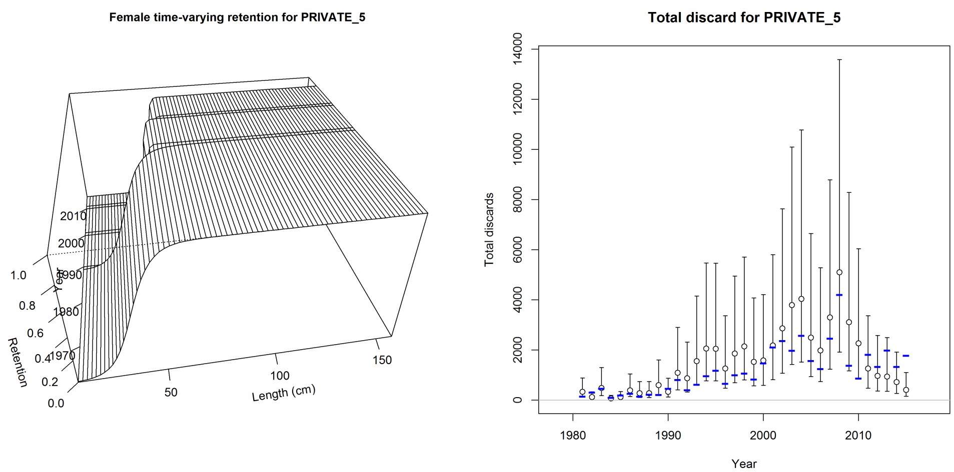
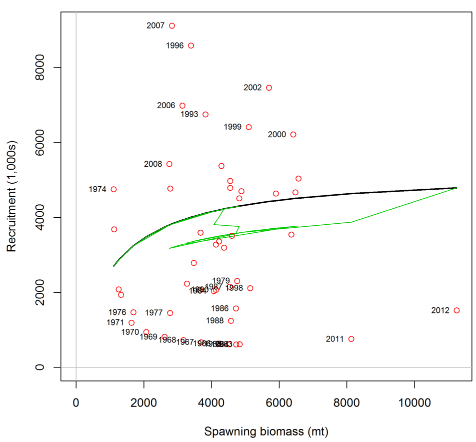
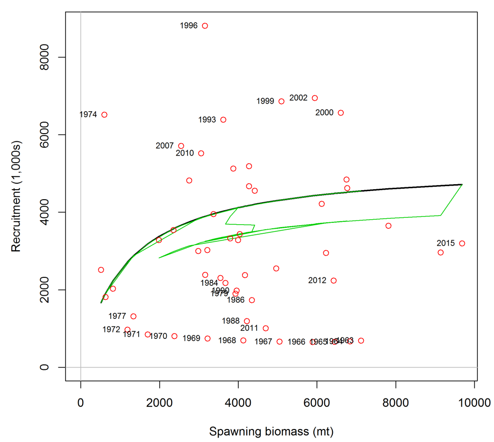

Female time-varying retention for PRIVATE_5
Retention
Year
Length (cm)
Total discard for PRIVATE_5
Total discards
Year

Figure D.12. Estimated stock-recruit relationship; a) SEDAR 33, b) continuity, and c) alternative.

a)



b)



c)