MEMORANDUM State of Alaska

DEPARTMENT OF FISH AND GAME

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DATE: April ~~15~~16, ~~2015~~2016

FILE NO.: DRAFT

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SUBJECT NSEI sablefish assessment for 2016 ABC

Summary Table			
Quantity	**2015**	**2016**	**Percent change**
Forecast exploited abundance	1,766,525	1,445,938	-18.15%
Forecast exploited biomass	15,212,730	12,951,596	-14.86%
F ABC = F 50%	0.0705	0.0677	-3.97%
ABC – F50% (round pounds)	**986,481**	**807,559**	-18.14%
ABC – F45% (round pounds)	1,166,987	954,364	-18.22%
ABC – F40% (round pounds)	1,379,963	1,126,343	-18.38%

Summary

- The Allowable Biological Catch (ABC) for 2016 for the Northern Southeast Inside Waters (NSEI – Chatham Strait) at a full-recruitment fishing mortality level of $F_{50\%}$ is 807,559 round pounds (Figure 1). This is a 179,000 pound decrease (18.14%) from the 2015 ABC of 986,481 round pounds;
- The population estimate from the 2015 mark-recapture project in Chatham Strait is 1,665,310 individuals. The forecast for 2016 is 1,445,938 individuals (Figure 2);
- Females are retained in greater proportion in the commercial fishery until roughly age 30, after which more males are retained. The longline survey shows more females until roughly age 20, at which point males begin to predominate. The proportion of females observed in the commercial catch is greater than the proportion of females in the longline survey for all ages (Figure 3).
- Catch per unit effort (CPUE) for the ADF&G Chatham Strait longline survey declined relative to 2014 from 0.199 to 0.179 (numbers-per-hook) (10.1%) and from 1.464 to 1.358 (pounds per hook) (7.2%) (Figure 4). Commercial longline fishery CPUE also decreased from 0.845 to 0.714

for pounds per hook (all depths) (15.5%) and from 0.871 to 0.787 for pounds per hook (depths > 450 meters) (9.6%) (Figure 5);

- Recruitment from the 2007 – 2008 brood year has been observed in the ADF&G longline survey age composition beginning in 2012 (Figure 6). This recruitment has not been observed in the commercial fishery age-composition data (Figure 7);
- The declines in Chatham Strait are similar to those reported in the federal stock assessment for sablefish in the Gulf of Alaska (GOA). The recommended federal ABC for the 2016 commercial longline sablefish fishery is 11,795 metric tons, a 14% decrease from the 2015 ABC of 13,657 metric tons (Hanselman et al. 2015). The F_{ABC} presented in the table above ($F_{50\%}$ = 0.0677) continues to be slightly more conservative than the federal harvest rate of $F_{40\%}$ at 0.078 (Figure 8).

Changes to the NSEI sablefish assessment for 2016 relative to 2015

1. Life-history data for sablefish (e.g. weight-at-age, maturity-at-age, etc.) show temporal variability (Figure 9). Previous stock assessments have incorporated more recent life-history trends in Chatham Strait (e.g. the 2015 assessment used weight-at-age from 2009 – 2014 to include recent declines in size rather than an overall average weight-at-age using all available data). There were concerns that this approach might capture noise instead of data signal due to sampling variability, especially in the commercial fishery, and the 2016 stock assessment returns to using all available data from all sampled years when calculating life-history parameters. This also direct comparison between the current stock assessment methods and those used to develop the age-structured assessment (ASA) model discussed below. A brief assessment of some of these dynamics is presented in Appendix I.
2. CPUE for both the ADF&G longline survey and the commercial longline fishery in the 2015 assessment was calculated using a simple ratio of catch to the number of standardized hooks for any given set. For 2016, a generalized additive model (GAM) was applied to account for changes in depth, hook size, location, and other factors that might affect catch. ADF&G survey CPUE remained unchanged, which was expected as the survey is already a standardized effort (Figure 4). Commercial fishery CPUE as estimated by the GAM was higher than the simple ratio of catch to hooks, but trends remained the same (Figure 5). A more detailed discussion of CPUE and the general additive models is presented in Appendix II.

Section I: 2016 Acceptable Biological Catch (ABC)

The 2015 marking survey released 6,859 marked fish. After applying a natural mortality of 0.1 (Johnson and Quinn 1988) for the time period between marking and recapture, and accounting for those individuals recovered outside NSEI waters or in the ADF&G longline survey, or for whom location could not be determined, and scaling for selectivity, a total of 5,070 marked fish were available to be recovered in the the commercial longline fishery. Of these marked fish, 242 were recovered during the NSEI commercial longline fishery from an examination of 70,031 fish by ADF&G port samplers. The mark-recapture point estimate of total exploited abundance for 2015 was 1,665,310 individuals (Eqs 3 –

6 below). Partitioning into sex-specific age-classes from 2015 commercial fishery catch-at-age/sex data and projecting into 2016 (Eq. 7 below) produced an estimated exploited abundance of 1,445,938 individuals; multiplying by mean commercial fishery weights-at-age produced an estimate of 12,951,596 round pounds exploited biomass.

Section II: Mark-recapture methods

In 2010, improvements were made to the mark-recapture methods to account for differences in selectivities between the ADF&G marking survey and the commercial longline fishery. In 2013, further revisions included the development of a time-stratified estimator. For 2016, these revisions were formalized and expanded to include a new binomial likelihood for the Chapman estimator of abundance and variance for each mark-recapture year.

The mark-recapture project is the basis of current sablefish management in Chatham Strait, and serves to scale absolute abundance in the age-structured model. Previous stock assessment have estimated sablefish abundance in Chatham Strait using a simple Chapman estimator, which is

$$\hat{N} = \frac{(M+1)(n+1)}{m+1} - 1 \qquad (1)$$

where $\hat{N}$ = the unknown (estimated) total abundance of a given population, M = the total number of animals marked at the beginning of the experiment, n = the total number of animals subsequently recaptured and examined for marks, and m = the total number of marked animals present in n.

The variance of this estimator is

$$\mathrm{var}(\hat{N}) = \frac{(M+1)(n+1)(M-n)(n-m)}{(n+1)^2(n+2)}. \qquad (2)$$

For each year that the mark-recapture project is implemented, the marking survey samples individuals in Chatham Strait and marks them with a floy tag, producing the value M for each year. In the time between the marking event (May) and the beginning of the commercial fishery (August), tagged fish are caught in other fisheries or by the longline survey. The total marks M available to be recaptured in each year are decremented accordingly. The commercial fishery is treated as the recovery event, with catches examined at various ports and the number of tagged fish recorded. At the close of the commercial fishery, these counts are summed to n and m in Eq. 1 above.

Assumptions

There are four primary assumptions integral to the Chapman estimator, although violations of these assumptions do occur:

1. *Closed population*

A closed population means there is no movement in or out of the study area, nor are there any births or deaths;

2. *Equal probability of recapture*
   It is assumed that all individuals marked have an equal probability of being recaptured in the commercial fishery;
3. *Sufficient time between marking and recapture to allow for marked individuals to be randomly distributed throughout the unmarked population*
   This is unquantified. The risk is that greater time between marking and recapture means that the assumption of a closed population is more likely to be violated;
4. *No tag loss or errors in reporting recovered tags*
   Tag loss can be estimated, but it is confounded if recovered tags are not accurately reported.

Violations

1. *Closed population*
   Sablefish can be highly mobile. Fish marked in the pot survey are regularly recovered outside of Chatham Strait. Hanselman et al. (2015) examined movement rates of sablefish in Chatham Strait, Clarence Strait and the Gulf of Alaska and conclude that there was a 10% - 14% chance that a fish would leave the Chatham Strait area after one year of occupancy. The current approach has been to treat the mark-recapture project as a snapshot of the population in each given year, and assume closure;

2. *Equal probability of recapture*
   The commercial longline fishery is not a random sampling of the population; it is designed to catch large fish with the least expenditure of time and resources. The longline gear used by both the department's longline survey and the commercial longline fishery is also age/length selective, meaning that not all fish are equally selected (sampled) by the gear. An examination of catch and survey data shows the following:
   a. The catch-at-length distributions for the pot survey and the commercial longline survey are different (Figure. 10). Smaller fish marked in the pot survey are not fully available to the longline fishery due to differences in gear selectivity. The total marks available for recovery must be decremented accordingly prior to application of the Chapman estimator. If n and m remain constant, an erroneously large value for M in Eq. (1) will overestimate total population abundance;
   b. The catch-at-length distributions for the ADF&G longline survey and the commercial longline fishery are different (Figure. 11). Both the survey and the commercial fishery use the same gear. Differences in catch distributions indicate selectivity on the part of the fishery that extends beyond gear selectivity (i.e. location, high-grading, etc.). The selectivity-at-age vectors calculated by NOAA for their longline surveys and the commercial longline fishery in the Gulf of Alaska also differ (Figure. 12). Rather than use the terms *exploited* and *exploitable*, which can become confusing, the terms used hereinafter are:

Vulnerable population: the population vulnerable to the longline gear itself under random sampling conditions;

Exploited population: the population targeted by the commercial fishery through location, high-grading, or other divergence from a simple random sampling of the population.

As the commercial fishery is the recovery event for the mark-recapture estimator, the output from Eq. (1) is an estimate of the *exploited* population, not total overall abundance;

c. The length-distribution of tagged fish retained in the commercial fishery is different than untagged fish retained in the commercial fishery (Figure. 13). This suggests that small tagged fish are retained, while small untagged fish are not. It also suggests that larger unmarked fish are retained at a greater rate than larger tagged fish;

d. The retention rates of males and females in the commercial longline fishery differ (Figure3). It is known that females reach larger sizes than males. The commercial fishery sex-composition is generally composed of a greater proportion of females than the department's longline survey (Figure 3). The Chapman estimator should be stratified for sex to account for potential differences in capture rates;

3. *Sufficient time between marking and recapture to allow for marked individuals to be randomly distributed throughout the unmarked population*

   The pot survey is implemented in late May. The commercial fishery lasts for roughly three months and closes in late November. During this six-month period, both immigration and emigration are highly likely. Until movement becomes quantifiable, the assumption of no immigration/emigration remains necessary. Natural mortality, however, is virtually certain. Stratifying the estimator by time allows natural mortality to be included. Stratifying by time also allows for greater precision in the estimates of abundance, as each time-period compensates for changes in *M, n,* and *m;*

4. *No tag loss or errors in reporting recovered tags*

   Tag loss can be estimated, but is conditional on accurate tag reporting. Some tags are returned by commercial fishery operators at the end of the season, losing identifying trip or countback data. Anecdotally, there are reports that some fishermen may discard recovered tags. Given the difficulty in quantifying tag loss and reporting accuracy, Eq. (1) is applied to counted and retained tagged individuals under the assumption of no tag loss. Decrementing *M* due to movement and/or capture in other fisheries is based on tag counts.

The above points require that the simple Chapman estimator be modified accordingly to compensate for capture probability, fishery selectivity, sex differential, tag loss and reporting, and natural mortality. Decrementing *M* to account for capture probability was implemented in 2010, following Mueter (2010), and a version of the sex- and time-stratified estimator was introduced in 2015. This estimator was further refined to address the above issues for 2016 and applied to past years (2003 – present).

Within each year:

1. Fish marked by the pot survey were divided into male/female proportions relative to the mean sex ratios estimated from all pot survey years (some years do not contain a sampling of sex ratios; all years were aggregated to increase sample size);
2. Fish marked in the pot survey were binned into 10 cm length increments between 40 cm and 110 cm, and the total number of marked fish *M* available to recapture events for a given year was the summed product of selectivity-at-length for the recovery gear (i.e. the *longline survey* selectivity-at-length) and the total number of marked fish present in a given length bin. This produces the total number of marks available to be recovered in the *vulnerable population*;
3. Recaptured fish were divided into males and females according to the sex-ratio of males and females within the commercial fishery;
4. Following Robson and Regier (1964), recaptured fish were binned into sample sizes based on the total number of potentially recoverable tags and the desired precision of the resulting abundance estimate. This meant that the total number of sampling time periods for any given year varied;
5. For each time period *i* and sex *s* define the following (gender subscripts have been omitted for clarity):

t_i	=	time in days since last event *i* (or since marking, if *i* == 1)
n_i	=	number of fish examined at event *i*
m_i	=	number of tagged fish recovered in event *i*
m_{early}	=	number of marks recovered after tagged release but before opening of the commercial fishery
M_0	=	total number of marks available to be recovered by the commercial longline fishery gear
M_i	=	total number of marks available for recovery during a recovery event *i*
mort	=	natural mortality decremented daily and set to 0.1 following Johnson and Quinn (1988)
$\hat{N}_i$	=	estimated total *exploited* abundance of population at event *i*
$\hat{N}$	=	estimated total *exploited* abundance of population prior to the first recovery event *i* (that is, at the beginning of the commercial longline fishery).

Then for any given event *i* and for each sex:

(3) $$M_i = \begin{cases} (M_0 - ms) * \exp(-mort * t_i) & i = 1 \\ (M_{i-1} - m_{i-1}) * \exp(-mort * t_i) & i > 1 \end{cases}$$

(4) $$\hat{N}_i = \begin{cases} (\hat{N} * \exp(-mort * t_i) & i = 1 \\ (\hat{N}_{i-1} * \exp(-mort * t_i) & i > 1 \end{cases}$$

(5) $$p_i = \frac{M_i}{\hat{N}_i}$$

and the probability in each event *i* of recapturing *m* marks given sample size *n* and probability of capture *p* for each sex*:*

(6) $$\Pr(m \mid n, p) = \binom{n}{m} p^m (1-p)^{n-m}.$$

The final estimate of $\hat{N}$ for each year is obtained by minimizing the sum of the negative log-likelihoods of Eq. (6) over all time periods *i* and for each sex. In previous years, as the commercial fishery lasts for three months, it was assumed that the Chapman estimator produced an estimate of average exploited abundance half-through the fishery. In this instance, use of the-time stratified estimator allows the estimation of the initial exploited abundance at the start of the commercial fishery. The binomial likelihood (Eq. 6) is merely a different implementation of the Chapman estimator and does not constitute a departure from it.

Selectivity-at-length values (Figure 12) used to decrement the total number of marked fish in any given year to the total number available for recapture M_0 were calculated using length-at-age tables and parameter values for males and females from Hanselman et al. (2015).

Section III: Determining Allowable Biological Catch

The method implemented by the department has been to calculate *vulnerable* abundance-at-age for ages 5+ by partitioning the estimated *exploited* abundance into cohorts according to the commercial fishery catch-at-age proportion and incrementing by one year as

(7) $$\hat{N}_{t,a} = \sum_{k=1}^{2} \left[\frac{\gamma_k * N_{t-1}\phi_{t-1,a-1}}{s_{k,a-1}} s_{k,a} \right]^{-((s_{k,a-1}F_{t-1})+M)}$$

for which

$\hat{N}_{t,a}$ = the estimated exploitable abundance-at-age *a* in year *t*,

$\hat{N}_{t-1}$ = the Chapman-estimated total exploitable abundance for year *t-1*,

$\phi_{t-1,a-1}$ = fishery catch-at-age proportion at age *a-1* in year *t-1*,

$s_{k,a-1}$ = the commercial fishery selectivity-at-age *a-1* for gender *k*,

$s_{k,a}$ = the commercial fishery selectivity-at-age for age *a*, gender *k*,

F_t = the full recruitment fishing mortality implemented in year *t-1*,

γ_k = the proportion of the commercial longline catch that was of gender *k,* and

M = natural mortality. Natural mortality is assumed constant over time and age, and is set to 0.1 (Johnson and Quinn, 1998).

It is the division of age-specific abundance by fishery selectivity-at-age that transforms *exploited* abundance into *vulnerable* abundance.

Vulnerable abundance for age 4, the youngest age-class considered in the commercial fishery, is not incremented as per Eq. (7) but is considered a proxy for recruitment into the fishery, and calculated as

$$\hat{N}_{t,4} = \sum_{k=1}^{2} \frac{\gamma_k * N_{t-1,} \phi_{t,4}}{s_{k,4}} s_{k,4} \,. \tag{8}$$

Application of the Baranov catch Equation for which full-recruitment fishing mortality $F = F_{50\%}$, calculated from yield-per-recruit tables, in conjunction with mean fishery weigh-at-age, has been the historical method for calculating allowable biological catch (ABC):

$$ABC = \sum_{k=1}^{2} \sum_{a=4}^{\max(a)} \frac{F\phi_a}{Z_a} N_a (1 - e^{-z_a}) * wt_a \tag{9}$$

where

wt_a = fishery weight-at-age for age *a,* and

Z_a = total mortality for age *a*. Z_a is the sum of natural mortality *M* and the product of *F* and selectivity-at-age ϕ_a.

Section IV: Physical parameters

Length, weight, and maturity

Mean length-at-age and weight-at-age are estimated from both survey and fishery catches for males and females. Maturity-at-age is calculated only for females from the survey data, as female spawning biomass serves as the Biological Reference Point for *F* levels under the assumption that a single male can fertilize multiple females and the limiting recruitment factor is female spawning biomass.

Length-at-age *L* is estimated as

$$L_t = L_\infty [1 - e^{-k(t-t_0)}] \tag{10}$$

for with L_t = length at some time t (age), L_∞ = asymptotic length, t_0 = the time (age) at which an individual is considered to have length 0, and k = growth rate.

Length is two-dimensional, whereas weight has three dimensions. Weight-at-age is calculated as

$$W_t = W_\infty[1 - e^{-k(t-t_0)}]^3 \tag{11}$$

Maturity-at-length for females is calculated from survey data as

$$m_t = \frac{1}{1 + e^{(-s(L_t - m_{50})}} \tag{12}$$

for which m_t = maturity at some time t, s = the slope of the fitted logistic curve, and m_{50} = length at 50% maturity.

Trends observed in 2015 have continued into 2016, primarily a narrower distribution of ages in terms of fewer older fish and a lack of strong recruitment into the commercial fishery. As sablefish are a long-lived species, this may only be indicative of life history cycles, but the loss of larger, older fish which have higher fecundity (Mason et al. 1983, Macewicz and Hunter, 1994) in conjunction with lack of strong recruitment events could have significant effects on the reproductive potential of the population. The recruitment of individuals into the commercial fishery prior to the onset of full maturity (Figure 14) compounds this effect.

Section V: Age-Structured Assessment Model

An age-structured assessment model has been under development by ADF&G for a number of years, and is scheduled to be for the 2017 stock assessment season. Current stock assessment methods for Chatham Strait sablefish construct a snapshot of stock condition for each year, and treat the mark-recapture estimates of exploitable abundance as if they are known without error. The age-structured assessment model places the mark-recapture estimates of exploitable abundance within a statistical framework, combined with other data sources, to construct a more fluid model of the stock as it changes over time. This improves estimates of stock abundance by utilizing multiple sources of information and tracks cohort progression over time. The latter is particularly relevant given current reductions in ADF&G budgets and the likelihood of reducing the mark-recapture project to every other year.

The model uses the marks recaptured in the ADF&G longline survey as a distinct estimate of population in addition to the mark-recapture estimates from the commercial longline fishery. These two data sets are critical to the scaling of absolute abundance in model outputs.

Standard age-structured population dynamics equations (Quinn and Deriso 1999) are used to model sablefish in Chatham Strait from 1980 onward, using AD Model Builder (Fournier et al. 2011). Modeled age classes run from 2 through 42, with 2 being the age of recruitment (the youngest age observed in ADF&G longline survey data), and 42 being a plus class. The model is sex-specific, with the assumption that sex-proportion at hatch is 50%, and natural mortality is the same for each sex.

Model estimates included spawning biomass, recruitment, abundance-at-age, commercial catch, CPUE for both the commercial fishery and the ADF&G longline survey, mark-recapture estimates of exploited abundance and vulnerable abundance, and full-recruitment fishing mortality levels for each modeled year.

Model Data

Data and derived quantities used in the age-structured model:

1. total annual catch (metric tons) from the Chatham Strait commercial longline fishery;
2. estimates of the vulnerable population from recovery of marked fish in the annual ADF&G Chatham Strait longline survey;
3. estimates of the exploited population from recovery of marked fish in the annual Chatham Strait commercial longline fishery;
4. age composition data from the commercial fishery;
5. age composition data from the ADF&G longline survey;
6. commercial fishery catch-per-unit effort (CPUE) derived from logbooks and fish tickets;
7. ADF&G longline survey catch-per-unit effort (CPUE);
8. estimates of length, weight, age, and maturity composition derived from Chatham Strait commercial fisheries from 2002 onward, and ADF&G longline surveys from 1980 to the present;
9. Estimates of selectivity-at-age from the commercial longline fishery and the ADF&G longline survey – input from the NOAA age-structured model for sablefish in the Gulf of Alaska;
10. Natural mortality from Quinn and Johnson (1988), set to 0.1 for all ages.

Parameter estimation

Model parameters are estimated by minimizing a penalized negative log-likelihood objective function. Log-normal likelihoods are assumed for total annual catch; normal distributions are assumed for mark-recapture estimates of exploited and vulnerable abundances, and CPUE estimates for both the commercial fishery and the ADF&G longline survey. Multinomial likelihoods are assumed for age composition data. Penalties are implemented in the objective function to facilitate scaling and parameter estimation. Variability in full-recruitment fishing mortality F, recruitment, and initial abundances in Year 1 are constrained by minimizing deviations from assumed log-normal prior probability distributions.

The model successfully converges to a set of parameter estimates and variances with no major performance issues. The model structure appears to be stable and ready for testing and additional refinement in preparation for being formally implemented in the 2017 stock assessment.

Literature Cited

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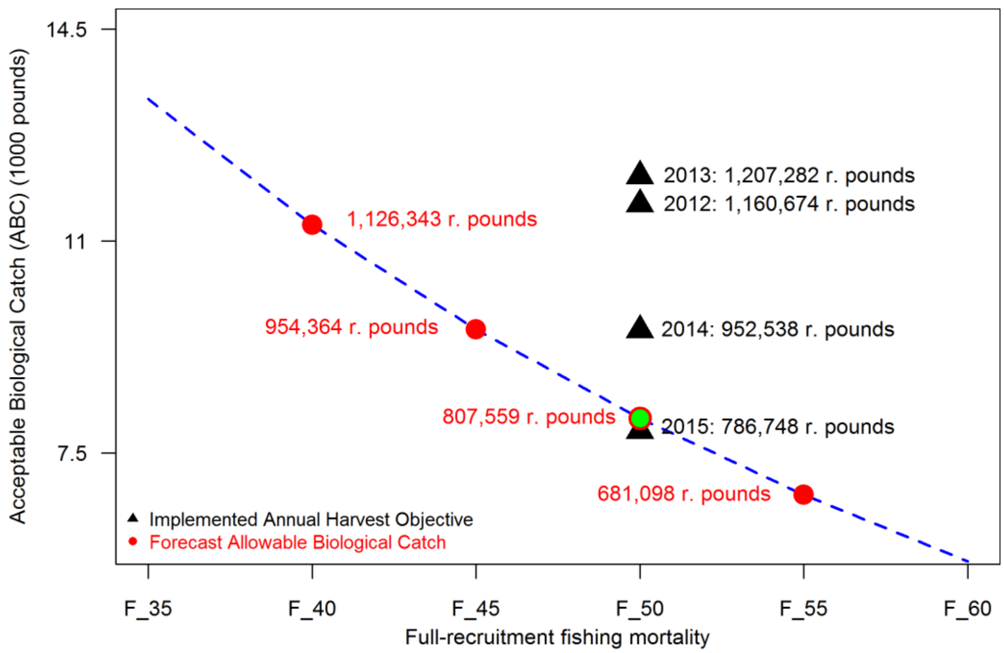

Figure 1. Potential 2016 NSEI commercial longline fishery allowable biological catch (ABC) levels relative to full-recruitment fishing mortality (dashed line), along with historical annual harvest objectives (AHO) implemented at $F_{50\%}$ (triangles) and point estimates of potential ABC levels at $F_{40\%}$ - $F_{55\%}$ (circles)

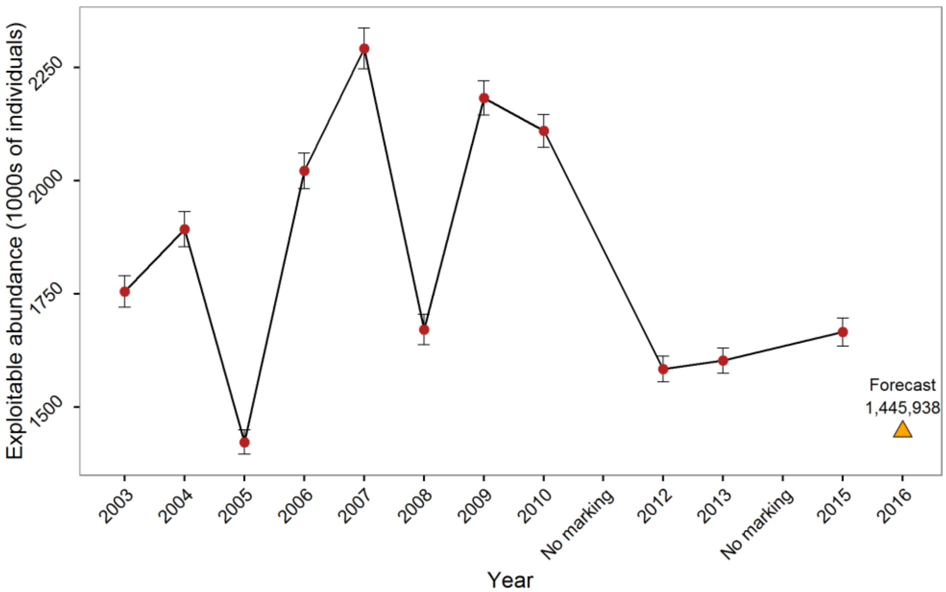

Figure 2. Estimates of total exploitable abundance from the binomial-likelihood Chapman time- and sex-stratified mark-recapture estimator applied to total marks and recoveries with the 2016 forecast (triangle) and 95% confidence intervals.

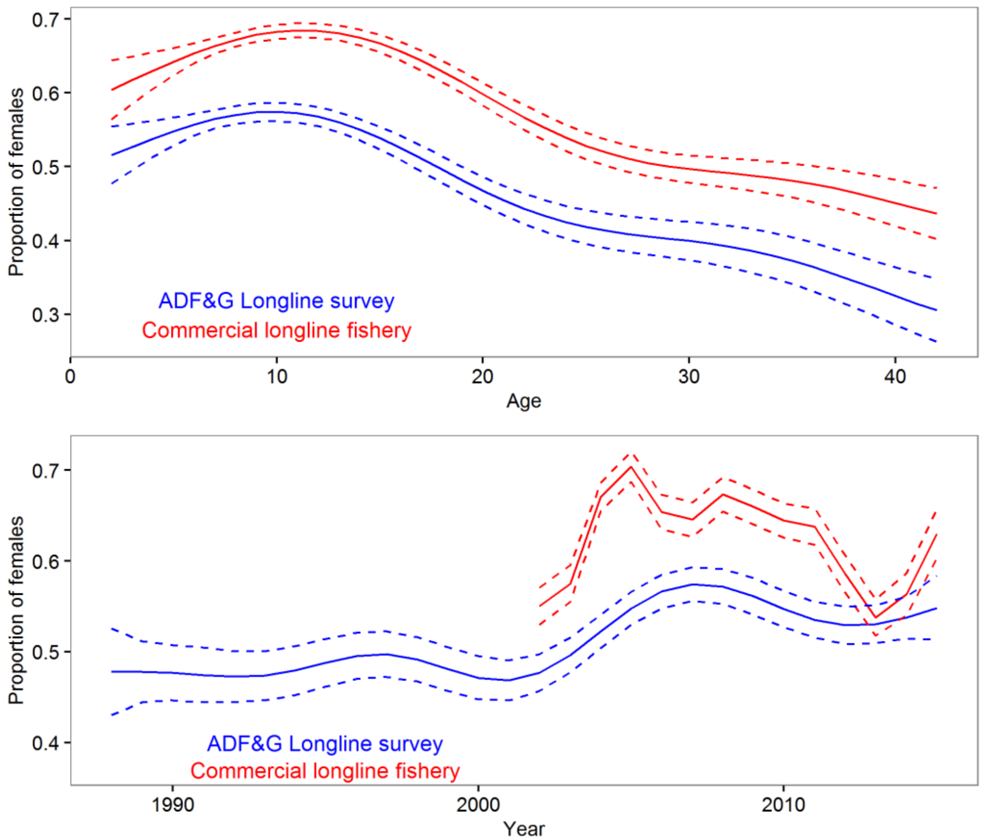

Figure 3. Relative proportions of females by age in the commercial longline fishery catch compared with the relative proportions of females by age in the ADF&G longline survey, and relative proportions of females by year in the commercial longline fishery catch compared with the relative proportions of females by age in the ADF&G longline survey.

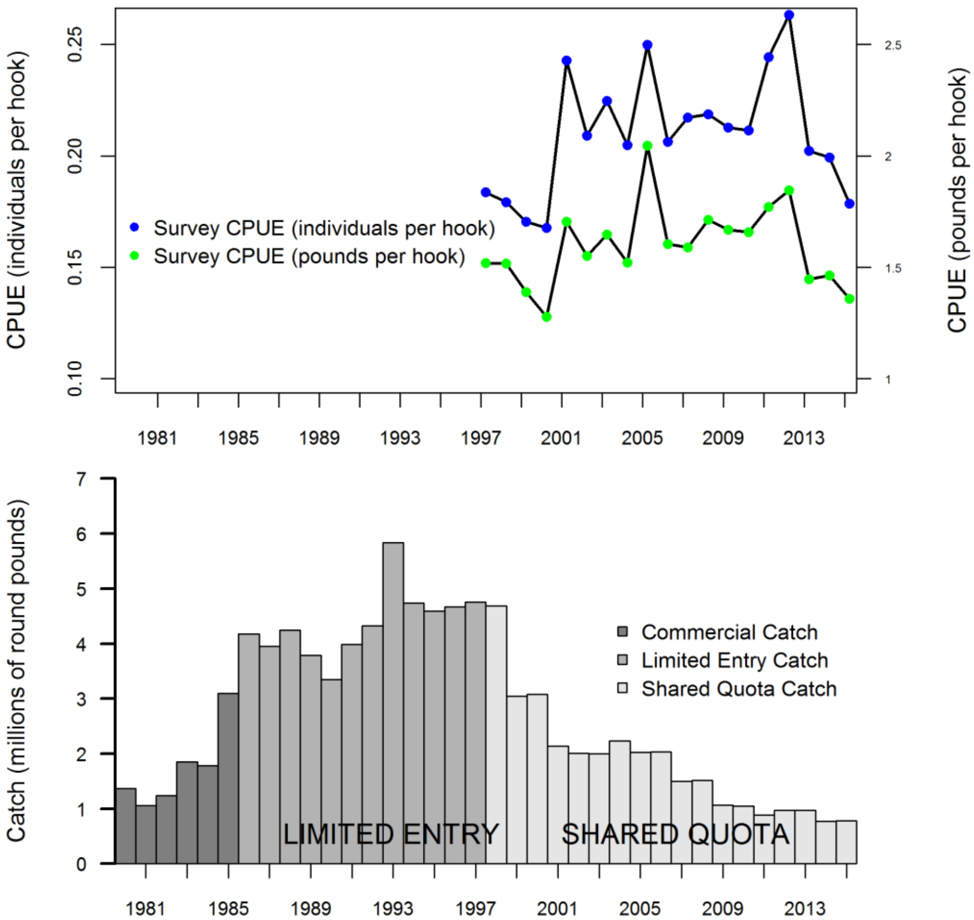

Figure 4. NSEI sablefish longline survey catch-per-unit-effort (CPUE) in fish-per-hook and pounds-per-hook, and commercial catch 1980 - 2015.

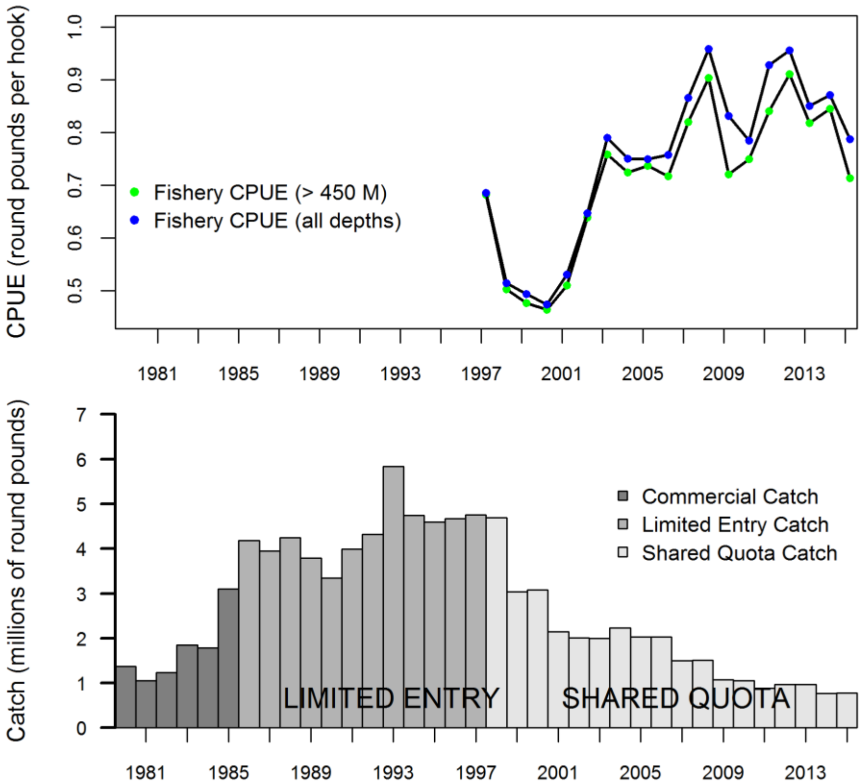

Figure 5. NSEI commercial longline fishery sablefish catch-per-unit-effort (CPUE) in round pounds-per-hook over all fished depths and depth greater than 450 meters from 1997 – 2015, and commercial catch from 1980 - 2015.

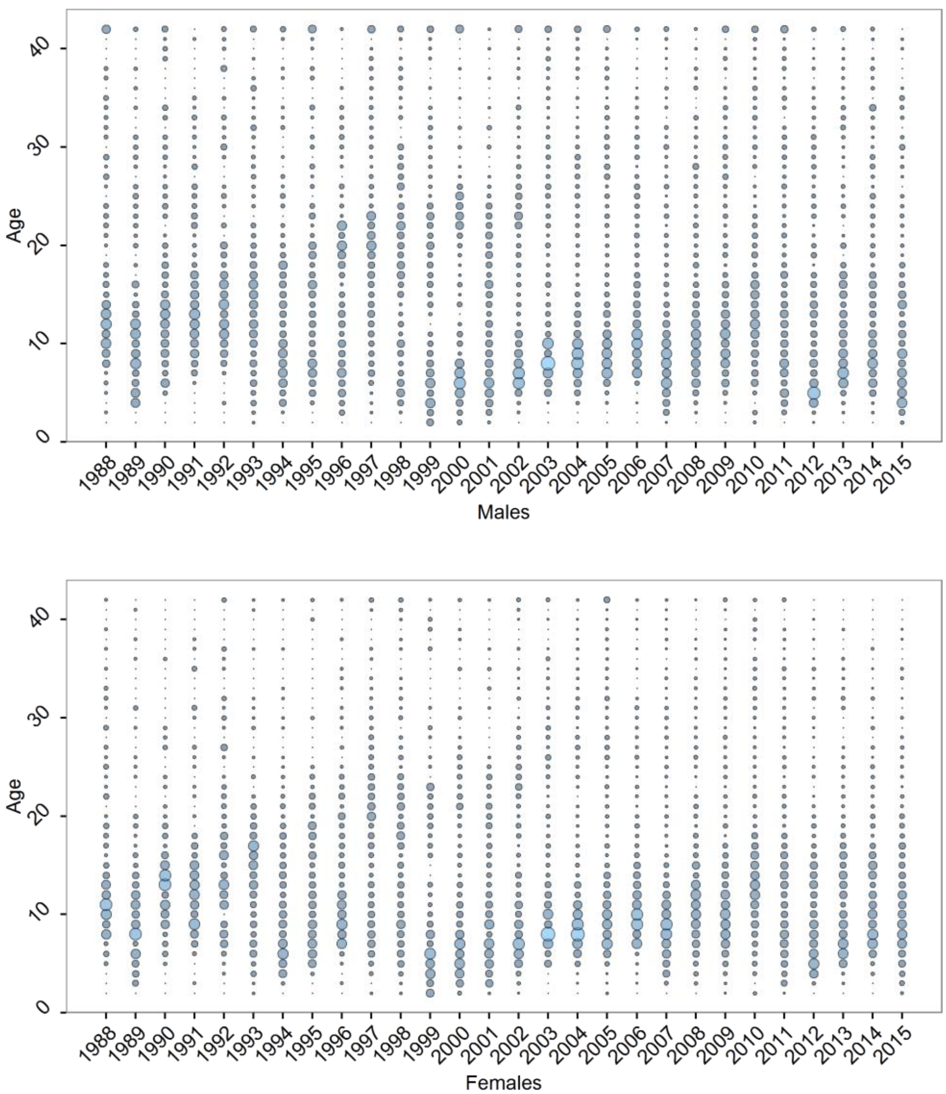

Figure 6. Proportions-at-age for males and females in the ADF&G longline survey, 1988 – 2015.

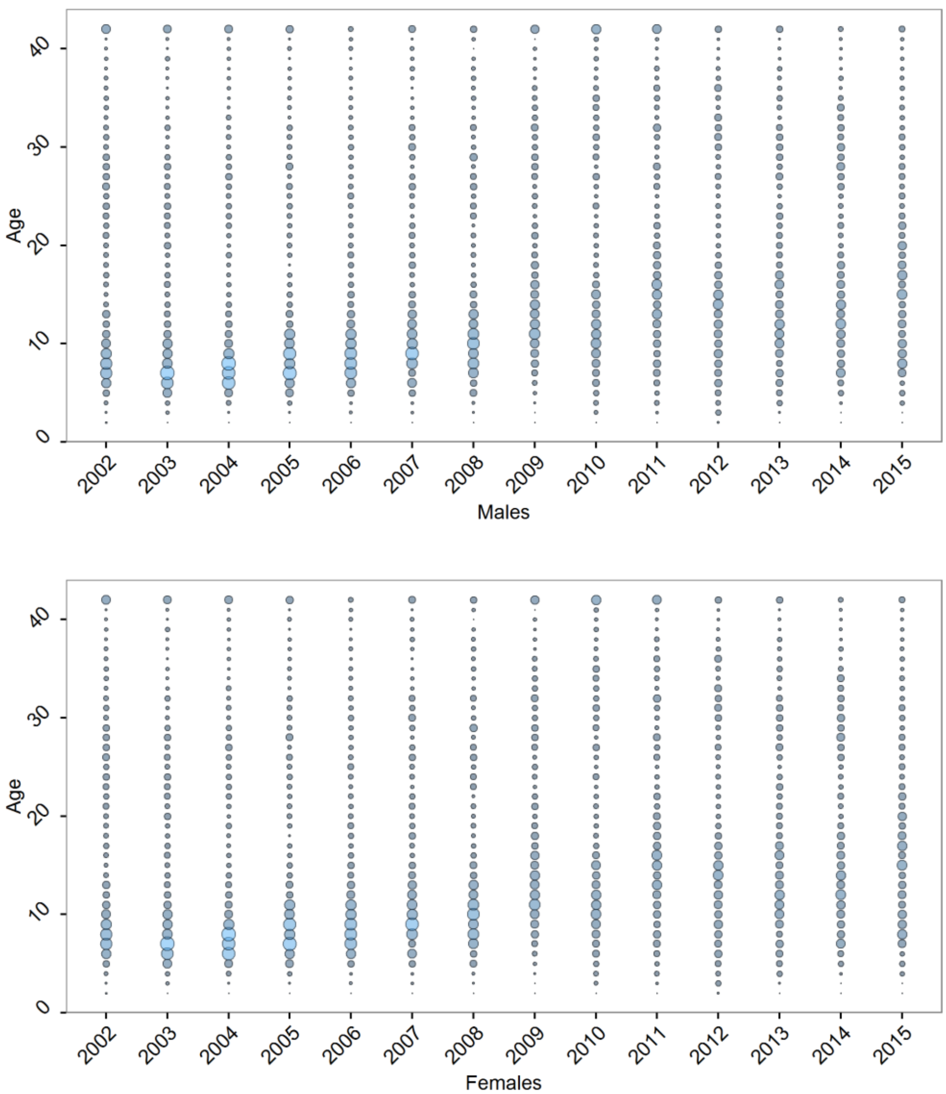

Figure 7. Proportions-at-age for males and females in the commercial longline fishery, 2002 – 2015.

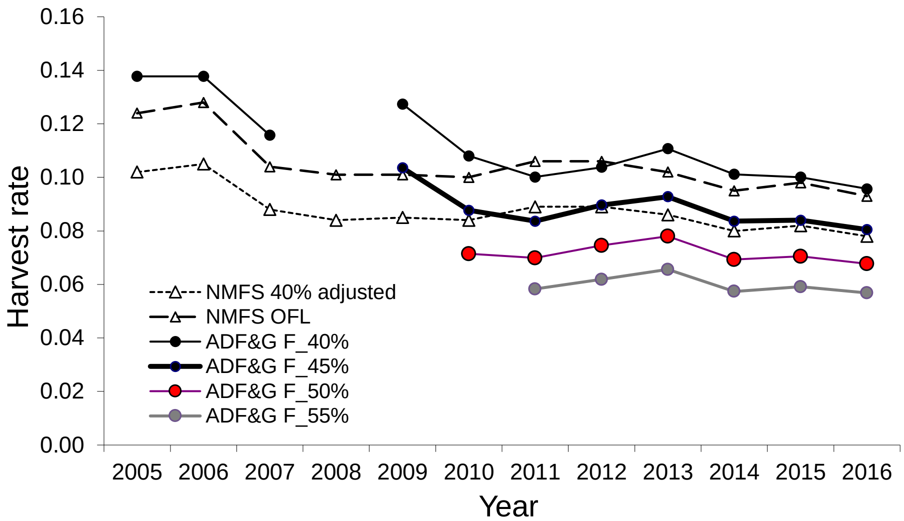

Figure 8. A comparison of sablefish harvest rates among years and between agencies. ADF&G used the $F_{40\%}$ harvest rate for calculating the acceptable biological catch (ABC) prior to 2009, the $F_{45\%}$ harvest rate in 2009, and the $F_{50\%}$ harvest rate since 2010. NOAA has recommended either the $F_{40\%}$ adjusted or more conservative harvest rate for the GOA/BSAI fishery, depending on the year. NOAA overfishing definition is Equal to the $F_{35\%}$ adjusted harvest rate.

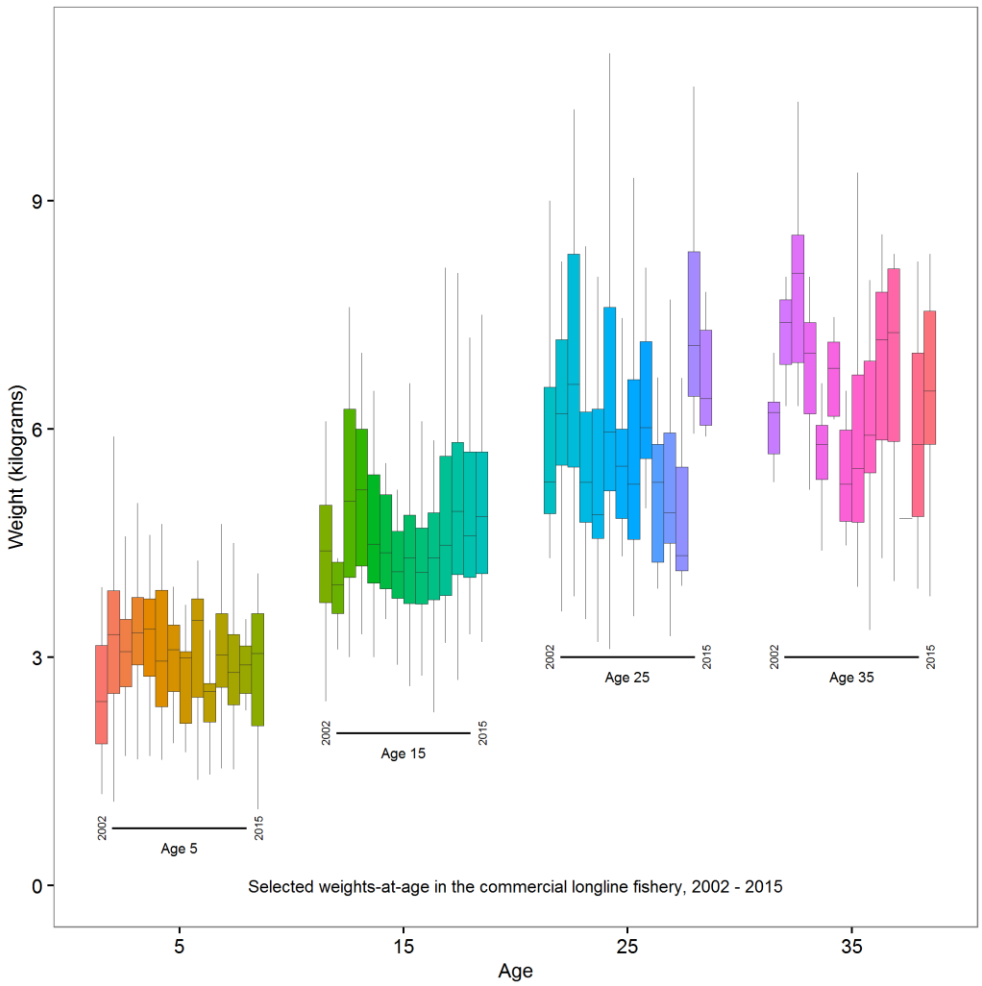

Figure 9. Boxplots with median, 25th and 75th percentiles for in selected weights-at-age sampled from the commercial longline fishery between 2002 - 2015.

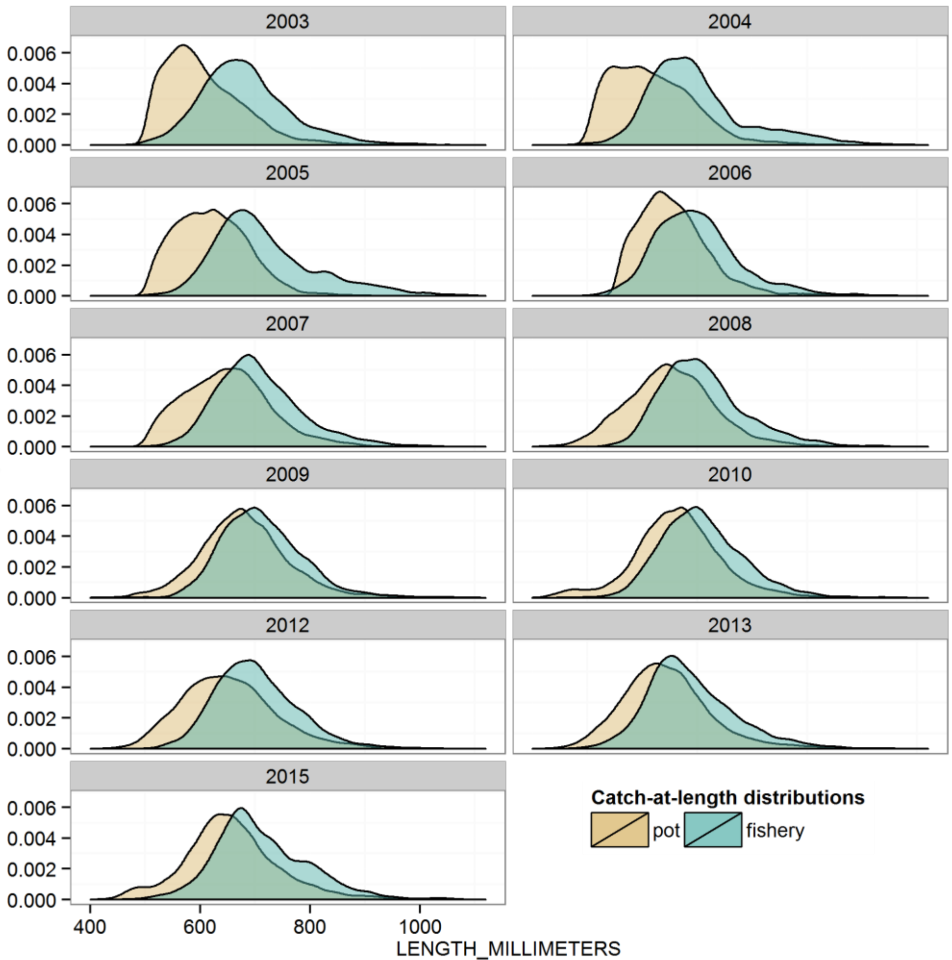

Figure 10. Catch-at-length distributions of the pot survey and the commercial longline fishery, both sexes combined.

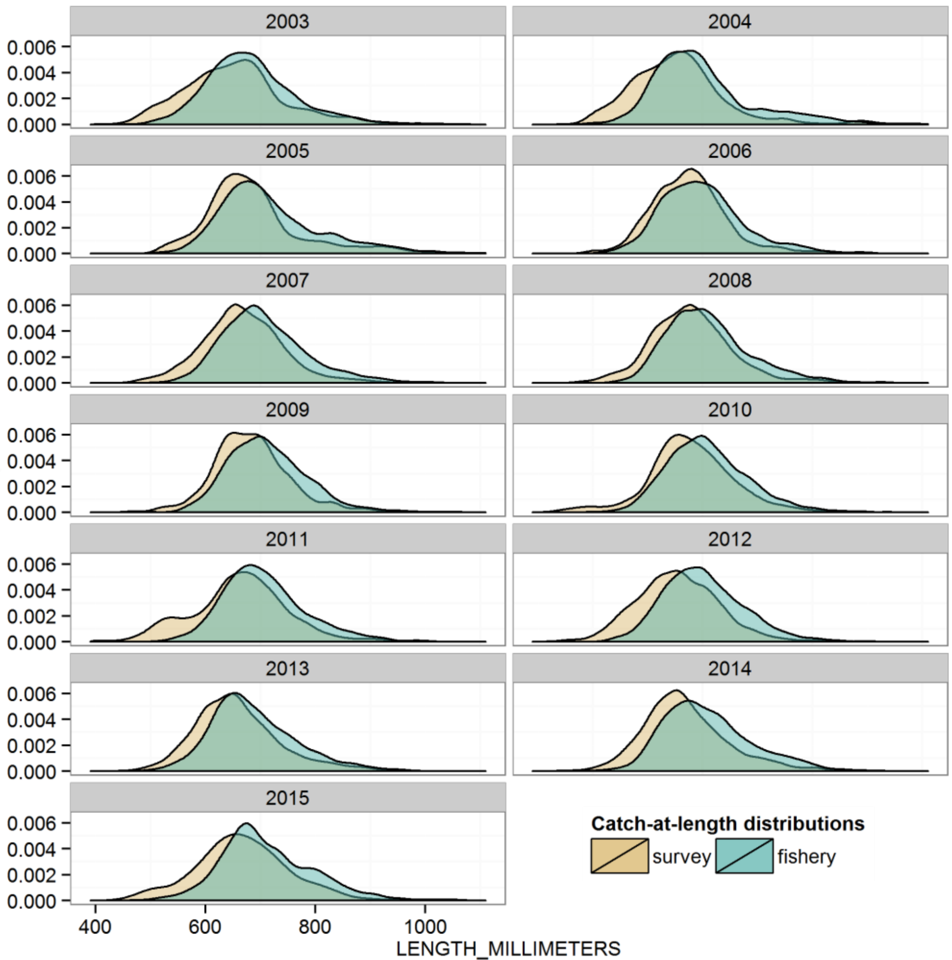

Figure 11. Catch-at-length distributions of the longline survey and the commercial longline fishery, both sexes combined.

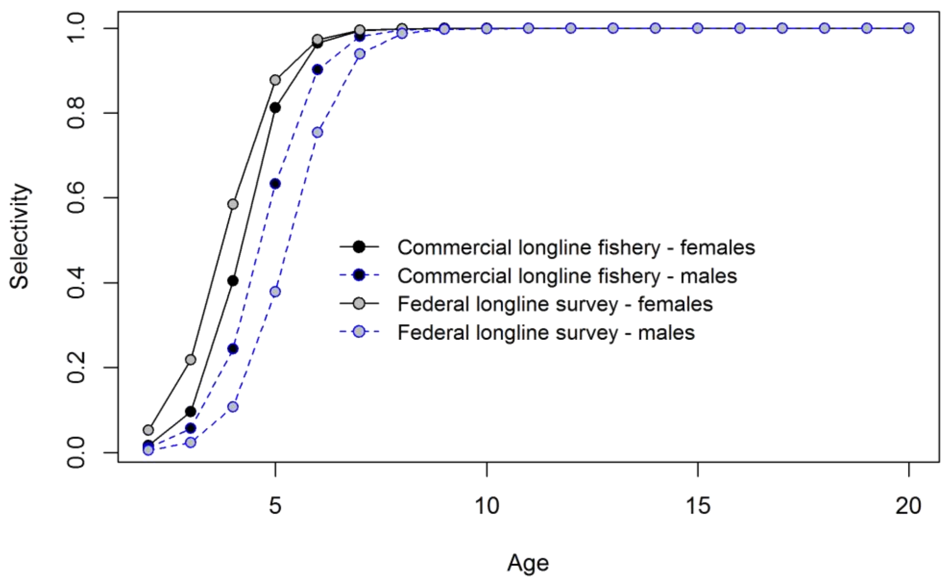

Figure 12. Selectivity-at-age vectors from the commercial longline fishery and the federal longline survey in the Gulf of Alaska.

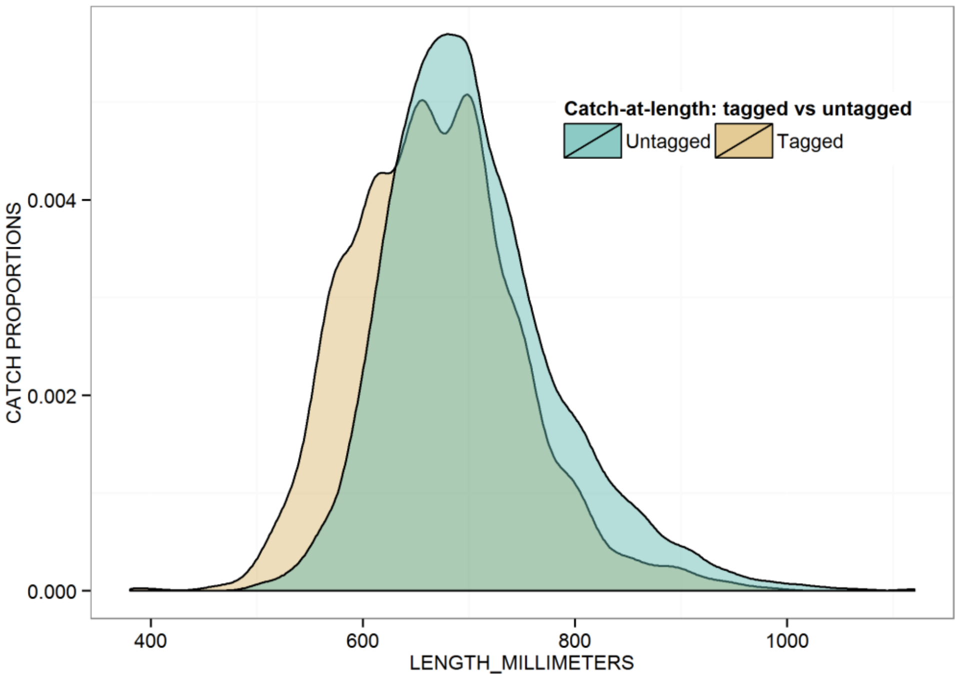

Figure 13. Catch-at-length distributions for tagged and untagged fish retained in the commercial longline fishery, both sexes combined, all years combined.

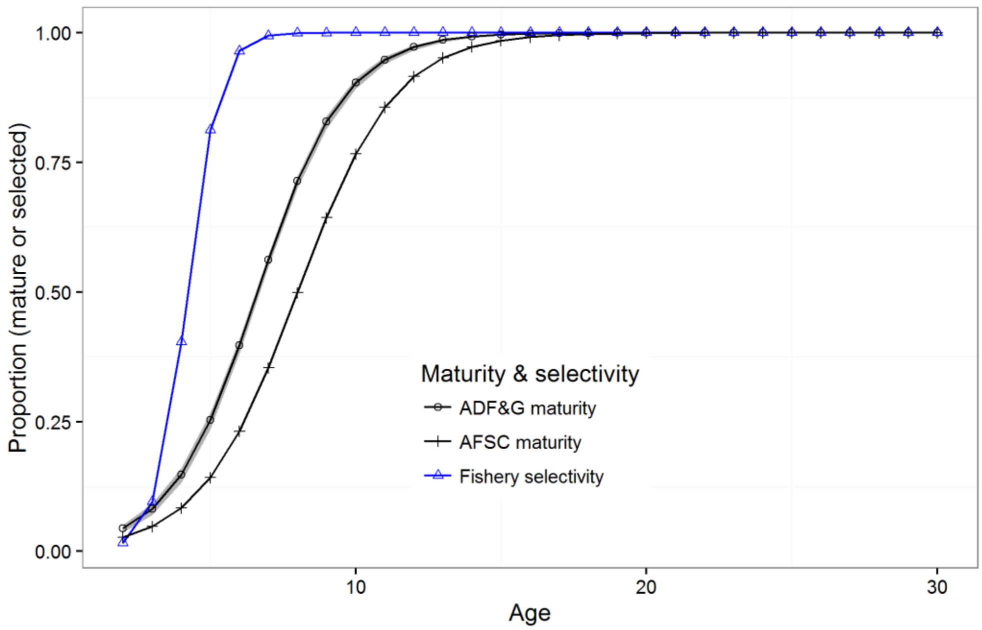

Figure 14. Female maturity-at-age from ADF&G longline survey data (with 95% confidence intervals from 10,000 parametric bootstrap iterations) and the Alaska Fisheries Science Center (AFSC) Gulf of Alaska sablefish stock assessment compared with commercial longline fishery selectivity-at-age for female sablefish.

APPENDIX I – DATA VARIABILITY

Variability in life-history parameters such as maturity-at-age or weight-at-age can affect calculations of biological reference points (e.g. female spawning biomass) and the catch quotas that are derived from them. Changes in estimates of life-history parameters over time can signify a trend in the population parameter of interest, or else indicate anomalies in the sampling protocols that produce the data (or both).

As the stock assessment methods for Chatham Strait sablefish have historically been centered around a snapshot in time, there has been interest in using life-history parameters calculated from a more recent set of years to better reflect the current population from which the harvest will be taken in the following year. Whether such efforts more accurately assess stock conditions or are more subject to sampling variability is undetermined. Length-at-age (Figure A1.1) shows less variability over time than weight (Figure A1.2) or maturity (Figure A1.3), which is expected. Annual anomalies relative to mean values for L_{inf} (Figure A1.4, Eq. 10) and W_{inf} (Figure A1.5, Eq. 11) suggest cyclic changes in size, but these cycles are not readily evident in annual anomalies for $m_{50\%}$ (Figure A1.6, Eq. 12).

Changes in weight and maturity can have a significant impact on the calculation of female spawning biomass. There does not, however, appear to be a defensible method for defining cut-offs for measuring these life-history parameters, nor has it been determined the degree to which this variability indicates changes to population dynamics as opposed to sampling or observation error.

The age-structured model due to be implemented in the 2017 stock assessment season uses mean measurements over all available years for calculating life-history parameters. Given the importance of comparisons between the current methods and the newer models, it is recommended to continue with overall mean measurements as opposed to temporal conditioning.

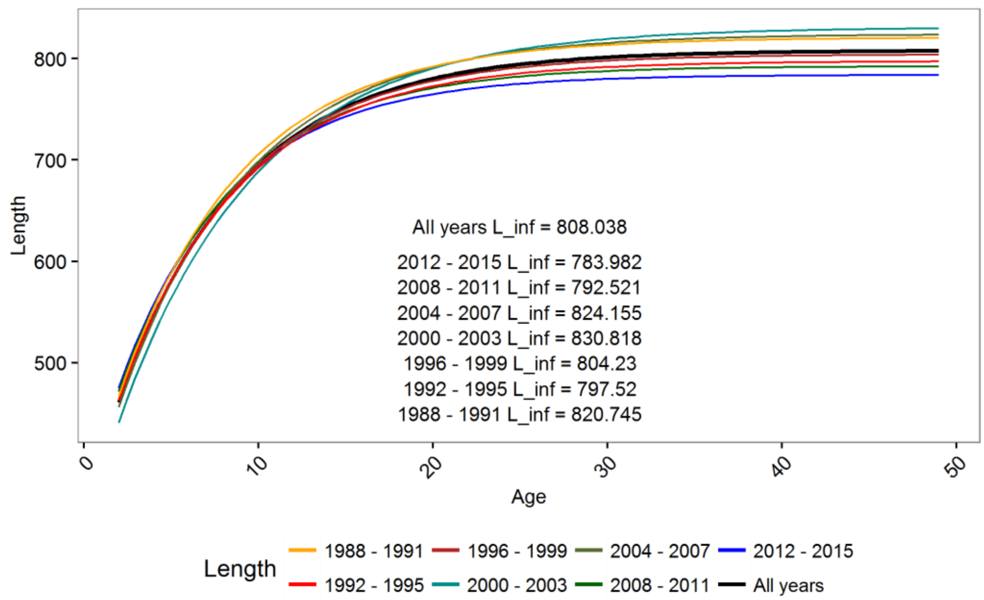

Figure A1.1. Changes in female length-at-age in four-year increments.

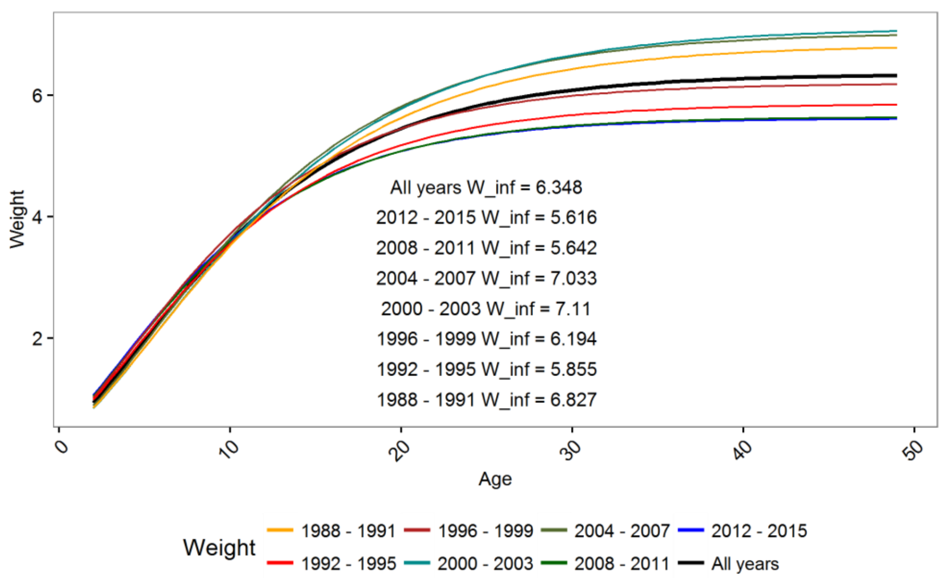

Figure A1.2. Changes in female weight-at-age in four-year increments.

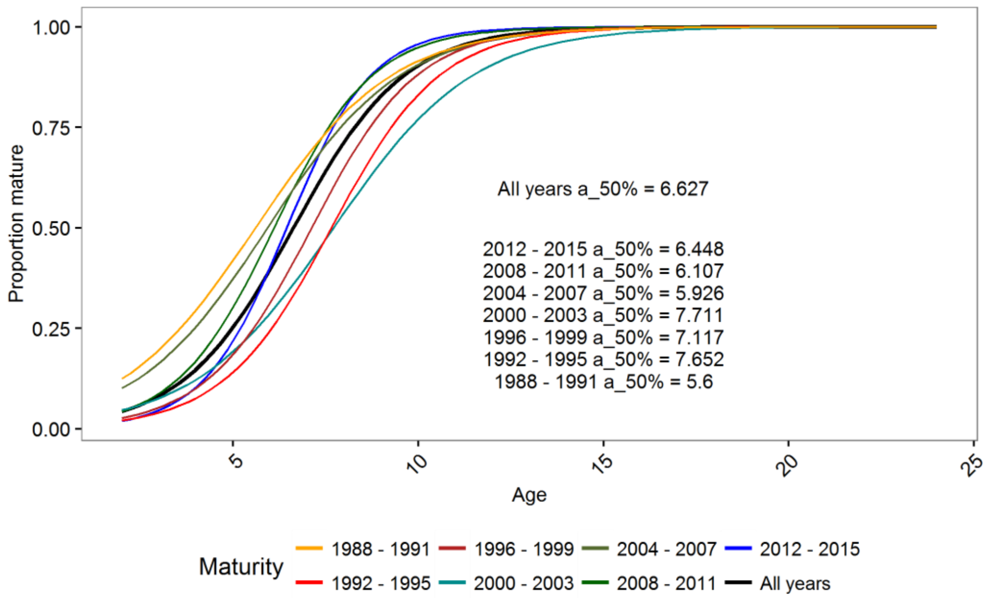

Figure A1.3. Changes in female maturity-at-age in four-year increments.

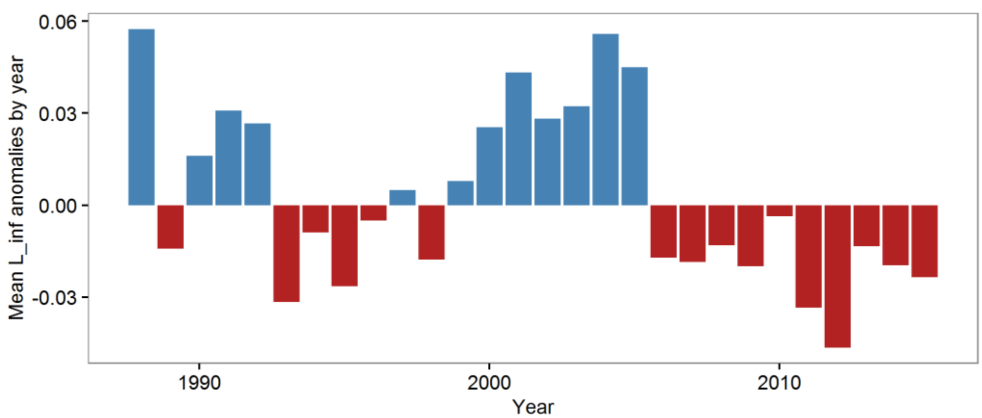

Figure A1.4 Annual L_{inf} anomalies relative to L_{inf} calculated over all years.

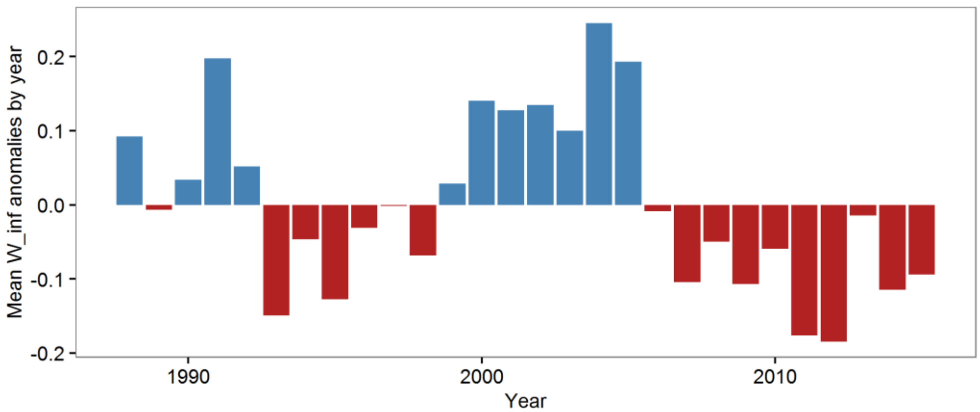

Figure A1.4 Annual W_{inf} anomalies relative to W_{inf} calculated over all years.

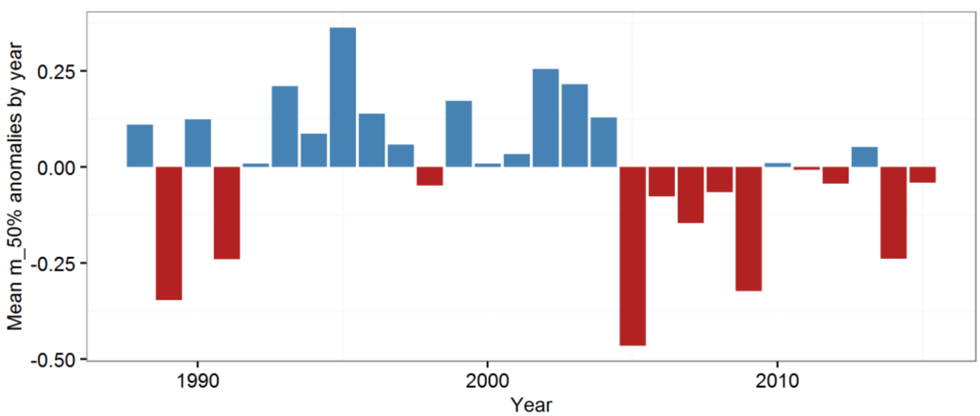

Figure A1.5 Annual $m_{50\%}$ anomalies relative to $m_{50\%}$ calculated over all years.

APPENDIX II – CPUE

CPUE is highly variable and dependent upon numerous drivers. This is especially true for fisheries CPUE, as fishing is not implemented in a statistically random or standardized manner. Accounting for this variability is important when attempting to observe population dynamics and trends in abundance.

In the discussion below, CPUE for the ADF&G longline survey is presented in individuals per hook, while the CPUE measurements for the commercial longline fishery are presented in pounds per hook.

As CPUE is calculated as the ratio of catch (individuals or pounds) to hooks deployed, the first step in standardizing CPUE is to standardize the number of hooks in a given set relative to spacing between the hooks per ganion as well as the spacing between ganions on the main line. Following Sigler and Lunsford (2001) the number of standardized hooks *N* for the commercial longline fishery and the ADF&G longline survey was calculated as:

$$N_{std} = N_{unstd} C_{\infty} (1 - \exp(-kh))$$

for which C_{∞} is the relative maximum catch per hook, *k* is a measure of the rate at which the maximum is reached, and *h* is the hook spacing.

Generalized additive models were applied to the survey and fishery to account for sources of variability beyond the number of standardized hooks. For the survey, the model included Station (Figure A2.1) and Stat Area (Figure A2.2) as

CPUE = Year + Station + Stat Area.

Although the depth for each set is recorded in the longline survey, these data are stored separately from the detailed hook accounting data used to calculate CPUE. While the survey is designed as random sampling event, addition of depth data may refine estimates of CPUE, and it is recommended that for the 2017 stock assessment efforts be made to include these data in the model.

For the commercial fishery, the GAM was

CPUE = Year + Stat Area + Julian Day + Depth + Sets + Hook Size + Vessel.

<u>Stat Area</u>: (Figure A2.3);

<u>Julian Day</u>: the commercial fishery lasts for roughly three months; CPUE can vary relative to timing if the fishery depletes the local population (Figure A2.4);

<u>Depth</u>: CPUE varies relative to depth (Figure A2.5);

<u>Sets</u>: the number of sets within a given trip can reflect abundance (Figure A2.6);

<u>Hook size</u>: hook size is constant in the longline survey but not in the commercial fishery (Figure A2.7);

Vessel: CPUE is affected by the relative experience of skipper and crew on a given vessel (Figure A2.8);

Output from the survey GAM showed little departure from the simple catch-to-hook ratio, as the surveu is already standardized relative to many potential sources of variability (Figure A2.9). CPUE for the commercial longline fishery estimated by the GAM was higher than the simple ratio, but trends were the same. As CPUE is used only as a general assessment of sablefish population trends in Chatham Strait and not directly as a quantitative input to calculating forecast abundance or catch levels, application of the GAM to the fishery CPUE will not result in changes to the quota or other management decisions.

Use of the GAM approach for both survey and fishery produces lower estimates of variance that the simple catch-hook ratio, and integration of CPUE into the age-structured model will benefit from this reduced variance.

Literature Cited

Sigler, M.F., and C.R. Lunsford. 2001. Effects of individual quotas on catching efficiency and spawning potential in the Alaska sablefish fishery. Can. J. Fish.Aquat.Sci. **85**: 1300 - 1312

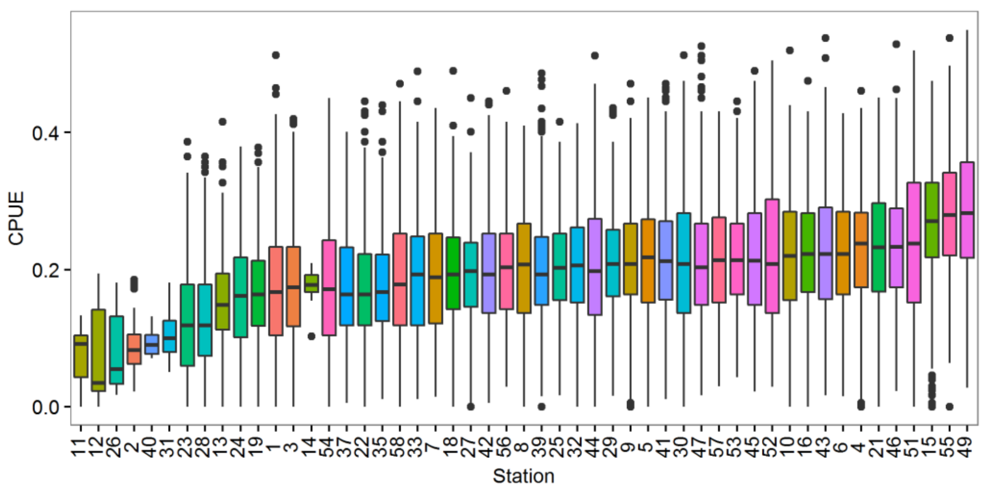

Figure A2.1 CPUE and Station (location within a given Stat area) in the ADF&G longline survey, 1988 – 2015.

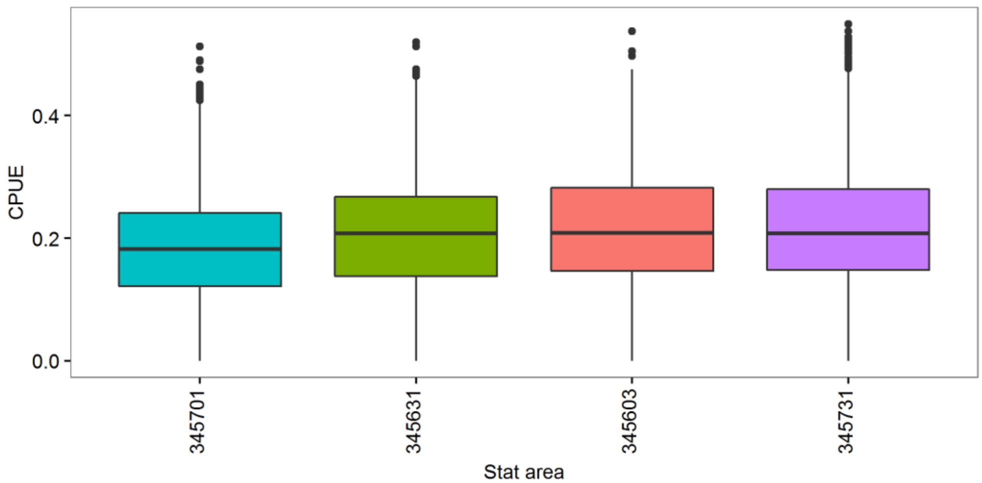

Figure A2.2 CPUE and Stat area within Chatham Strait in the ADF&G longline survey, 1988 – 2015.

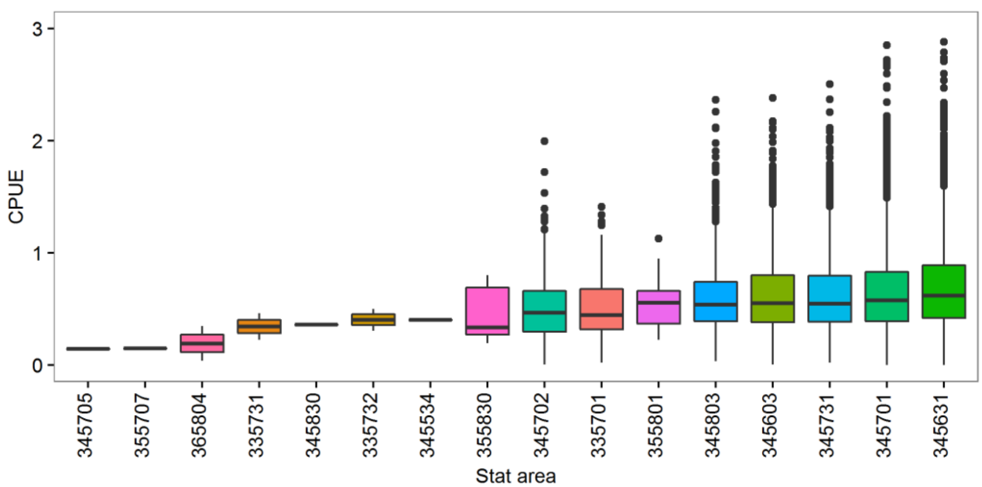

Figure A2.3 CPUE and Stat area in the commercial longline fishery 1997 – 2015; some outliers have been truncated for legibility.

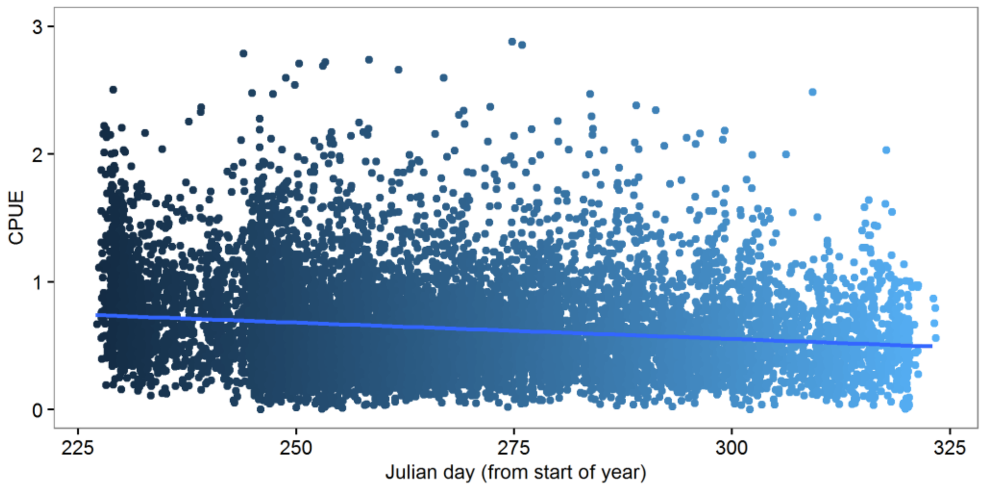

Figure A2.4 CPUE and Julian day in the commercial longline fishery 1997 – 2015; some outliers have been truncated for legibility.

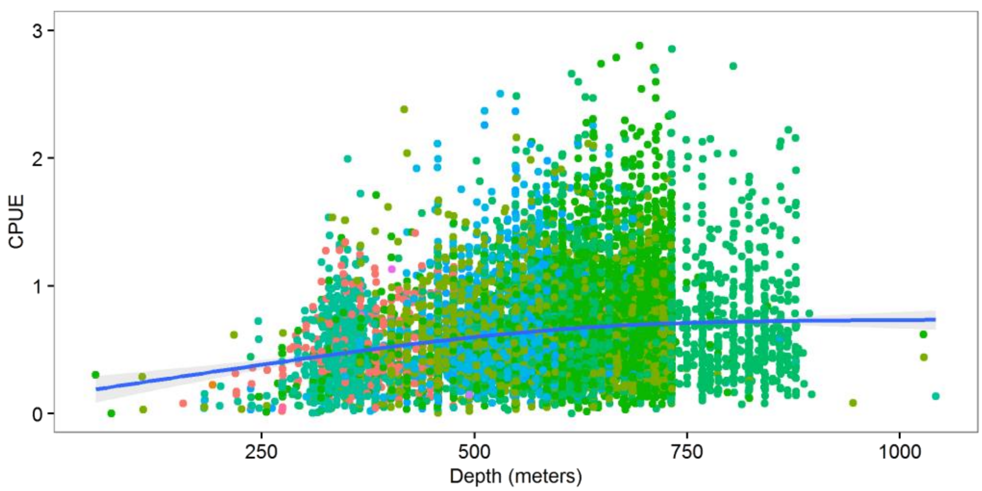

Figure A2.5 CPUE and depth in the commercial longline fishery 1997 – 2015; some outliers have been truncated for legibility.

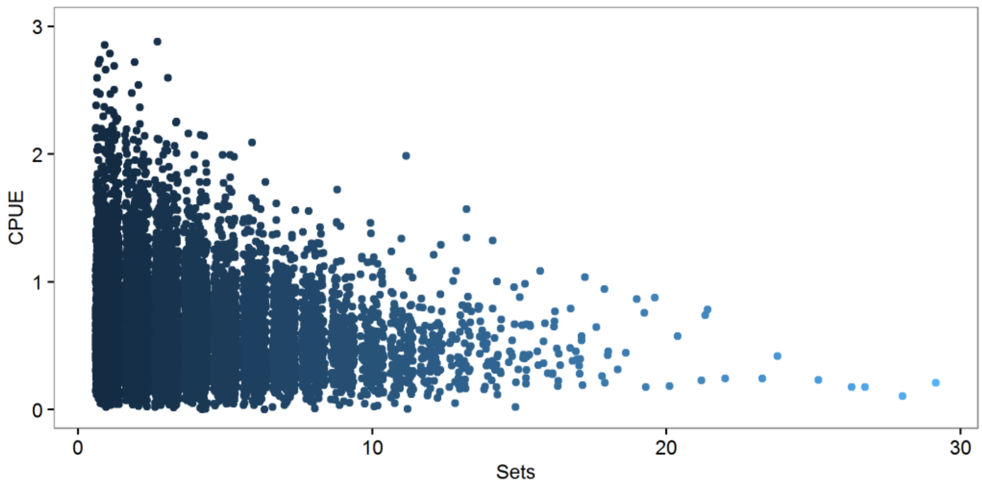

Figure A2.6 CPUE and sets per trip in the commercial longline fishery 1997 – 2015; some outliers have been truncated for legibility.

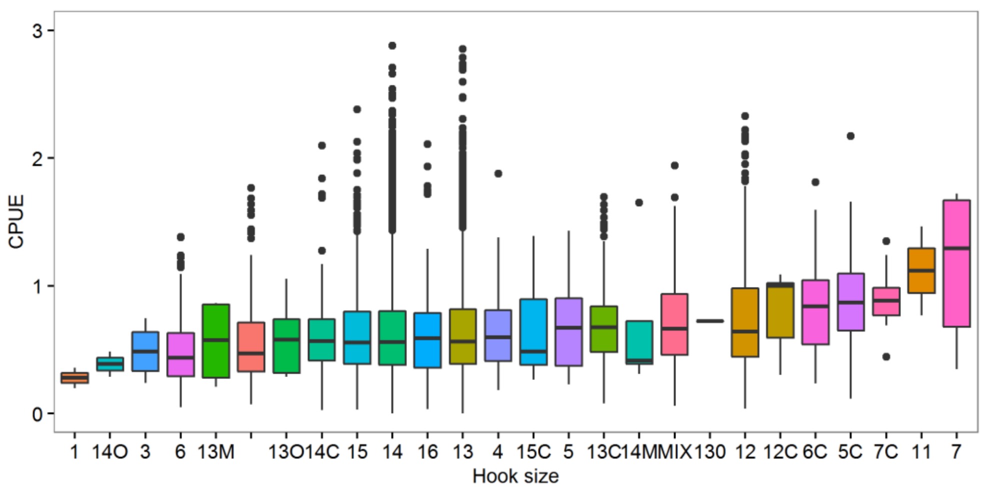

Figure A2.7 CPUE and hook size in the commercial longline fishery, 1997 – 2015; some outliers have been truncated for legibility.

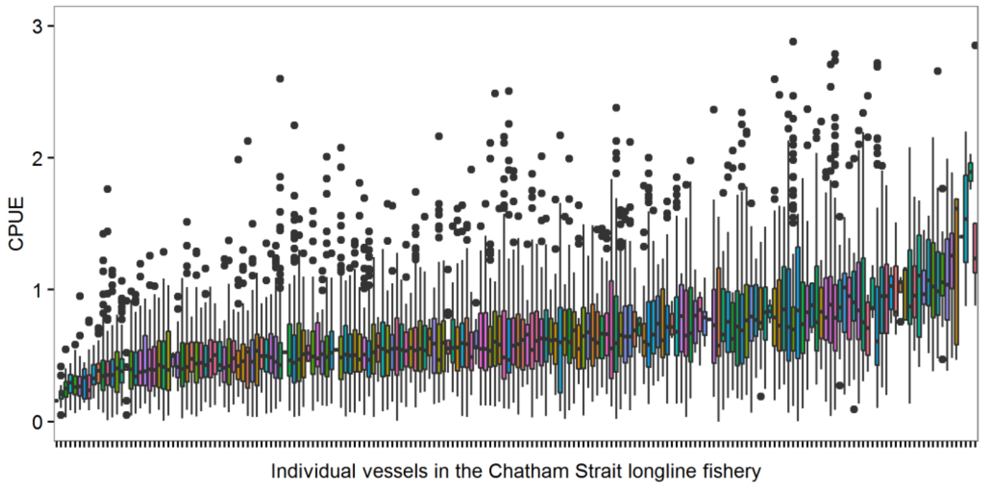

Figure A2.8 CPUE relative to individual permitted vessel in the commercial longline fishery 1997 – 2015; some outliers have been truncated for legibility.

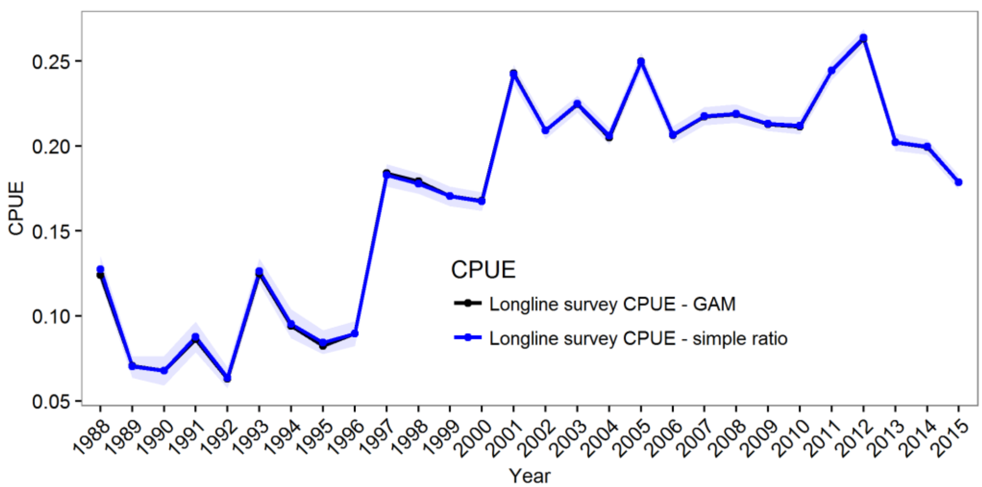

Figure A2.9. ADF&G longline annual survey CPUE from both the GAM and simple ratio with 95% confidence intervals (virtually identical).

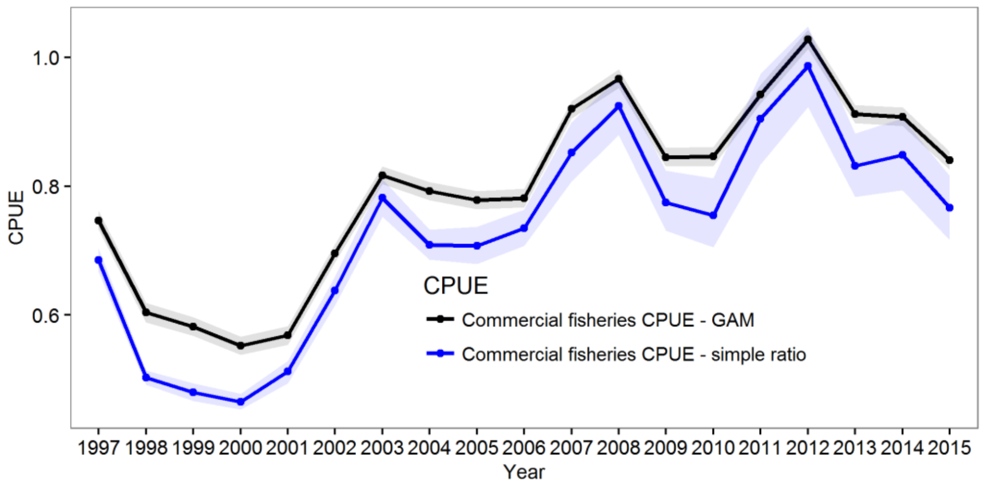

Figure A2.10. Commercial fisheries annual CPUE from both the GAM and simple ratio with 95% confidence intervals, constructed from a subset of total CPUE data that conditioned against NULL values for GAM drivers.