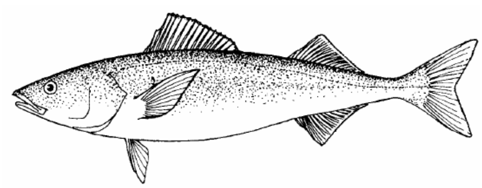
Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2016/015

A REVISED OPERATING MODEL FOR SABLEFISH (*ANOPLOPOMA FIMBRIA*) IN BRITISH COLUMBIA, CANADA



Sablefish (Anoplopoma fimbria), Courtesy DFO

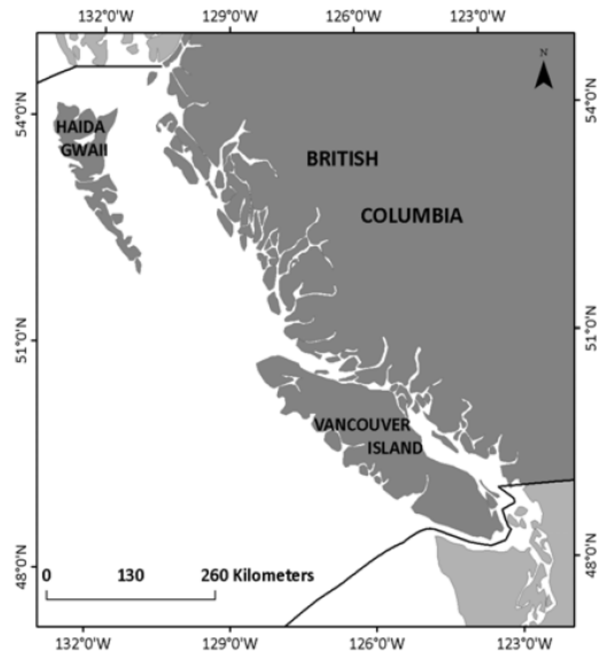


Figure 1: Assessment and management area for sablefish in British Columbia, excluding seamounts.

Context:

Fisheries and Oceans Canada (DFO) and the British Columbia (BC) Sablefish fishing industry collaborate on a management strategy evaluation (MSE) process intended to develop and implement a transparent and sustainable harvest strategy. The sustainability of harvest strategies is determined by simulation testing of alternative management procedures against operating models that represent a range of hypotheses about uncertain Sablefish stock dynamics.

The existing Sablefish operating models were developed in 2010 to represent alternative hypotheses about processes fundamental to population dynamics. These models were fitted to available data for the BC Sablefish fishery to estimate model parameters conditional on each hypothesis for subsequent simulation testing of alternative management procedures.

Fisheries Management has requested that Science Branch continue development of the Sablefish operating model to improve model structure and the ability to represent uncertain biological and fishery processes prior to a full collaborative MSE process planned for 2016/2017.

This Science Advisory Report is from the January 20, 2016 regional peer review on a revised operating model for Sablefish (Anoplopoma fimbria) in British Columbia, Canada. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

SUMMARY

- The British Columbia (BC) Sablefish (*Anoplopoma fimbria*) harvest strategy is designed around a management procedure that is simulation-tested against operating model scenarios that capture quantifiable uncertainties in Sablefish stock dynamics and fisheries. A revised operating model that accounts for structural mis-specifications and lack of fit to key observations recognized in the 2010 operating model (Cox et al. 2011; DFO 2011) was reviewed at a regional peer review meeting held January 20, 2016.
- The revised operating model is a multi-gear, age-structured, statistical catch-at-age model with modifications that include:
  - (i.) Implementation of a two-sex growth model to account for differences in growth, mortality, and maturation of male and female Sablefish,
  - (ii.) Application of an ageing error matrix to model age proportions,
  - (iii.) Estimating prior distributions for fishery selectivity from tagging data to allow time-varying selectivity for each fishery, and
  - (iv.) Revisions to the way in which age composition data are modeled to reduce sensitivity to small age proportions, particularly in the age-35+ group.
- The revised operating model was fitted to Sablefish landed catch data (1965-2015), three indices of total abundance and age-composition (1990-2015), and at-sea releases (1996-2015) in each of the commercial fisheries to evaluate model quality and fit to historical data, both of which are important for closed-loop harvest strategy simulations. The sensitivity of operating model biomass estimates to input data and prior assumptions was evaluated by running the model with different combinations of data weighting on abundance indices, male and female age composition data, and the inclusion of an ageing error matrix, resulting in seven data scenarios (D1-D7).
- Estimates of Sablefish stock status, productivity, and biomass trends over the past several years produced by the revised operating model are consistent with previous harvest strategy simulations. The revised operating model estimated harvest rates for sub-legal Sablefish (<55 cm fork length) that are much higher (7-8%) than the sub-legal harvest rates estimated by the 2010 operating model (1-2%).
- Although analysis of tagging data supports the hypothesis that size-selectivity in all commercial Sablefish fisheries has changed over time, models with constant selectivity assumptions were more stable than time-varying models, and tended to produce better fits to the historical data, especially at-sea releases.
- The new features in the revised operating model (two-sex structure, ageing error matrix) are appropriate and follow standard practice in fisheries science. Recruitment estimates with reduced auto-correlation, improved fits to the age-35+ group and the temporal pattern of at-sea releases in the trawl fishery from 2000 to the present are notable achievements. However, the lack of fit to some at-sea releases in the trawl fishery (1996 to 1999) and in the trap fishery (2006 and 2007) requires further investigation. Based on these findings, the revised operating model is an improvement relative to the 2010 operating model and is recommended for BC Sablefish harvest strategy simulations.
- Six of the seven data scenarios (D2-D7) represent plausible operating model scenarios for stock size and productivity and are recommended for future evaluations of Sablefish management procedures. Model D2, which is a two-sex model with an ageing error matrix applied to model ages, was adopted as the base operating model. It is recommended that

the D3 scenario, which is identical to D2 but with a shorter estimated recruitment time series (1990-2015), be explored as an alternative base operating model because it may reduce poor model behaviour that occurs due to low information content in the early part of the historical period.

- The revised operating model does not account for spatial dynamics among Sablefish stocks on the west coast of North America. Interactions with stocks in United States waters (Alaska, south of BC) through trans-boundary movements may have important effects on Sablefish stock dynamics in BC that are not currently captured by the revised operating models.
- It is recommended that future model development explore ways to more fully integrate tagging data into the sex- and age-structured operating models to address issues related to correlations among estimates of unfished biomass (B_0), the steepness of the stock-recruitment relationship (h), and length-based selectivity.
- Inconsistent sampling of age composition data in commercial catches (only Trap fishery age composition data are currently available) has contributed to model issues that have been consistently identified during BC Sablefish harvest strategy evaluations (Cox et al. 2011; DFO 2011, 2014). It is recommended that a properly designed commercial catch sampling program be developed and applied across all fishery sectors.
- Harvest strategy evaluation is an iterative process of change and improvement. It is recommended that BC Sablefish operating models be reevaluated for suitability at 5-year intervals.

INTRODUCTION

Measureable and quantifiable fishery objectives guide the management strategy evaluation (MSE) process for the British Columbia (BC) Sablefish (*Anoplopoma fimbria*) fishery. Objectives are developed via consultations between fishery managers, scientists and industry stakeholders, and are specifically chosen to be consistent with the DFO Fishery Decision-Making Framework Incorporating the Precautionary Approach (DFO 2009). Objectives have been revised in each phase of the MSE process to reflect both industry concerns and DFO updates to Canadian fisheries policy.

The existing Sablefish harvest strategy has four components:

1. Operational fishery objectives used to assess the acceptability of alternative management procedures (MP);
2. A MP that specifies the data used (total landed catch and three abundance indices), an assessment method (a tuned Schaefer state-space production model) and a precautionary harvest control rule using B_{MSY}, F_{MSY}, and exploitable biomass estimated by the production model;
3. A simulation-based evaluation of the MP against several operating models representing alternative hypotheses about Sablefish stock dynamics; and
4. Application and monitoring of the MP in practice.

The operational objectives and management procedure components of the harvest strategy evaluation were developed at the same time (Cox et al. 2011, 2013) and simulation testing to date is based on an operating model selected as part of a 2010 process. Potential structural mis-specification (combined sex, constant selectivity assumption) and lack of fit to key observations (the accumulator age-class at age-35+, and at-sea releases in the commercial trawl fishery) have been recognized as key areas for improvement of the 2010 operating model. In this paper, the Sablefish operating model was revised to address these issues and model quality and fit to historical data were evaluated.

BACKGROUND

Sablefish Fishery Management

Sablefish are caught in directed longline trap and hook and trawlfisheries, and are also intercepted by the non-directed longline hook fisheries targeting Pacific Halibut (*Hippoglossus stenolepis)*, Rockfishes (*Sebastes* sp.) and Lingcod (*Ophiodon elongatus*). Sablefish fisheries in BC are managed through Individual Transferable Quotas (ITQ) that are allocated annually to 48 Sablefish license eligibilities (accounting for 91.25% of the total allowable catch (TAC)), and 139 groundfish trawl license eligibilities (8.75% of TAC). Harvesters in the directed fisheries (those targeting Sablefish) and the non-directed commercial groundfish fisheries are required to acquire ITQ to account for landed and discarded Sablefish mortalities. Individual Sablefish smaller than 55 cm fork length (FL) are released by regulation in all fisheries since 1977. The BC Integrated Groundfish Fishery (DFO 2013) operates on a February 21 to February 20 fishing year, with allowances for carryover of quota overage and underage. The TAC for the 2015/16 fishing year, excluding overages and underages, was set at 1,992 metric tonnes (t), down from 2,129 t in the 2014/15 fishing year.

Sablefish landings have ranged from 1,713 t (2014) to 7,408 t (1975) since 1969 and averaged about 4,741 t annually over the 1969 to 1999 period (Figure 2). Landings have declined from 4,642 t in 2005 to 1,713 t in 2014 in response to TAC reductions over the same period.

Released catch prior to 1996 was voluntarily reported, primarily by the trawl sector, and included reports of very large releases in the few years following the occurrence of the large 1977 year class. Releases of Sablefish reported by the trawl sector increased in 1996, when the at-sea observer program was implemented and increased markedly after 2006 when auditing of at-sea electronic monitoring was broadly introduced. Mortality attributable to releases of Sablefish greater than 55 cm FL is deducted from the ITQ holdings using gear-specific estimates of mortality rates.

Mortality of fish released at sea represents a large uncertainty in estimates of Sablefish fishing mortality (*F*) because release mortality is not directly measured. Determinants of release mortality for Sablefish are related to gear type, size-specific differences in sensitivity to stress due to interacting environmental factors and delayed mortality after release due to cumulative stress effects or post-release predation. Deductions are made from quota holdings when legal-sized Sablefish are released, but no quota deductions are applied to releases of sub-legal fish because these fish must be released by regulation (DFO 2014).

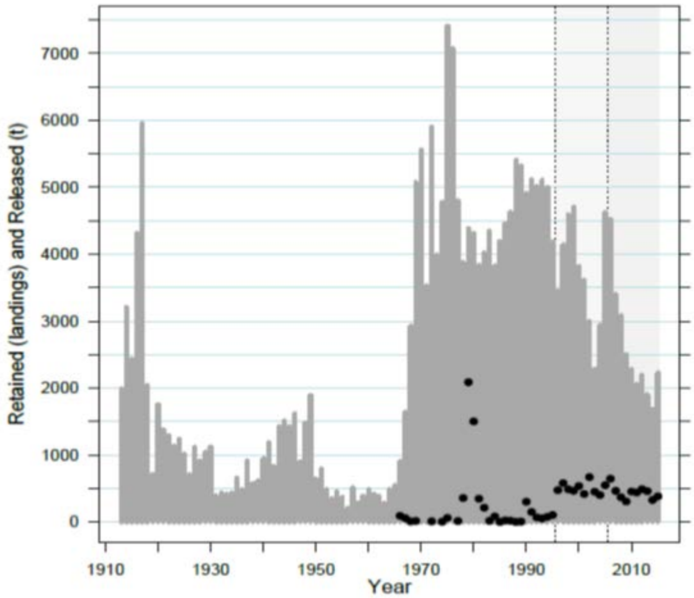


Figure 2. Annual Sablefish retained catch (metric tonnes, t) from 1913 to 2015 from commercial sources (grey bars). Annual released catches are shown as reported. Vertical dotted lines demarcate the trawl at-sea observer period from 1996 to 2006. Catch data for 2015 are complete to October 31 for both retained catch (grey bar) and released catch (black circle).

Biology

Sablefish are characterized by rapid growth at young ages, followed by extremely slow growth at older ages (Kimura et al. 1993). The species exhibits sexually dimorphic growth, with females attaining larger size-at-age than males after maturing at about 5-7 years. Sablefish in BC and Alaska are thought to spawn from January through April (Beamish and McFarlane 1983, Hanselman et al. 2015), with peak spawning occurring in February.

ANALYSIS

Four modifications to the 2010 operating model were implemented and tested by Cox et al.[1]:

1. changing from an age-/growth group operating model in which the sexes are combined to a two-sex age-structured model to account for sex-related differences in growth, mortality, and maturation of Sablefish;
2. adjusting model age proportions using an ageing error matrix to improve model fit to observed age-composition data;
3. evaluating the effects of a time-varying fishery selectivity, is estimated from the Sablefish tagging return data, on model performance in fitting to age composition data and at-sea releases by the trawl fishery; and
4. revising the way in which age composition data are modeled to reduce operating model sensitivity to small age proportions.

[1] Cox, S.P., Kronlund, A.R., Lacko, L., and Jones, M. A revised operating model for Sablefish in British Columbia, Canada. CSAP Working Paper 2014GRF03. In revision.

A two-sex/age-structured operating model (OM) was fitted to fishery specific landed catch (1965-2015), indices of total abundance and age-composition data from the Trap fishery (1999-2015), Standardized survey (1991-2009), Stratified Random Survey (2003-2014), and at-sea releases (2006-2015) in the commercial longline trap, longline hook, and trawl fisheries. Sablefish mean length (cm) for age *a* is modeled using a von Bertalanffy growth function with sex-specific growth rates, based on a literature review of estimates currently used in Sablefish stock assessments in the United States (US). Although estimated growth rates are available from biological samples obtained in BC, these estimates are believed to be biased high and were not used because they would lead to optimistic estimates of stock status based on fishery reference points. However, the BC Sablefish growth parameter estimates could be considered for possible alternative operating models in management strategy simulations.

An ageing error matrix describes how the true proportions-at-age are spread among adjacent age classes as a result of under or over estimation of fish ages. Since no ageing error matrix is available for Canadian-aged Sablefish, a matrix was developed based on Hanselman et al. (2012) who used known-aged fish from tagging studies to develop an ageing error relationship for Alaska Sablefish aged 3-18 years. It was assumed that the geometric model parameter values for ages 10-18 years extended to all fish aged 18+ years old.

Size-selectivity of the fishery was estimated from tag release-recovery data collected from 1996 through 2012. Natural mortality was assumed constant for all size-classes included in the analysis. Annual recoveries were restricted to Sablefish recaptured within one year of release and separated by the recovery gear and length class to remove the need to estimate growth rates necessary with multi-year recoveries.

Input Data

Biomass index observations consist of both fishery dependent (e.g., catch rate (CPUE) observations from the fishery), and fishery-independent data (e.g., a fixed location standardized survey, and a stratified random survey). Fishery CPUE from the 1988-2009 period provides the only data source that extends into the 1980s when some of the largest and most influential cohorts entered the fishery and dominated the dynamics for many years. The fishery CPUE time series extends back to 1979, but the 1979-1987 observations were removed because the trap fishery was just beginning at that time and catch rates appeared qualitatively different (and lower). In previous studies, estimated abundance trends with or without the 1979-1987 observations are similar, probably because the operating model does not fit these observations well. The fishery CPUE and standard survey CPUE time-series (a fishery-independent index) were truncated at 2009 based on the results of simulation analyses (Cox et al. 2011). The stratified random survey CPUE is the main source of fishery-independent abundance trend information for BC Sablefish since 2009.

Information on changes in population age-structure consists of proportions-at-age in trap fishery catches (1982-2009 with several missing years), standardized surveys (1990-2009), and the stratified random survey (2003-2014). Fishery age composition data are available back to 1979; however, data from 1979-1984 were not used because they were not randomly sampled or were based on small sample sizes. The operating model estimates the true age proportions, which are subsequently adjusted by the ageing error matrix to account for ageing errors. Specimens were assigned equal weight for each of the three data sources. The first age class was set to 3 years and a plus group was created for fish aged 35 years and older. The fishery age composition data do not track strong Sablefish cohorts through time well. The survey age proportions show better coherence in cohort tracking over time, with the stratified random survey being the most consistent in tracking strong cohorts known to have occurred in Alaska Sablefish. In addition, female age composition data appear to show clearer cohort patterns compared to male age composition data. The clearer cohort patterns in the female age composition data could arise from differences in ageing errors for each sex and/or differences in movement into/out of BC waters.

Seven data scenarios (D1-D7) were constructed and used to test the operating model (Table 1). These scenarios consist of different combinations of data weighting on abundance indices, male and female age composition data, and the inclusion of an ageing error matrix. The D1 data scenario represents the sex-structured alternative to the previous age-structured 2010 operating model used for BC Sablefish (e.g., Cox et al. 2011). Model D2 is considered the base model and is the same as model D1 with the addition of an ageing error matrix applied to the model ages. The D3 model scenario is identical to D2 but with a shorter estimated recruitment time series (1990-2015) and is included because it may reduce pathological behaviour that occurs due to poor information content in in the early part of the historical period. Models D4 to D7 sequentially remove or down-weight data until only the stratified random survey remains in D7. Scenario D4 examines the implications of using fishery CPUE as a biomass index, D5 reduces the influence of male age-composition data from the standard survey (which seems to show very large proportions in the age 35+ class), D6 uses only the stratified random survey biomass index, and D7 is the most reduced survey-only model that remains feasible to implement.

Table 1: Data scenarios created by excluding particular data series and ageing error corrections. The weights listed are in order of the trap fishery, standardized survey, and stratified random survey. Weights are multipliers of the data likelihoods; so for example, a weighting of 50% on all age likelihood components for males is indicated by (0.5, 0.5, 0.5). Long and Short labels indicate recruitment series 1980-2015 (Long) and 1990-2015 (Short).

	Description	Label	Index Weight	Male Age Weight	Female Age Weight	Ageing Error Correction
D1	Base-Long	Base-L	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	No
D2	Base with ageing error correction-Long	Base-AE-L	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	Yes
D3	Base with ageing error correction –Short	Surv-AE-L	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	Yes
D4	Exclude trap fishery index	Surv-AE-S	(0, 1, 1)	(1, 1, 1)	(1, 1, 1)	Yes
D5	Exclude trap fishery index, male age data weights reduced	Surv-F-AE-S	(0, 1, 1)	(0.5, 0.5, 0.5)	(1, 1, 1)	Yes
D6	Exclude trap fishery and Std Survey indices, male age data weights reduced, ageing error correction	StRS-F-AE-S	(0, 0, 1)	(0.5, 0.5, 0.5)	(1, 1, 1)	Yes
D7	StRS survey index and age composition only	StRS-AE-S	(0, 0, 1)	(0, 0, 1)	(0, 0, 1)	Yes

Results

Estimates of key model parameters, stock biomass quantities and their standard errors for data scenarios D1-D7 are shown in Table 2. Model parameter estimates are quite similar among models D1, D2 and D3, except unfished female biomass (B_0) and current biomass (B_{2015}), which increase about 25% with the addition of the ageing error matrix and the shorter recruitment time series (1990-2015). As data are removed, (scenarios D4-D7) some parameter estimates, notably steepness of the stock recruitment relationship (*h*), become increasingly implausible (see D6 and D7) and residual error variances increase because the data series used (2003-2014) is not long enough for a long-lived species such as Sablefish; there is little contrast in spawning biomass since 2003. Data scenario model fits were compared to one another and to the 2010 model (Cox et al. 2011) and it was noted that there are no marked differences in residual error variances across scenarios D1-D6. None of these models fully converged, so the solutions shown may not be unique.

The separation of male and female Sablefish in the data and operating model appears to provide similar results to the 2010 operating model where sexes were combined. One benefit of the two-sex operating model is improved model fit to the age 35+ class in the data and also preliminary estimates of natural mortality by sex (male, M ~ 0.06; female, M ~ 0.09).

Data scenarios D1-D7 produced qualitatively similar patterns in female spawning biomass over time, although the scaling differs among scenarios depending on the amount and length of the data series used (Figure 3). The estimates of Sablefish stock status, productivity, and biomass trends over the past several years produced by the revised operating model under different data scenarios are consistent with previous estimates from similar harvest strategy simulations. The revised operating model estimated harvest rates for sub-legal Sablefish (<55 cm FL) that are much higher (7-8%) than the rates estimated by the 2010 operating model (1-2%). Higher sub-legal Sablefish harvest rates could be a potential explanation for the slower than expected Sablefish population recovery. Harvest rates estimated for legal-sized fish (> 55 cm FL) are similar between models.

Although analysis of BC Sablefish tagging data supports the hypothesis that size-selectivity in all commercial Sablefish fisheries has changed over time, time-varying selectivity parameters could not be estimated in most model runs. Instead models assuming constant dome-shaped (Normal) selectivity for all fisheries tended to be more stable and provide better fits to the data, especially at-sea releases (see Appendix E in Cox et al.[1]). A constant selectivity assumption was used in all model runs reported here.

The revised operating model achieved better fits to female age composition data than to the male data. In most cases, age composition residuals included large patterned groups of residuals (e.g., runs of positive or negative values), which may mean that the model is not able to estimate the magnitude and possibly timing of some recruitment events (such as the 2000 year class). Persistent random effects in the observations are also likely to be missed by the model (e.g., time-varying selectivity, availability). The model might also miss short-term events involving seasonal immigration and emigration of Sablefish through BC waters.

The revised operating model achieves better fit to recent at-sea releases in the trap and trawl fisheries, but it continues to display a lack of fit to at-sea releases from 1996 to 1999 in the trawl fishery and from 2006 to 2007 in the trap fishery. These issues require further investigation to identify causality.

Table 2. Key parameters, estimated states (first row), and their standard errors (second row) for operating model data scenarios D1-D7: stock recruitment steepness (h), natural mortality rates for males and females (M_m, M_f), unfished female spawning biomass (B_0), female spawning stock biomass in 2015 (B_{2015}), spawning stock depletion ($D_{2015}=B_{2015}/B_0$), total male and female legal biomass in 2015 (LB_{2015}), harvest rate on legal-sized (LHR_{2015}) and sub-legal-sized ($SLHR_{2015}$) fish. Biomass units are thousands of metric tonnes (t) and natural mortality is yr^{-1}.

Model	Label	h	M_m	M_f	B_0	B_{2015}	D_{2015}	$LB_{2015,L}$	LHR_{2015}	$SLHR_{2015}$
D1	Base-L	0.589	0.041	0.084	48.90	7.94	0.162	19.88	0.098	0.071
		0.069	0.000	0.001	0.97	0.78	0.014	1.96	0.010	0.011
D2	Base-AE-L	0.537	0.043	0.086	55.10	8.74	0.159	22.20	0.088	0.069
		0.072	0.002	0.002	2.33	0.91	0.014	2.34	0.009	0.011
D3	Base-AE-S	0.567	0.046	0.087	60.74	9.87	0.162	24.74	0.079	0.065
		0.077	0.002	0.002	2.43	1.06	0.014	2.65	0.008	0.011
D4	Surv-AE	0.559	0.045	0.089	55.65	7.70	0.138	19.38	0.101	0.081
		0.069	0.002	0.002	2.24	1.00	0.016	2.58	0.013	0.015
D5	Surv-F-AE	0.573	0.043	0.089	54.13	7.39	0.137	18.85	0.104	0.081
		0.064	0.002	0.002	2.33	0.98	0.016	2.57	0.014	0.015
D6	StRS-F-AE	0.255	0.042	0.087	54.45	5.72	0.105	14.57	0.134	0.108
		0.001	0.002	0.002	2.78	1.09	0.018	2.83	0.026	0.024
D7	StRS-AE	0.386	0.058	0.104	54.10	6.08	0.112	15.41	0.127	0.141
		0.069	0.003	0.003	3.10	0.90	0.014	2.23	0.018	0.028

Accounting for ageing errors in the operating model decreased temporal auto-correlation and improved the resolution of cohort strength estimates of year classes, particularly the influential year classes that occurred in the late 1970s, 2000 and 2008. The revised operating model is better at accounting for higher at-sea releases in the trawl fishery during the early 2000s than is the 2010 operating model. Including ageing errors led to higher, more concentrated at-sea releases around 2001/2002 as a result of two factors:

1. the ageing error matrix creating a more distinct and larger 2000 year-class, and
2. strongly dome-shaped selectivity.

Recruitment estimates with reduced auto-correlation, improved fits to the age 35+ group. Combined with the improved fit to the temporal pattern of at-sea releases in the trawl fishery from 2000 to the present, these are notable achievements resulting from the modifications to the operating model.

Reducing the length of the recruitment series estimated in the model from 1980-2015 to 1990-2015 (D2 and D3 scenarios) had little effect on the time-series of estimated recruitment or parameter estimates (Table 2). For the short recruitment series model, average recruitment increased slightly for the 1965-1979 period, mainly because unfished biomass increased relative to the long recruitment series model.

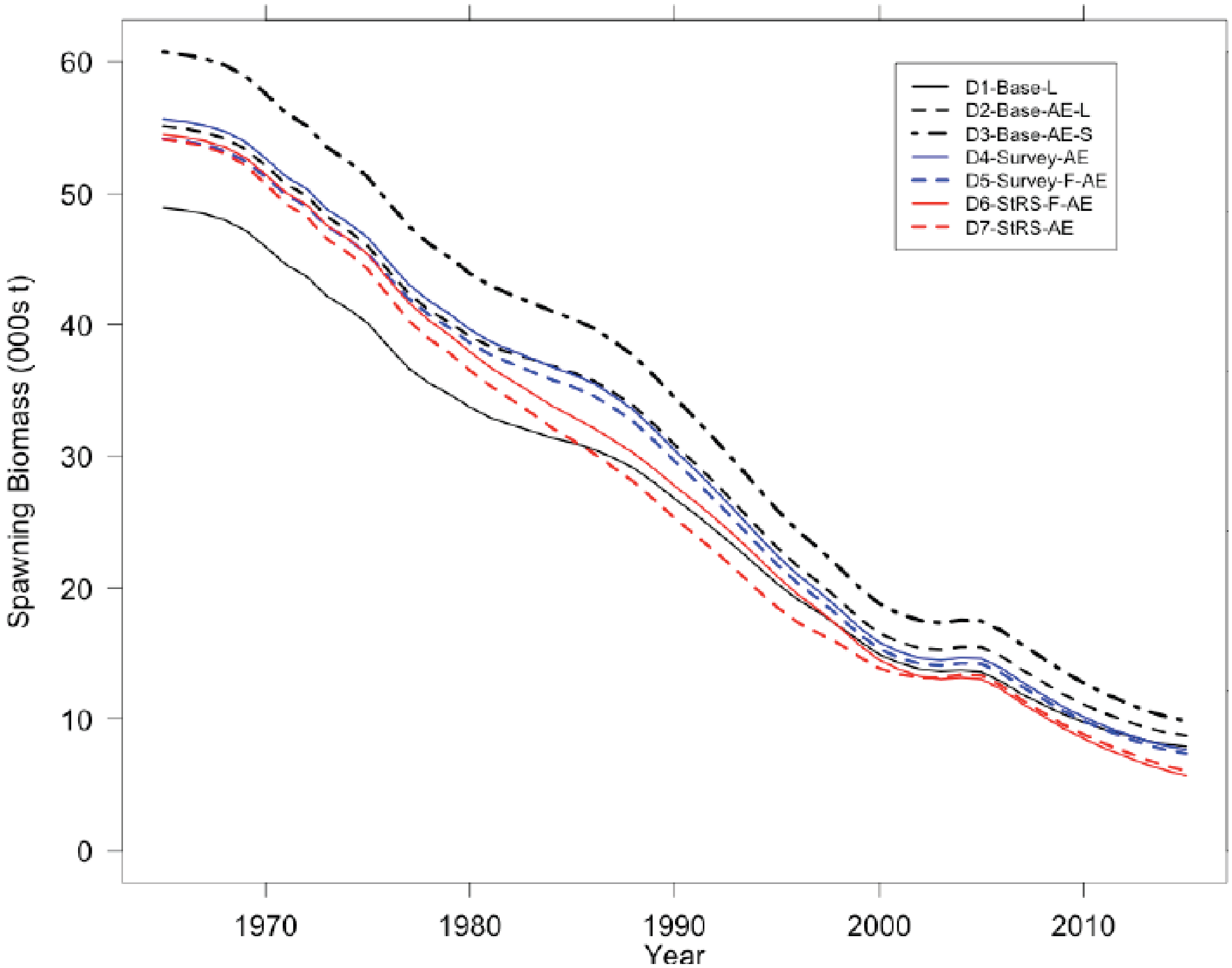


Figure 3. Annual female Sablefish spawning biomass for seven operating model scenarios D1-D7 described in Table 1.

Sources of Uncertainty

The revised operating model does not account for spatial dynamics among Sablefish stocks on the west coast of North America. Although the model assumes that BC Sablefish comprise a closed population, there is substantial evidence of widespread movement throughout the northeast Pacific Ocean. Interactions with stocks in US waters (Alaska, south of BC) through trans-boundary movements may have important effects on Sablefish stock dynamics in BC that are not currently captured by the revised operating model.

Since none of the models evaluated fully converged, the reported solutions may not be unique.

Estimated growth parameters (k_m, k_f) based on BC trap fishery samples (2003-2014) are higher than estimates currently used for Sablefish assessments in the US, which were used in the revised operating model.

The estimates of age at 50% and 95% maturity used in the revised operating model may be biased low because the revised operating model does not account for size-selectivity in sampling the population.

CONCLUSIONS AND ADVICE

The new features in the revised operating model (two-sex structure, ageing error matrix) are appropriate and follow standard practice in fisheries science. Recruitment estimates with reduced auto-correlation, improved fits to the age-35+ group and the temporal pattern of at-sea releases in the trawl fishery from 2000 to the present are notable achievements. However, the lack of fit to some at-sea releases in the trawl fishery (1996 to 1999) and in the trap fishery (2006 and 2007) requires further investigation. Based on these findings, the revised operating model is an improvement relative to the 2010 operating model and is recommended for BC Sablefish harvest strategy simulations.

Six of the seven data scenarios (D2-D7) represent plausible operating model scenarios for stock size and productivity and are recommended for future evaluations of Sablefish management procedures. Model D2, which is a two two-sex model with an ageing error matrix applied to model ages, was adopted as the base operating model. It is recommended that the D3 scenario, which is identical to D2 but with a shorter estimated recruitment time series (1990-2015), be explored as an alternative base operating model because it may reduce poor model behaviour that occurs due to low information content in in the early part of the historical period.

It is recommended that an ageing error matrix specific to BC Sablefish be developed and used in operating models for Sablefish harvest strategy evaluation.

It is recommended that future model development explore ways to more fully integrate tagging data into the sex- and age-structured operating model to address issues related to correlations among estimates of unfished biomass (B_0), the steepness of the stock-recruitment relationship (h), and length-based selectivity.

Inconsistent sampling of age composition data in commercial catches (only Trap fishery age composition data are currently available) has contributed to model issues that have been consistently identified during BC Sablefish harvest strategy evaluations (Cox et al. 2011; DFO 2011, 2014). It is recommended that a properly designed commercial catch sampling program be developed and applied across all fishery sectors.

Harvest strategy evaluation is an iterative process of change and improvement. It is recommended that BC Sablefish operating models be reevaluated for suitability at 5-year intervals.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 20, 2016 regional peer review on A revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Beamish, R.J., MacFarlane, G.A. 1983. Summary of results from the Canadian Sablefish Tagging Program. *In* Proceedings of the international sablefish symposium. Lowell Wakefield Fisheries Symposia Series, p. 147-83. Univ. of Alaska Sea Grant Report 83-8.

Cox, S.P., Kronlund, A.R., and Benson, A.J. 2013. The roles of biological reference points and operational control points in management procedures for the Sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. Environ. Cons. 40: 318-328.

Cox, S.P., Kronlund, A.R., Lacko, L. 2011. Management procedures for the multi-gear Sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/063. viii + 45 p.

DFO. 2009. A Fishery Decision-making Framework Incorporating the Precautionary Approach. (Accessed 16 March 2016)

DFO. 2011. Regional Science Advisory Process on Management procedures for the multi-gear sablefish (*Anoplopoma fimbria*) fishery in British Columbia, January 17, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/053. vi + 16 p.

DFO. 2013. A Review of Sablefish Population Structure in the Northeast Pacific Ocean and Implications for Canadian Seamount Fisheries. DFO Can. Sci. Advis. Sec. Sci. Resp. 2013/017.

DFO. 2014. Performance of a revised management procedure for Sablefish in British Columbia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014/025.

Hanselman, D.H., Clark, W.G., Heifetz, J., Anderl, D.M. 2012. Statistical distribution of age readings of known-age sablefish (*Anoplopoma fimbria*). Fish. Res. 131-132: 1-8.

Hanselman, D.H., Heifetz, J., Echave, K.B., and Dressel, S.C. 2015. Move it or lose it: movement and mortality of sablefish tagged in Alaska. Can. J. Fish. Aquat. Sci. 72: 238-251. 10.1139/cjfas-2014-0251

Kimura, D.K., Shimada, A.M., Lowe, S.A. 1993. Estimating Von Bertalanffy growth parameters of sablefish *Anoplopoma fimbria* and Pacific cod *Gadus macrocephalus* using tag recapture-data. Fish. Bull. 91:271-280.

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: (250) 756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2016. A revised operating model for Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/015.

Aussi disponible en français :

MPO. 2016. Élaboration du modèle d'exploitation de la morue charbonnière (*Anoplopoma fimbria*) en Colombie-Britannique, au Canada. Secr. can. de consult. sci. du MPO, Avis sci. 2016/015.