14. ASSESSMENT OF THE DEMERSAL SHELF ROCKFISH STOCK COMPLEX IN THE SOUTHEAST OUTSIDE DISTRICT OF THE GULF OF ALASKA

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Executive Summary

The demersal shelf rockfish (DSR) complex (yelloweye, quillback, copper, rosethorn, canary, China, and tiger rockfish) (Table 1) is assessed on a biennial cycle, with full stock assessments typically conducted in odd calendar years. Historically, the stock assessment was based on relative abundance estimates from a manned submersible (*Delta*), however as of 2010, the submersible was retired from use. No surveys were conducted in 2010 and 2011 while an alternate vehicle was sought. In 2012, we transitioned the survey from a submersible to a remote operated vehicle (ROV), and conducted stock assessment ROV surveys in 2012, 2013, and 2015. The recommended acceptable biological catch (ABC) and overfishing level (OFL) for this year's SAFE (Table 2) are based on the most recent ROV and submersible density estimates of yelloweye rockfish in each management area using our historical methodology (e.g., Brylinsky et al. 2009). Per the Science and Statistical Committee/Plan Team's request, we also present the results of the ROV and submersible survey data in a random effects model in Appendix A. In addition, the results of a preliminary statistical age-structured model, which incorporates submersible and ROV yelloweye rockfish density estimates, commercial, recreational, and subsistence fishery data, and International Pacific Halibut Commission (IPHC) survey data, are presented in Appendix B.

Summary of Changes in Assessment Inputs

Changes in the input data:

Catch information and average weights for yelloweye rockfish catch from the commercial fishery were updated for 2015. Average weight of yelloweye rockfish changed from 3.69 kg to 3.96 kg in East Yakutat (EYKT), from 3.34 kg to 3.47 kg in Central Southeast Outside (CSEO), and 3.68 to 3.95 kg in Northern Southeast Outside (NSEO). There was not a directed fishery in Southern Southeast Outside (SSEO) in 2014 or 2015, and no samples were taken from the halibut fishery in this area so average weight from 2013 was used (3.53 kg). Yelloweye rockfish density was updated in this stock assessment for EYKT using the 2015 survey data (ROV-derived).

Changes in the assessment methodology:

The only change to the status quo assessment methodology is that we present an option for calculating the non-yelloweye DSR component using Tier 6 calculations based on catch data from 2010 to 2014 for recreational, commercial and subsistence data. This time period was the only range when all three catch data sets overlapped. We recommend the Tier 6 option because it is consistent with other stock assessments that do not have reliable biomass estimates and is based on historical catch rather than an expansion of yelloweye rockfish biomass. These values are presented in the summary table below.

Although not a recommended change to the status quo methodology, an updated random effects model (last presented in 2013) is presented in Appendix A. As in 2013, the random effects model-derived density estimates were similar to the survey density estimates for 2015, but the CVs were greater and the overall calculated biomass estimate was lower. At this time, we do not recommend the use of the random effects model due to limited time to fully evaluate the results. The survey data analyses were not completed until October 2015, thus precluding inclusion in the September document.

Summary of Results

DSR are managed under Tier 4 of North Pacific Fishery Management Council (NPFMC) harvest rules, where maximum allowable $F_{ABC} \leq F_{40\%}$ and $F_{OFL}=F_{35\%}$. The maximum allowable ABC for 2016 is 280 t (260 t YE + 20 t non-YE DSR) based on Tier 4 status for the DSR complex. DSR are particularly vulnerable to overfishing given their longevity, late maturation, and habitat-specific residency. As in previous years, we recommend a harvest rate lower than the maximum allowed under Tier 4; $F=M$=0.02. This results in an author's recommended ABC of 231 t (211 t YE + 20 t non-YE DSR) for 2016, a slight increase from the 2015 ABC of 225 t. The overfishing level (OFL) is set using $F_{35\%}$=0.032; which is 346 t for 2016. The ABC and OFL are calculated based on Tier 6 calculations for non-yelloweye DSR added to the Tier 4 values for yelloweye. We recommend the use of this Tier 6 option for non-yelloweye because it is based on historical catch rather than an expansion of yelloweye biomass.

Per the 2009 Board of Fisheries (BOF) decision, subsistence DSR removals are deducted off the ABC prior to the allocation of the total allowable catch (TAC) between the commercial and recreational fisheries. In the current assessment, 7 t was deducted from the ABC for DSR caught in the subsistence fisheries, for a TAC of 224 t. In 2006 the BOF allocated the SEO DSR TAC in the following manner: 84% to the commercial fishery and 16% to the recreational fishery. Thus 188 t is allocated to commercial fisheries, and 36 t is allocated to recreational fisheries for 2016.

Reference values for DSR are summarized in the following table, with the recommended ABC and OFL values in bold. The stock was not subjected to overfishing last year.

Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
M (natural mortality rate)	0.02	0.02	0.02	0.02
Tier	4	4	4	4
Yelloweye Biomass (t)	10,933		10,559	
Specified/recommended F_{ABC}	0.020	0.020	**0.020**	**0.020**
$F_{OFL} = F_{35\%}$	0.032	0.032	0.032	0.032
$maxF_{ABC}$	0.026	0.026	0.026	0.026
Recommended DSR ABC (t)	225[1]	225[1]	**231[2]**	**231[2]**
DSR OFL (t)	361[1]	361[1]	346[2]	346[2]
DSR maxABC (t)	293[1]	293[1]	280[2]	280[2]
Status	As determined last year for: 2013	2014	As determined this year for: 2014	2015
Is the stock being subjected to overfishing?	No	n/a	No	n/a

[1] The DSR ABC and OFL were increased by 3% to determine the percentage of non-yelloweye DSR for the ABCs and OFL last year.

[2]For 2016 and 2017 the non-yelloweye DSR ABCs and OFLs are calculated using Tier 6 methodology. Non-yelloweye Tier 6 ABCs and OFLs are added to the Tier 4 yelloweye ABCs and OFL for total DSR values. Data for Tier 6 calculations for "other DSR" are presented in Appendix C.

Updated catch data (t) for DSR in the Gulf of Alaska as of October 15, 2015 (NMFS Alaska Regional Office Catch Accounting System via the Alaska Fisheries Information Network (AKFIN) database, http://www.akfin.org are summarized in the following table.

Year	EGOA Catch Total[1]	EGOA ABC	EGOA TAC[1]
2014	98	274	224
2015	103[2]	225	182

[1] TAC and Catch are for the commercial fishery only. The recreational harvest (retained harvest plus estimated discard) for the SEO was 40 t in 2014 and 46 t in 2015.

[2]Updated commercial catch data (t) for demersal shelf rockfish in the Southern Outside District as of November 3, 2015.

Area Apportionment

The ABC and OFL for DSR are for the SEO Subdistrict. The State of Alaska manages DSR in the Eastern regulatory area with Council oversight and any further apportionment within the SEO Subdistrict is at the discretion of the State.

Summaries for Plan Team

Species	Year	Biomass	OFL	ABC	TAC[1]	Catch[2]
	2013	14,588	487	303	249	212
	2014	13,274	438	274	224	98
	2015	10,933	361	225	182	103[2]
	2016	10,559	364	231	188	

[1] TAC and Catch are for the commercial fishery only. The TAC is calculated after the subsistence projected catch is deducted from the ABC. The recreational harvest (retained harvest plus estimated discard) for the SEO was 34 t in 2013, 40 t in 2014 and 46 t in 2015.

[2]Updated commercial catch data (t) for demersal shelf rockfish in the Southern Outside District as of November 3, 2015.

Responses to SSC and Plan Team Comments on Assessments in General

The Teams recommend that the random effects survey smoothing model be used as a default for determining current survey biomass and apportionment among areas.

We ran a random effects model for survey data in 2013 and the resulting biomass was much lower than the status quo. The team rejected the model and recommended the status quo methodology (Green et al. 2013). We provided an updated random effects model for the ROV/submersible survey data since we have new survey data for 2015 in EYKT (Appendix A); however, these estimates, although improved, are lower than the status quo methods. The author's recommendation is to use the status quo methods until the ASA can be sufficiently developed for management use or the random effects model can be more fully evaluated.

For this year's final assessments, the Teams recommend that each author of an age-structured assessment use one of the following model naming conventions ("TPA" represents the alternative described in the Team procedures document).

We will adhere to this naming convention for the revised ASA model once a formal model is adopted, per the Plan Team's direction. The current model is still in development.

Responses to SSC and Plan Team Comments Specific to this Assessment

The Team recommends using direct habitat measures (e.g., depth strata) rather than yelloweye rockfish presence as a means for screening data to be used for evaluating changes in yelloweye population density (CPUE index).

The commercial fishery CPUE indices have been replaced with simple pounds-per-hook evaluations for each region, and skates with zero yelloweye have not been removed. The CPUE indices for the IPHC longline survey also use this methodology for calculating CPUE, but both sonar data as well as yelloweye presence were used as screening criteria. These datasets will be reanalyzed for the 2016 assessment.

The Team recommends that the assumed standard errors by year be presented for evaluation (e.g., the implied CV which results from the combination of the "weights" applied to the likelihood components and the annual specifications of the observation errors (if they vary by year).
Comments from the September Plan Team meeting have resulted in replacement of the likelihoods in the ASA model with a set of penalized log-likelihoods, and the *ad hoc* secondary weightings have been removed. The author would be very interested in receiving further input on detailed evaluation metrics that can be applied to model development and refinement.

The Team recommends fixing natural mortality rates at acceptable values (the current prior mean?) during model development and explorations. The model is complex and adding mortality estimation may create more difficulties in interpreting how data are fitting and confound other aspects (e.g., movement among areas).
The current age-structured model fixes M at the Tier 4 assumed value of 0.026. An effort was made to estimate natural mortality as a random walk, with some marginal success, and the results are briefly discussed in Appendix B.

The SSC is concerned that this may signal a considerable conservation concern for this species group and recommends that assessment development be fast-tracked.
We agree that the stock declines in the models are concerning but recognize that they are not fully developed yet. Neither the ABC nor the OFL has been exceeded. We agree that the ASA model should continue to be revised for management purposes, but feel that our current stock assessment methodology is conservative and results in sustainable ABCs and OFLs.

The Team recommends that an age error matrix for yelloweye rockfish be developed (perhaps using the software and methods provided by Punt et al. 2008).
Earlier model versions have used an age error matrix constructed from National Marine Fisheries Service age readers. The current model includes a new age error matrix constructed with code provided by Pete Hulson of the NMFS Auke Bay Lab and using the age-reader data from the Alaska Department of Fish and Game's Age Determination Unit.

The Team also recommends that the working group evaluate the feasibility of developing a southeast Alaska yelloweye/DSR age structured model and a GOA wide yelloweye/DSR age structured model. The SSC also recommends the authors' complete the stock structure template and provide clarification of what catch data are being used and whether discards are fully incorporated.
A working group for yelloweye rockfish was created and met in 2015. A stock structure template for Yelloweye in conjunction with the Other Rockfish was completed in consultation with the working group and presented to the Plan Team in September (Tribuzio et al. 2015). The authors of this DSR stock assessment agree with the recommended alternatives in Other Rockfish/DSR document. For DSR in this document, catch data are included through early November. Since the DSR directed and incidental commercial fisheries are completed by early November each year, and full retention of DSR is in effect, our recommendation is to use the actual catch data rather than projected catch. This is consistent with our historic methodology. The commercial halibut fishery season ends November 7, 2015, and our estimates go through November 3rd, 2015, thus encapsulating nearly all the actual catch.

Introduction

Biology and Distribution

Rockfishes of the genus *Sebastes* are found in temperate waters of the continental shelf off North America. At least thirty-two species of *Sebastes* occur in the Gulf of Alaska. The DSR assemblage is comprised of the seven species of nearshore, bottom-dwelling rockfishes (Table 1). These fish are located on the continental shelf, reside on or near the bottom, and are generally associated with rugged, rocky habitat. For purposes of this report, emphasis is placed on yelloweye rockfish, as it is the dominant species in the DSR fishery (O'Connell and Brylinsky 2003).

All DSR are considered highly K-selective, exhibiting slow growth and extreme longevity (Adams 1980, Gunderson 1980, Archibald et al. 1981). Estimates of natural mortality are very low. These types of fishes are very susceptible to over-exploitation and are slow to recover once driven below the level of sustainable yield (Leaman and Beamish 1984, Francis 1985). An acceptable exploitation rate is assumed to be very low (Dorn 2000).

Life History

Rockfishes are considered viviparous although different species have different maternal contribution (Boehlert and Yoklavich 1984, Boehlert et al. 1986, Love et al. 2002). Rockfishes have internal fertilization with several months separating copulation, fertilization, and parturition. Within the DSR species complex, parturition occurs from February through September with the majority of species extruding larvae in spring. Yelloweye rockfish extrude larvae over an extended time period, with the peak period of parturition occurring from April through June, peaking in May in Southeast Alaska (O'Connell 1987). Although some species of *Sebastes* have been reported to spawn more than once per year in other areas (Love et al. 1990), no incidence of multiple brooding has been noted in Southeast Alaska (O'Connell 1987).

Rockfishes have a closed swim bladder that makes them susceptible to embolism mortality when brought to the surface from depth. Full retention regulations for the commercial fleet have been in place since 2005. Full retention of DSR had been required for the recreational fleet, but beginning in the 2013 season, all charter operators in Southeast Alaska were required to possess and utilize deep-water release devices for releasing non-pelagic (i.e. DSR) rockfish. Historically, release mortality biomass has been estimated using the assumption that released rockfish experience 100% mortality (Green et al. 2013).

Stock structure

Siegle et al. 2013 detected subtle population genetic structure in yelloweye rockfish from the outer British Columbia coast and inner waters, but a lack of genetic structure on the outer coast (between the Bowie Seamount and other coastal locations in British Columbia). These data suggest that due to the long pelagic larval duration for *Sebastes* spp. (several months to one year) there is not significant genetic stock structure for the DSR complex in the SEO management area. However, additional life history data analyses at finer spatial scales are needed to evaluate DSR stock structure in the Eastern GOA. The limited movements of adult yelloweye rockfish can contribute to serial depletion of localized areas if overharvest occurs.

Fishery

Description of Directed Commercial Fishery

The directed fishery for DSR began in 1979 as a small, shore-based, hook and line fishery in Southeast Alaska. This fishery targeted the nearshore, bottom-dwelling component of the rockfish complex, with fishing occurring primarily inside the 110 m contour. The early directed fishery targeted the entire DSR complex (Table 1), which at that time also included silvergray, bocaccio, and redstripe rockfish (Appendix A). In more recent years the fishery has targeted yelloweye rockfish and fished primarily between the 90 m and the 200 m contours. Over the past five years, yelloweye rockfish accounted for 96 to 98% (by weight) of the total DSR catch (Table 5). Quillback rockfish are the next most common species landed in the complex, accounting for approximately 2% of the landed catch between 2008 and 2015 (Table 5). The directed fishery is prosecuted almost exclusively by longline gear. Although snap-on longline gear was originally used in this fishery, most vessels now use conventional (fixed-hook) longline gear. Markets for this product are domestic fresh markets and fish are generally brought in whole, bled, and iced. Processors will not accept fish delivered more than three days after being caught.

In SEO, regulations stipulate one season only for directed fishing for DSR opening January 5th (unless closed by emergency order) and continuing until the allocation is landed or until the day before the start of the IFQ halibut season (to prevent over-harvest of DSR), whichever comes first. The directed DSR fleet requested a winter fishery, as the ex-vessel price is highest at that time. Directed fisheries are opened by management area if there is sufficient commercial TAC remaining after subtracting the estimated DSR incidental catch in other fisheries.

Management Units

Prior to 1992, DSR was recognized as a Fishery Management Plan (FMP) assemblage only in the waters east of 137° W. longitude. In 1992, DSR was recognized in EYKT, and management of DSR extended westward to 140° W. longitude. This area is referred to as the Southeast Outside (SEO) Subdistrict and is comprised of four management sections: EYKT, NSEO, CSEO, and SSEO. In the SEO, the State of Alaska and the National Marine Fisheries Service (NMFS) manage DSR jointly. The two internal state water Subdistricts, Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) are managed entirely by the State of Alaska and are not included in this stock assessment (Figure 1). Please see Appendix D for a more complete description of historical DSR management changes.

Description of Effort and CPUE

Figure 14 in Appendix B discusses the CPUE for each of three of the four management areas since 1997, when the commercial logbook program became mandatory. There has not been directed fishery in the NSEO area since 2001; thus it is not shown. Prior to the logbook requirement, the department did not have access to location and effort by set from the commercial fishery. Some fishermen kept logbooks voluntarily, but this was not required.

Commercial Fishery Catch History

Although the DSR fishery has been active since the late 1970s, catch reconstruction for DSR prior to 1992 is problematic due to changes in the species assemblage as well as the lack of a directed fishery harvest card prior to 1990 for CSEO, SSEO, and NSEO, and 1992 for EYKT (Appendix A). Thus, the history of domestic landings of DSR from SEO is shown from 1992–2014 in Table 2. The directed DSR catch in SEO was above 350 mt in the mid-1990s. Since 1998, landings have been below 250 mt, and since 2005, directed landings have typically been less than 100 mt. During the reported years (1992 to 2014), total catches peaked at 604 mt in 1994, and directed catch peaked at 381 mt in 1994. Although directed landings were higher in the 1990s, since 2000, most of the DSR total reported catch is from incidental catch of DSR in the halibut fishery. It should be emphasized, however, that prior to 2005, unreported mortality from incidental catch of DSR associated with the halibut and other non-directed fisheries is unknown and may have been as great as a few hundred tons annually. Directed commercial fishery landings have often been constrained by other fishery management actions. In 1992, the directed DSR fishery was allotted a separate halibut prohibited species cap (PSC) and is therefore no longer affected when the PSC is met for other longline fisheries in the GOA. In 1993, the fall directed fishery was closed early due to an unanticipated increase in DSR incidental catch during the fall halibut fishery.

Directed fisheries are held in the four management areas (EYKT, NSEO, SSEO, and CSEO) if there is sufficient quota available after the DSR mortality in other commercial fisheries (primarily the IFQ halibut fishery) is estimated. The directed fishery in NSEO has been closed since 1995; small apportionments for that management area have precluded prosecution of a fishery since that time. The directed commercial DSR fisheries in the CSEO and SSEO management areas were not opened in 2005 because it was estimated that total mortality in the recreational fishery was significant and combined with the directed commercial fishery would likely result in exceeding the TAC. No directed fisheries occurred in 2006 or 2007 in the SEO district as ADFG took action to: 1) to enact management measures to maintain DSR catch in the recreational fishery within the recreational allocation, and 2) evaluate the accuracy of DSR incidental commercial catch estimation methodology compared to actual landings (after full retention regulations). Between 2006 and 2013, there was sufficient TAC to hold directed commercial fisheries in at least two of the four SEO management areas. In 2014 and 2015, only the EYKT area was opened to directed fishing. Directed commercial fishery performance for EYKT, CSEO, and SSEO is shown in Appendix B (Figure 13–15). The directed CPUE has generally been between 0.4 lbs per hook and 0.6 lbs per hook in all areas. EYKT has the most variability in fishery performance data over the time series, but trends in all areas are fairly stable. Variability in commercial directed CPUE is likely artificially reduced as the directed fishery quotas are small (< 40 t) and the fisheries occur over a short time period with low trip limits (6,000 to 12,000 lbs).

DSR Mortality in Other Commercial Fisheries

DSR have been taken as incidental catch in domestic longline fisheries, particularly the halibut fishery, for over 100 years. Some incidental catch was also landed by foreign longline and trawl vessels targeting slope rockfish in the EGOA from the late 1960s through the mid-1970s. Other sources of DSR incidental commercial catch are the lingcod, Pacific cod, and sablefish fisheries; however the halibut longline fishery is the most significant contributor to the commercial mortality of DSR.

In 1998, the NPFMC passed an amendment to require full retention of DSR in federal waters. Seven years later, in mid-season 2005, the final rule was published and fishermen must retain and report all DSR caught in federal waters; any poundage above the 10% incidental catch allowance may be donated or kept for personal use but may not enter commerce. In July of 2000, the State of Alaska enacted a parallel regulation requiring DSR landed in state waters of Southeast Alaska to be retained and reported on fish tickets. Proceeds from the sale of DSR in excess of legal sale limits are forfeited to the State of Alaska.

Since the implementation of the state and federal full retention regulations for DSR, over 95% of the landed overages of DSR in the state and federal waters are now retained for personal use rather than being donated or sold. There appears to be increasing compliance with the full retention. In addition, the Alaska Longline Fishermen's Association has developed a database of rockfish "hotspots" so that halibut and sablefish longline fishermen can avoid making sets in these areas in an effort to reduce rockfish incidental catch.

The projected DSR mortality in the halibut fishery is deducted from the commercial TAC before the directed fisheries can be prosecuted. From 2006 to 2011, we estimated the amount of DSR incidental catch in the halibut fishery using the IPHC stock assessment survey data to determine the weight ratio of yelloweye rockfish to halibut by depth and area. The yelloweye/halibut weight ratio by strata was applied to the IPHC halibut catch limit by strata. For a complete description of the methodology used before 2011, please see Brylinsky et al. (2009). Since 2012, we have used full retention data to calculate the ratio of DSR lbs to halibut lbs landed in the halibut fishery, by management area, and applied this to the estimated halibut quota for the following year. The results of this analysis showed that on an annual basis, the commercial fleet incidental DSR catch rate was consistent (8 to 10%) over a five year period, while the IPHC survey incidental catch rate was highly variable by strata and year (ranging from 3 to 20%). An additional 10% is added to the preseason estimation for unreported discard. Our modeled estimates using the full retention data are accurate (within 10%) when compared to actual catch. The incidental catch of DSR in the halibut fishery is trending downward (Table 2). The decrease in DSR catch has generally paralleled the decreases in the halibut quotas in Area 2C and 3A, which overlap with our DSR management jurisdiction. In recent years, (2014 and 2015) the halibut quotas have increased. The DSR incidental harvest has increased only slightly relative to the halibut quota (Table 2).

Discards in the Directed Commercial DSR Fishery

Discards in the directed DSR fishery include lingcod, Pacific cod, spiny dogfish, skates, and other rockfishes (Table 6). The magnitude of at-sea discard in the directed DSR fishery is difficult to quantify, as the fleet was unobserved until 2013, when the observer program was expanded to the small boat fleet in Southeast Alaska. Logbook data indicate that the primary discards were halibut and small numbers of lingcod and skates when fishermen reached their incidental catch allowance for those species.

Other Removals

Other removals (subsistence, recreational, and research catch) are documented in Table 2. In July 2009, the ADF&G Division of Subsistence published the results of a study done to estimate the subsistence harvest of rockfish near four Alaskan communities, one of which was Sitka (Turek et al. 2009). ADF&G Subsistence Division conducted a call-out survey of "high harvesting households" to obtain additional information on the species composition of subsistence-caught rockfish. This survey revealed that 50% of the rockfish harvested are DSR species, predominantly quillback rockfish. These "high harvesting households" fished predominantly in the Sitka Local Area Management Plan (LAMP) area. The DSR subsistence harvest is reported in numbers of fish by location (northern southeast, southern southeast, and the Sitka LAMP area); these data are converted to biomass using the average weights provided from creel sampled recreational harvest. The most recent voluntary mail survey (2011) indicated 9,116 rockfish (not defined by species) had been taken in the EGOA subsistence fisheries.[1] Applying the data methodology described above to make a prediction about what might be taken in the subsistence fishery in 2016, the total anticipated harvest is 7 t.

Small research catches of yelloweye rockfish occur during the annual IPHC longline survey (Table 2). Research catch data are based on yelloweye rockfish reported on fish tickets from the IPHC survey. These are deducted, by management area, from the TAC prior to the opening of the directed commercial fishery.

Recreational Fishery Removals

The Alaska Board of Fisheries has allocated 16% of the DSR TAC for the Southeast Outside District to the recreational fishery after deduction of the estimated subsistence harvest. The recreational fishery allocation includes estimated harvest and release mortality. Prior to 2006, the daily bag limit in the Southeast Alaska recreational fishery for nonpelagic (DSR and slope/other) rockfish was 3 to 5 fish, depending upon the area fished, and there were no annual limits on any rockfish species. Since then, the board has established management provisions that may be implemented by the department on an annual basis to manage the recreational fishery within the allocation. Recreational fishery regulations for the Southeast outside waters during 2013 to 2015 were as follows:

1. For resident anglers, the daily bag limit was two nonpelagic rockfish, only one of which could be a yelloweye rockfish; the possession limit was four nonpelagic rockfish, only two of which could be yelloweye.
2. For nonresident anglers, the daily bag limit was two nonpelagic rockfish, only one of which could be a yelloweye; the possession limit was four nonpelagic rockfish, only one of which could be a yelloweye. In addition, nonresidents were restricted to one yelloweye per year. Immediately upon harvesting a yelloweye, the angler was required to log the harvest in ink on the back of their fishing license or on a nontransferable harvest record.
3. All nonpelagic rockfish caught were required to be retained until the angler's daily bag limit was reached.
4. Guides and crew members were not allowed to retain nonpelagic rockfish when clients were on board the vessel.

In addition, effective January 1, 2013, all nonpelagic rockfish released from a charter vessel are required to be released with a deepwater release device at the depth of capture or at a depth of at least 100 feet. All charter vessels are required to have at least one functional deepwater release device on board, have it readily available for use while anglers are fishing, and present it for inspection upon request by department or enforcement personnel.

Data sources for the recreational fishery include the ADF&G statewide harvest survey (SWHS), mandatory charter logbooks, and interview and biological sampling data from dockside surveys in major ports throughout Southeast Alaska. The SWHS is an annual mail survey sent to a stratified random sample of approximately 45,000 households containing resident and nonresident licensed anglers. The survey provides estimates of harvest and catch (retained plus released) in numbers of fish, for all rockfish species

[1] With the exception of the fish reported from the Sitka LAMP area, it cannot be determined how many of DSR were caught in the SEO Subdistrict versus internal state waters.

combined. Up to three questionnaires may be mailed to unresponsive households. Responses are coded by mailing, which allows adjustments for nonresponse bias. Estimates are provided for SWHS reporting areas, which closely mirror ADF&G Recreational Fishery management areas.

Logbooks have been mandatory for the charter fishery since 1998. Before 2006, charter logbook data were reported for pelagic and non-pelagic rockfish assemblages. Since 2006 logbooks have required reporting of the numbers of pelagic rockfish, yelloweye rockfish, and all other non-pelagic species kept and released by each individual angler. Charter operators are also required to report the primary ADF&G statistical area for each boat trip.

Creel survey sampling is conducted at public access sites in major ports throughout Southeast Alaska. There is also some sampling of fish landed at private docks and lodges. Prior to 2006, there were no biological data collected by creel samplers beyond species composition of recreationally-caught rockfish. Length and weight data were collected in 2006 and 2007 to estimate length-weight functions for each species. Only species composition and length have been collected since 2008. The numbers of rockfish kept and released per boat-trip have been collected by DSR species since 2006. The creel survey interviews also include reporting of the primary statistical area fished for each boat trip.

Most recreational rockfish harvest in the Yakutat area occurs primarily in the Icy Bay Subdistrict (NMFS Area 640); less than 5% of the rockfish harvest occurs in the EYKT Section. Due to minimal data from EYKT, the IBS rockfish species composition and average weights were substituted to make EYKT projections.

Final estimates of recreational fishery removals used a combination of data from the SWHS, creel survey, and charter logbook. The total removals were estimated as the sum of the mass of the harvest (retained catch) and release mortality. Harvest biomass *HB* was estimated for the outside waters portion of SWHS areas B, D, G, and H, which correspond roughly with the SSEO, CSEO, NSEO, and EYKT groundfish management districts, and summed:

$$HB = \sum_a \sum_c \sum_s \hat{H}_{ac} \hat{p}_{ac} \hat{\imath}_{acs} \hat{\hat{w}}_{acs}$$

where:

$\hat{H}_{ac}$ = the SWHS estimate of the number of rockfish (all species combined) harvested in SWHS area *a* by class *c* (charter or noncharter),

$\hat{p}_{ac}$ = the estimated proportion of harvest by class *c* from outside waters portion of area *a*,

$\hat{\imath}_{acs}$ = the estimated proportion of species *s* in the recreational harvest of all rockfish by class *c* from the outside waters of area *a*, and

$\hat{\hat{w}}_{acs}$ = the estimated average round weight of species *s* in the recreational harvest by class *c* from outside waters of area *a*.

Because the SWHS areas include inside waters, harvest estimates must be apportioned to obtain the outside waters harvest using $\hat{p}_{ac}$. Neither SWHS estimates nor creel survey interviews are adequate for this apportionment. SWHS reporting locations are not precise enough to identify outside waters, and many survey respondents are too unfamiliar with where they were fishing to report accurately. Creel survey data are precise, but surveys are only conducted in major ports and interviewed anglers may not accurately represent the spatial distribution of total harvest. Logbook data are mandatory and presumably represent a complete census of the charter harvest. Therefore, logbook data were used to apportion both charter and noncharter harvest to outside waters. This proportion is treated as a constant in calculation of variance.

Average weight was estimated for each species by applying species-specific length-weight relationships to length measurements of all harvested fish from outside waters in each SWHS area (Brylinsky et al. 2009).

Release mortality biomass (*RB*) was estimated by area and species for each class using different methods. For the noncharter sector, the mortality rate of all species of rockfish released was assumed to be 100 percent, and the average weight of released rockfish was assumed to equal the average weight of harvested rockfish for each species. Therefore, release mortality was estimated as a function of harvest biomass and the release rate by SWHS area for the noncharter sector:

$$RB_{Noncharter} = \sum_{a}\sum_{s}\left(\frac{\widehat{HB}_{as}}{1-r_{as}} - \widehat{HB}_{as}\right)$$

where:

$\widehat{HB}_{as}$ = the estimated harvest biomass of species *s* in SWHS area *a* by noncharter anglers, and

r_{as} = the proportion of the catch of rockfish species *s* that was released in area *a*.

The release rate r_{as} for the noncharter and charter sectors was obtained using charter logbook data from outside waters. Logbook data were used for noncharter sector estimates because SWHS estimates are for all species combined and could not be apportioned to species for the noncharter sector. Creel survey interview data on noncharter fishery releases were spotty and incomplete. Given the similarity in resident (mostly noncharter) and nonresident (mostly charter) bag limits, logbook data were felt to provide a reasonable proxy for release rates in the noncharter fishery.

Starting in 2013, release biomass was estimated for the charter sector taking into account a higher survival rate due to mandatory use of deepwater release devices. There is now substantial evidence that survival of benthic rockfish species is dramatically increased when fish are released at depth (Jarvis and Lowe 2008, Hochhalter and Reed 2011, Hannah et al. 2012, GMT 2014). Hannah et al. (2012) caught yelloweye, canary, quillback, copper, and China rockfish at depths of 19-64 m and held them in cages for two days. Although no fish died, LaPlace estimates of survival, corrected for small sample sizes, ranged from 0.80 to 0.98. Hochhalter and Reed (2011) user mark-recapture methods to estimate 17-day survival of yelloweye rockfish caught and released at the depth of capture in the wild at 0.988. They captured yelloweye at depths of 18-72 m but were unable to discern any effect of depth of capture on survival. Hannah et al. (2014) looked specifically at the effect of depth on survival of yelloweye and canary rockfish. LaPlace estimates of survival of yelloweye rockfish ranged from 0.83 at depths of 135-174 m to 0.91-0.92 at depths of 46-84 m. Survival of canary rockfish showed a relationship with depth, ranging from 0.76 to 0.93 between 46 and 84 m, to 0.25 at 135-174 m. The Pacific Fishery Management Council has adopted depth-specific mortality rates for yelloweye, canary rockfish, and cowcod. The mortality rates for yelloweye rockfish are based on lower 90% confidence limits and range from 0.22 to 0.27 for depths shallower than 50 fathoms, and 0.57 for depths of 50-75 fathoms (GMT 2014). The rates are depth-specific, despite weak evidence of such a relationship for yelloweye.

Based on the above studies, we assumed a mortality rate of 20% for estimation of 2014 and 2015 charter release mortality for DSR species. This mortality rate is higher than the results cited above for most demersal shelf species and depths fished by the sport fishery, but is precautionary in order to take into account the lack of depth information for sport-caught fish, expected variation in types of gear used, less than ideal handling, and potential noncompliance with the release requirement. The choice of 20% is somewhat arbitrary and will be adjusted if better information becomes available.

Release mortality biomass *RB* was estimated for the charter sector as:

$$RB_{Charter} = \sum_{a}\sum_{s} \hat{R}_{as}\,\widehat{MR}\hat{\hat{w}}_{as}$$

where:

$\hat{R}_{as}$ = the estimated number of rockfish of species *s* released in the outside waters of SWHS area *a* by charter anglers,

$\widehat{MR}$ = the assumed short-term mortality rate due to capture, handling, and release of demersal shelf rockfish (all species, all depths), and

$\hat{\hat{w}}_{as}$ = the estimated average round weight of species *s* released by charter anglers from outside waters of area *a*.

As noted above, the assumed mortality rate was 0.20, with a standard error of 0.03. The assumed standard error was “borrowed” from the Pacific Council adopted mortality rates for yelloweye rockfish (GMT 2014). The average weight of harvested rockfish was used as a proxy for the average weight of released rockfish because there are no size data available for rockfish released in the charter fishery. This is not an unreasonable proxy given the requirement that anglers must retain all rockfish until their bag limit is reached.

The number of rockfish released in each area in the equation above (R_{acs}) was estimated as:

$$\hat{R}_{as} = r_{as}\frac{\hat{H}_{as}}{(1 - r_{as})}$$

where $\hat{H}_{as}$ is the estimated charter harvest in SWHS area *a* of species s, and r_{as} is proportion of rockfish catch by charter anglers that was released, as described above.

As noted previously, SWHS estimates were used to calculate final estimates of the biomass of harvest and release mortality. However, SWHS estimates are not available until September of the year following harvest. In order to produce a preliminary harvest estimate for the current year, the number of rockfish of all species harvested in each SWHS was projected. Charter harvest estimates were projected using regressions of SWHS estimates on partial-year logbook data (through July 31). Regression through the origin was used because some SWHS areas had very little contrast in the harvest estimates, producing insignificant slopes and illogical intercepts. Harvest projections for the noncharter sector were obtained from time series forecasts of SWHS estimates. The Box-Jenkins procedure was used to identify suitable ARIMA models (Box and Jenkins 1976). All models were evaluated using Akaike's Information Criteria corrected for small sample sizes (AICc). For most SWHS areas, no autoregressive or moving average components were identified, leaving the naïve forecast, or the previous year's harvest, as the best model. However, for 2015, a simple exponential smoother (SAS 2011: Proc ESM) produced superior forecasts for all areas. For SWHS Area G (Glacier Bay), rockfish harvest has increased dramatically in the last three years, departing from the previous trend. Therefore, even though the exponential forecast has the lowest AICc, the previous year's harvest was higher and was used for the preliminary estimate in order to be precautionary.

Final estimates of 2014 recreational fishery removals and preliminary estimate of 2015 removals (in mt) are as follows:

Type of Estimate		***2014***	***2015***
Retained Harvest	Estimate	38.0	43.7
	StdErr	1.8	2.3
	95% CI[a]	34.5-41.4	39.1-48.2
Release Mortality	Estimate	1.9	2.2
	StdErr	0.2	0.2
	95% CI[a]	1.5-2.2	1.8-2.6
Total	**Estimate**	**39.8**	**45.9**[1]
	StdErr	1.9	2.5
	95% CI[a]	36.2-43.5	41.1-50.7

[1]The preliminary results for 2015 indicate that the recreational harvest has exceeded the 2015 allocation by 11 mt. Appropriate management action will be applied in 2016 to maintain harvest within the allocation.

Data

Fishery Age Compositions

Length frequency distributions are not particularly useful in identifying individual strong year classes because individual growth levels off at about age 30 (O'Connell and Funk 1987). Sagittal otoliths are collected for aging. The break and burn technique is used for distinguishing annuli (Chilton and Beamish 1983). Radiometric age validation has been conducted for yelloweye rockfish otoliths collected in Southeast Alaska (Andrews et al. 2002). Radiometry of the disequilibrium of ^{210}Pb and ^{226}Ra was used as the validation technique. Although there was some subjectivity in these techniques, generally agreement between growth-zone-derived ages and radiometric ages was good with a low coefficient of variation. In addition, Andrews et al. (2002) conclude strong support for age that exceeds 100 years from their observation that as growth-zone-derived ages approached and exceeded 100 years, the sample ratios of ^{210}Pb and ^{226}Ra approached equilibrium with a ratio equal to 1. Maximum published age for yelloweye is 118 years (O'Connell and Funk 1987), but one specimen from the SSEO 2000 samples was aged at 121 years.

Survey: Submersible and ROV surveys

ADF&G began conducting a fishery-independent, habitat-based stock assessment for DSR using visual survey techniques to record yelloweye rockfish observations on line transects in rock habitat in 1988. The DSR stock assessment surveys have historically rotated among management areas on a biannual basis; it would be time and cost-prohibitive to survey the entire SEO in one field season due to the large size of the area (Figure 1). Instead, the most recent abundance estimate from a management area is used to update the annual stock assessment for SEO, but four to six years may elapse between surveys (Brylinsky et al. 2009). Between 1988 and 2010, density estimates derived from yelloweye rockfish counts from submersible video observations were extrapolated over the total yelloweye rockfish habitat. Average weight for yelloweye rockfish landed in the halibut and directed commercial fisheries was applied to the density estimate to obtain a biomass estimate for each management area (O'Connell and Carlile 1993, Brylinsky et al. 2009).

In 2012, ADF&G transitioned to using an ROV for visual surveys given the unavailability of a cost-effective and appropriate submersible. ROVs are a low-cost and versatile tool that have been increasingly used to study marine habitats and organisms (e.g. Pacunski et al. 2008). Although the survey vehicle has changed, the basic methodology to perform the stock assessment for the DSR complex remains unchanged. We use a Phantom ROV (HD 2+2) "*Buttercup*" that is owned and operated by ADF&G Central Region. The ROV is outfitted with a pair of high definition machine-vision stereo cameras that are used to record video data from line transects. Two additional cameras are mounted to the ROV, the "main" camera, which is a wide-angle, color camera that the pilot uses to drive the ROV, and a "forward-facing" camera. In 2015, a third 'belly' camera was added to record any fish directly under the ROV. Two scaling lasers, mounted 10 cm apart and in line with the camera housing, are used as a measurement reference for objects viewed in the non-stereo cameras. However, objects viewed in the stereo cameras are most accurately measured during video review in the stereo camera software viewing package. All stereo camera video data are reviewed and analyzed using SeaGIS software (SeaGIS Pty Ltd., EventMeasure version 3.50). SeaGIS is a measurement science software used to log and archive events in digital imagery (Seager 2012).

Habitat

Visual surveys are conducted only in yelloweye rockfish habitat; which is defined as rock habitat inshore of the 100-fathom depth contour. Seafloor is designated as "rock" from sonar survey classification, directed commercial fishery logbook data, and substrate information from NOAA charts. Substrate information obtained from sonar surveys is considered the best information available on rock habitat. In the absence of sonar data, directed commercial fishery logbook data are considered a proxy for rocky habitat (O'Connell and Carlile 1993, Brylinsky et al. 2009). In the NSEO management area, commercial fishery logbook data are limited; yelloweye rockfish habitat was delineated by buffering locations designated as coral, rock, or hard seafloor on NOAA charts by 0.5 miles. Locations were only considered preferred yelloweye rockfish habitat between 35 and 100 fm; this criterion was based on submersible observations that 90% of yelloweye rockfish were recorded between those depths. The first sonar survey in the NSEO area was conducted in May 2015. We surveyed a total of 600 km^2 offshore of Cross Sound, in collaboration with the USGS on the ADF&G *R/V Solstice*. However, as these data were recently processed, the final updated estimate of total rock habitat in NSEO will not be available until next year's stock assessment. The new rock habitat will be included as potential dive locations for the May 2016 ROV survey.

Analytic approach

Modelling Approach

We use a biomass based approach based on distance sampling methodology to estimate yelloweye rockfish density from ROV and submersible surveys. Density estimates are limited to adult and subadult yelloweye rockfish, the principal species targeted and caught in the directed DSR fishery, and our ABC recommendations for the entire assemblage have historically been based on yelloweye biomass and expanded for other DSR.

Biomass of yelloweye rockfish is derived as the product of estimated density, the estimate of rocky habitat within the 200 m contour, and average weight of fish for each management area. Variances are estimated for the density and weight parameters but not for area. Estimation of both transect line lengths and total area of rocky habitat are difficult and contribute to the uncertainty in the biomass estimates. The 'account' for the unknown variance in the habitat area, the lower 90% confidence interval of the biomass estimate is used to calculate the ABC.

Yelloweye Rockfish Density Estimates from Submersible Surveys (1988-2009)

In a typical submersible dive, two transects were completed per dive with each transect lasting 30 minutes. During each transect, the submersible pilot attempted to maintain a constant speed of 0.5 km and to remain within 1 m of the bottom, terrain permitting. A predetermined compass heading was used to orient each transect line. Line transect sampling entails counting objects on both sides of a transect line. Due to the configuration of the submersible, with primary view ports and imaging equipment on the starboard side, we only counted fish on the right side of the line. All fish observed from the starboard port were individually counted and their perpendicular distance from the transect line recorded (Buckland et al. 1993). An externally mounted video camera was used on the starboard side to record both habitat and audio observations. In 1995, a second video camera was mounted in a forward-facing position. This camera was used to ensure 100% detectability of yelloweye rockfish on the transect line, a critical assumption when using line transect sampling to estimate density. The forward camera also enabled counts of fish swimming away as the vehicle approached and removals of fish that swam into the transect from the left side because of interaction with the submersible. Yelloweye rockfish have distinct coloration differences between juveniles, subadults, and adults, so these observations were recorded separately.

Hand-held sonar guns were used to calibrate observer estimates of perpendicular distances, but it was not practical to make a sonar gun confirmation for every fish. Observers calibrated their eye to making visual estimates of distance using the sonar gun to measure the distance to stationary objects (e.g. rocks) at the beginning of each dive prior to running the transect and between transects.

Yelloweye Rockfish Density Estimates from ROV Surveys (2012-present)

With the exception of the 2012 survey, where we re-surveyed the 2007 submersible transects, random dive locations for line transects were selected in preferred yelloweye rockfish habitat using ArcGIS (Figure 4). Random locations were removed from the survey design if they were in depths ≥200 m, which is the maximum operating depth for the ROV. Transects of 1-km length were mapped at each suitable random point with four possible orientations along the cardinal directions and crossing through the random point (Figure 5). A transect length of 1-km was selected after consideration of visual surveys conducted by other agencies (personal communication, Robert Pacunski, WDFW, Mike Byerly, ADF&G), the encounter rate of yelloweye rockfish based on our previous surveys, and ROV pilot fatigue.

The number of planned transects was based on yelloweye rockfish encounter rates from previous surveys and our targeted precision (CVs of less than 15%).

Transect Line Lengths – Submersible

Beginning in 1997, we positioned the support ship directly over the submersible at five-minute time intervals and used the corresponding Differential Global Positioning System (DGPS) fixes to determine line length. In 2003 the submersible tracking system was equipped with a gyro compass, enabling more accurate tracking of the submersible without positioning the vessel over the submersible. In 2007 and 2009, in addition to collecting the position of the submersible using five minute time intervals, we also collected position data every 2 seconds using the WinFrog tracking software provided by *Delta*. Outliers were identified in the WinFrog data by calculating the rate of travel between submersible locations. The destination record was removed if the rate of travel was greater than 2 meters per second. For these two years, the edited WinFrog data were smoothed using a running average (a 9-point in 2007 and a 9- or 27-point, dependent on transect line, in 2009), and then smoothed data were visually examined in ArcGIS. If any additional irregularities in data were observed, such as loops or back tracks, then these anomalies were removed and the data resmoothed.

Transect Line Lengths - ROV

Transect line length is estimated by editing ROV tracking data generated from Hypack software. Tracking data are filtered for outliers using Hypack® singlebeam editor (positioning errors are removed and data are filled in to one second intervals using linear interpolation). Video data are "prescreened" to remove any video segments where poor visibility would obscure yelloweye rockfish observations or when the ROV was not moving forward (i.e. stalled, or stopped due to some logistical problem). Navigation data are mapped in ArcGIS after treatment with a smoothing spline and video quality segments are overlaid navigation data using linear referencing. The total line length for each transect is estimated using the "good" quality video segments only.

Video Review-Submersible

The side-facing and forward-facing video from the submersible dives were reviewed post-dive while listening to the verbal recording made by the scientist-observer in the submersible. The audio transcript includes the scientist's observations of the species observed, and each individual fish's distance away from the submersible. These data are recorded in the database, as well as any additional yelloweye rockfish seen in either camera that the observer may have missed underwater. The observer is able to see farther out the window than the camera field of view, thus the verbal transcript is critical for data collection.

Video Review-ROV

Fish are recorded on the right and left side of the "center line" of the line transect when reviewing video within the SeaGIS Event Measure software (Figure 6). The video reviewer will identify and enumerate yelloweye rockfish for density estimation, and other DSR, lingcod, halibut and other large-bodied fish, as time allows, for species composition. Fish total length will be recorded for individual yelloweye rockfish, lingcod, and halibut. Fish behavior and maturity stage are recorded for yelloweye rockfish only.

For each fish, a perpendicular distance from the origin of the transect line to the fish will be obtained through the SeaGIS software. The precision of a 3D point is a geometric function of the camera resolution, camera focal length, camera separation, camera distance from object (close is better precision) and object distance from center of field of view (center of field of view is more precise than at the edges). Fish will be marked in both the left and right stereo cameras to obtain a 3D point measurement with coordinates of x, y, and z; the perpendicular distance to the fish corresponds to “x” (Figure 7). Fish that swim into the field of view more than once will not be double counted (this behavior is obvious, and based on our observations, rare for yelloweye rockfish).

Fish total length is recorded from the tip of the snout to the tip of the caudal fin. Length measurements are most accurate when fish are close, straight (i.e. not curled), and parallel, relative to the cameras; the video reviewer will measure each fish in the best possible orientation and position. The best possible horizontal direction will be obtained; the horizontal direction is the angle between the horizontal component of the measured length and the camera base and represents the degree to which a fish is turned away from the camera. For example, if a fish is parallel to the camera then it has a horizontal direction of 0° and if a fish is facing directly toward or away from the camera, the horizontal direction is 90°. As the horizontal direction increases, the precision (standard deviation, σ_d) of a length measurement will become worse, because the Δz (the difference in the z coordinate between the snout and tail) becomes larger (Δz=0 when fish parallel) as:

$$\sigma_d = \frac{1}{d}\sqrt{2(\Delta x^2\sigma_x^2 + \Delta y^2\sigma_y^2 + \Delta z^2\sigma_z^2)} \tag{4}$$

Precision is expressed in terms of the difference between the x, y, and z coordinates for each endpoint of the length measurement (Δx, Δy, Δz), the standard deviation (precision) of x, y, and z (σ_x, σ_y, σ_z), and the length of the fish (d). The standard deviation of x and y is equivalent and small compared to the standard deviation of z. When a fish is parallel $\Delta z = 0$ and there is no contribution to the error from Δz, but as a fish turns away from the camera, Δz increases resulting in a less precise measurement (σ_d).

In 2015, a ‘belly’ camera was added to the ROV. We reviewed this camera, and added one additional juvenile yelloweye, which are cryptic and hard to see. One adult fish was observed with the stereo cameras after the transect end, but could be viewed with the belly camera before the transect end, and thus was included. One other adult yelloweye was added to the density estimate after review with the belly camera on a dive where we had difficulty with the camera lighting. If the lighting issues had been resolved, this fish would have been seen in the stereo cameras. The belly camera is a useful addition to the ROV, but these data do not indicate that a significant number of fish were omitted from previous surveys without this camera.

Density and Biomass Estimates

Yelloweye rockfish density is estimated using DISTANCE 6.0 software (Thomas et al. 2010) which utilizes the following equations to estimate density with the principal function to estimate the probability of detection evaluated at the origin of the transect line ($\hat{f}(0)$):

$$\hat{D} = \frac{n\hat{f}(0)}{2L} \tag{5}$$

$$\hat{f}(0) = \frac{1}{\mu} = \frac{1}{wP_a} \tag{6}$$

where:

n = total number yelloweye rockfish included in the density estimate

$\hat{f}(0)$ = the probability density function evaluated at the origin of the transect line

L = total line length

μ = the effective width

w = width of line transect

P_a = probability of observing an object in the defined area

Yelloweye rockfish lengths are examined to determine whether to exclude any small yelloweye rockfish identified as adults or subadults from the density model data. We have selected a minimum size limit of 340 mm total length for sub-adults observed with the ROV. This is based on the minimum size of yelloweye rockfish port sampled in the commercial fishery (Figure 9). While the ASA model accounts for selectivity or catchability, q (Appendix B), the current methodology does not account for 'catchability' of yelloweye observed with the ROV or submersible versus the commercial fishery. The average weight of yelloweye rockfish sampled from the directed commercial fishery and from the halibut fishery has been used to expand density estimates to biomass for each management area. To avoid potential overharvest by applying an average weight to fish that are much smaller than are caught in the commercial fishery, we use this minimum length. However, it should be noted that few subadult yelloweye observed in the ROV survey do not meet this minimum length (seven fish in 2012, zero in 2013, and four fish in 2015).

In 2013, the SSC inquired about using the length data collected from yelloweye rockfish with the ROV to apply a weighted average to the density estimate. We now have three years of length frequency data using the ROV, but our sample sizes are small (100–250 fish per area) and we are still in the process of evaluating whether those length data are robust enough for this purpose.

The best probability detection model is selected in order to obtain a valid density estimate. Models are explored with and without binning and truncation of distance data and with different key model functions and adjustment terms. The best model is selected based on visual fit of model, the Akaike information criterion (AIC) value, X^2 goodness of fit test, and the CV for the density estimate ($cv_t(\widehat{D})$). Probability detection functions are visually examined to determine if the model fits the data well; it is most important to have a good fit at the origin. In addition, the model is examined to determine if the shape is biologically realistic, and if the model has the preferred "shoulder" at the origin of the transect line (Burnham et al. 1980). The probability detection functions for the most recent survey (ROV and submersible) in each management area are shown in Figure 8a–8d.

Evaluation of Distance Sampling Assumptions

Distance sampling (Buckland et al. 1993) requires that three major assumptions are met to achieve reliable estimates of density from line transect sampling: (1) objects on the line must be detected with certainty (i.e. every object on the line must be detected); (2) objects must be detected at their initial location, (i.e. animals do not move toward or away from the transect line in response to the observer before distances are measured); (3) distances from the transect line to each object are measured accurately. Failure to satisfy these assumptions may result in biased density estimates. All assumptions were carefully evaluated and met during the ROV and submersible surveys.

To ensure assumption (1): all objects on the transect line are detected with certainty, the probability detection function and histograms of the distance data are examined. If the detectability at the transect line is close to 100%, then the probability detection function will have a broad shoulder at the line that will drop off at some distance from the line (Buckland et al. 1993). In the past submersible surveys, the observer looked out the side window for fish identification, and fish under or in close proximity to the submersible were sometimes missed on the main camera prior to installing a “forward-facing” camera in 1995. The ROV stereo cameras are already oriented forward, so the video reviewer can easily detect fish on the transect line.

The second assumption (2): that yelloweye rockfish are detected at their initial location and are not moving in response to the vehicle (submersible or ROV) prior to detection in the video is evaluated by examining the probability detection function and the behavioral response of yelloweye rockfish to the vehicle. The shape of the probability detection function may indicate if there is yelloweye rockfish movement response to the vehicle. If the probability detection function has a high peak near the origin line, this may indicate an attraction. Whereas, if there are lower detections near the line and an increase in detection at some distance away from the origin of the line this may indicate avoidance behavior. Yelloweye rockfish behaviors during the 2012 survey indicate that yelloweye rockfish are not moving in response to the ROV; generally yelloweye rockfish moved very little or slowly (85%), with the majority (76%) not indicating any directional movement (i.e. milling, resting on the bottom). These results are consistent with those observed in other ROV and submersible surveys and indicate that yelloweye rockfish move slowly relative to the speed of the survey vehicle. If undetected movements are random and slow relative to the speed of the vehicle then this assumption will not be violated (Buckland et al. 1993). Byerly et al. (2005) found that yelloweye rockfish movement prior to detection by the ROV cameras was random.

The third assumption of distance sampling (3): distances from the transect line to the fish are recorded accurately is met through the use of the stereo cameras in conjunction with the SeaGIS software (Seager 2012). In the submersible surveys, the observer visually estimated the perpendicular distance from the submersible to a fish, which is subject to measurement error despite observer calibration before a dive using a hand-held sonar gun.

Parameter Estimates

Mortality Estimates

The historical methodology used to estimate F, M, and Z are described in this section, however, we are currently revising catch curve analyses to update these parameters. An estimate of Z=0.0174 (± 0.0053) from a 1984 “lightly-exploited” stock in SSEO was historically used to estimate M=0.02.

The 2003 catch curve analysis of available age data, using port sampling data from 2000–2002 and a line fit to the data between the majority of the ages (approximately 20–60 years) indicates that the estimate of Z is 0.03 for SSEO, 0.04 for EYKT, and 0.056 for CSEO.

Estimates of instantaneous mortality (Z) of yelloweye rockfish in Southeast Alaska (SE).

AREA	YEAR	SOURCE	Z	N
SSEO	1984	Commercial Longline	0.017*	1049
CSEO	1981	Research Jig	0.020*	196
CSEO	1988	Research Longline	0.042	600
EYKT	2000-2002	Commercial Longline ages 24-62	0.040	295
CSEO	2000-2002	Commercial Longline Ages 20-60	0.056	514
SSEO	2000-2002	Commercial Longline (ages 24-67)	0.030	602
SE		Hoenig's equation max age 121 (parameters from combined taxa)	0.038	
SE		Hoenig's equation max age 121 (fish parameters)	0.033	

*Z approximately equal to instantaneous rate of natural mortality (M) as there was very little directed fishing pressure in these areas at that time (1981 for CSEO, 1984 for SSEO).

There is a distinct decline in the log frequency of fish after age 95. This may be due to increased natural mortality in the older ages, perhaps senescence. The M=0.02 is based on a catch curve analysis of age data grouped into two-year intervals (to avoid zero counts) between the ages of 36 and 96. This number is similar to the estimate of Z from a small sample from CSEO in 1981 and to the 0.0196 estimated for a lightly exploited stock of yelloweye on Bowie Seamount (Lynne Yamanaka, Department of Fisheries and Oceans Canada, Pacific Biological Station, pers. comm.). Hoenig's geometric mean method ($\ln Z = a + b\ln(t\text{max})$) for calculating Z yields estimates of 0.033 when using parameters (a=1.46, b=-1.01) derived from fish species and 0.038 when using parameters (a=1.44, b=-0.982) derived from a combination of taxa (mollusks, fish and crustaceans) when a maximum age (tmax) of 121 years for yelloweye rockfish is used (Hoenig 1983). Wallace (2001) set natural mortality equal to 0.04 in his stock assessment of west coast yelloweye. For the northern California and Oregon data the model performed better when M was set constant until 50% maturity then increased linearly until age 70 (Wallace 2001).

Initial analyses to update the catch curve estimates (using catch data between 1992 and 2013, conditioned on ages 8 to 97 years) indicate similar estimates of Z for each area to the 2003 CSEO estimate, (0.055 to 0.057). We will revise and finalize these analyses for the 2017 stock assessment.

Growth Parameters

Updated life history attributes were estimated externally in 2014 from data collected through port sampling of commercial fisheries catches from 1992–2013. Von Bertalanffy growth parameters and length, weight, and maturity parameters for yelloweye are listed below:

Weight-at-age (kilograms)

Mean weight-at-age *W* was estimated by fitting observed weights-at-age to the equation

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

for which W_t = weight at time t (age), W_∞ = asymptotic weight, t_0 = the time (age) at which an individual is considered to have weight 0, and k = growth rate. Mean weight-at-age was assumed consistent across all management areas and equivalent between males and females (Fig. 4).

W_∞	k	t_0
6.027	0.039	-10.13

Maturity-at-age

Proportions mature-at-age m_a were calculated for females only, fitting observed maturity-at-age to the equation:

$$m_a = \frac{mat_\infty}{1 + \exp(-slope * (age - mat_{50\%}))}$$

for which $mat_{50\%}$ is the age at which 50% of the population is reproductively mature, *slope* is the slope of the sigmoid curve at the $mat_{50\%}$ point, and mat_∞ = asymptotic maturity.

slope	$mat_{50\%}$
-0.341	17.634

Results

Habitat

Seafloor mapping has been performed across 3,658 km^2 of SEO (Figure 3). Backscatter data have been collected during side scan and multibeam surveys and comprehensive bathymetry data during multibeam surveys with some limited bathymetric soundings collected during side scan surveys. Seafloor has been classified into habitat type by Moss Landings Marine Laboratories' Center for Habitat Studies using bathymetry, backscatter, and direct observations from the *Delta* submersible and reduced to substrate induration of soft, mixed, or hard (Greene et al. 1999). Seafloor identified as hard substrate is considered yelloweye rockfish habitat.

In CSEO management area, 832 km^2 have been surveyed with 442 km^2 of this area considered rocky habitat (Table 4). A side scan survey covering 538 km^2 was performed west of Cape Edgecumbe (located on Kruzof Island) in 1996 (Figure 3), and in 2005, a high resolution 8 km^2 multibeam survey, which encompasses the Pinnacles Marine Reserve, was performed within the southern portion of the area originally side scanned. In 2001, a 294 km^2 area west of Cape Ommaney (located on the southern tip of Baranof Island) was surveyed.

In EYKT management area, 1,072 km^2 have been surveyed on the Fairweather grounds with 500 km^2 of this area composed of rocky habitat. A total of 784 km^2 were side scanned on the west bank in 1998 and 288 km^2 multibeamed on the east bank in 2002 and 2004 (Table 4).

In SSEO management area, 1,154 km^2 have been multibeamed, with 322 km^2 considered rocky habitat. Multibeam surveys have been performed around the Hazy Islands west of Coronation Island in 2001 (400 km^2), west of Cape Addington on Noyes Island in 2006 (84 km^2), at Learmonth Bank in Dixon Entrance in 2008 (530 km^2), and south of Cape Felix on Suemez Island in 2010 (140 km^2) (Table 4; Figure 3).

For areas without seafloor mapping information, we delineate rocky habitat using directed commercial fishery logbook data. Locations where catch per unit effort is ≥ 0.04 yelloweye rockfish per hook are considered preferred yelloweye rockfish habitat. Longline sets with only start positions are buffered by 0.5 miles (this established buffer size was retained for consistency). Starting in 2003, fishermen were required to include both start and end set positions; sets with both locations are buffered 0.5 km around the entire track. This buffering criterion was based on the minimum range of travel of four yelloweye rockfish tagged with transmitters in Oregon (P. Rankin, Oregon Department of Fish and Wildlife, personal communication). Buffered logbook sets were merged, and segments were included in the delineated habitat if ≥2,300 m in length (to ensure rocky segments were large enough for two non-overlapping submersible transects). To consider habitat segments as "continuous", no gaps > 0.5 nautical miles were allowed.

Total yelloweye rockfish habitat is estimated for SEO at 3,892 km^2. The Fairweather grounds in EYKT management area composes 739 km^2 of rocky habitat with 68% derived from sonar; CSEO management area is composed of 1,661 km^2 rocky habitat with 27% from sonar; SSEO composed of 1,056 km^2 of rock with 30% from sonar; and NSEO with 436 km^2 rock; rock habitat from the 2015 sonar survey will be available in 2016 (Table 4).

Density estimates

Overall density estimates have declined in all management areas in recent years (Table 3). CSEO exhibits the biggest downward trend. In SSEO trends increased through 2003, and then declined. The EYKT density estimates are more variable and relatively stable through the survey time series. For a more complete description of previous submersible estimates, please see Brylinsky et al. (2009).

The initial ROV survey was conducted in 2012 in the CSEO management area. Forty-six transects were conducted, and the resulting yelloweye rockfish density estimate was 752 fish/km^2 (CV= 13%) (Table 3; Figure 2). Ralston et al. (2011) examined stock assessments for 17 data-rich groundfish and coastal pelagic species, and found the mean CV for biomass estimates to be 18%. In this context, a CV of 13% was considered a high level of precision, a view supported by Robson and Regier (1964) and Seber (1982). Although we were not able to compare the ROV results directly with the submersible or account for natural changes in the yelloweye rockfish population between years, the ROV-based yelloweye rockfish density estimate for 2012 was comparable to previous submersible estimates with a similar magnitude (Figure 3). The ROV was successfully deployed in most weather conditions and able to navigate the seafloor and currents in the preferred direction and orientation for the majority of the planned dive transects. In 2013, 31 transects were successfully surveyed in the SSEO; the density estimate was 986 fish/km^2 (CV=22%).

In 2015, the most recent survey, a total of 34 transects were conducted on the Fairweather Grounds in EYKT between May 13 and 18th, 2015 (Figure 4). In EYKT area, the density was 1,755 fish/km^2 (CV=0.17). There was one dive in 2015 where large numbers of schooling yelloweye affected counts. We have never been observed such behavior of yelloweye in previous surveys and we suspect these groups may have been feeding aggregations. However, we also observed many gravid females in these schools. It is unknown whether yelloweye rockfish aggregate before parturition. The timing of the 2015 survey was during peak parturition for yelloweye rockfish (May); most other submersible and ROV surveys were conducted in August. When reviewing this dive, we counted all schooling yelloweye that we could reasonably assume were individual fish. We also did not count any fish that we suspected would result in double counting. We plan to survey both the CSEO/NSEO together in May 2016.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set the OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set the ABC (F_{ABC}) may be less than this maximum permissible level but not greater. DSR are managed under Tier 4 because reliable estimates of spawning biomass and recruitment are not available. Demersal shelf rockfish are particularly vulnerable to overfishing given their longevity, late maturation, and habitat-specific residency. We recommend and use a harvest rate lower than the maximum allowed under Tier 4; F=M=0.02. This rate is more conservative than would be obtained by using Tier 4 definitions for setting the maximum permissible F_{ABC} is $F_{40\%}$ ($F_{40\%}$=0.026). Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

Specification of F_{OFL} and the maximum permissible ABC

Under Tier 4 projections of harvest scenarios for future years is not possible.

Yields for 2016 are computed for scenarios 1-5 as follows:

Scenario 1: F equals the maximum permissible F_{ABC} as specified in the ABC/OFL definitions. For Tier 4 species, the maximum permissible F_{ABC} is $F_{40\%}$. $F_{40\%}$ equals 0.026 corresponding to a yield of 280 t (including 20 t for non-yelloweye DSR).

Scenario 2: F equals the stock assessment author's recommended F_{ABC}. In this assessment, the recommended F_{ABC} is F=M=0.02, and the corresponding yield is 231 t (including 20 t for non-yelloweye DSR).

Scenario 3: F equals the 5-year average F from 2010 to 2014. The true past catch is not known for this species assemblage so the 5-year average is estimated at F=0.02 (the proposed F in all 5 years), and the corresponding yield is 231 t (including 20 t for non-yelloweye DSR).

Scenario 4: F equals 50% of the maximum permissible F_{ABC} as specified in the ABC/OFL definitions. 50% of $F_{40\%}$ is 0.013, and the corresponding yield is 140 t.

Scenario 5: *F* equals 0. The corresponding yield is 0 t.

Ecosystem Considerations

In general, ecosystem considerations for the DSR complex are limited. Table 7 consolidates information regarding ecosystem effects on the stock and the stocks effect on the ecosystem. Specific data to evaluate these effects are lacking

Ecosystem Effects on the Stock

Prey availability

Like many rockfishes, the DSR complex is highly influenced by periodic abundant year classes. Zooplankton prey availability and favorable environmental conditions may affect the survivability of larval rockfishes. Yelloweye rockfish consume rockfishes, herring, sandlance, shrimps, and crabs and seasonally lingcod eggs, and changes in the abundance of these food sources could impact yelloweye rockfish abundance (Love et al. 2002).

Predator population trends

Many predators, including other rockfishes consume larval and juvenile yelloweye rockfish. Adult yelloweye rockfish have been found in the stomachs of longline caught lingcod and halibut but this may be opportunistic feeding as the yelloweye rockfish were caught on the fishing gear. A yelloweye rockfish was also found in the stomach of an orca whale (Love et al. 1990). Yelloweye rockfish are considered mid to high in trophic level (Kline et al. 2007). Predator effects, or an increase in predation on any one of the life stages of the DSR complex could have negative effects on the stock.

Changes in physical environment:

Strong year classes for many species of fish correlate with good environmental conditions. Black et al. (2011) documented seasonal (winter and summer modes) upwelling as an index for predicting rockfish productivity. For yelloweye rockfish, increased growth was associated with the winter upwelling mode but not summer upwelling in the California Current Ecosystem. Thorson et al. (2013) found that a multi-species approach to estimating recruitment may be promising for some species (e.g. for yelloweye rockfish, a shared index of cohort strength decreased coefficient of variation for recruitment for the modeled year by 40%). Thus, recruitment estimates for data poor species such as yelloweye rockfish may be improved by using multispecies recruitment indices.

Availability of physical bottom habitat would impact yelloweye rockfish at many different stages of life. Both juveniles and adults are associated with high relief rock habitat, as well as corals and sponges (O'Connell and Carlile 1993). Bottom trawling is not a legal gear type in the Eastern Gulf of Alaska so the effects of commercial fishing on the bottom habitat are minimal, although there is some removal of coral and sponges from non-trawl gear that comes in contact with the bottom (e.g. hook and line, dinglebar gear.)

Fishery Effects on the Ecosystem

Fishery specific contribution to HAPC biota

HAPC biota such as corals and sponges are associated with some of the same habitats that yelloweye and other demersal shelf rockfish inhabit. On ROV and submersible dives, we have recorded many observations of yelloweye rockfish in close association with corals and sponges. However, as described above, bottom trawling is prohibited in the EGOA, so contact with the bottom and therefore biogenic habitat removal is limited to primarily hook and line and dinglebar gear. The expanded observer program should provide additional data on invertebrate incidental catch in the DSR directed and halibut fisheries.

Fishery specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components
Insufficient research exists to determine yelloweye rockfish catch relative to predator needs in time and space. Yelloweye rockfish are winter/spring spawners, with a peak period of parturition in April and May in Southeast Alaska (O'Connell 1987). The directed fishery, if opened, occurs between late January and early March, but the bulk of the mortality for the DSR complex is taken as incidental catch in the halibut longline fishery. Reproductive activities do overlap with the fishery, but since parturition takes place over a protracted period, there should be sufficient spawning potential relative to fishery mortality.

Fishery-specific effects on amount of large size target fish
Full retention of the DSR complex is required in the EGOA, therefore highgrading should be minimized in the reported catch and lengths sampled in port should be representative of yelloweye rockfish captured on the gear. The commercial directed fisheries landing data indicate the majority of fish are captured between 450 and 650 mm (Figure 9). There are some differences in the length compositions of yelloweye rockfish from the commercial fishery compared with the measurements of yelloweye rockfish derived from the ROV survey, and we are exploring the source of those differences.

Fishery contribution to discards and offal production
Full retention requirements of the DSR complex became regulation in 2000 in state waters and 2005 in federal waters of the EGOA. Thus, discard at sea of DSR is illegal; however, there may still be some unreported discard in the fishery. Data from the observer restructuring program may shed additional light on the magnitude of unreported catch.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery
Fishery effects on age-at-maturity and fecundity are unknown. Age composition of the fishery, by management area, is shown in Figure 10. The age at 50% maturity used in this stock assessment for yelloweye rockfish in Southeast Alaska is 17.6 years. This age is based on a maturity-at-age curve for males and females combined and was derived from directed DSR commercial fishery data from 1992 – 2013 from all four management areas (Figure 13 in Appendix B). Most yelloweye rockfish are captured at ages greater than the length at 50% maturity (Figure 10).

Fishery-specific effects on EFH living and non-living substrate:
Effects of the DSR fishery on non-living substrates are minimal since no trawl gear is used in the fishery. Occasionally fishing gear is lost in the fishery, so longline and anchors may end up on the bottom. There is likely minimal damage to EFH living substrate as the gear used in the fishery is set on the bottom but does not drag along the bottom.

Data Gaps and Research Priorities

There is a need for better estimation of rockfish habitat through more complete geophysical surveys (NSEO, SSEO areas in particular) and validation of the technique of using commercial fishery logbook data as a proxy for rock habitat in areas without geophysical surveys. We have initiated a collaboration with USGS to conduct mapping in the NSEO area (2015, and 2017).

We also plan to explore the conversion of yelloweye rockfish lengths collected from the ROV video observations to weight using length-weight relationships for yelloweye rockfish. We will determine if weights derived from length-weight relationships are appropriate for estimating biomass while considering the sample size of the length data obtained from the ROV.

There is limited information on yelloweye rockfish fecundity; a fecundity study specific to southeast Alaska would be useful. Little is known about the timing of settlement for yelloweye rockfish larvae or post larval survival. A recruitment index for yelloweye rockfish would improve modeling estimates for total yelloweye rockfish biomass.

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Table 1. Species included in the demersal shelf rockfish assemblage.

Common name	Scientific Name
canary rockfish	*S. pinniger*
China rockfish	*S. nebulosus*
copper rockfish	*S. caurinus*
quillback rockfish	*S. maliger*
rosethorn rockfish	*S. helvomaculatus*
tiger rockfish	*S. nigrocinctus*
yelloweye rockfish	*S. ruberrimus*

Table 2. Reported landings of demersal shelf rockfish (t) from research, incidental commercial, directed commercial, recreational and subsistence fisheries in the Southeast Outside Subdistrict (SEO), 1988–2014[a], acceptable biological catch (ABC), Overfishing Level (OFL) and total allowable catch (TAC) for commercial and recreational sectors combined.

YEAR	Research	Directed	Incidental[d]	Recreational[b]	Subsistence[c]	Total[d]	ABC[e]	OFL	TAC
1988							660		660
1989							420		420
1990							470		470
1991							425		425
1992		359	119			478	550		550
1993	13	334	188			535	800		800
1994	4	381	219			604	960		960
1995	13	155	103			271	580		580
1996	11	344	81			436	945		945
1997	16	267	97			380	945		945
1998	2	241	118			361	560		560
1999	2	241	125			368	560		560
2000	8	183	104			295	340		340
2001	7	173	144			324	330		330
2002	2	136	147			285	350	480	350
2003	6	102	167			275	390	540	390
2004	2	174	153			329	450	560	450
2005	4	42	191			237	410	650	410
2006	2	0	203	75		280	410	650	410
2007	3	0	196	60		259	410	650	410
2008	1	42	152	68		263	382	611	382
2009	2	76	139	36		253	362	580	362
2010	7	30	131	47	8	223	295	472	287
2011	5	22	87	32	6	152	300	479	294
2012	4	105	77	40	7	223	293	467	286
2013	4	129	84	31	7	255	303	487	296
2014	5	33	65	38	7	148	274	438	267
2015	4	33	69	44	8	158	225	361	217
2016					7		218	348	211

[a]Landings from ADF&G Southeast Region fish ticket database and NMFS weekly catch reports through November 3[rd], 2015.
[r]Recreational harvest from 2006 to 2008 include EYKT and IBS. These data are not available prior to 2006. Estimate for 2015 is preliminary.
[c]Projected subsistence catch for the fishery year, i.e. 2010 is for the 2010 fishery. These data were not available or deducted from the ABC prior to 2009.
[d]Data are from reported landings. Full retention of DSR went into effect in 2005, and unreported DSR discard associated with halibut fishery prior to 2005 is not reported in these totals.
[e]No ABC prior to 1988, 1988–1993 ABC for CSEO, NSEO, and SSEO only (not EYKT).

Table 3. Submersible (1994–1995, 1997, 1999, 2003, 2005, 2007, 2009) and ROV (2012–2013, 2015) yelloweye rockfish density estimates with 95% confidence intervals (CI) and coefficient of variations (CV) by year and management area. The number of transects, yelloweye rockfish (YE), and meters surveyed included in each model are shown, along with the encounter rate of yelloweye rockfish. Values in bold were used for this stock assessment. The 2012 CSEO density estimate was used as a proxy for the NSEO management area yelloweye rockfish density estimate. The NSEO area was surveyed in 2001, but too few yelloweye rockfish were observed to be used for a density estimate.

Area	Year	# transects	# YE[b]	Meters surveyed	Encounter rate (YE/m)	Density (YE/km^2)	Lower CI (YE/km^2)	Upper CI (YE/km^2)	CV
EYKT[a]	1995	17	330	22,896	0.014	2,711	1,776	4,141	0.20
	1997	20	350	19,240	0.018	2,576	1,459	4,549	0.28
	1999	20	236	25,198	0.009	1,584	1,092	2,298	0.18
	2003	20	335	17,878	0.019	3,825	2,702	5,415	0.17
	2009	37	215	29,890	0.007	1,930	1,389	2,682	0.17
	2015	**33**	**251**	**22,896**	**0.008**	**1,755**	**1,065**	**2,891**	**0.25**
CSEO	1994[c]					1,683			0.10
	1995	24	235	39,368	0.006	2,929			0.19
	1997	32	260	29,273	0.009	1,631	1,224	2,173	0.14
	2003	101	726	91,285	0.008	1,853	1,516	2,264	0.10
	2007	60	301	55,640	0.005	1,050	830	1,327	0.12
	2012	**46**	**118**	**38,590**	**0.003**	**752**	**586**	**966**	**0.13**
SSEO	1994[c]	13	99	18,991	0.005	1,173			0.29
	1999	41	360	41,333	0.009	2,376	1,615	3,494	0.20
	2005	32	276	28,931	0.010	2,357	1,634	3,401	0.18
	2013	31	118	30,439	0.004	986	641	1,517	0.22
NSEO	**1994[c]**	**13**	**62**	**17,622**	**0.004**	**765**	**383**	**1,527**	**0.33**

[a] Estimates for EYKT management area include only the Fairweather grounds, which is composed of a west and an east bank. In 1997, only 2 of 20 transects and in 1999, no transects were performed on the east bank that were used in the model. In other years, transects performed on both the east and west bank were used in the model.

[b] Subadult and adult yelloweye rockfish were included in the analyses to estimate density. A few small subadult yelloweye rockfish were excluded from the 2012 and 2015 models based on size; length data were only available for the ROV surveys (not submersible surveys). Data were truncated at large distances for some models; as a consequence, the number of yelloweye rockfish included in the model does not necessarily equal the total number of yelloweye rockfish observed on the transects.

[c] Only a side-facing camera was used in 1994 and earlier years to video fish. The forward-facing camera was added after 1994, which ensures that fish are observed on the transect line.

Table 4. Area estimates for sonar locations and rocky habitat by management area in Southeast Alaska.

	Sonar location	Sonared area (km^2)	Area rocky habitat (km^2)
EYKT	Fairweather West Bank	784	402
	Fairweather East Bank	288	98
Total Sonar		1,072	500
Total rock (Sonar & fishery)			739
Percentage rocky habitat from sonar			68%
CSEO	Cape Edgecumbe	538	328
	Cape Ommaney	294	114
Total Sonar		832	442
Total rock (Sonar & fishery)			1,661
Percentage rocky habitat from sonar			27%
SSEO	Hazy Islands	400	120
	Addington	84	47
	Cape Felix	140	78
	Learmonth Bank	530	77
Total Sonar		1,154	322
Total rock (Sonar & fishery)			1,056
Percentage rocky habitat from sonar			30%
NSEO			
	Cross Sound	600	In review
Total Sonar		600	In review
NOAA chart			364
Total rock (NOAA chart & fishery)			436

Table 5. Commercial landings (t) of demersal shelf rockfish species in Southeast Outside Subdistrict between 2008 and 2015. Discards (Harvest Code 98 (Discard at sea) included.

Species	2008	2009	2010	2011	2012	2013	2014	2015	Sum (t)
Canary rockfish	0.67	0.86	0.87	0.34	3.34	3.12	0.51	0.57	10.3
China rockfish	0.01	0.04	0.03	0.02	0.02	0.05	0.91	0.02	1.1
Copper rockfish	0.01	0.04	0.01	0.01	0.04	0.03	0.03	0.01	0.2
Quillback rockfish	2.88	3.82	4.08	1.68	4.06	3.89	1.96	2.43	24.8
Rosethorn rockfish	0.09	0.01	0.00	0.00	0.02	0.04	0.00	0.02	0.2
Tiger rockfish	0.26	0.50	0.28	0.11	0.41	0.31	0.26	0.22	2.4
Yelloweye rockfish	189.71	209.34	155.62	106.16	173.99	206.16	94.16	98.79	1,233.9
Sum (t)	193.63	214.61	160.89	108.32	181.88	213.61	97.84	102.08	1,272.8
% yelloweye of total	98.0%	97.5%	96.7%	98.0%	95.7%	96.5%	96.2%	96.8%	96.9%

Table 6. Other Fishery Management Plan (FMP) groundfish species landed (t) in DSR directed commercial fisheries in the Southeast Outside Subdistrict.

Species	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Black rockfish					0.3	0.9		
Bocaccio rockfish	0.1					0.1		
Pacific cod	0.5	0.4	0.9	1.0	2.3	5.1	0.2	0.1
Redbanded rockfish	0.2	0.1		0.1	1.1	1.7		
Dark rockfish		0.1						
Dusky rockfish	2.1	2.0	0.5	0.3	3.8	5.3	2.1	3.2
Rougheye rockfish	0.1							
Shortraker rockfish	0.1							
Silvergray rockfish	0.7	0.5	0.4	0.3	0.7	1.9	0.2	0.1
Skate, general		1.7			0.2			
Spiny dogfish shark					0.2			
Yellowtail rockfish					0.1	0.1		
Total	**3.8**	**4.8**	**1.8**	**1.7**	**8.7**	**15**		

Table 7. Ecosystem effects on GOA DSR

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post larval survival but no information known	May help determine recruitment strength, no time series.	Possible concern if more information known
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Pollock, Pacific cod, halibut)	Stable	No effect	No concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift		No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different Phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings nutrients to the Gulf	Some years highly variable, i.e. El Nino 1998	Probably no concern, contributes to high variability in rockfish recruitment

GOA DSR fishery effects on the ecosystem

Prohibited species	Halibut are taken as incidental catch but released	Minor contribution to mortality, soak times are short for DSR gear, separate PSC cap for DSR	Little concern
Forage (including herring, Atka mackerel, cod, and pollock)	A small amount of cod incidental catch is taken in this fishery	Incidental catch levels small relative to forage biomass	No concern
HAPC biota	Low incidental catch levels of Primnoa coral, hard coral, and sponges.	Longline gear has some incidental catch but levels small relative to HAPC biota	Little concern
Marine mammals and birds	Minor take associated with longline gear, little impact	Data limited for discards, fishery has been largely unobserved until recently.	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be harvested in proportion to their abundance.	No concern
Fishery concentration in space and time	Majority of catch is harvested during halibut IFQ season (March to November), the directed fishery is concentrated during the winter	Fishery does not hinder reproduction	Little concern
Fishery effects on amount of large size target fish	Fishery is catching primarily adults but difficult to target largest individuals over others	Large and small fish both occur in population	Little concern
Fishery contribution to discards and offal production	Discard rates low for DSR fishery but can include dogfish and skates	Data limited for discards, fishery has been largely unobserved until recently	Possible concern
Fishery effects on age-at-maturity and fecundity	Fishery is catching some immature fish but small proportion of total catch. Larger fish likely contribute more to spawning output via exponentially greater and higher quality larvae.	If increased could reduce spawning potential and yield	Possible concern

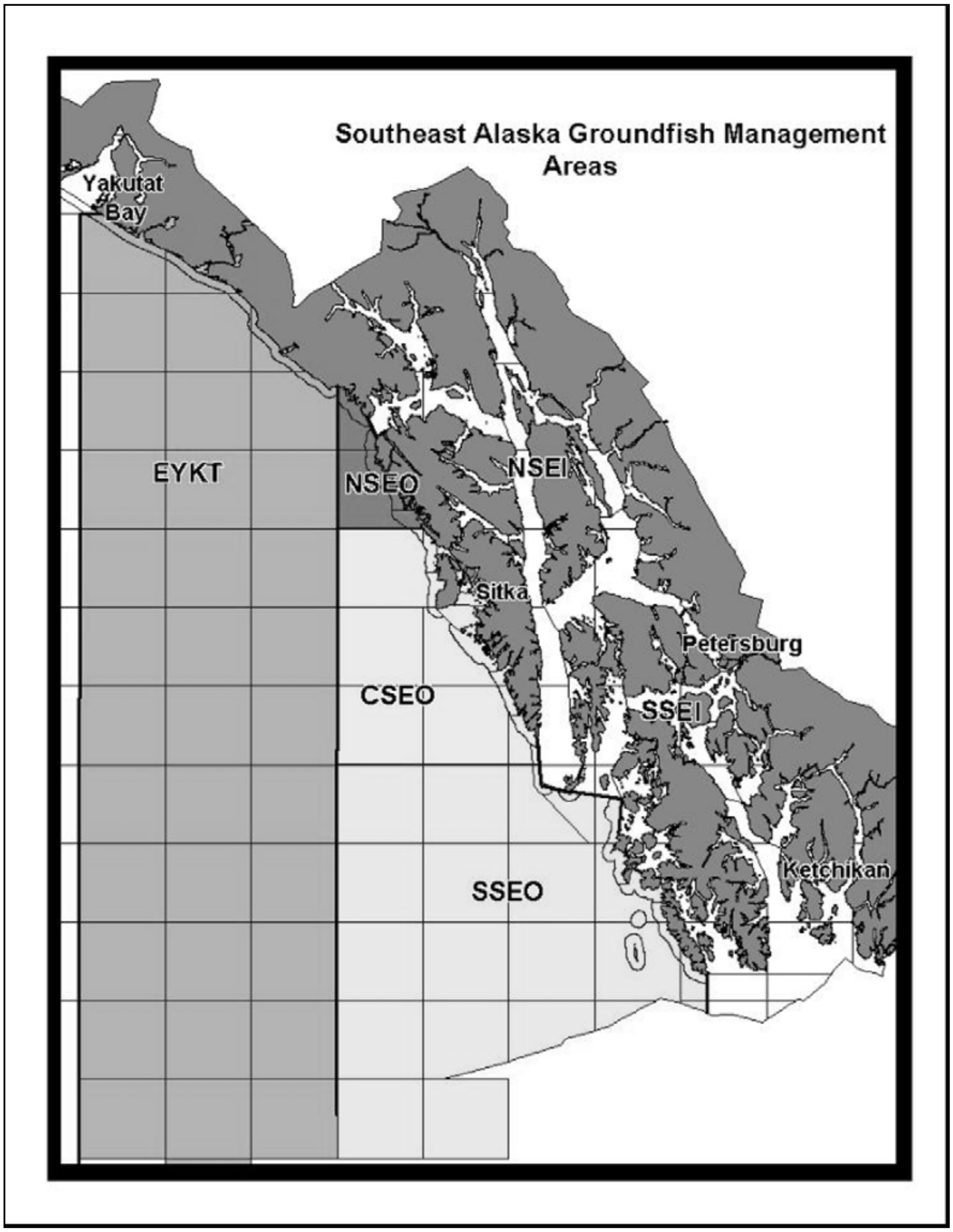

Figure 1. Southeast Alaska Outside Waters (SEO), or Eastern Gulf of Alaska (EGOA) with the Alaska Department of Fish and Game groundfish management areas; East Yakutat (EYKT), Central Southeast Outside (CSEO), Northern Southeast Outside (NSEO), and Southern Southeast Outside (SSEO).

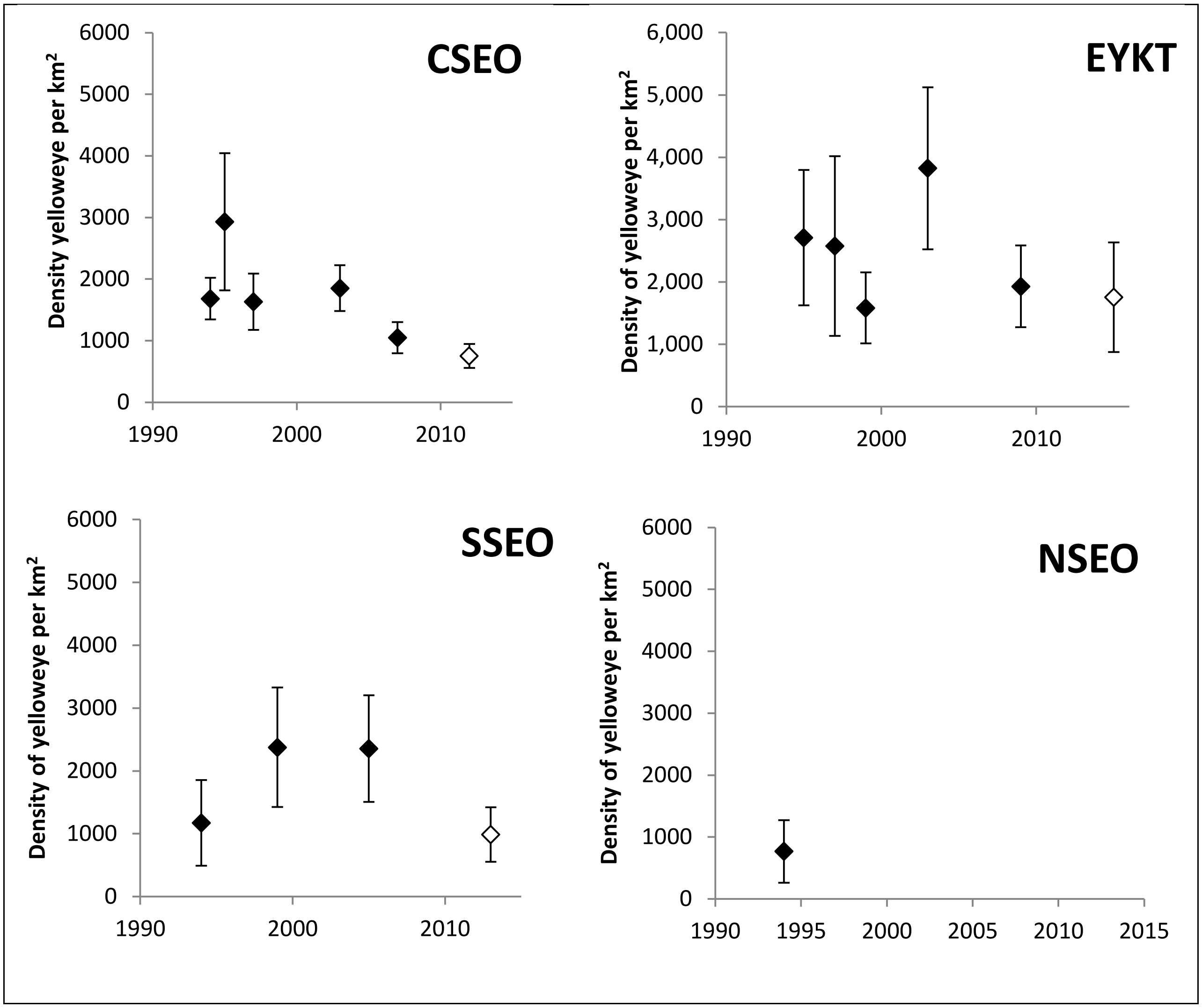

Figure 2. Density yelloweye rockfish predicted by DISTANCE (circles) +/- two standard deviations in each management area (Central Southeast Outside (CSEO), East Yakutat (EYKT), Southern Southeast Outside (SSEO), and Northern Southeast Outside (NSEO)).

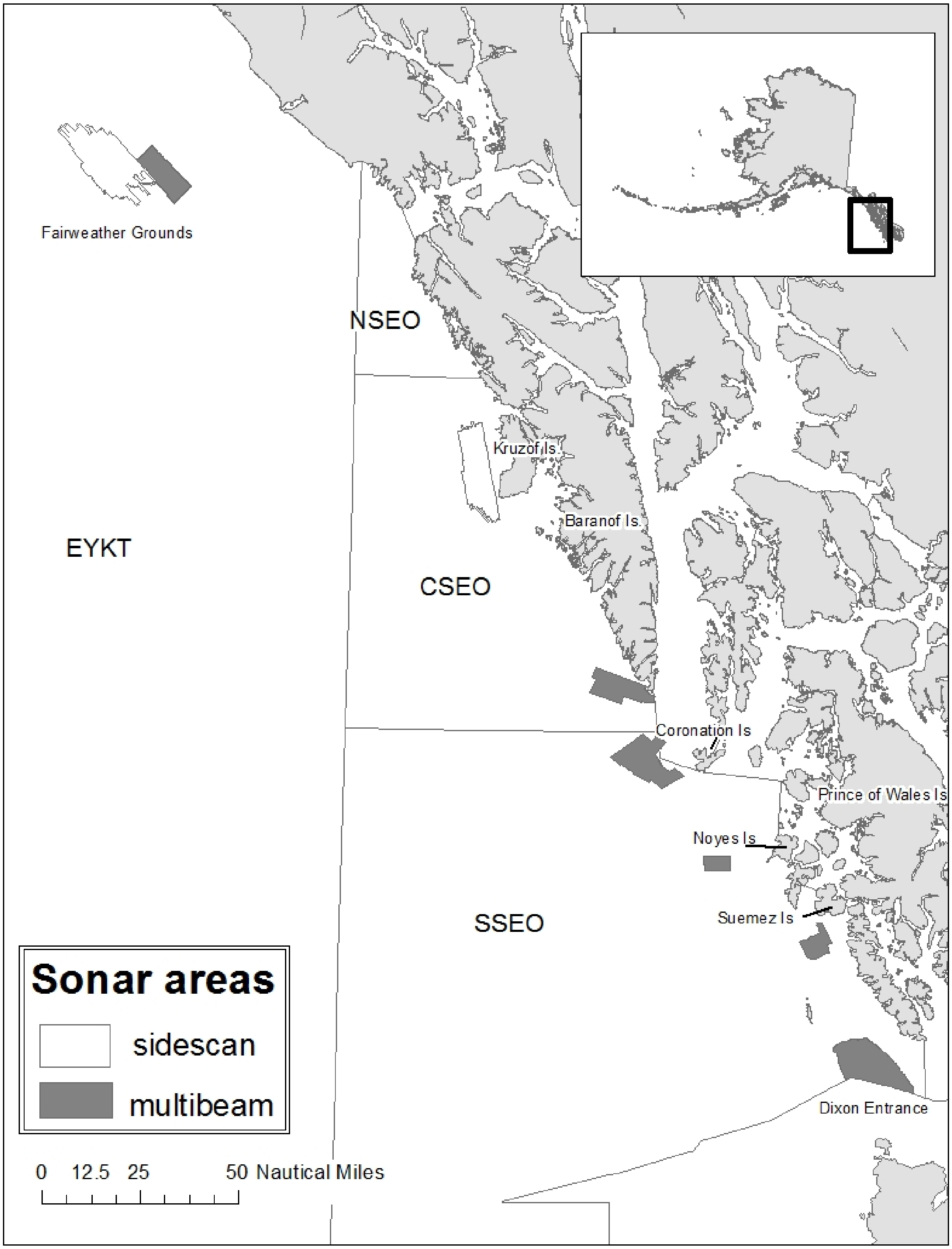

Figure 3. Sonar surveys performed in southeast Alaska and used in yelloweye rockfish habitat delineation.

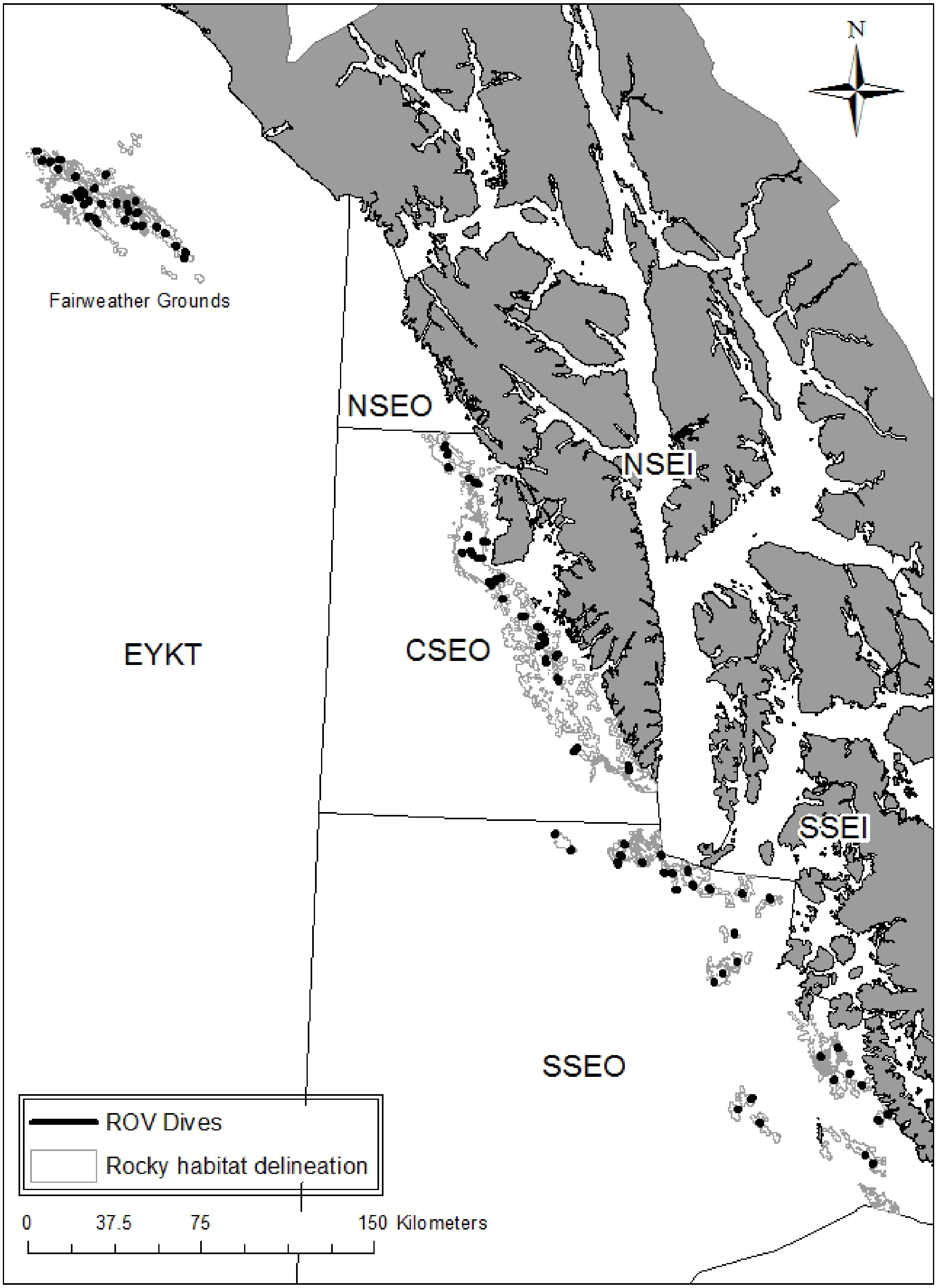

Figure 4. ROV transects conducted in Central Southeast Outside (CSEO) in 2012, Southern Southeast Outside (SSEO) in 2013, and East Yakutat (EYKT) in 2015.

Figure 5. Example of 1-km transect plan lines for remote operated vehicle (ROV) dives. Plan lines have been adjusted in some cases to remain within the delineation of rocky habitat (solid gray).

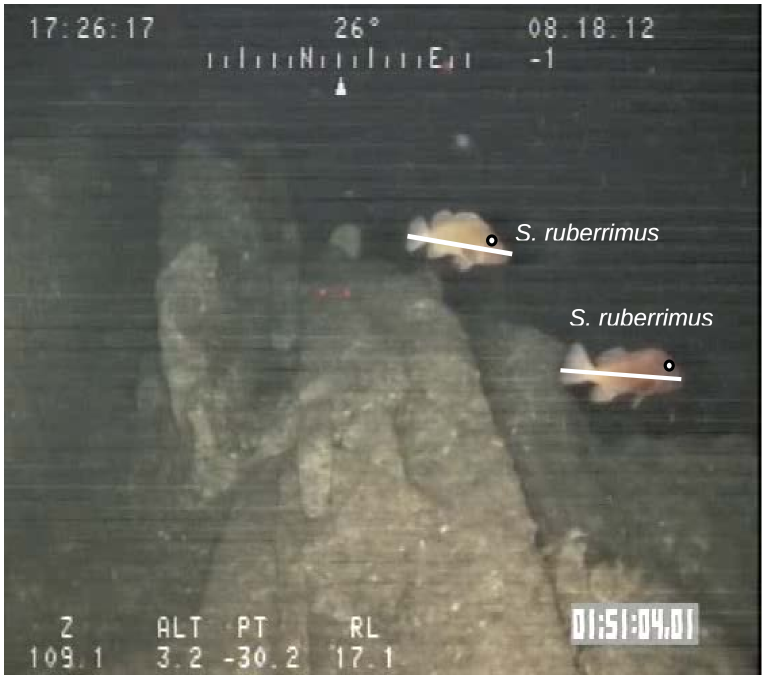

Figure 6. Yelloweye rockfish with a 3D point (circle with black outline) and a total length (white line) measured in the stereo camera overlapping field of view in the SeaGIS Event Measure software.

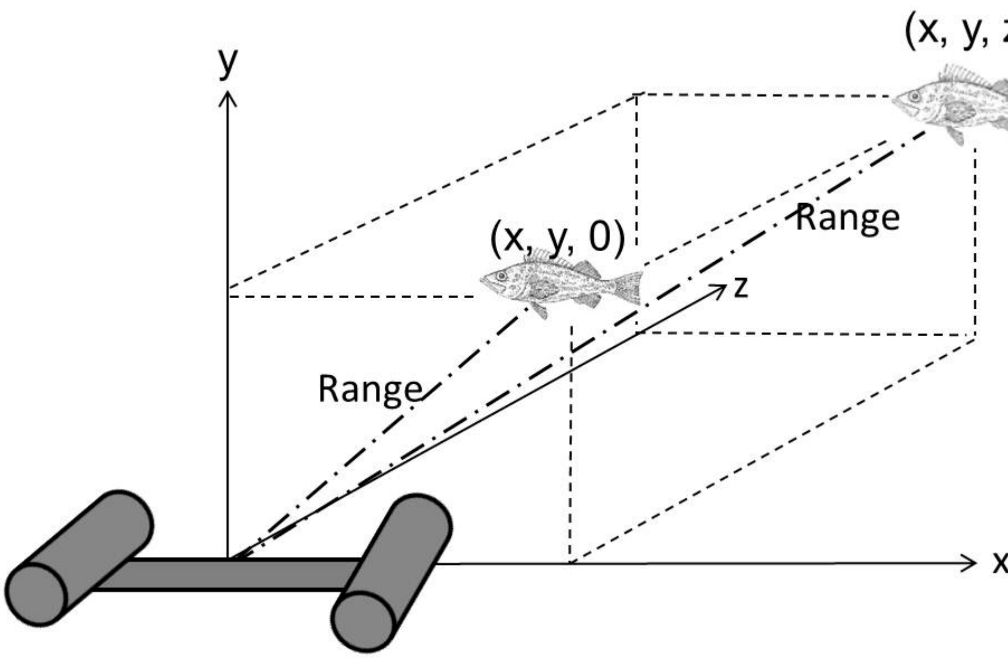

Figure 7. The components of a 3D point measurement.

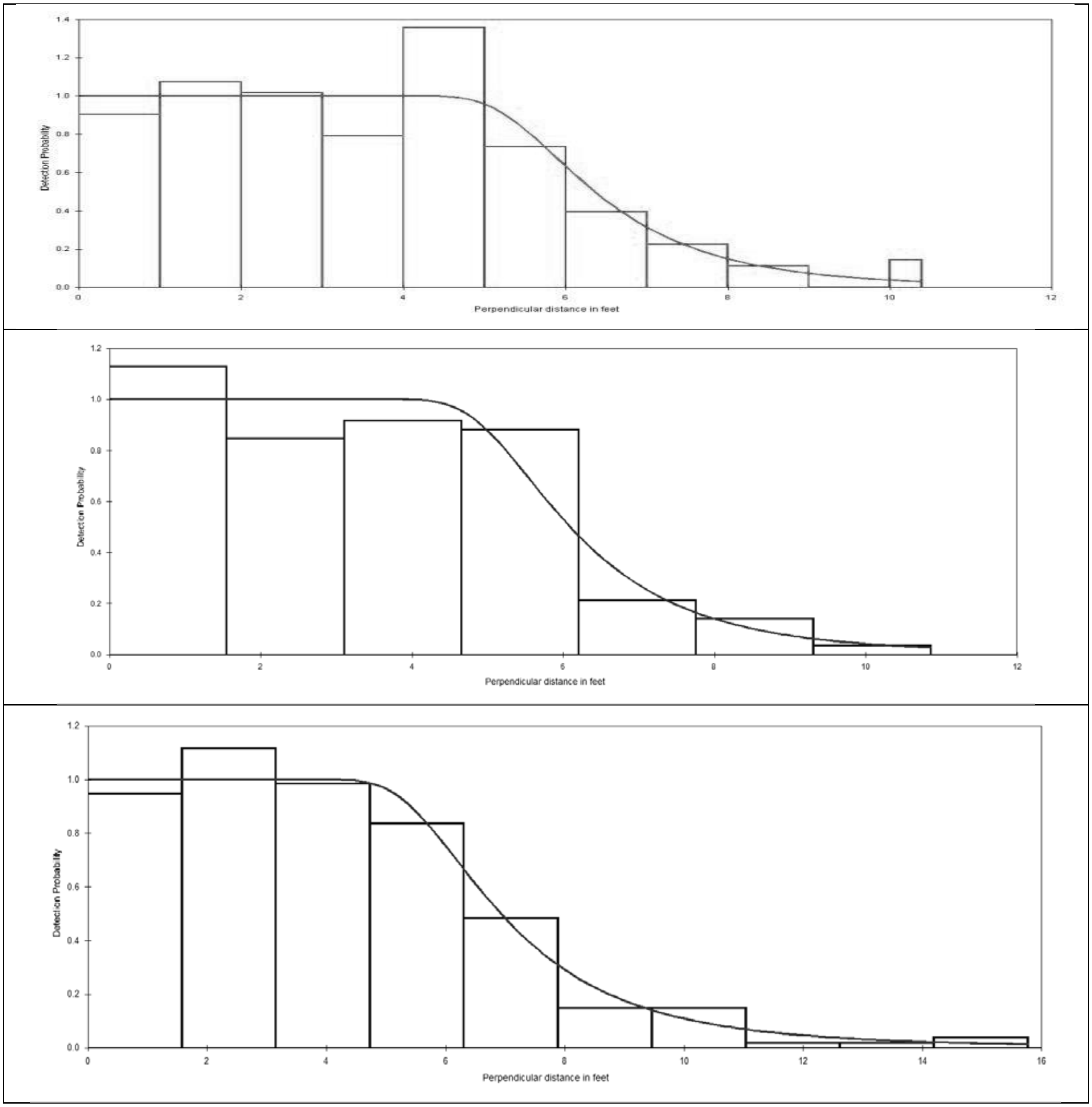

Figure 8a. The selected probability detection function for yelloweye rockfish from the 2012 ROV survey in Central Southeast Outside (CSEO) shown with expected data bins at 1-ft intervals. Data were not binned to estimate density in the CSEO selected model. The CSEO data were used as a proxy for the Northern Southeast Outside (NSEO) management area in this stock assessment, because over 13 years have elapsed since the last usable NSEO survey.

Figure 8b. The selected probability detection function for yelloweye rockfish from the 2013 ROV survey in Southern Southeast Outside (SSEO) shown with expected data bins at 1.55 ft intervals. Data were not binned to estimate density with the selected model.

Figure 8c. The probability detection function for East Yakutat (EYKT) for 2015 shown with 1.58 ft bins and truncation after11 ft. Data were not binned to estimate density with the selected model.

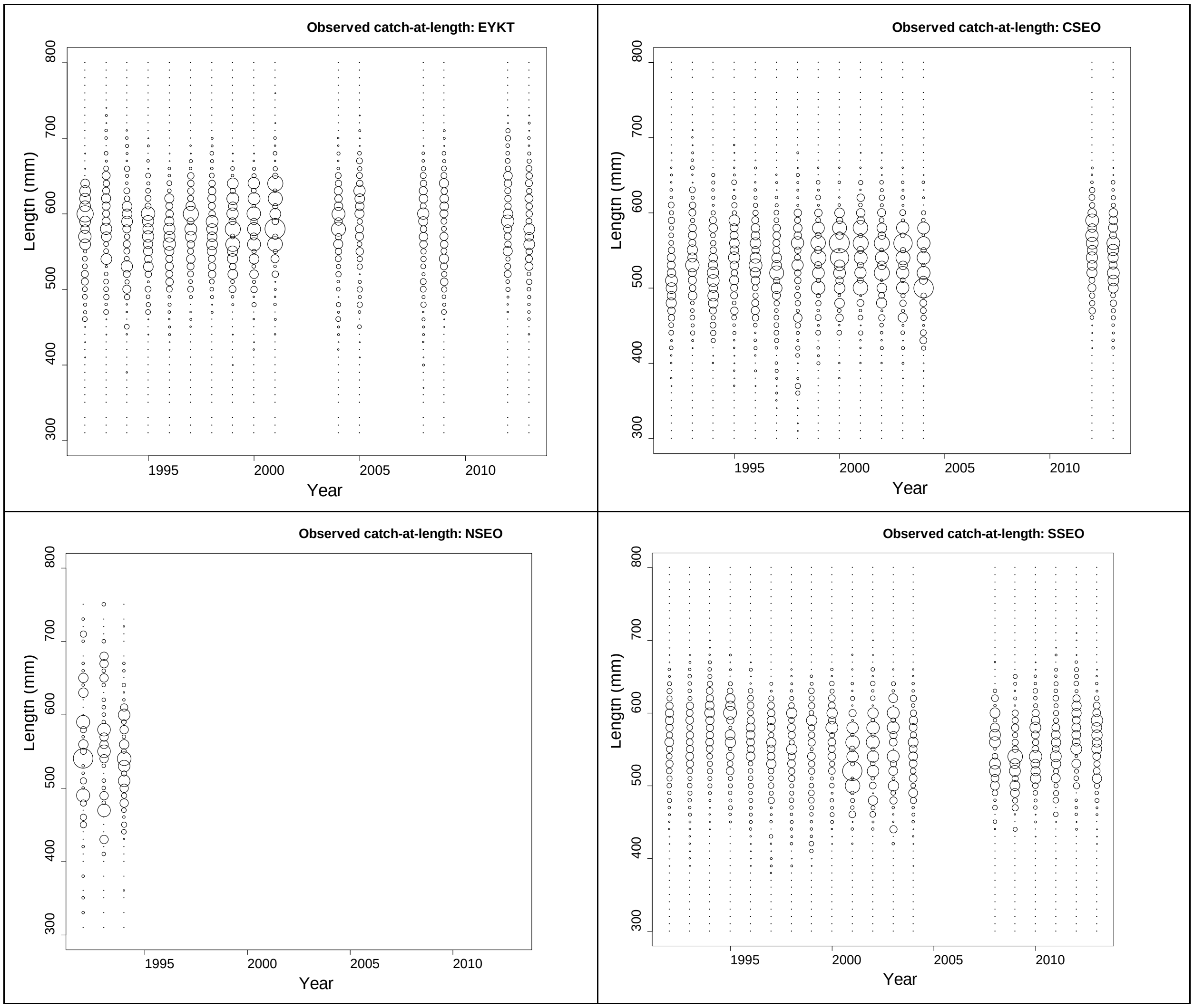

Figure 9. Length compositions from DSR captured in the directed fishery in East Yakutat (EYKT), Central Southeast Outside (CSEO), Northern Southeast Outside (NSEO), and Southern Southeast Outside (SSEO).

Appendix A. Time Series Random Walk Model Approach

Historically, total yelloweye rockfish biomass is estimated for each management area in the EGOA as the product of density, mean fish weight, and area estimates of rockfish habitat. Yelloweye rockfish density is derived using line transects conducted from the most recent submersible or ROV survey in each management area. However, at the Plan Team's recommendation, we present an updated model-based approach developed by the Plan Team's survey averaging working group. In this approach, the estimates of yelloweye rockfish density in each management area were obtained by a random walk time series model in which process errors are the difference in density between successive years and are estimated as random effects.

Tables A1–A4 summarize model outputs for each management area. Figures A1–A4 show a graphical representation of the model estimated density and survey densities of yelloweye rockfish. **The random walk model was not used to calculate biomass, only densities.** The point estimate of model output density (Tables A1–A4) was used to calculate area biomass for the current year. The lower 90% confidence interval of the biomass estimate is used for management, as has been done historically. Biomass was calculated from the model-derived densities as the product of yelloweye rockfish density, average weights from yelloweye rockfish sampled in the commercial fisheries, and area (km^2) of DSR habitat. Using the new model-derived density estimates, (but the same average weights and habitat area as in the main document), the total yelloweye rockfish biomass estimate using is 9,113 mt (versus status quo method in the main document of 10,559 mt). This alternate option would result in an ABC of 188 mt, a difference of 30 mt from Option 1 provided in the main document. Model estimates of density for 2015 were close to the survey densities. Point estimates of yelloweye rockfish densities for all areas for 2015 were forecasted to increase slightly using the model, however, the larger CVs associated with the model resulted in a lower biomass estimate. Provided below is a summary of the two options. At this time, we recommend Option 1, until there is time to more fully evaluate the model results.

	Option 1 (historic approach)	Option 2 (model-based approach)
Yelloweye biomass (t)	10,559	9,113
DSR biomass (t)	10,886	9,395
ABC (t)	218	188
OFL (t)	348	300
Max ABC (t)	283	244

Table A1. Central Southeast Outside (CSEO) management area. Density is the model derived density estimate. Upper (UCI) and Lower (LCI) are the model-derived upper and lower 90% confidence intervals of the Mean (est). All density estimates are number of yelloweye rockfish per square kilometer.

Year	Density	UCI	LCI	CV
1994	1771.3	2134.95	1469.59	0.094064
1995	2206.06	3102.15	1568.82	0.149474
1996	1952.93	2790.73	1366.64	0.179487
1997	1728.84	2214.95	1349.41	0.125274
1998	1739.79	2660.34	1137.77	0.217552
1999	1750.8	2887.05	1061.74	0.25669
2000	1761.88	2964.68	1047.07	0.267162
2001	1773.04	2900.57	1083.81	0.252561
2002	1784.26	2677	1189.24	0.207662
2003	1795.56	2180.56	1478.53	0.096876
2004	1578.48	2318.05	1074.86	0.196791
2005	1387.64	2136.45	901.282	0.221478
2006	1219.87	1804.83	824.508	0.200905
2007	1072.39	1339.02	858.859	0.112503
2008	1004.08	1510.87	667.287	0.209066
2009	940.125	1514.07	583.749	0.244034
2010	880.241	1421.49	545.08	0.245334
2011	824.172	1251.91	542.576	0.213582
2012	771.674	990.471	601.209	0.12585
2013	771.674	1241.86	479.507	0.243174
2014	771.674	1441.49	413.1	0.320046
2015	771.674	1624.96	366.458	0.381739

Table A2. East Yakutat (EYKT) management area. Density is the model-derived density estimate. Upper (UCI) and Lower (LCI) are the model-derived upper and lower 90% confidence intervals of the Mean (est). All density estimates are number of yelloweye rockfish per square kilometer.

Year	Density	UCI	LCI	CV
1994	2609.25	3723.25	1828.56	0.180013
1995	2506.96	3883.26	1618.45	0.225883
1996	2408.69	3743.64	1549.77	0.228443
1997	2314.27	3343.18	1602.01	0.189457
1998	2097.82	3123.48	1408.96	0.20311
1999	1901.62	2718.35	1330.28	0.1624
2000	2180.4	3359.73	1415.03	0.22086
2001	2500.04	3940.38	1586.19	0.237181
2002	2866.54	4421.85	1858.28	0.220912
2003	3286.76	4710.86	2293.18	0.162541
2004	3029.68	4857.78	1889.54	0.235395
2005	2792.7	4725.18	1650.56	0.269554
2006	2574.26	4413.25	1501.58	0.279582
2007	2372.91	3970.23	1418.23	0.2682
2008	2187.3	3419.4	1399.16	0.232283
2009	2016.22	2742.68	1482.18	0.155685
2010	1979.16	3123.87	1253.91	0.235878
2011	1942.77	3307.37	1141.2	0.276068
2012	1907.06	3354.61	1084.14	0.293194
2013	1872	3284.33	1067	0.291353
2014	1837.59	3102.19	1088.5	0.270156
2015	1803.81	2800.65	1161.78	0.224178

Table A4. Southern Southeast Outside (SSEO) management area. Density is the model-derived density estimate. Upper (UCI) and Lower (LCI) are the model-derived upper and lower 90% confidence intervals of the Mean (est). All density estimates are number of yelloweye rockfish per square kilometer.

Year	Density	UCI	LCI	CV
1994	1377.96	2362.03	803.878	0.255562
1995	1513.05	2703.69	846.739	0.282417
1996	1661.38	2987.7	923.848	0.289208
1997	1824.25	3191.21	1042.83	0.277415
1998	2003.09	3276.05	1224.76	0.244362
1999	2199.46	3164.02	1528.94	0.178619
2000	2202.11	3635.58	1333.85	0.245274
2001	2204.78	3887.84	1250.32	0.277201
2002	2207.44	3966.36	1228.53	0.286266
2003	2210.11	3878.68	1259.34	0.27474
2004	2212.78	3613.67	1354.97	0.239671
2005	2215.46	3114.65	1575.86	0.16682
2006	2025.03	3331.35	1230.96	0.245477
2007	1850.98	3328.89	1029.21	0.289838
2008	1691.89	3199.83	894.572	0.314754
2009	1546.47	2985.36	801.095	0.324734
2010	1413.54	2711.01	737.033	0.321172
2011	1292.05	2394.2	697.263	0.303593
2012	1180.99	2045.59	681.833	0.269265
2013	1079.49	1665.36	699.722	0.210132
2014	1079.49	1979.53	588.671	0.295721
2015	1079.49	2262.26	515.101	0.361589

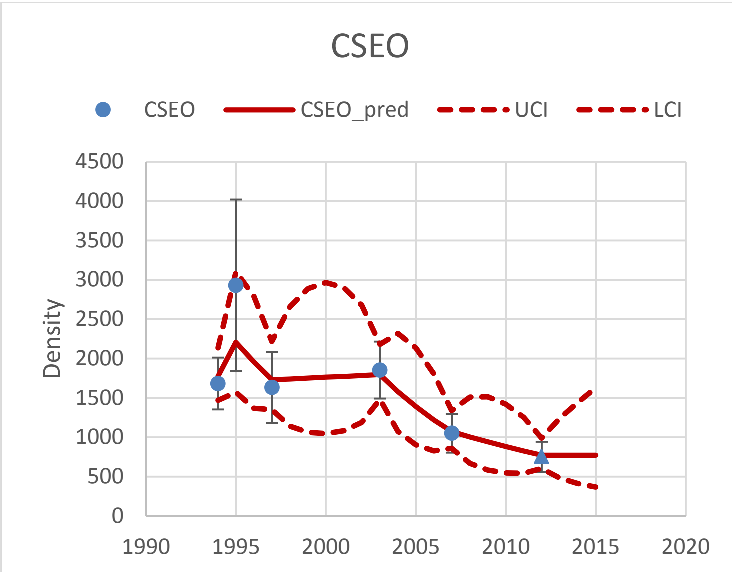

Figure A1. Central Southeast Outside (CSEO) observed (blue dots) and model-derived (red line) density estimates of yelloweye rockfish in (#/km^2). The triangle (2012 density) is the observed survey density from the remote operated vehicle (ROV). All other observed data are based on submersible surveys.

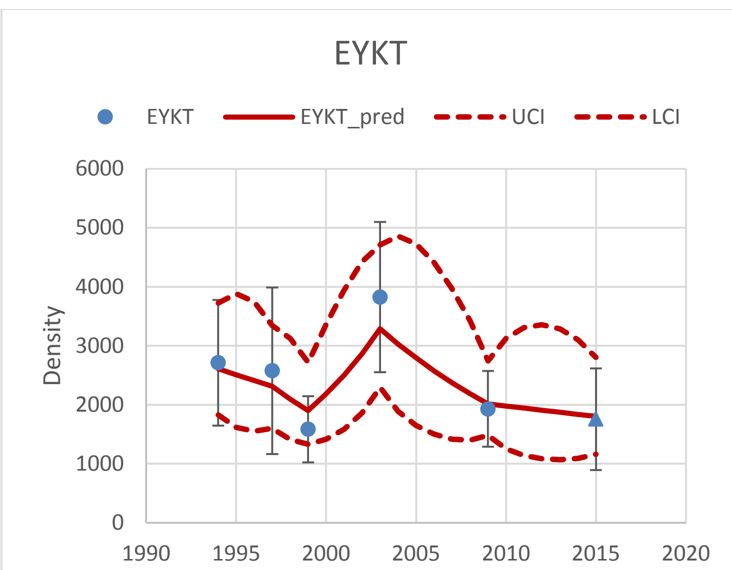

Figure A2. East Yakutat (EYKT) observed (blue dots) and model-derived (red line) density estimates of yelloweye rockfish in (#/km^2). Dashed lines are 90% confidence intervals. The triangle (2015 density) is the observed survey density from the remote operated vehicle (ROV). All other observed data are based on submersible surveys.

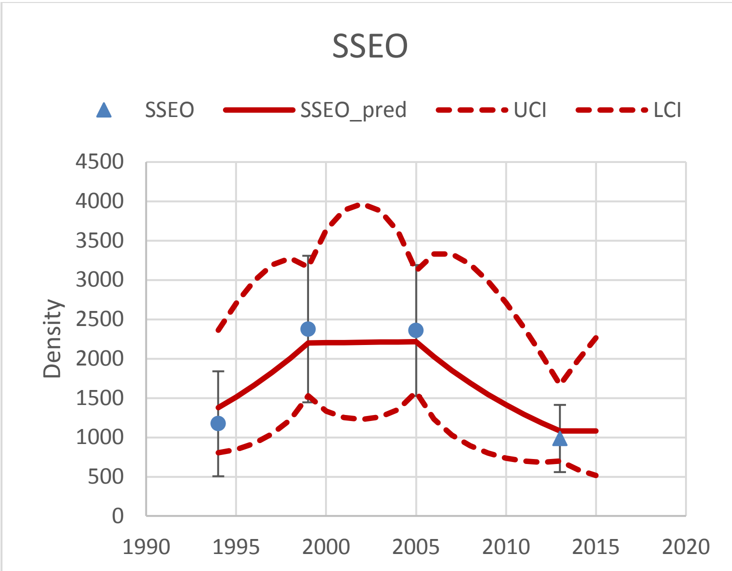

Figure A4. Southern Southeast Outside (SSEO) observed (blue dots) and model-derived (red line) density estimates of yelloweye rockfish in (#/km^2). Dashed lines are 90% confidence intervals. The triangle (2013 density) is the observed survey density from the remote operated vehicle (ROV). All other observed data are based on submersible surveys.

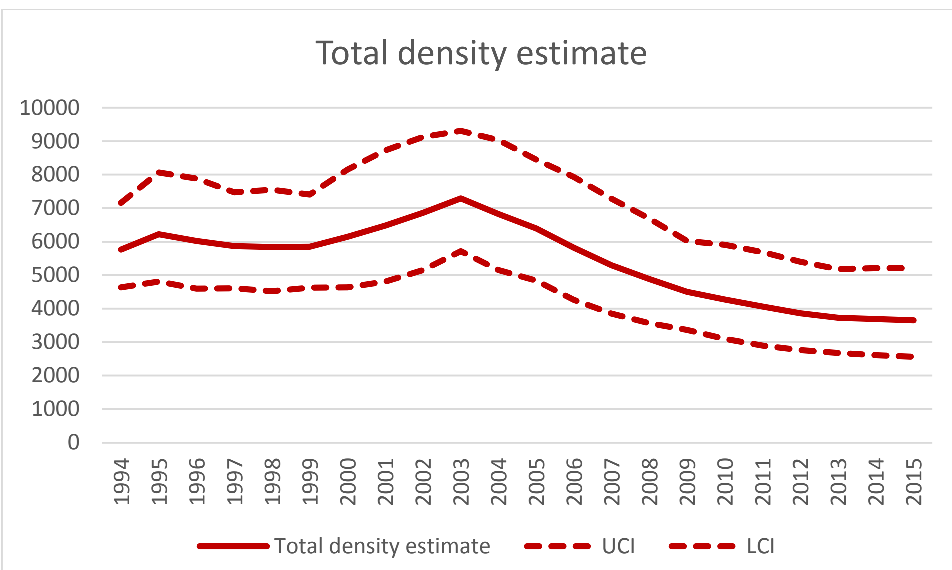

Figure A5. Combined model-derived (red line) density estimates of yelloweye rockfish in (#/km^2) for all management areas. Dashed red lines are 90% confidence intervals.

Appendix B**.** An age-structured model for yelloweye rockfish (Sebastes ruberrimus) in Southeast Alaska Outside Waters (East Yakutat, Central Southeast Outside, and Southern Southeast Outside)

Kray Van Kirk

This appendix to the 2015 Demersal Shelf Rockfish SAFE presents the current development status of an age-structured assessment (ASA) model written in AD Model Builder for yelloweye rockfish in Southeast Alaska outside waters (East Yakutat, Central Southeast Outside, and Southern Southeast Outside).

Summary of Changes in Assessment Model

Changes in input data

1. ADF&G Remote Operated Vehicle (ROV) Survey: 2015 East Yakutat density estimates added;

Changes in assessment methodology

The age-structured model is similar to the model presented at the September 2015 Plan Team meeting. The following changes have been applied following input from the Plan Team and SSC, consultation with Pete Hulson and Dana Hanselman of the NOAA Auke Bay Lab in Juneau, Alaska, and other considerations:

1. Implemented penalized log-likelihoods for objective function components and penalties, and removed the secondary weightings previously used for model fitting (see Revised Likelihood Forms, and BOX 3). This resulted in improved model performance, and allowed for the removal of earlier penalties needed to stabilize model output. These likelihood forms were applied to total annual catch in the directed commercial fishery, total annual incidental catch in the Pacific halibut fishery, total annual recreational catch, the ADF&G submersible and remote-operated vehicle surveys, and the catch-per-unit-effort (CPUE) calculations for directed commercial catch and the International Pacific Halibut Commission (IPHC) longline survey. Multinomial likelihoods for age-composition elements have remained unchanged;
2. Added a second variance term to the likelihood for the ADF&G survey data. These survey data were analyzed using DISTANCE 6.0 software; the additional variance term compensates for overly precise estimates of density produced by the program (see Revised Likelihood Forms, and BOX 3);
3. Replaced an unnecessarily complex set of CPUE Box-Cox transformations with a simple ratio of pounds catch per hook for the directed fishery CPUE and numbers per hook for the IPHC longline survey CPUE;
4. Combined catch from the directed yelloweye commercial fishery and incidental catch of yelloweye in the Pacific halibut fishery into a single dataset, including both annual removals and age-composition data. The directed longline yelloweye commercial fishery and the halibut longline fishery use similar gear; this reduces the number of model parameters;
5. Estimated Year 1 abundance-at-age and annual recruitment at age-8 as deviation vectors from mean values, as opposed to vectors of free parameters;

6. Set natural mortality *M* to the Tier 4 assumption of 0.026, correcting an earlier error in which the Tier 4 assumption was incorrectly specified as 0.02;
7. Re-estimated the aging error matrix using data from the ADF&G Age Determination Unit and analysis code provided by Pete Hulson. This replaces the previous aging error matrix that was calculated using NOAA age-reader data;
8. Experimented with modeling natural mortality as a random walk for EYKT only. This is not presented in the base case scenario and analyses, but briefly discussed as a separate model form.

Summary of Results

Estimates of density and biomass similar to Dicamptodon 12.1b for which $M = 0.02$ or 0.03 were obtained with fewer model parameters and fewer constraints than previous modeling efforts. Density of subadult/adult yelloweye continued to steadily decline in all areas, although spawning biomass in East Yakutat (EYKT) increased.

The addition of the second variance term to the ADF&G density likelihood greatly increased model uncertainty not only for density, but also for CPUE and other indices.

Estimates for catchability, *q*, for both the directed commercial fishery and the IPHC longline survey were markedly reduced relative to Dicamptodon 12.1b even though absolute abundances remained comparable, likely due to the modified form of the CPUE equations.

Density and abundance trends continued to be highly sensitive to natural mortality. As density is conditioned on the results of the submersible and remote operated vehicle surveys in both the current management methods as well as the ASA model structure, overall estimates of total biomass from both methods were of the same magnitude.

Summary Table[1]				
Quantity	**Current assessment**		**ASA model**	
	2015	**2016**	**2015**	**2016**
M	0.02		0.026	
Tier	4		4	
Biomass - total (metric tons)	10,933[3]	10,559[3]	11,179[3]	11,137[3]
Female spawning biomass (metric tons)			4,772[3]	4,734[3]
$F_{OFL} = F_{35\%}$	0.032		$F_{35\%} = 0.042$[2]	
Max F_{ABC} (maximum = $F_{40\%}$)	0.026		$F_{40\%} = 0.033$[2]	
F_{ABC} (*recommended* = $F_{45\%}$)	0.02		$F_{45\%} = 0.028$[2]	

[1]ASA structures are from models in which natural mortality was set to the Tier 4 assumption ($M = 0.026$).
[2]Mean F over all management areas scaled by relative area (km^2).
[3]Summed over all management areas

Model Data

Data used in the age-structured model:

1. total annual catch from the directed DSR commercial fishery in the three SEO management areas (Southern Southeast Outside Waters (SSEO), Central Southeast Outside Waters (CSEO), and East Yakutat (EYKT)) (Table 1);
2. total annual incidental catch from the commercial Pacific halibut longline fishery (Table 2);
3. total annual catch (metric tons) from the recreational fishery from 1996 – 2013 (Table 3);
4. estimates of yelloweye density (individuals per square kilometer) derived from ADF&G submersible and remote operated vehicle (ROV) bottom surveys (Table 4);
5. estimates of total rockfish habitat per management area in square kilometers derived from sonar surveys and fishery data (Table 4);
6. age composition data from the directed commercial yelloweye fishery and commercial longline Pacific halibut fishery incidental catch;
7. commercial fishery catch-per-unit effort (CPUE) derived from logbooks and fish tickets;
8. International Pacific Halibut Commission (IPHC) longline survey yelloweye catch;
9. estimates of length, weight, age, and maturity composition derived from commercial fisheries data from 1985 - 2014.

Total Annual Catch

Estimates of total annual catch were obtained through analyses of fisheries logbook and fish ticket data for each year in which a directed commercial fishery for yelloweye was prosecuted in any of the three management areas. Fisheries data prior to the early 1990s are characterized by varied record-keeping methods in addition to changes in management areas and harvest regulations. Logbook data were re-assessed in construction of model data sets, and the numbers presented in Table 1 may differ somewhat from previous DSR stock assessments (Table 1, Fig. 2).

In contrast to the directed commercial fishery for yelloweye, which has not been opened in every management area for every year included in the assessment model, incidental catch removals in the commercial longline Pacific halibut fishery have occurred every modeled year in each management area (Fig. 2).Prior to 2006, yelloweye rockfish incidental catch data from the commercial Pacific halibut longline fishery were taken from halibut processor fish tickets; since 2006 these data were taken from the Interagency Electronic Reporting System (IERS), a joint effort between ADF&G, the IPHC, and the National Marine Fisheries Service (NMFS) to consolidate landing, IFQ, and logbook reporting (Table 2, Fig. 2).

For this assessment, removals from the directed commercial fishery and incidental catch in the directed Pacific halibut fishery were combined into a single vector of removals.

Recreational and Subsistence Catch

Recreational catch refers to total removal from subsistence and recreational efforts, with an assumption of 100% mortality for any fish released. Total tonnage is calculated as the product of total number and the estimated mean weight over all ages for a given year. Data are available from 2006 – present (Table 3, Fig. 2). The assumption of 100% mortality may be relaxed in future assessment with the implementation of mechanisms designed to reduce mortality of released fish.

Density - Submersible and ROV surveys

ADF&G utilized a manned submersible to conduct line-transect surveys with direct observations of yelloweye abundance from 1990 - 2009. Survey locations were selected randomly but constrained to fall within rocky habitat considered appropriate for rockfish (a detailed description of ADF&G submersible and ROV survey methods is found in the main section of this document). After 2009, the submersible became unavailable, and was replaced by a ROV controlled topside from the survey vessel. Surveys utilizing the ROV were conducted from 2012 onward. Line transect methods implemented in the software package DISTANCE 6.0 (Thomas et al. 2010) were used to calculate density of adult and sub-adult yelloweye from both submersible and ROV surveys along with estimates of variance (Table 4). For the purposes of the ASA model, density and variance estimates from the submersible and ROV are assumed equivalent.

Fishery Age Composition

Estimates of fishery age composition for each management area were derived from data collected through port sampling of catch from the directed commercial fishery and incidental catch taken in the commercial Pacific halibut longline fishery. Sampled otoliths were sent to the ADF&G Age Determination Unit for aging and the results used to construct length-age relationships. Age-composition was estimated from the catches specific to each area to potentially identify region-specific differences in age composition and recruitment. Years in which sample size was less than 50 were omitted.

CPUE

IPHC survey

The IPHC standardizes survey effort into "effective skates" relative to hook spacing and hook type as

$$\text{effskt} = \text{noskt} * 1.52 * (1 - e^{-0.05*\text{hkspc}}) * \text{nohk}/100 * \text{hkadj}$$

where *noskt* = the number of skates hauled, *hkspc* = the mean spacing between hooks on a given skate, *nohk* = mean number of hooks per skate, and *hkadj* = hook type. If no hook type is available, a circle hook is assumed. Prior to 2009, yelloweye were counted for the first 20 hooks of each skate; total skate counted were extrapolated. From 2009 onward, yelloweye have been counted in full for each skate. For model fitting, skates for which no yelloweye were retained were discarded from CPUE consideration under the assumption that they were set over Pacific halibut habitat unsuitable for rockfish, and only stations shown to be located over suitable rocky habitat were analyzed. IPHC CPUE was expressed as numbers of yelloweye per hook.

Commercial fisheries

Catch-per-effort data for the directed commercial fishery, expressed as total pounds of rockfish per hook, were taken from logbook entries and fish tickets. A linear mixed-effects model was used to fit the pounds of yelloweye rockfish caught to hook spacing, average depth fished, and number of boats participating in the fishery, factored by year, management area, and specific vessel (to account for relative experience levels).

CPUE for both the directed fishery and the IPHC survey was calculated as the ratio of catch to standardized effort for each reported set for a given vessel, for each management area in a given year.

Model years and management areas with associated data

Data set	*Years available*
Directed total annual fishery catch:	1985-2004, 2012, 2013
CSEO	1985- 2004, 2008 – 2012, 2013
SSEO	1985, 1987-2001, 2004-2005, 2008-2009, 2012, 2014

EYKT	
Directed fishery age composition:	1988, 1992 – 2004, 2012, 2013
CSEO	1991 – 2005, 2009 – 2013
	1992 – 2001, 2004 – 2005, 2008 – 2009, 2012, 2013
SSEO	
EYKT	
Pacific halibut longline fishery total annual incidental catch	1985 – 2014 for all management areas
Pacific halibut incidental catch fishery	2008 - 2011
CSEO	None
age-composition	2010 - 2011
SSEO	
EYKT	
Directed DSR fishery CPUE	As for total annual catch
IPHC survey CPUE	1998 – 2014 for all management areas
Recreational fishery total annual catch	2006 - 2013
Submersible /ROV survey density:	1995, 1997, 2003, 2007, 2012
CSEO	1999, 2005, 2013
	1995,1997, 1999, 2003, 2009, 2015
SSEO	
EYKT	

Each management area (EYKT, CSEO, SSEO) was considered a distinct population, with recruitment, mortality, fishery removals, Pacific halibut longline fishery incidental catch, survey density estimates, and estimates of suitable rockfish habitat specific to each area. Length-weight-age keys and maturity-at-age were assumed the same for all areas, estimated external to the model. Selectivity-at-age was estimated for each area for the combined directed commercial longline fishery and incidental catch in the directed Pacific halibut longline fishery. Males and females were separated only for the calculation of female spawning biomass and female maturity-at-age. NSEO was not modeled due to the paucity of the data available and small geographic size.

Analytic approach

Model structure

Standard age-structured population dynamics equations (Quinn and Deriso 1999) were used to model yelloweye rockfish in SEO waters using AD Model Builder (Fournier et al. 2011) (BOX 1). Modeled age classes ran from 8 – 97, with 8 being the age of recruitment (the youngest age observed in commercial fisheries data), and 97 being a plus class. Recruitment and initial abundances in Year 1 were estimated as deviations from respective mean value. Model estimates included spawning biomass, recruitment, abundance-at-age, commercial catch, incidental catch in the commercial longline Pacific halibut fishery, recreational catch, CPUE for both the commercial fishery and the IPHC Pacific halibut longline survey, and density (number of individual per square kilometer) for each management area.

Density

Although the line transect surveys count all observed yelloweye, density calculations are completed in DISTANCE 6.0 only for adults and sub-adults, omitting juveniles. The distinction between juvenile and sub-adult classification is based on assessment of changes in coloring and morphology that occur as a fish ages. The ROV surveys provided the opportunity to measure yelloweye lengths via the stereo cameras, allowing for construction of a classification-at-age curve which was used to scale model estimates of total abundance to model estimates of adult and sub-adult density. Estimates of maturity-at-age and suitable rockfish habitat for each management area in square kilometers were assumed known without error. As survey density scales model estimates of absolute abundance, catchability for the submersible and ROV line transects was set to one, with the assumption that catchability and detection are equivalent and that the line-transect sampling analysis produced by DISTANCE 6.0 is complete.

Catch-at-age

Catch-at-age for each management area was a function of the Baranov catch equation, with fishing mortality-at-age *a* in year *y* $F_{y,a}$ the product of an asymptotically increasing selectivity-at-age f_a and a full-recruitment fishing mortality term F_y (BOX 1). Selectivity-at-age f_a in the recreational fishery was assumed the same as for the combined directed commercial fishery and incidental catch in the Pacific halibut fishery.

Spawning biomass

For each management area, female spawning biomass for a given year *y* was estimated under the assumption of equal male/female proportions (BOX 2). Yelloweye have internal fertilization and potentially extended periods of parturition; for convenience, it was assumed that parturition occurs in May, following O'Connell (1987).

CPUE

For each year and management area, CPUE was modeled as the mean ratio of pounds caught per hook per area per year for the directed commercial fishery, or mean ratio of numbers caught per hook in the IPHC longline survey.

Selectivity-at-age

Selectivity vectors were estimated for each management area as:

$$f_a = \frac{1}{1 + e^{-slope*age_{50}}}$$

for which age_{50} is the age at which 50% of the population is selected into the fishery, *slope* is the slope of the sigmoid curve at the age_{50} point.

Natural Mortality

The baseline models had an input natural mortality of 0.026, which is the Tier 4 management assumption. Efforts were also made to estimate natural mortality either as a model parameter or as a random walk from an estimated starting value in Year 1. For model years *y* 1 through 30, the random walk for natural mortality was modeled as

if (y = 1) $M_{\mathrm{y}} = M_1$

if (y > 1) $M_{\mathrm{y}} = M_{\mathrm{y}-1} e^{delta_{\mathrm{y}-1}}$

for which M_1 was a model parameter, and *delta* is the random walk vector.

The test model in which the random walk was implemented had two additional two penalties that are defined in the ***Penalties*** section below

Parameter estimation

Model parameters were estimated by minimizing the sum of penalized negative log-likelihood objective functions and penalties (BOX 3 and below). Log-normal likelihoods were assumed for total annual combined catch, recreational catch, and density for each management area. Multinomial likelihoods were assumed for age composition data. Penalties were implemented for deviations in full-recruitment fishing mortality F, recruitment, and initial abundances in Year 1 to facilitate scaling and parameter estimation (BOX 3 and below).

Total estimated parameters for each management area

Parameter	
1) mean recruitment	1
2) annual recruitment deviations	30
3) initial mean population, year 1	1
4) age-specific year 1 deviations	90
5) annual fishing mortality deviations for the combined directed fishery and Pacific halibut fishery incidental catch	30
6) annual fishing mortality deviations for recreational catch	8
7) additional variance for ADF&G survey likelihood	1
8) Selectivity and CPUE parameters	4
Total	165

Revised likelihood forms

Total Annual Catch (combined fishery and incidental catch; recreational catch)

$$L = 0.5\ln(2\pi) + \ln(\sigma_{catch}) + 0.5\frac{(\ln(obs\_catch) - \ln(pred\_catch))^2}{2\sigma_{catch}^2}$$

$\sigma_{catch} = 0.05$ for all fisheries.

Submersible and ROV density surveys

$$L = 0.5\ln(2\pi) + \ln(\sigma_{density} + \sigma_{extra}) + 0.5\frac{(\ln(obs\_density) - \ln(pred\_density))^2}{2(\sigma_{density}^2 + \sigma_{extra}^2)}$$

$\sigma_{density}$ = the logarithm of the DISTANCE-estimated normal-distribution variance $\sigma_{DISTANCE}$ as

$$\log\left(1+\frac{\sigma_{DISTANCE}}{obs\_density^{\wedge}2}\right)$$

σ_{extra} is a model-estimated parameter.

CPUE (both directed fishery and IPHC longline survey)

$$L = 0.5\ln(2\pi) + \ln(\sigma_{CPUE}) + 0.5\frac{(\ln(obs\_CPUE) - \ln(pred\_CPUE))^2}{2(\sigma_{CPUE}^2)}$$

σ_{CPUE} = the logarithm of the normally-distributed CPUE variance σ_{CPUE} as

$$\log\left(1+\frac{\sigma_{CPUE}}{obs\_CPUE^{\wedge}2}\right)$$

Penalties

Full-recruitment fishing mortality (combined directed fishery and incidental catch; not implemented for recreational catch)

$$P_1 = 0.5\ln(2\pi) + \ln(\sigma_F) + 0.5\frac{(F_{devs})^2}{2\sigma_F^2}$$

σ_F was set to 1 prior to the final model phase to improve model stability; during the final model phase, it was set to 2 to ensure full exploration of the parameter space.

Recruitment

$$P_2 = 0.5\frac{(rec_{devs} + \sigma_r^2)^2}{2\sigma_r^2} + number\_of\_years * \ln(\sigma_r)$$

σ_r is set to 1. The form of the penalty implements a bias-correction after Methot and Taylor (2011).

Initial Year 1 abundance-at-age

$$P_2 = 0.5\frac{(y1_{devs} + \sigma_{y1}^2)^2}{2\sigma_{y1}^2} + number\_of\_ages * \ln(\sigma_{y1})$$

σ_{y1} is a model-estimated parameter. The form of the penalty implements a bias-correction after Methot and Taylor (2011).

Random-walk natural mortality

For the initial mortality M_1 in Year 1:

$$P_5 = 0.5\ln(2\pi) + \ln(\sigma_{M1}) + 0.5\frac{(M_1 - M_0)^2}{2(\sigma_{M1}^2)}$$

σ_{M1} was set to 0.01, and M_0 was set to the Tier 4 assumption that M = 0.026.
For natural mortality in all other model years:

$$P_4 = \ln(\sigma_m) + 0.5\frac{\sum_{y=2}^{30}(delta)^2}{2\sigma_m^2}$$

σ_m was set to 0.3.

Externally estimated parameters

Life history attributes were estimated externally from data collected through port sampling of commercial fisheries catches from 1992 - 2013. These were assumed constant over all areas and years, and include:

- Weight-at-age
- Maturity-at-age
- Age-error matrix

Weight-at-age (kilograms)

Mean weight-at-age W was estimated by fitting observed weights-at-age to the equation

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

for which W_t = weight at time t (age), W_∞ = asymptotic weight, t_0 = the time (age) at which an individual is considered to have weight 0, and k = growth rate. Mean weight-at-age was assumed consistent across all management areas and equivalent between males and females (Fig. 4).

W_∞	k	t_0
6.027	0.039	-10.13

Maturity-at-age

Proportions mature-at-age m_a were calculated for females only, fitting observed maturity-at-age to the equation:

$$m_a = \frac{mat_\infty}{1 + \exp(-slope * (age - mat_{50\%}))}$$

for which $mat_{50\%}$ is the age at which 50% of the population is reproductively mature, *slope* is the slope of the sigmoid curve at the $mat_{50\%}$ point, and mat_∞ = asymptotic maturity.

slope	$mat_{50\%}$
-0.341	17.634

Age-error matrix

The age-error matrix defines the probability of correctly aging a fish based on otolith analysis. Earlier models used a matrix constructed by Dana Hanselman (Auke Bay Lab, National Marine Fisheries Service (NMFS)) that used NMFS age-reader data instead of the ADF&G Age Determination Unit (ADU). For this model iteration, a new matrix was constructed using ADU reader data and a set of R/ADMB scripts from Pete Hulson, Auke Bay Lab.

Model Results

The changes implemented since the September Plan Team improved model function while reducing the number of estimated parameters and applied parameter constraints.

Model fits to ROV and submersible estimates of area-specific yelloweye rockfish per square kilometer are presented in Figs. 1 – 3. Trends generally follow Dicamptodon 13.1c for which M = 0.02 or 0.03, although absolute abundance has increased. Including the additional variance term in the density likelihood increased model uncertainty.

Spawning biomass trends appear steady or slightly increasing in EYKT (Figures 4 – 6), somewhat in contrast to the declining trends in overall density.

Variability in annual recruitment (Figures 7 – 12) was constrained by setting σ_r to 1; experiments in estimating σ_r required such narrow limits that it was better to set the value.

Variability in Year 1 initial abundance σ_1 appeared to be estimable with no additional penalties, and was close to 1 for all regions (below).

Catchability q for both the commercial fishery and the IPHC longline survey was highly reduced from the September model estimates, although this was likely due more to the replacement of the Box-Cox transformations with simple CPUE forms than to the increased biomass in the current model structure. Estimates of fishery CPUE and IPHC longline survey CPUE continue to fit general trends without being responsive to any specific point (Figures 13 – 18); the increased uncertainty from the change to the density likelihood can also be seen in these figures.

	CSEO	EYKT	SSEO
q (commercial fisheries)	0.00009	0.00014	0.00017
q (iphc survey)	0.00048	0.00004	0.00004
σ_1	0.928	0.913	0.952
σ_{extra}	0.0904	0.0493	0.005

Selectivity-at-age vectors for all regions appeared reasonable (Figure 19) and did not appear to be affected by combining the directed commercial fishery with the incidental catch from the directed Pacific halibut fishery.

Natural Mortality

Efforts to estimate a single natural mortality parameter for each region were generally unproductive, requiring extremely narrow limits on potential parameter values, relegating it to little more than an input value.

Experiments with implementing a random walk for natural mortality were somewhat more successful. Figures 19 – 21 show values for the random walk in EYKT relative to input natural mortality, with a comparison of density and spawning biomass estimates from the baseline model and the random walk configuration.

Discussion

The modified likelihoods markedly improved model performance and stability without the previously implemented penalties or parameter constraints. The Plan Team recommended setting natural mortality to reasonable and acceptable levels, and the author has implemented this for each regional model. Improved model stability may allow the assumption of a fixed natural mortality to be relaxed and explore whether the data are able to inform an appropriate estimate. Natural mortality has a considerable effect on model output. Fixing *M* to a set value severely limits the range of possible model outcomes, especially for such a long-lived species. The author would like to explore this further in future model revisions.

Generally speaking, no correlations between recruitment and age-composition data were observed in CSEO and SSEO. In EYKT, however, increased recruitment in 1994 and 1995 appeared to be driven by an abundance of fish ages 18 - 22 observed in the commercial fishery and Pacific halibut fishery incidental catch age composition data (Figures 9 and 10). This passage of strong cohorts through the system also provides a context for the apparent contradiction in EYKT of declining density (Figure 2) but increasing spawning biomass (Figure 5). It should be noted, however, that neither CSEO nor SSEO show similarly strong entry into the mature population, and without such an entry, density and biomass are anticipated to continue their observed declines.

The author looks forward to comments and suggestions from the Plan Team and SSC regarding these points and any other suggestions or recommendations for improving model performance.

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Table 1. Total annual directed commercial yelloweye catch (t) for each management district for all modeled years 1985-2014.

Year	CSEO	SSEO	EYKT	Total
1985	215.38	26.85	5.15	247.38
1986	204.82	77.74	0.00	282.56
1987	171.75	288.66	64.79	525.2
1988	127.19	211.13	39.17	377.49
1989	118.65	112.16	35.56	266.37
1990	70.22	86.02	15.69	171.93
1991	76.61	87.31	173.08	337
1992	101.11	131.41	46.92	279.44
1993	122.17	62.72	87.48	272.37
1994	128.32	72.57	110.38	311.27
1995	73.61	22.69	46.12	142.42
1996	162.25	62.94	95.86	321.05
1997	136.15	49.62	63.51	249.28
1998	110.44	50.17	64.44	225.05
1999	97.78	57.46	72.55	227.79
2000	58.74	58.94	55.59	173.27
2001	58.94	56.52	48.91	164.37
2002	70.89	57.02	0.00	127.91
2003	57.99	36.33	0.00	94.32
2004	55.51	23.71	86.88	166.1
2005	0.00	0.00	41.90	41.9
2006	0.00	0.00	0.00	0
2007	0.00	0.00	0.00	0
2008	0.00	19.70	21.72	41.42
2009	0.00	29.28	44.40	73.68
2010	0.00	28.49	0.00	28.49
2011	0.00	21.39	0.00	21.39
2012	31.05	31.99	35.99	99.03
2013	35.69	5.27	36.64	77.6
2014	0	0	32.5	32.5

Table 2. Total annual yelloweye incidental catch (t) in the commercial longline Pacific halibut fishery for each management district for all modeled years 1985-2014.

Year	CSEO	SSEO	EYKT	Total
1985	7.61	0.67	1.49	9.77
1986	4.28	0.92	0.27	5.47
1987	4.52	2.14	1.33	7.99
1988	1.57	3.09	0.11	4.77
1989	22.65	23.59	5.73	51.97
1990	13.01	29.97	5.08	48.06
1991	24.65	11.97	17.59	54.21
1992	43.81	22.30	16.48	82.59
1993	73.91	36.19	11.21	121.31
1994	103.13	44.80	14.61	162.54
1995	34.32	6.68	11.03	52.03
1996	28.18	8.63	14.09	50.9
1997	45.95	6.86	22.79	75.6
1998	49.54	10.20	35.26	95
1999	44.97	13.97	33.40	92.34
2000	40.20	14.37	24.61	79.18
2001	55.73	23.92	34.00	113.65
2002	56.06	23.10	34.97	114.13
2003	56.61	27.09	47.12	130.82
2004	47.17	32.72	45.76	125.65
2005	59.02	47.42	53.14	159.58
2006	67.03	54.17	39.16	160.36
2007	66.42	43.05	54.39	163.86
2008	48.61	26.08	46.73	121.42
2009	41.08	27.08	52.82	120.98
2010	32.54	23.32	57.02	112.88
2011	24.86	7.34	44.24	76.44
2012	20.18	9.96	33.69	63.83
2013	26.23	10.09	33.56	69.88
2014	22.4	6.3	19.7	48.4

Table 3. Total annual yelloweye recreational catch (t) for each management district for 2006 – 2013.

Year	CSEO	SSEO	EYKT	Total
2006	36.973	21.859	0.804	59.636
2007	50.687	18.484	0.270	69.441
2008	34.829	12.313	0.399	47.541
2009	7.825	7.406	0.002	15.233
2010	28.605	9.666	0.004	38.275
2011	16.160	5.820	0.004	21.984
2012	20.665	7.707	0.011	28.383
2013	14.147	7.135	0.001	21.283

Table 4. Submersible (1995, 1997, 1999, 2003, 2005, 2007, 2009) and ROV (2012–2015) yelloweye rockfish density estimates with 95% confidence intervals (CI) and coefficient of variations (CV) by year and management area. The number of transects, yelloweye rockfish (YE), and meters surveyed included in each model are shown, along with the encounter rate of yelloweye rockfish. Values in bold were used for this stock assessment. (Table adapted from Green at al. 2015).

Area	Year	Area (km^2)	# YE[b]	Meters surveyed	Encounter rate (YE/m)	Density (YE/km^2)	Lower CI (YE/km^2)	Upper CI (YE/km^2)	CV
EYKT[a]	1995	744	330	22,896	0.014	2,711	1,776	4,141	0.20
	1997		350	19,240	0.018	2,576	1,459	4,549	0.28
	1999		236	25,198	0.009	1,584	1,092	2,298	0.18
	2003		335	17,878	0.019	3,825	2,702	5,415	0.17
	2009		215	29,890	0.007	1,930	1,389	2,682	0.17
	2015		**251**	**22,896**	**0.008**	**1,755**	**1,065**	**2,176**	**0.25**
CSEO	1995	1404	235	39,368	0.006	2,929			0.19
	1997		260	29,273	0.009	1,631	1,224	2,173	0.14
	2003		726	91,285	0.008	1,853	1,516	2,264	0.10
	2007		301	55,640	0.005	1,050	830	1,327	0.12
	2012		**118**	**38,590**	**0.003**	**752**	**586**	**9,66**	**0.13**
SSEO	1999	732	360	41,333	0.009	2,376	1,615	3,494	0.20
	2005		276	28,931	0.010	2,357	1,634	3,401	0.18
	2013		**118**	**30,439**	**0.004**	**986**	**641**	**1,517**	**0.22**

[a] Estimates for EYKT management area include only the Fairweather grounds, which is composed of a west and an east bank. In 1997, only 2 of 20 transects and in 1999, no transects were performed on the east bank that were used in the model. In other years, transects performed on both the east and west bank were used in the model.

[b] Subadult and adult yelloweye rockfish were included in the analyses to estimate density. A few small subadult yelloweye rockfish were excluded from the 2012 model based on size; length data were only available for the ROV surveys. Data were truncated at large distances for some models; as a consequence, the number of yelloweye rockfish included in the model does not necessarily equal the total number of yelloweye rockfish observed on the transects.

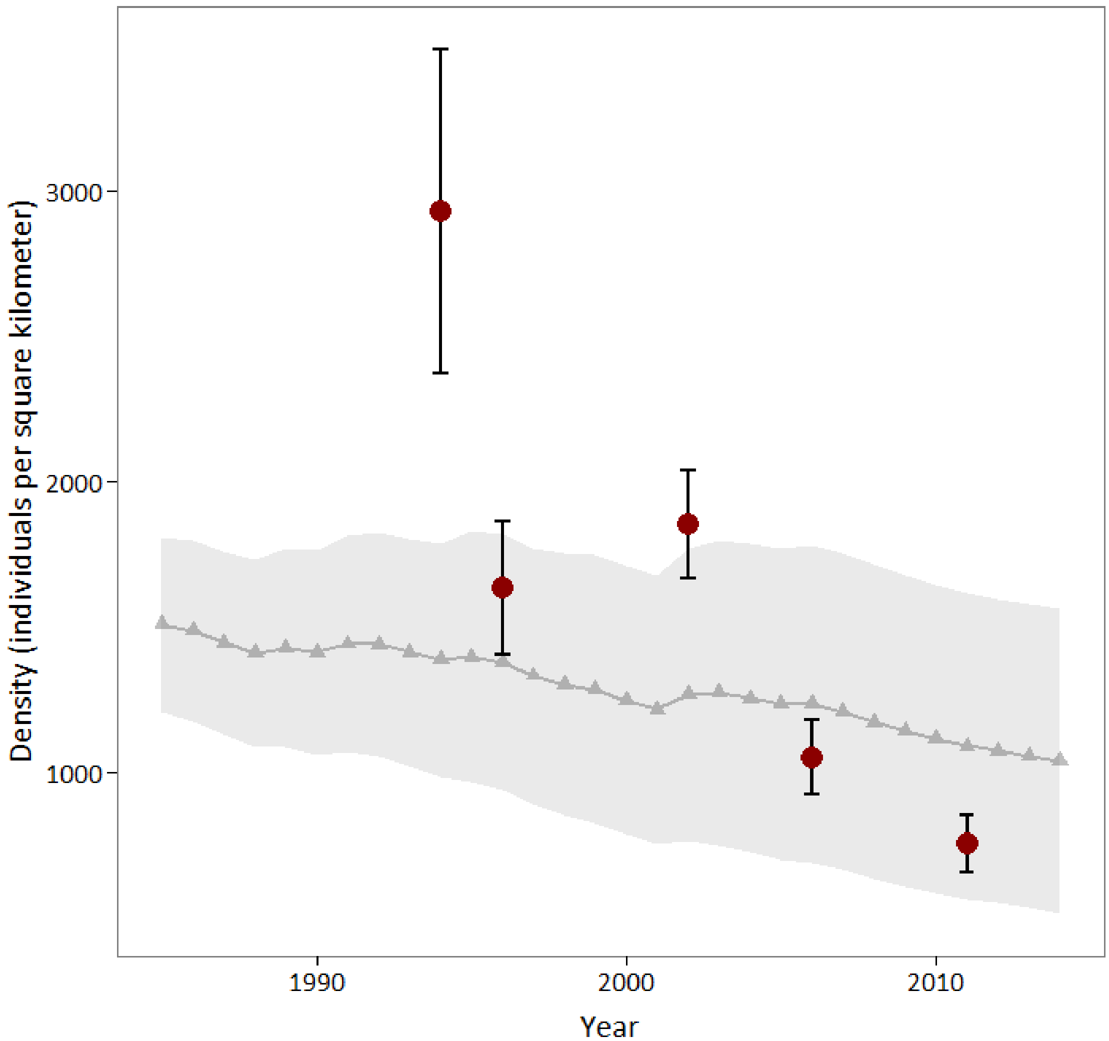

Figure 1. Model estimates of adult and subadult density +/- 2 standard deviations in Central Southeast Outside relative to Alaska Department of Fish and Game Remove Operated Vehicle and submersible survey estimates of density +/- 2 standard deviations (circles).

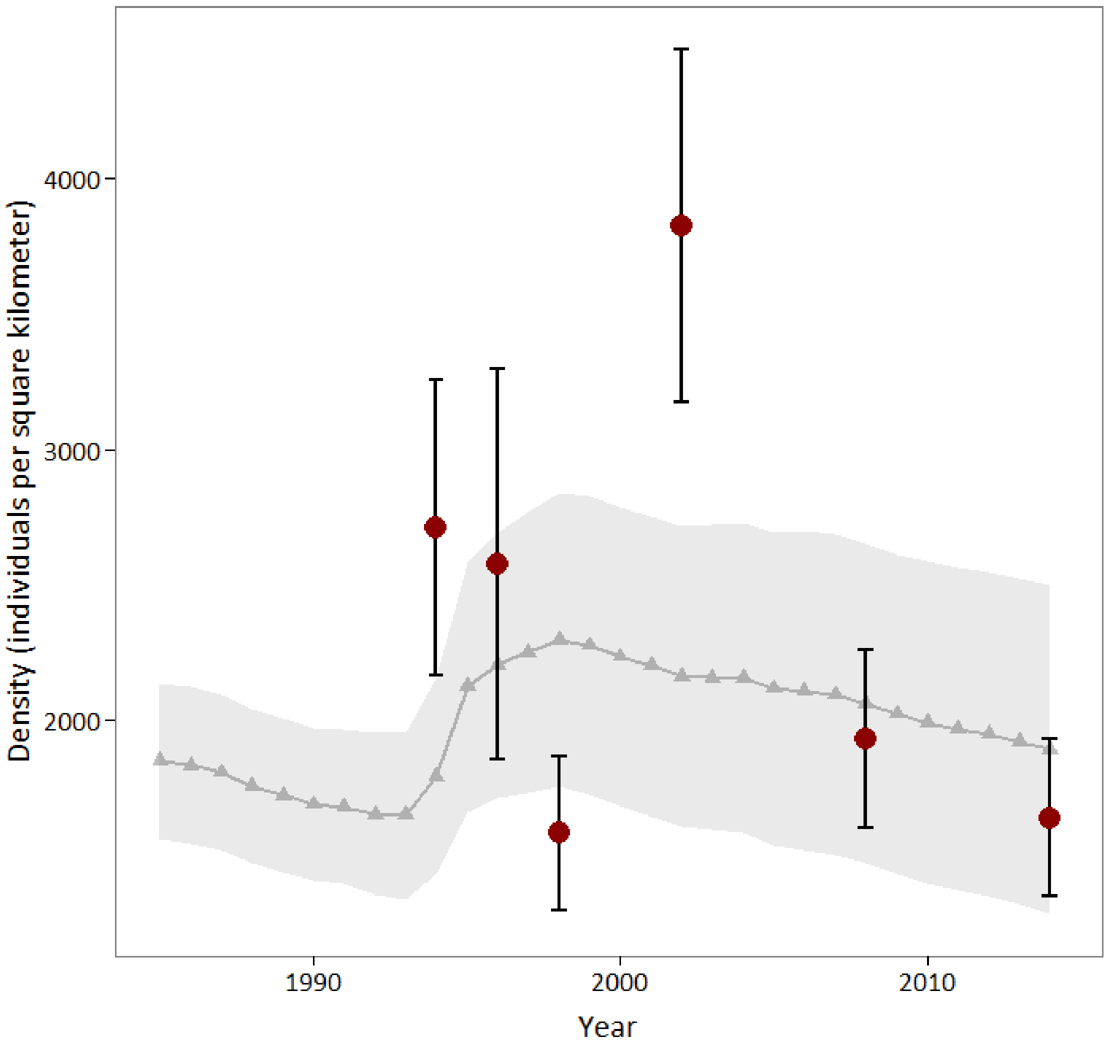

Figure 2. Model estimates of adult and subadult density +/- 2 standard deviations in East Yakutat relative to Alaska Department of Fish and Game Remove Operated Vehicles and submersible survey estimates of density +/- 2 standard deviations (circles).

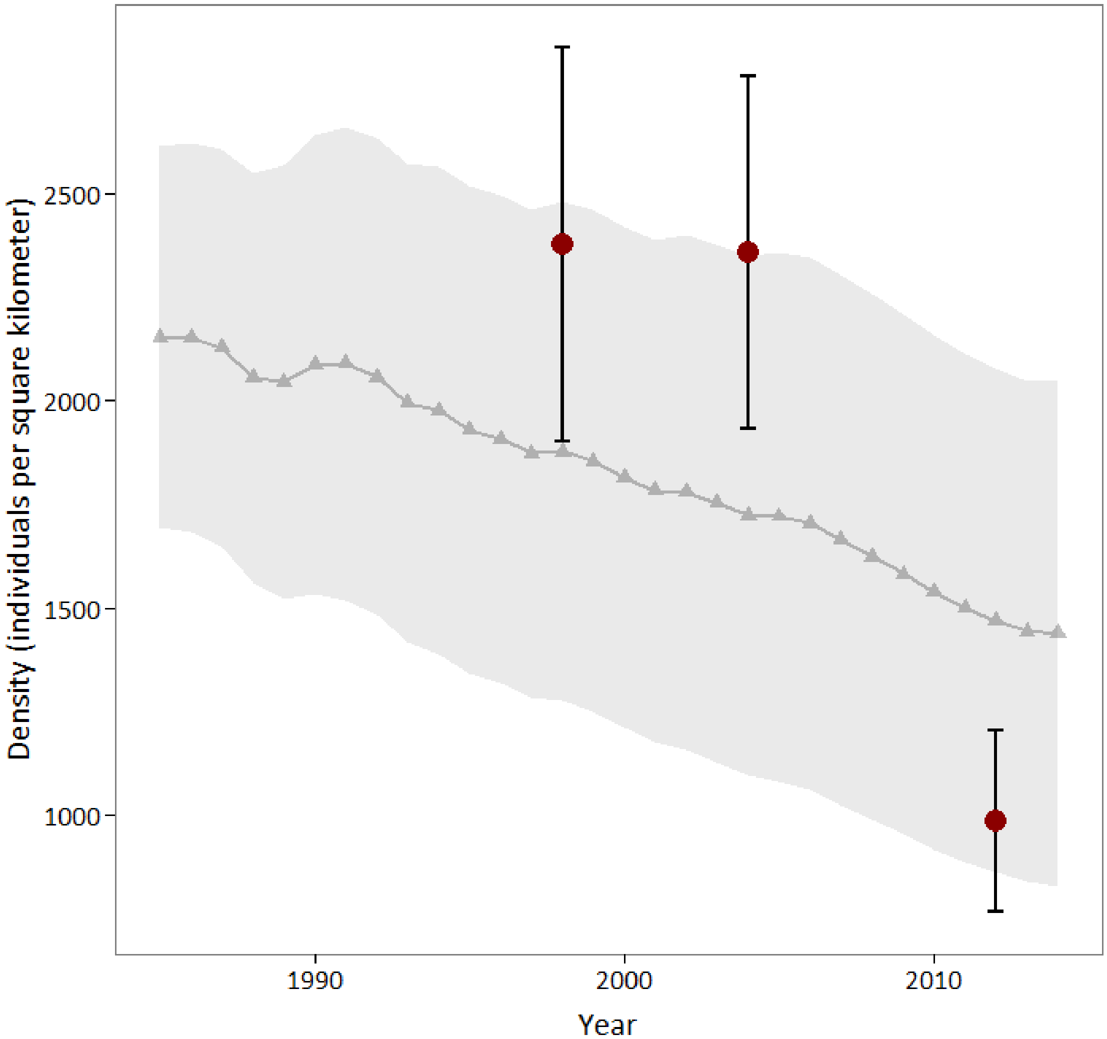

Figure 3. Model estimates of adult and subadult density +/- 2 standard deviations in Southern Southeast Outside relative to Alaska Department of Fish and Game Remove Operated Vehicle and submersible survey estimates of density +/- 2 standard deviations (circles).

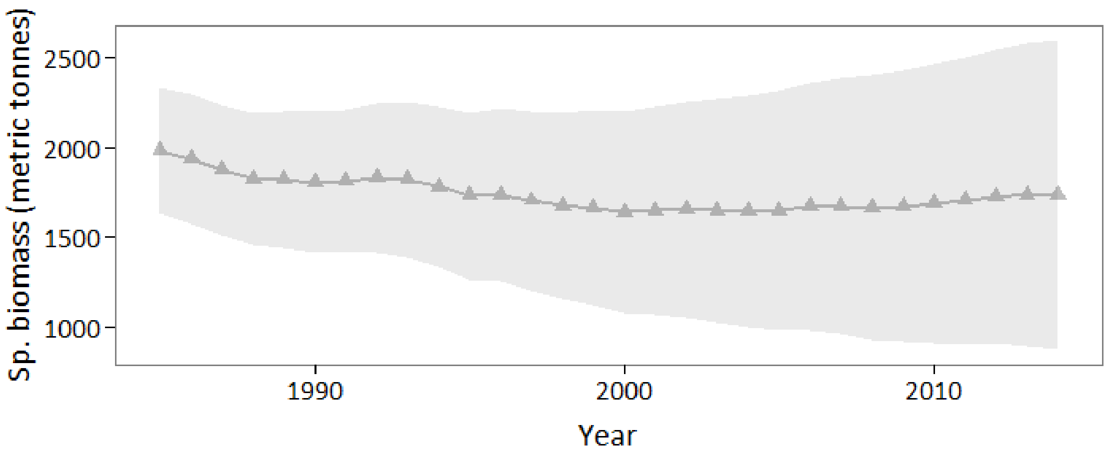

Figure 4. Model estimates of yelloweye spawning biomass +/- 2 standard deviations in Central Southeast Outside.

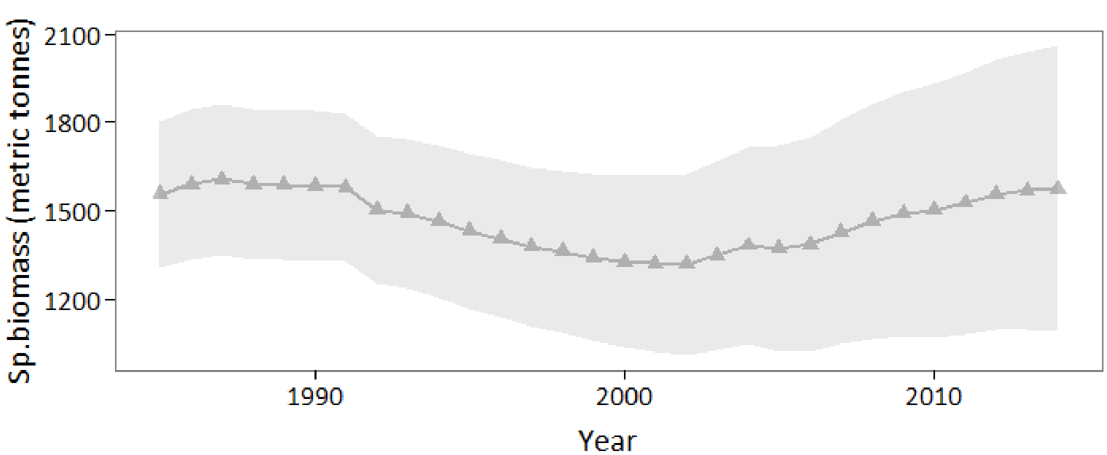

Figure 5. Model estimates of yelloweye spawning biomass +/- 2 standard deviations in East Yakutat.

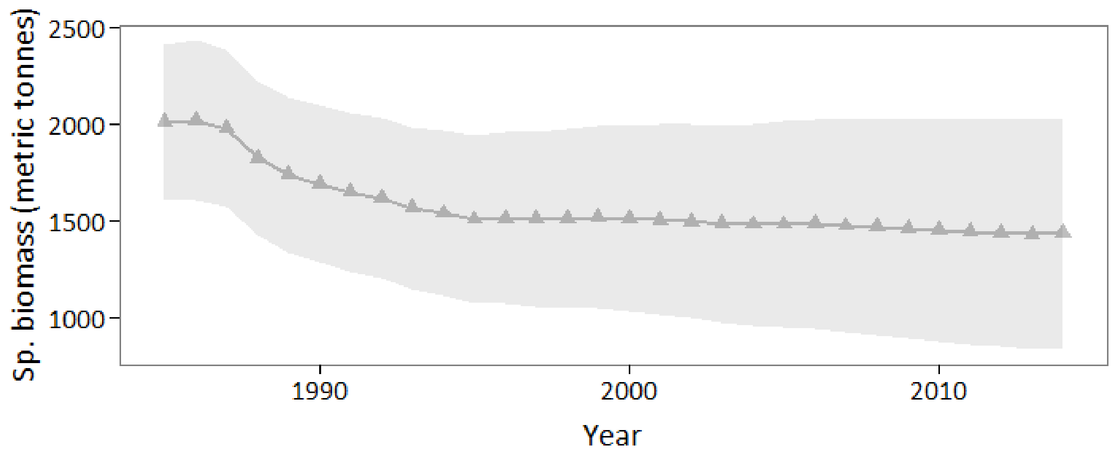

Figure 6. Model estimates of yelloweye spawning biomass +/- 2 standard deviations in Southern Southeast Outside.

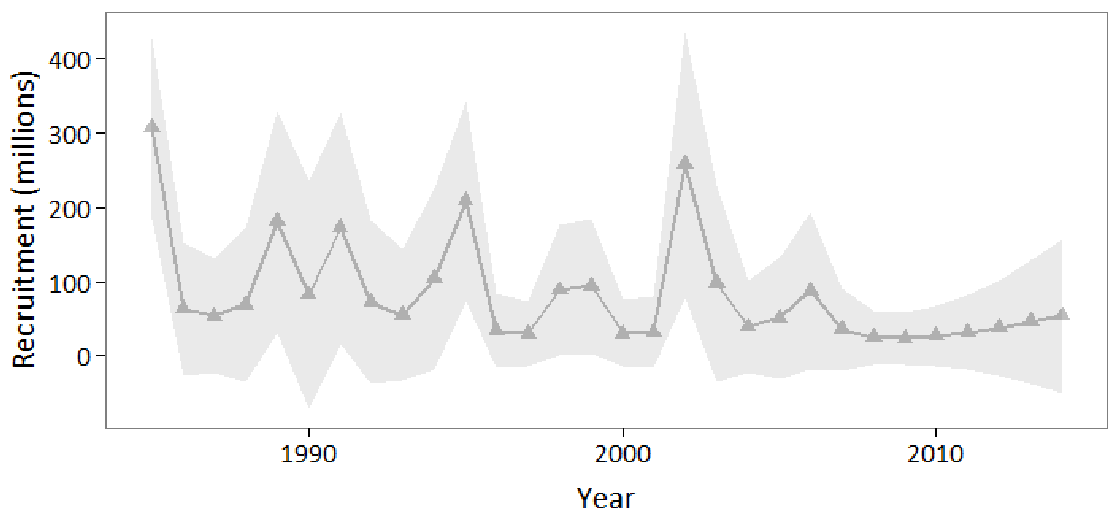

Figure 7. Model estimates of yelloweye recruitment +/- 2 standard deviations in Central Southeast Outside.

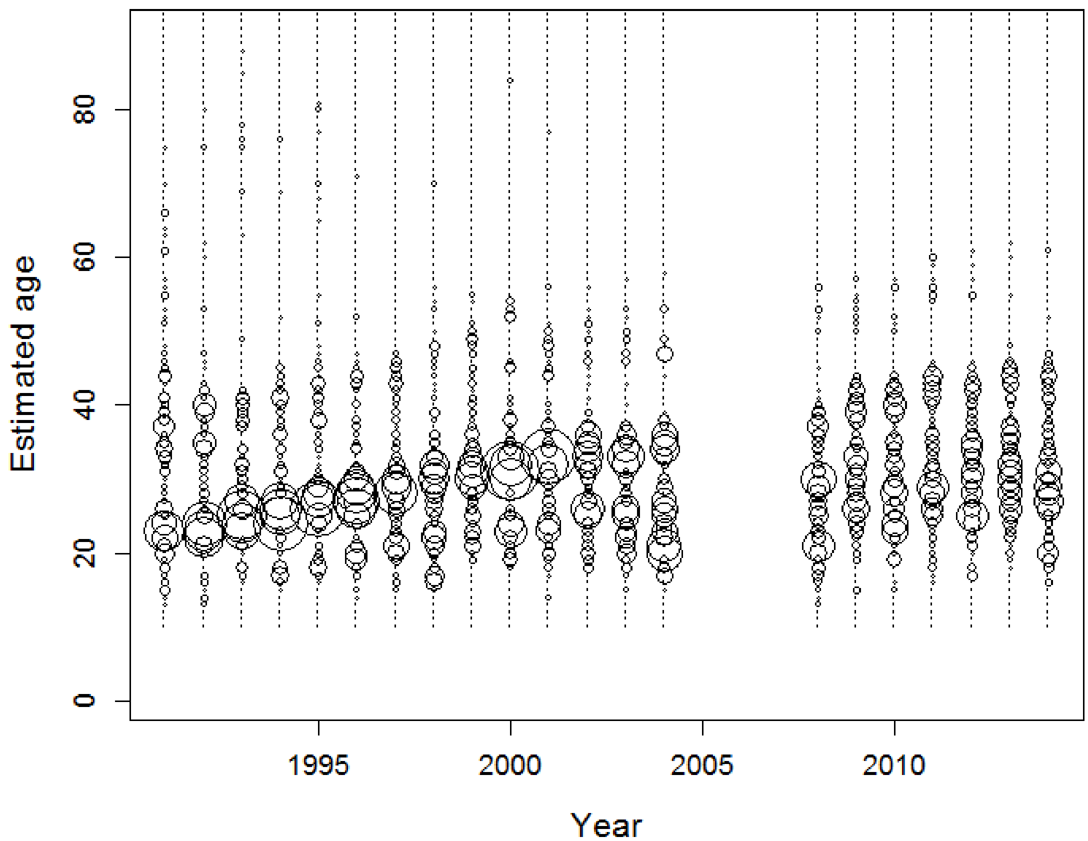

Figure 8. Observed commercial fishery (directed and incidental catch) age-composition in Central Southeast Outside.

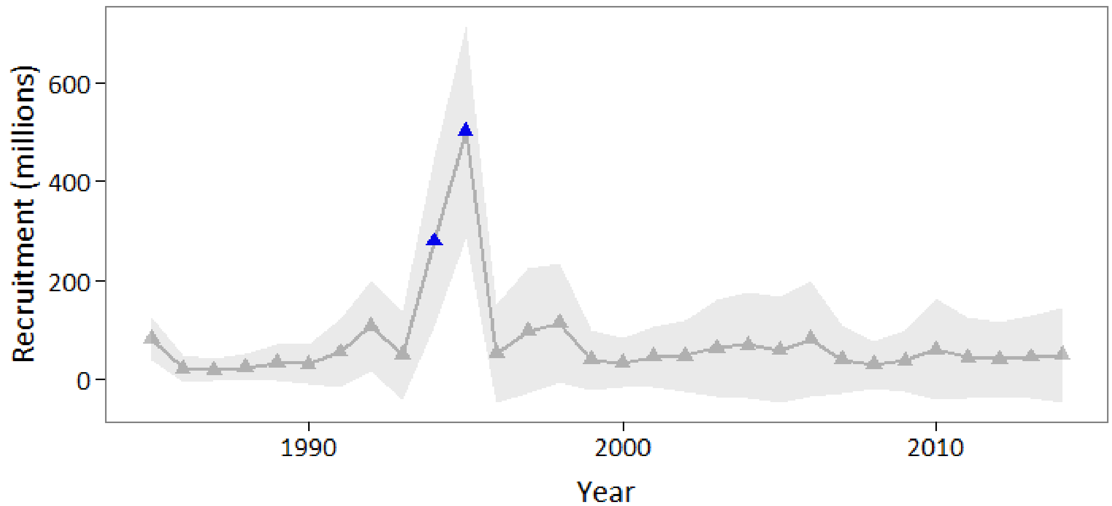

Figure 9. Model estimates of yelloweye recruitment +/- 2 standard deviations in East Yakutat.

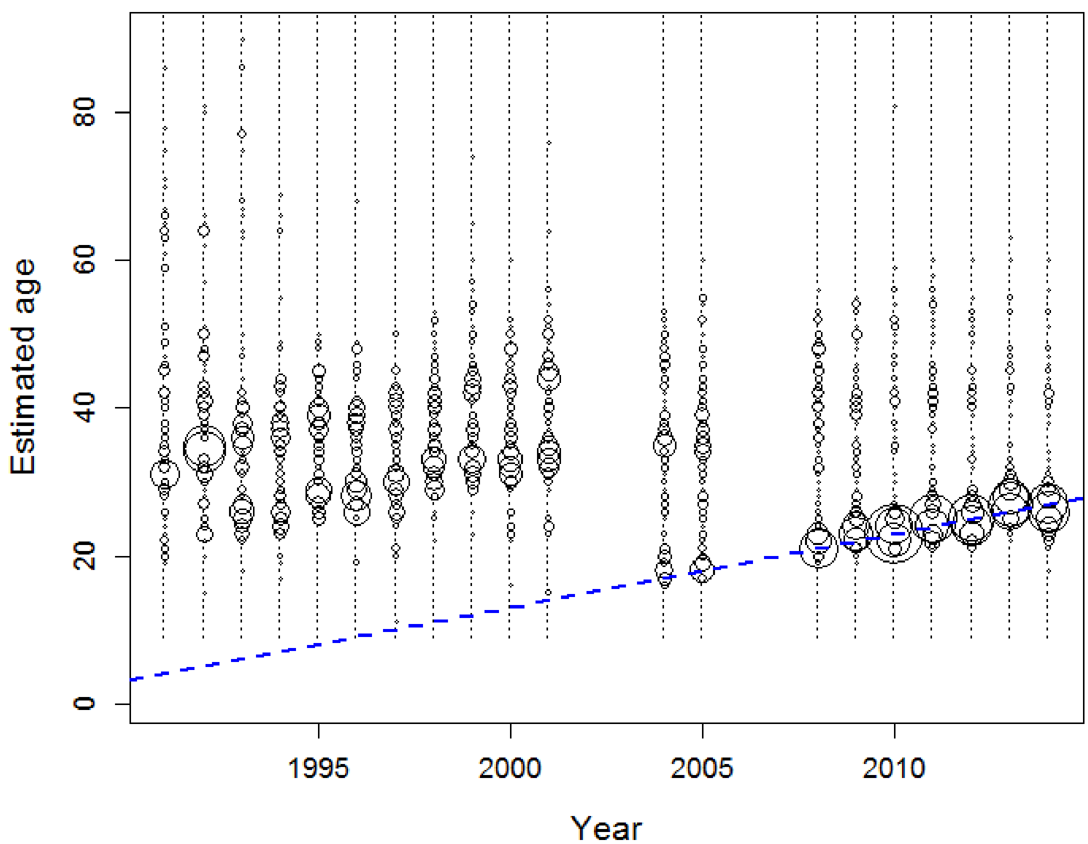

Figure 10. Observed commercial fishery (directed and incidental catch) fishery age-composition in East Yakutat.

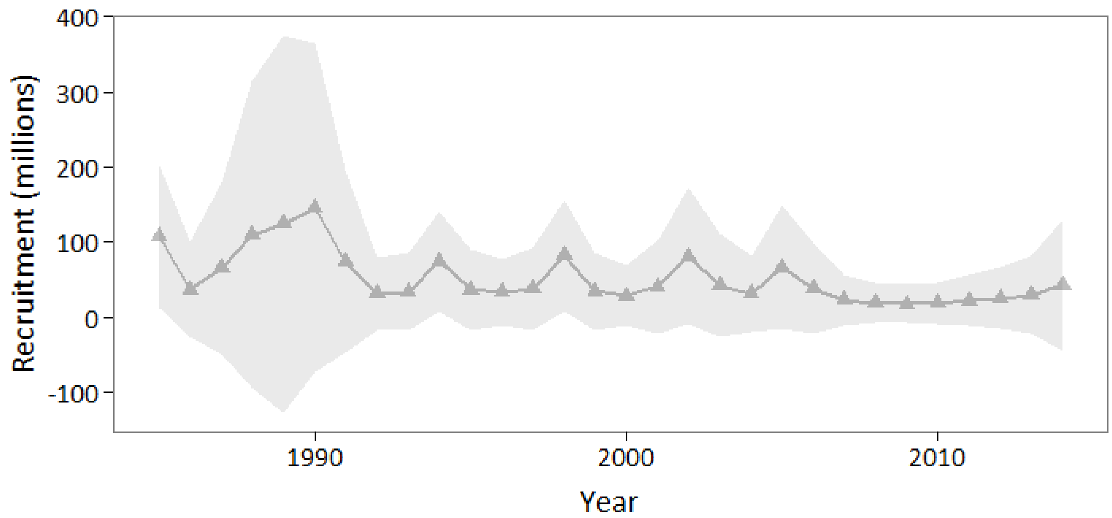

Figure 11. Model estimates of yelloweye recruitment +/- 2 standard deviations in Southern Southeast Outside.

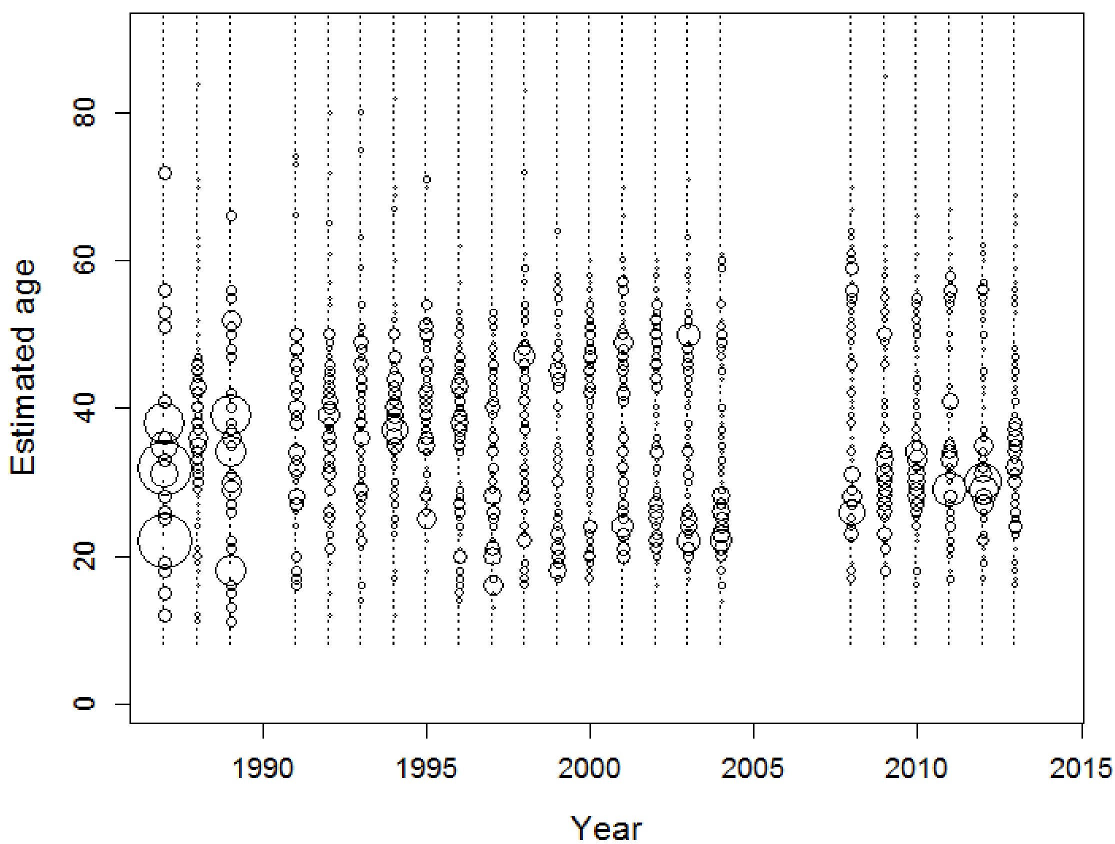

Figure 12. Model of estimates of commercial fishery (directed and incidental catch) age-composition in Southern Southeast Outside.

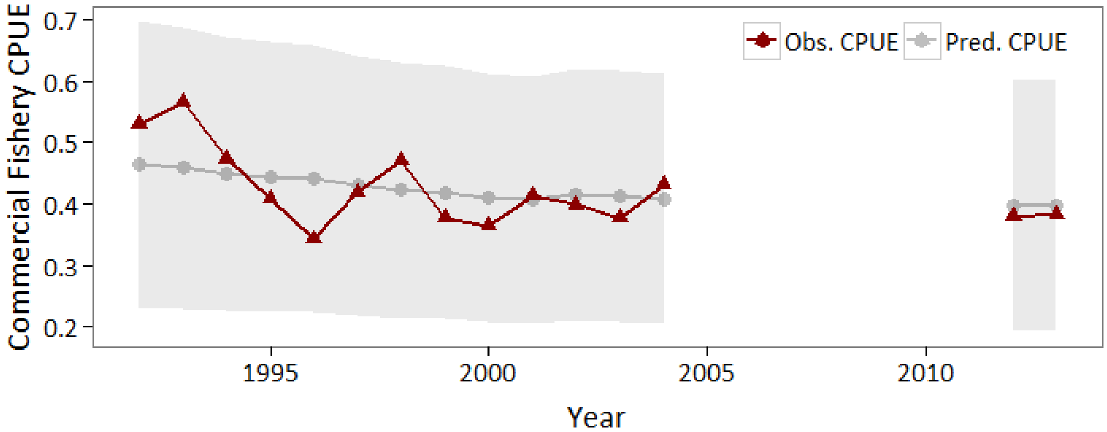

Figure 13. Model of estimates of commercial fishery CPUE lbs/hook +/- 2 standard deviations in Central Southeast Outside.

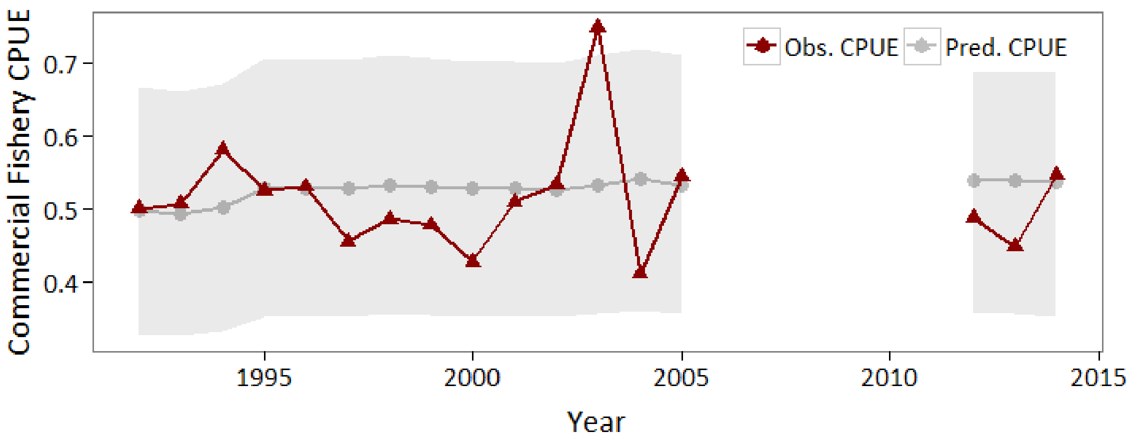

Figure 14. Model of estimates of commercial fishery CPUE in lbs/hook +/- 2 standard deviations in East Yakutat.

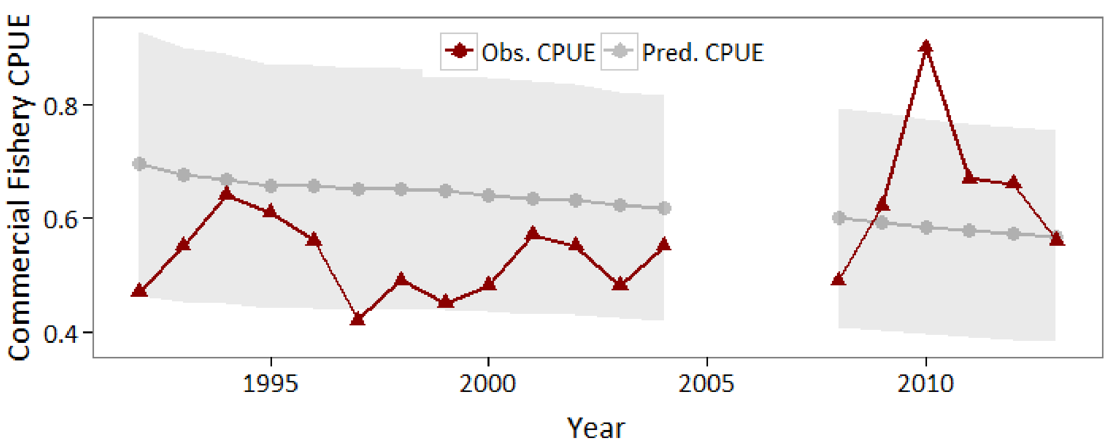

Figure 15. Model of estimates of commercial fishery CPUE lbs/hook +/- 2 standard deviations in Southern Southeast Outside.

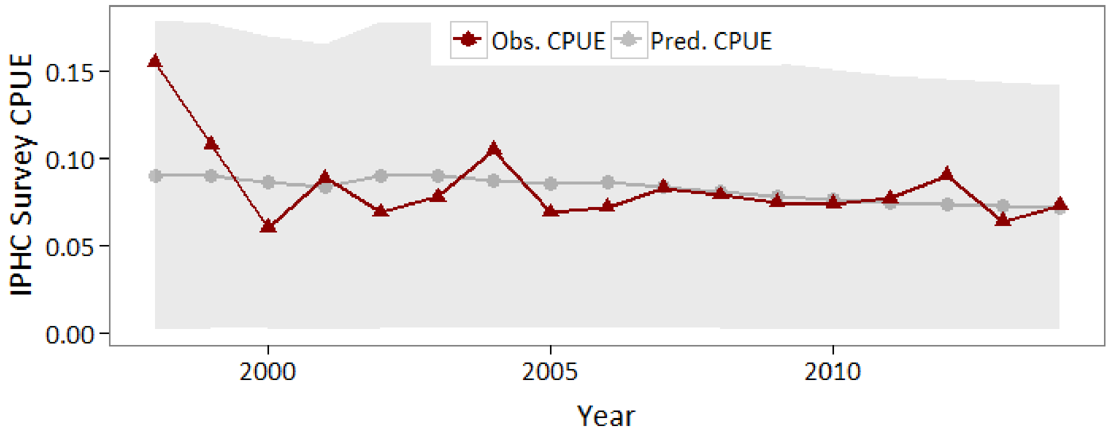

Figure 16. Model of estimates of IPHC survey CPUE fish/hook +/- 2 standard deviations in Central Southeast Outside.

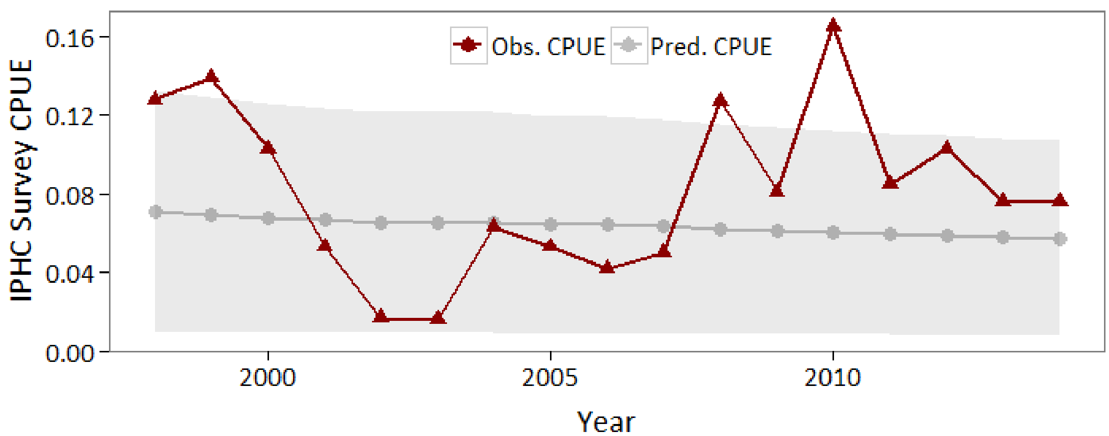

Figure 17. Model of estimates of IPHC survey CPUE fish/hook +/- 2 standard deviations in East Yakutat.

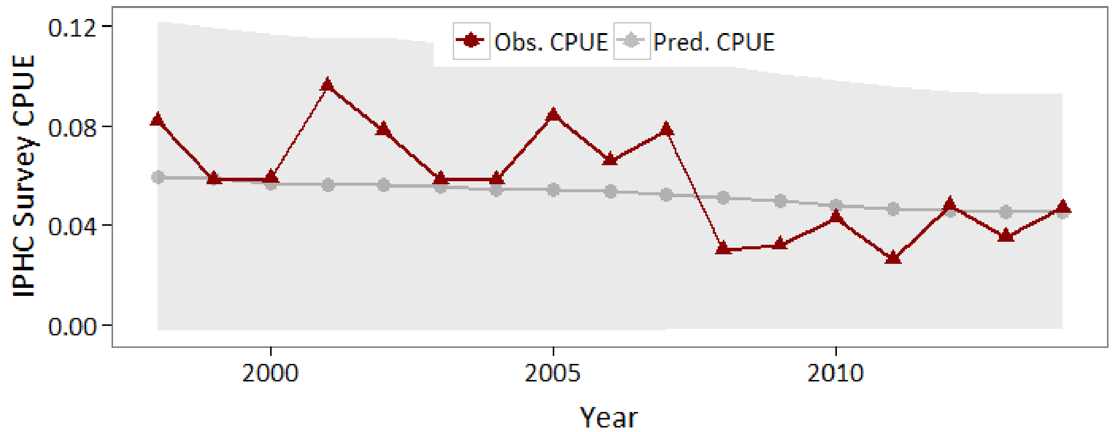

Figure 18. Model of estimates of IPHC survey CPUE fish/hook +/- 2 standard deviations in Southern Southeast Outside.

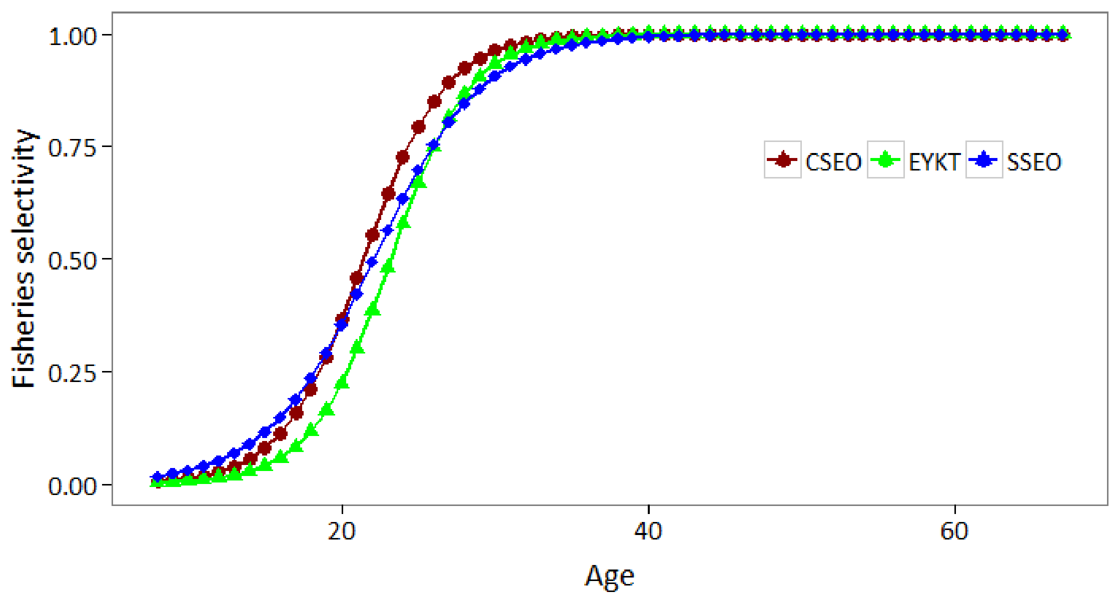

Figure 19. Fisheries selectivity-at-age (truncated at age 60) for all areas.

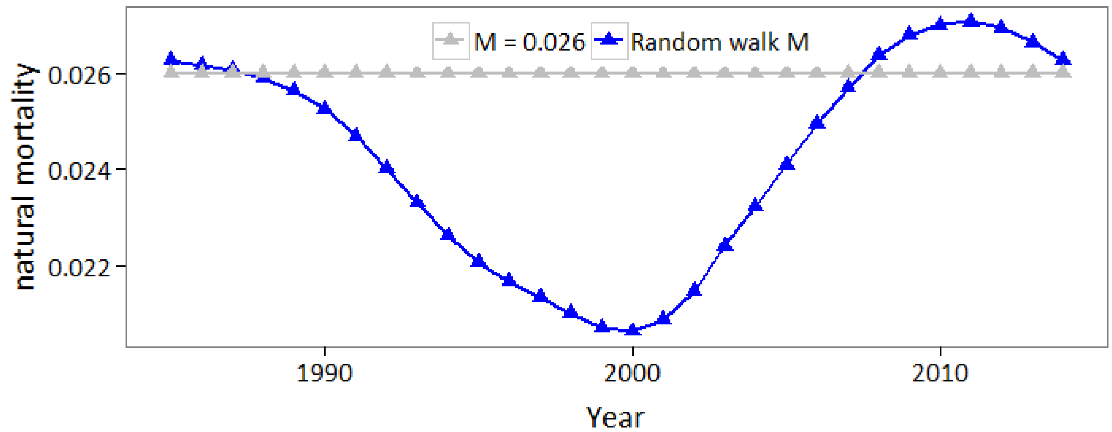

Figure 20. Random-walk-estimated natural mortality for East Yakutat compared with assumption that M = 0.026.

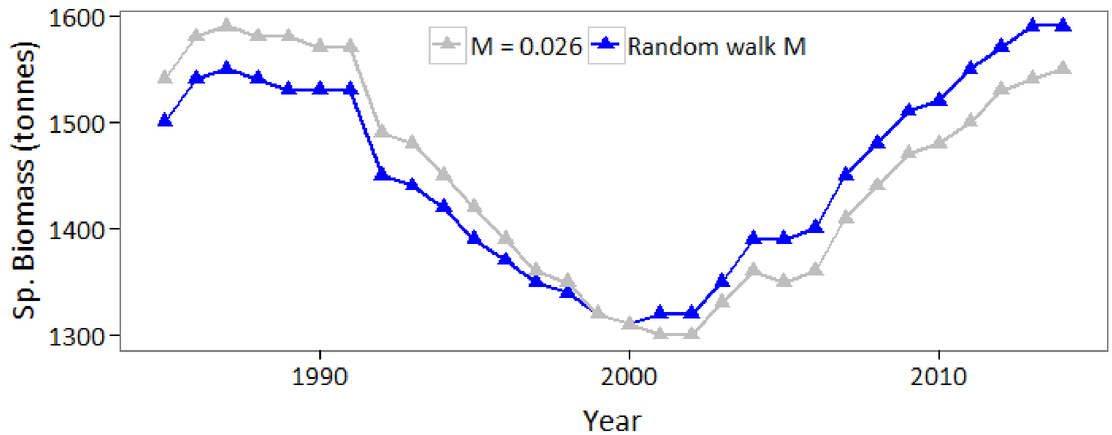

Figure 21. Comparison of spawning biomass from baseline and random-walk in East Yakutat.

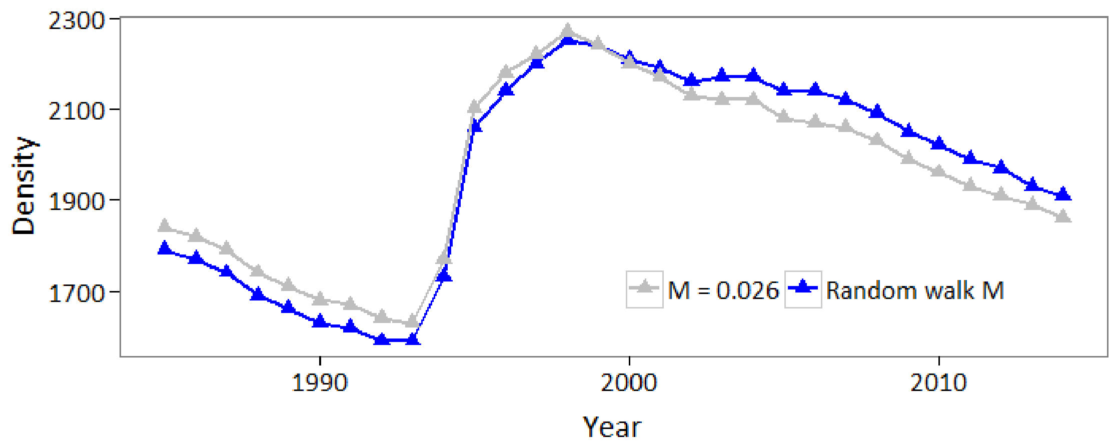

Figure 22. Comparison of density from baseline and random-walk in East Yakutat.

BOX 1: Model parameters and quantities

y	Year
a	Age classes
w_a	Vector of estimated weight-at-age, a_0 -> a_+; model input
mat_a	Vector of estimated maturity-at-age, a_0 -> a_+; model input
a_0	Age at model recruitment (8)
a_+	Plus class (ages 97+)
μ_r	Mean annual recruitment
μ_f	Mean annual full-recruitment fishing mortality (log)
ϕf_y	Annual fishing mortality deviation for directed DSR fishery
ϕs_y	Annual fishing mortality deviation for recreational removals
τ_y	Annual recruitment deviation ~ (0, σ_r)
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities-at-age for all fishery removals, a_0 -> a_+;
M	Natural mortality (set to 0.026 for all years and regions)
$F_{y,a}$	Fishing mortality by year y and age a $F_{y,a} = fs_a e^{(\mu_f + \phi f_y + \phi s_y)}$
$Z_{y,a}$	Total mortality by year y and age a ($Z_{y,a} = F_{y,a} + M$)
$S_{y,a}^{m\_s}$	Survival by year and age at the month *m_s* of the submersible /ROV survey
$S_{y,a}^{m\_sp}$	Survival by year and age at the spawning month *m_sp*
$T_{a,a'}$	Aging-error matrix

BOX 2: Population Dynamics

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * (1 - e^{-Z_{y,a}})}{Z_{y,a}} * w_a$$

Catch equation (directed yelloweye fishery and commercial longline Pacific halibut incidental catch (combined), and recreational removals)

$$\hat{D}_y = \sum_a \frac{N_{y,a} * s_{t,a}^{m\_s} * mat_a}{km^2}$$

Survey density (numbers of adults and sub-adults per km^2)

$$\hat{P}_{y,a} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition

$$\text{CPUE}_y = qB_y$$

CPUE for the directed fishery

$$\text{CPUE}_{ipch\_y} = q_{iphc} N_y$$

CPUE for the IPHC longline survey

Start year

$$N_a = \begin{cases} e^{(\mu_r + \tau_{styr})}, & a = a_0 \\ e^{(\mu_r + \tau_{styr+a_0-a})} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \dfrac{e^{\mu_r} e^{-(a-a_0)M}}{1 - e^{-M}}, & a = a_+ \end{cases}$$

Number at age of recruitment (8)
Number at ages between recruitment and plus class
Number in plus class (97+)

Subsequent years

$$N_a = \begin{cases} e^{(\mu_r + \tau_y)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}} & a = a_+ \end{cases}$$

Number at age of recruitment (8)
Number at ages between recruitment and plus class
Number in plus class (97+)

$$SB_y = \sum_{a=a_0}^{a+} N_{y,a} s_{y,a}^{m\_sp} mat_a w_a / 2$$

Annual female spawning biomass

BOX 3: Likelihood components

Combined commercial catch and halibut longline fishery incidental catch; recreational catch

$$L = 0.5\ln(2\pi) + \ln(\sigma_{\mathrm{catch}}) + 0.5\frac{(\ln(obs\_catch) - \ln(pred\_catch))^2}{2\sigma_{catch}^2}$$

Density

$$L = 0.5\ln(2\pi) + \ln(\sigma_{density} + \sigma_{extra}) + 0.5\frac{(\ln(obs\_density) - \ln(pred\_density))^2}{2(\sigma_{density}^2 + \sigma_{extra}^2)}$$

Commercial CPUE, IPHC survey CPUE

$$L = 0.5\ln(2\pi) + \ln(\sigma_{CPUE}) + 0.5\frac{(\ln(obs\_CPUE) - \ln(pred\_CPUE))^2}{2(\sigma_{\mathrm{CPUE}}^2)}\$$$

Fishery age composition (*n*$_{\mathrm{y}}$ = sample size)

$$L = \mathrm{n} * \sum_{\mathrm{a,t}} p_{a,t} \ln(\hat{p}_{a,t})$$

Penalty for year 1 abundance deviations

$$P_1 = 0.5\frac{(y1_{devs} + \sigma_{y1}^2)^2}{2\sigma_{y1}^2} + number\_of\_ages * \ln(\sigma_{\mathrm{y1}})$$

Penalty on recruitment deviations

$$P_2 = 0.5\frac{(rec_{devs} + \sigma_r^2)^2}{2\sigma_r^2} + number\_of\_years * \ln(\sigma_r)$$

Penalty on full-recruitment fishing mortality *F* deviations

$$P_3 = 0.5\ln(2\pi) + \ln(\sigma_F) + 0.5\frac{(F_{devs})^2}{2\sigma_F^2}$$

Appendix C. Catch data for Tier 6 calculations for non-yelloweye demersal shelf rockfish (DSR). These catch data represent for each species, the highest year (maximum sum) of commercial, subsistence, and recreational catch during 2010–2014. The 2010–2014 time period is used because the three time series (commercial, recreational, and subsistence) of catch data overlap.

Species	Max catch (t) 2010–2014	OFL (t)	ABC (t)
Canary rockfish	5.6	5.6	4.2
China rockfish	1.4	1.4	1.1
Copper rockfish	4.4	4.4	3.3
Quillback rockfish	13.9	13.9	10.4
Rosethorn rockfish	0.0	0.0	0.0
Tiger rockfish	0.8	0.8	0.6
Sum Tier 6 (t)		**26.1**	**19.6**

Appendix D. History of DSR management action, Board of Fisheries (BOF), North Pacific Management Council (NPFMC) and Alaska Department of Fish and Game (ADF&G).

YEAR	ACTION
1984	Marine reserves recommended to BOF by ADF&G – rejected 600 t Guideline harvest limit for 10 species of DSR in CSEO directed fishery NPFMC defines 10 species assemblage as DSR (yelloweye, quillback, china, copper, canary, rosethorn, tiger, silvergrey, bocaccio, redstripe) October 1-Sept 30 accounting year
1986	ADF&G restricts gear for rockfish in the Southeast Region to hook and line only NPFMC gives ADF&G management authority for DSR to 137^0 W long. (Southeast Outside SEO) Guideline harvest limit (GHL) for directed fishery reduced to 300 t (CSEO) GHL for directed fishery set for SSEO (250 t), SSEI (225 t), NSEO (75 t), and NSEI (90 t)
1987	Sitka Sound closed to commercial fishing for DSR
1988	NPFMC implements 660 t total allowable catch for all fisheries (TAC) for SEO
1989	NPFMC imposes TAC of 470 t (catch history average) Industry working group discusses ITQ options with NPMFC (rejected) IWG recommends 7,500 lb trip limits, mandatory logbooks, and seasonal allocations (10/1-11/31 43%, 12/1-5/15 42%, 7/1-9/30 15%). Ketchikan area closure implemented GHL for directed fishery reduced in all areas (CSEO 150 t, SSEO 170 t, NSEO 50 t).
1990	Directed permit card required for CSEO, SSEO, NSEO, NPFMC TAC of 470 t
1991	NPFMC TAC of 425 t. Change in assemblage to 8 species (removed silvergrey, bocaccio, redstripe added redbanded). Craig and Klawock closures implemented
1992	East Yakutat area included in SEO (NPFMC extends ADF&G mgt authority to 140^0) NPFMC TAC of 550 t. Directed fishery permit card required in EYKT. Submersible line transect data used to set ABC in EYKT
1993	BOF changes seasonal allocation to calendar year: 1/1-5/15 (43%), 7/1-9/30 15%, and 10/1-12/31 (42%), DSR opened for 24 hour halibut opening 6/10 (full retention) NPFMC TAC of 800, yelloweye line transect data used to set TAC NPFMC institutes a separate halibut prohibited species cap (PSC) for DSR
1994	Trip limits reduced to 6,000 in SE and 12,000 lb trip limit implemented in EYKT NPFMC TAC 960 t line transect yelloweye plus 12% for other species. Last time a directed fishery in NSEO was held.
1995	NPFMC TAC 580 t
1996	NPFMC TAC 945 t
1997	NPFMC TAC 945 t, redbanded removed from assemblage definition
1998	NPFMC TAC 560 t, revised estimates of rock habitat in EYKT, 10% included for other species, Directed fishery season changed to prevent overlap with IFQ fishery 1/1-3/14 (67%), 11/16-12/31 (33%)
1999	NPFMC TAC 560 t

2000 NPFMC TAC 340 t, revised estimates of rock habitat in SEO. Regulation to require full retention for all DSR landed incidentally in the commercial halibut fishery was adopted for state waters.
2001 NPFMC TAC 330 t , Fall directed fishery season initially 24 hours in CSEO and SSEO due to small quota then re-opened 11/26 until quotas taken, no directed fishery NSEO
2002 NPFMC TAC 350 t, no directed fishery in EYKT due to changes in estimated incidental mortality in that area, no directed fishery in NSEO.
2003 NPFMC TAC 390 t, no directed fishery in EYKT or NSEO, protocol for classifying habitat revised resulting in changes in TAC. Registration required before participating in directed fishery.
2004 NPFMC TAC 460 t, directed fishery reopened in EYKT, no directed fishery in NSEO.
2005 NPFMC Final rule to require full retention for all DSR landed incidentally in the commercial halibut fishery for federal waters.
2006 DSR TAC is allocated as follows: 84% to the commercial fleet, 16% to the recreational fleet. SEO DSR restricted to winter fishery only and must close before the start of the halibut fishery. All directed fisheries closed.
2007 All directed fisheries closed.
2008 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2009 Subsistence catch to be deducted from the ABC before allocation of the TAC to the commercial and recreational sectors. SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2010 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2011 SSEO and EYKT directed fisheries opened. CSEO and NSEO closed.
2012 Rockfish release devices required on recreational charter vessels. SSEO, CSEO and EYKT directed fisheries opened. NSEO closed.
2013 SSEO, CSEO and EYKT directed fisheries opened. NSEO closed.
2014 EYKT directed fishery opened. SSEO, CSEO, and NSEO remain closed.
2015 EYKT directed fishery opened. SSEO, CSEO, and NSEO remain closed.