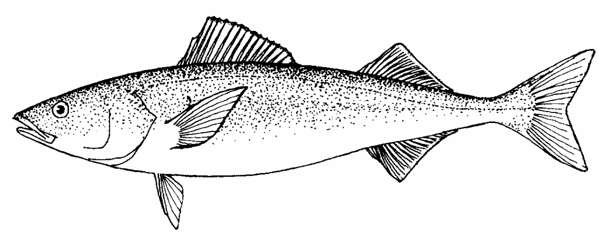
MANAGEMENT PROCEDURES FOR THE MULTI-GEAR SABLEFISH (*ANOPLOPOMA FIMBRIA*) FISHERY IN BRITISH COLUMBIA, CANADA



Sablefish (Anoplopoma Fimbria), Courtesy DFO

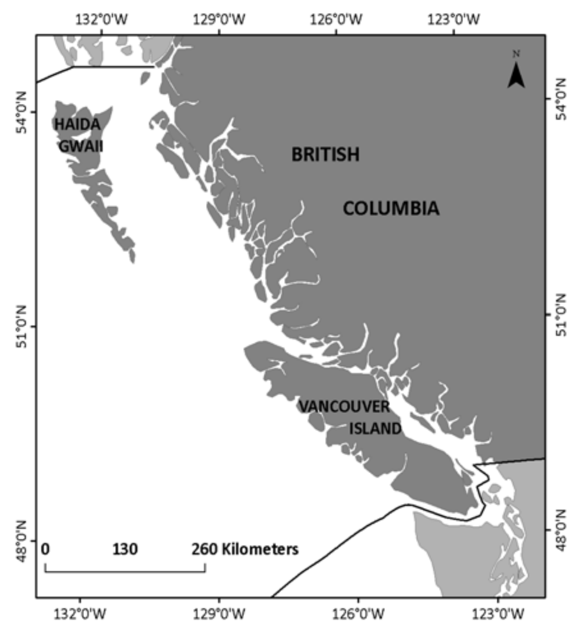


Figure 1: Assessment and management area for sablefish in British Columbia, excluding seamounts.

Context:

Sablefish (Anoplopoma fimbria) are caught in directed fisheries by the longline trap and hook K license category sector and the T license category trawl sector. The trawl sector is allocated 8.75% of the total allowable catch. Sablefish are also intercepted by the non-directed groundfish longline hook fisheries primarily directed at Pacific halibut, rockfishes, lingcod and spiny dogfish. Sablefish are released by regulation when measuring less than 55 cm fork length. Research, assessment, management, and enforcement activities are augmented by a collaborative agreement between Fisheries and Oceans Canada (DFO) and an industry association that represents the K sector license holders. In 2008, a management strategy evaluation (MSE) approach was developed for sablefish assessment and management in British Columbia and was reviewed through a Canadian Science Advisory process. The collaborative MSE approach requires active involvement of fishery managers, stakeholders, and analysts in the evaluation of fishery conservation and catch performance.

Fisheries and Aquaculture Management requested advice to inform planning for the 2011/12 fishing year. Two requirements of the advice were to: (1) update the MSE approach used in 2008 to reflect fishery objectives introduced by the 2009 “DFO Sustainable Fisheries Framework” (SFF) policy and “A fishery decision-making framework incorporating the Precautionary Approach” (PA) policy, and (2) evaluate whether at-sea release mortality of sablefish presents a conservation risk as defined in the SFF. The MSE approach combines extensive stakeholder consultation to develop candidate management procedures and scenarios for closed-loop simulation analyses. Simulations are used to evaluate candidate management procedures against uncertainties regarding sablefish natural mortality,

growth, and future recruitment variability. The population model component of the simulations incorporates size-based selectivity and at-sea release processes by trap, hook and trawl gear. Candidate management procedures, which include options that mimic avoidance or full retention of sub-legal sablefish, are ranked using performance statistics related to conservation and catch objectives.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Regional Advisory Process. Additional publications resulting from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- Fishery reference points are based on a target spawning biomass at maximum sustained yield, B_{MSY}, with limit and upper stock reference points at $0.4B_{MSY}$ and $0.8B_{MSY}$, respectively;
- Quantitative conservation objectives relate to (1) maintaining the spawning biomass above the limit reference point of $0.4B_{MSY}$ in 95% of years projected over two sablefish generations (~36 years), and (2) implementing an acceptable probability of stock decline over 10 years that is scaled from 0.5 at the target biomass to 0.05 at the limit reference point;
- A multi-gear, age-structured, catch-at-age model is fitted to historical data to create stock scenarios that captures uncertainty in natural mortality, growth, and future recruitment variability;
- Stock reconstructions suggest that stock status is currently below B_{MSY} for all scenarios, with the stock currently positioned in the mid-Cautious to low-Healthy zones;
- A closed-loop feedback simulation approach is used to evaluate the relative performance of candidate management procedures that are distinguished by the choice of survey data, assessment model assumptions, harvest control rule specifications, and future regulations related to at-sea release of sub-legal sablefish;
- Candidate management procedures were robust to the uncertainties considered as indicated by a consistently low probability ($p < 5\%$) of breaching the limit reference point over two sablefish generations (~36 years) regardless of the management procedure or stock scenario;
- Expectations for stock growth toward the target reference point over two sablefish generations range from B_{MSY} or greater to levels near, but not above B_{MSY} under the more pessimistic scenarios;
- Performance of management procedures based on the stratified random trap survey alone suggested the legacy standardized trap survey could be discontinued without creating a conservation concern, and could also achieve reduced catch variability relative to the use of both surveys;
- Increases in expected conservation and catch performance due to adopting an avoidance option for sub-legal sablefish, or a full retention option, were small relative to the performance attained by the existing size limit tactic, but these effects are likely underestimated due to suspected violations of assumptions related to trawl gear selectivity.

INTRODUCTION

Sablefish (*Anoplopoma fimbria*), also referred to as Blackcod, inhabit shelf and slope waters to depths greater than 1500 m, from central Baja California to the Bering Sea and Japan. Spawning is observed from January to March along the continental shelf at depths greater than 300 m. Larval sablefish are found in surface waters over the shelf and slope in April and May. Juveniles migrate inshore over the following six months and rear in near shore and shelf habitats until ages 2 to 5 when they migrate offshore and recruit to deeper waters where they become vulnerable to trawl, longline trap and longline hook fisheries. Sablefish can be highly migratory, with tagged fish traveling from the inside waters of Hecate Strait and mainland inlets to the offshore waters of B.C., as far north as the Aleutian Islands, and south to U.S. waters off Oregon. The oldest fish recovered from British Columbia was aged at 92 years. Age, growth and maturity parameters vary markedly among areas and depths. Initial growth is rapid, with mature females reaching an average length of 55 cm fork length in 3 to 5 years. Maximum sizes are reported at ~110 cm fork length. Large year classes occur infrequently, with stock production characterized by periods of moderate to relatively low recruitment.

Sablefish harvesting in B.C. is managed via a coast-wide total allowable catch (TAC) over a fishing year (common to all sectors) beginning February 21 and ending February 20 the following year. Sablefish smaller than 55 cm fork length are subject to at-sea release by regulation. Total annual landings since 1969 ranged from 2,290 t (2003) to 7,410 t (1975) and averaged about 4,740 t over the 1969 to 1999 period. Landings declined from 4,620 t in 2005 to 2,350 t in 2010 in response to TAC reductions over the same period. The TAC for the 2010/11 fishing year was 2,300 t. Reliable estimates of at-sea releases of sablefish are available for the trawl sector beginning in 1996 and for other longline hook and trap fisheries since 2006 by virtue of fishery-independent at-sea monitoring.

Fisheries and Aquaculture Management requested advice to inform planning for the 2011/12 fishing year that incorporates the 2009 DFO Sustainable Fisheries Framework (SFF) policy and considers the potential impacts of at-sea releases. Analysis to meet this request extended the management strategy evaluation approach reviewed through a Canadian Advisory process in 2008 to (1) develop a more flexible operating model that could account for at-sea releases and post-release mortality; (2) test a wider range of population dynamics assumptions about growth, natural mortality, growth and recruitment variability; (3) evaluate management procedures that simulate full retention of sablefish and avoidance of sub-legal sablefish; and (4) evaluate management procedures that depend only on landed catch and one or two fishery-independent surveys in the future.

Fishery reference points are set relative to a target spawning biomass at maximum sustained yield, B_{MSY}, with limit and upper stock reference points at $0.4B_{\mathrm{MSY}}$ and $0.8B_{\mathrm{MSY}}$, respectively. Fishery objectives for sablefish were chosen based on review of the SFF and ongoing consultations with fishery managers and industry stakeholders. Conservation and catch objectives included:

1. Maintain spawning stock biomass above the limit reference point $0.4B_{\mathrm{MSY}}$ in 95% of years measured over two sablefish generations (~36 years);
2. Ensure the probability of stock decline over the next 10 years does not exceed an acceptable level defined by increasing the probability linearly from very low (0.05) at the limit reference point to moderate (0.5) at the target reference point;
3. Maintain the spawning biomass above the target reference point of B_{MSY} in 50% of the years measured over two sablefish generations;
4. Maximize the average annual catch over 10 years subject to meeting Objectives 1-3.

ASSESSMENT

Management strategy evaluation (MSE) is the systematic determination of the expected performance of a fishery management plan against a set of objectives. Such evaluation implements the Precautionary Approach by dealing explicitly with multiple levels of uncertainty (e.g., data, modelling, implementation) when choosing a management strategy. Analysis is accomplished by fitting several population dynamics model "scenarios" to historical data, where each scenario reflects assumptions about uncertain natural mortality, growth and future recruitment processes. Each resulting stock scenario is used to generate future data available for assessment and decision-making, as well as sablefish stock responses to exploitation. Simulation projections are used to test the performance of alternative choices for survey data, stock assessment methods, harvest control rule specification, and future at-sea release regulations. Each unique combination of these elements defines a management procedure. The relative performance of eight management procedures is compared based on performance statistics related to conservation, catch, and inter-annual stability of catch.

The population dynamics model is structured by age and by growth group, where the latter dimension is required to allow evaluation of size-based at-sea releases and potential measures to mitigate the impact of post-release mortality. Sexes are combined and a stochastic Beverton-Holt stock-recruitment relationship is assumed. Leading model parameters include stock-recruitment steepness, natural mortality, and unfished equilibrium spawning biomass. Estimated fishery reference points include (1) the spawning biomass at MSY, B_{MSY}, and (2) the annual harvest rate of legal-size sablefish at MSY, U_{MSY}. The model is fit to annual retained catch (1965-2010), annual at-sea releases (1996-2010 for trawl, 2006-2010 for longline trap and hook gears), a legacy “standardized” trap-gear survey (1990-2009), a stratified random trap-gear survey (2003-2009), commercial trap gear catch per unit effort (1979-2009), and proportions-at-age determined from sampling the two surveys and the trap fishery. Four base stock scenarios were constructed based on assumptions about natural mortality and growth rate and four additional scenarios were developed by assuming auto-correlation in future recruitment and by selecting a "low probability, low productivity” case. The performance of procedures against these latter four “robustness testing” scenarios was considered relative to Objective 1, i.e., to ensure that the limit reference point was not breached in greater than 5% of the years over two sablefish generations.

Operating model fitting to historical data under the four base scenarios suggest that (1) the spawning stock biomass is currently estimated to be below B_{MSY}, and in the mid- to upper-Cautious Zone for three scenarios and the low-Healthy Zone for the other (Figure 2), and (2) the harvest rate of legal sablefish is close to the harvest rate at maximum sustained yield, U_{MSY}, for all four scenarios largely due to the series of quota reductions from 4,600 t to 2,300 t between 2007 and 2010 (Figure 3).

In contrast to the age-/size-structured operating model used to simulate the sablefish population, management procedures for setting future TACs used an aggregated (ages, sexes, sizes combined) surplus production model fitted to only landed catch and the three historical abundance indices. It is important to note that only one or two fishery-independent survey indices are used by the production model in the future. Production model performance was adjusted, or “tuned”, by setting the precision of Bayesian prior distributions on key management parameters to be relatively high or low. Production model outputs are translated into retained catch using a PA-compliant harvest control rule (DFO 2006) configured to reduce the removal rate at either 80% or 60% of the estimated B_{MSY}.

The performance of management procedures evaluated through closed-loop simulation projections indicates that Objective 1 is highly likely to be met, regardless of the procedure or the operating model scenario, because all procedures tended to produce both short-term and long-term stock growth. The ability of management procedures to meet Objectives 2 and 3 depended on the operating model scenario, because these two objectives were tied to reference points, which differed among scenarios. For instance, under the more pessimistic scenarios (i.e., current biomass in mid-Cautious Zone, lower productivity), all procedures allowed the spawning biomass to grow towards B_{MSY}, but none could maintain spawning biomass above B_{MSY} in 50% of years because the time horizon (36 years) is simply too short. Even a perfect information procedure failed to achieve Objective 3 in some of these cases. On the other hand, procedures generally maintained the spawning biomass in the Healthy Zone in at least 50% of years for all scenarios except the most pessimistic one.

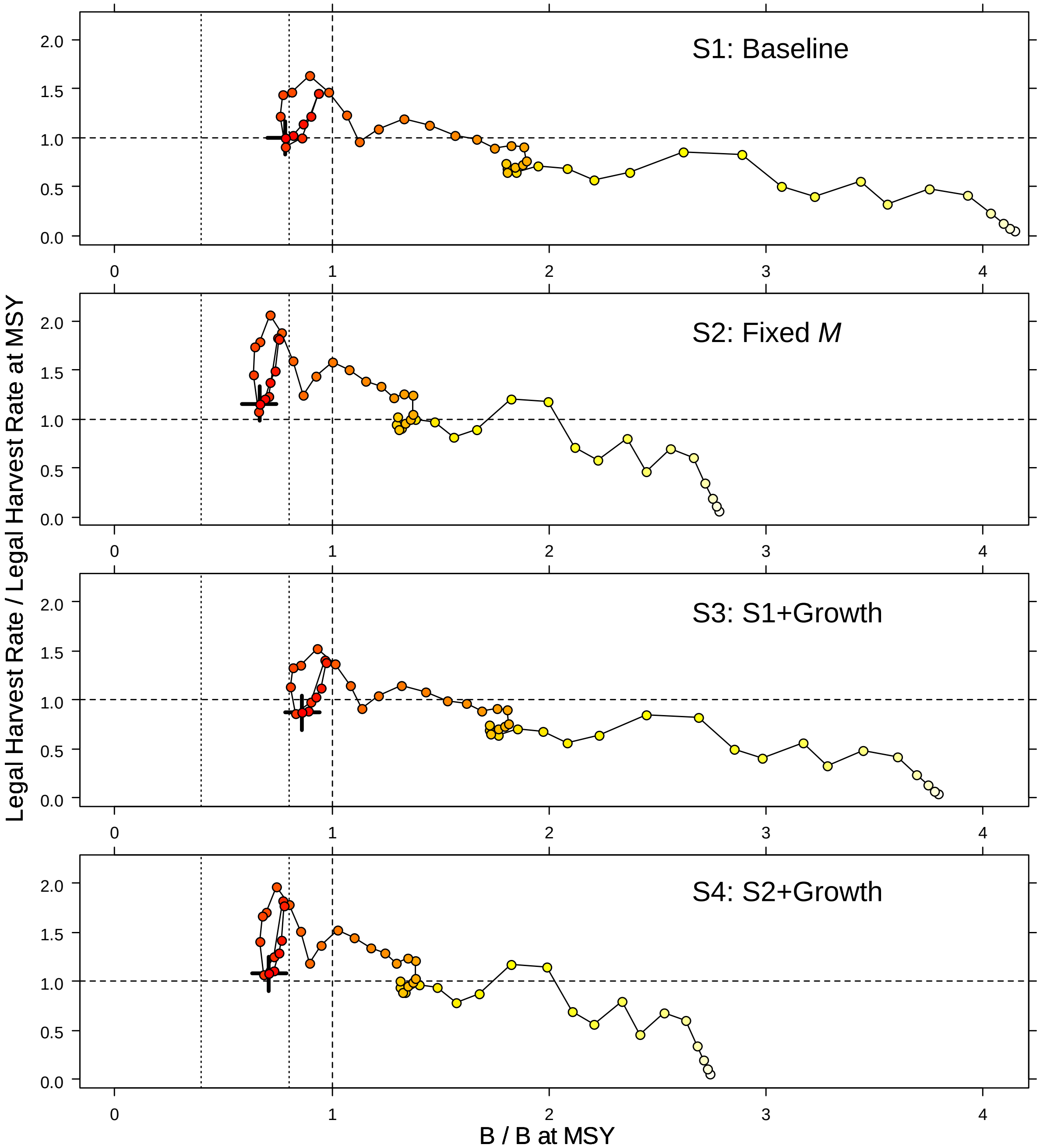


Figure 2: Estimated phase trajectories of sablefish spawning biomass relative to B_{MSY} versus legal harvest rate relative to legal harvest rate at MSY from 1965 (light shading) to 2010 (dark shading). Panels show trajectories for four operating model scenarios that vary with respect to assumptions about natural mortality and growth. The crosshair indicates the state estimate for 2010.

Management procedures that mimicked either avoidance or retention of sub-legal sablefish lead to small improvements in annual catch and conservation performance compared to the existing mandatory at-sea release regulation, but expected gains are small. No specific sub-legal regulation measures are recommended at this time, mainly because sub-legal releases predicted by the operating models underestimated trawl releases from 1996 to the early 2000s, most likely due to violations of the assumption of time-invariant selectivity. Changes in selectivity over this period are most likely influenced by improvements in monitoring, the groundfish integration program (beginning in 2006), trawl gear modifications, and increased communication among fishing masters for the purposes of avoiding sablefish since the early 2000s.

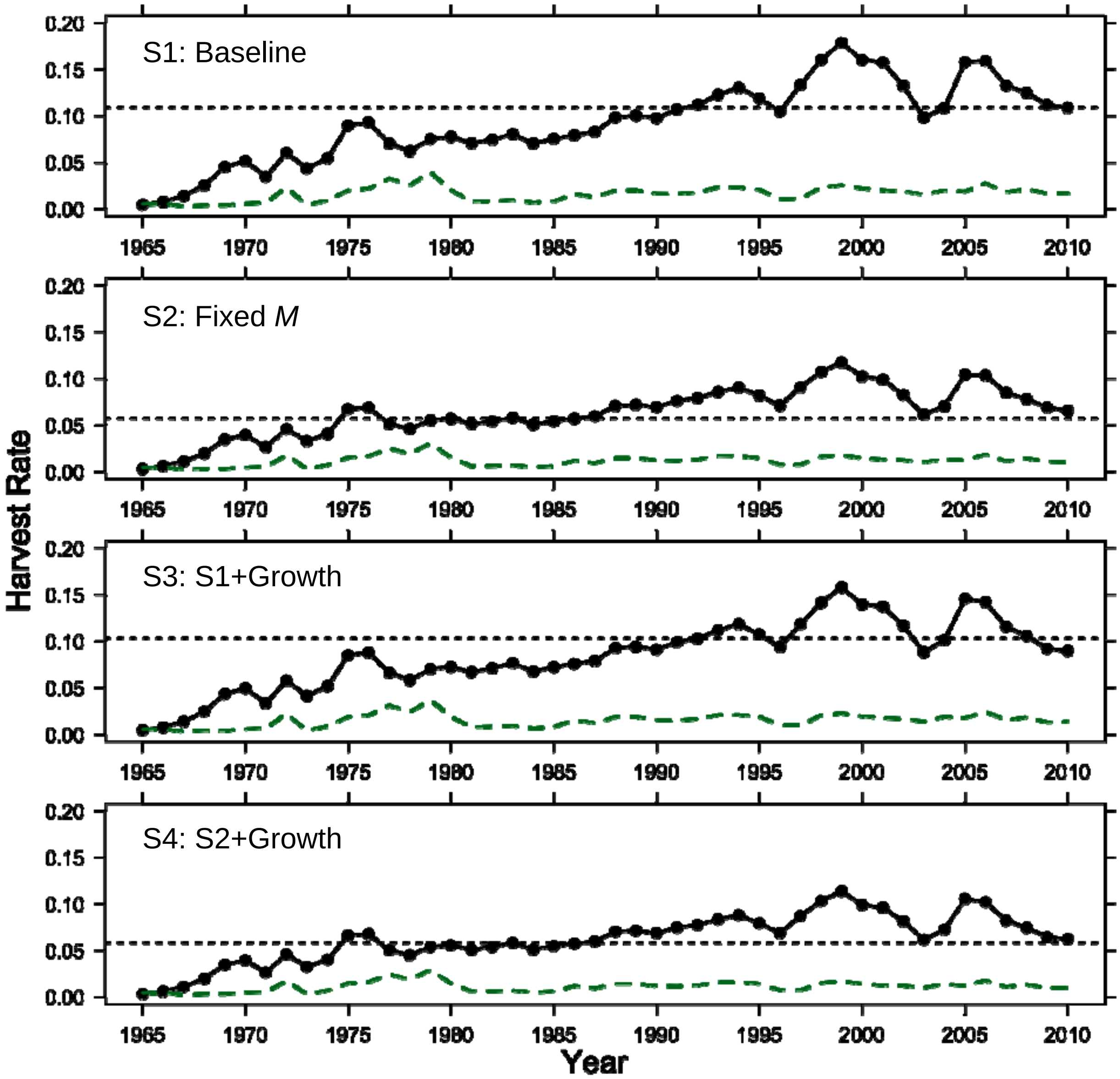


Figure 3: Four operating model scenario estimates of the harvest rate on legal (solid lines and circles) and sub-legal (dashed lines) sablefish. Scenarios vary with respect to assumptions about natural mortality and growth. The legal harvest rate at MSY for each scenario is shown by the horizontal dashed lines.

The use of two surveys in the future leads to improved conservation performance, but also leads to lower average annual catch and much greater catch variability compared to using the stratified random survey alone. Management procedures using the stratified random trap survey alone do not violate Objective 1 and therefore do not appear to create a conservation concern.

Sources of Uncertainty

Scenarios focused on B.C. sablefish stock productivity, growth, and future recruitment variability. Although these uncertainties are amongst the most critical to evaluate in management strategy simulations, these scenarios do not capture the broader range of uncertainties associated with the B.C. sablefish stock and fishery. Advice is subject to several limitations based on current representation of sablefish population dynamics in the operating model scenarios, assumptions about gear selectivity, and the ability to anticipate change in the allocation of catch among gear types as the integrated groundfish fishery management program evolves. In addition, sablefish are distributed along the entire west coast of North America and undergo long distance movement among management jurisdictions. Management of U.S. sablefish stocks may therefore be an important determinant of management performance in B.C., so future work should examine trans-boundary movement hypotheses aimed at determining the best management procedures to apply in B.C. in response to stock trends in U.S. waters.

CONCLUSIONS AND ADVICE

Stock assessment for B.C. sablefish involves an ongoing management strategy evaluation process in which stakeholders and fishery managers develop fishery objectives that are consistent with the DFO SFF. Fishery objectives are defined using limit and upper stock reference points of 0.4 and $0.8B_{MSY}$, respectively, that delimit Critical, Cautious and Healthy stock zones, as well as a target reference point of B_{MSY}. Because all of these reference points are uncertain, the assessment constructs eight plausible operating model scenarios that are each consistent with historical data. Biomass estimates using these models suggest that spawning stock status is currently below B_{MSY} for all scenarios, and is currently estimated in the mid-Cautious zone to low-Healthy zone. Candidate management procedures for setting fishery quotas in the future were developed based on (1) expected reductions in future survey funding and (2) alternative harvest control rules that attempt to reduce catch variability. Expected performance of each management procedure was evaluated via closed-loop simulation using each of the eight operating models as a test scenario. A single management procedure was chosen based on its ability to satisfy conservation and catch objectives given future funding and operational constraints. This selected procedure, labeled StRsHiTuneH46, included: (1) only the stratified random sablefish survey (StRs); (2) a "highly tuned" prior distribution on production model parameters used to estimate stock biomass and reference points annually in the future (HiTune); and (3) a harvest control rule in which the harvest rate on legal-sized sablefish is reduced linearly from U_{MSY}, when the estimated stock is above $0.6B_{MSY}$, to zero when the estimated stock size is less than $0.4B_{MSY}$ (labeled H46). Expected annual catches under StRsHiTuneH46 are projected to be lower over the next 10 years (~2,370 t) compared to the historical average attained as the stock was fished down between the 1960s and 1990s. The harvest rate of legal-size sablefish is currently close to the harvest rate at maximum sustained yield, U_{MSY}, and the selected procedure shows a high probability of maintaining this harvest rate near or below U_{MSY} in the future despite several levels of uncertainty.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Regional Advisory Meeting of January 17, 2011 on Management Procedures for the Multi-Gear Sablefish (*Anoplopoma Fimbria*) Fishery in British Columbia. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Cox, S.P., Kronlund, A.R., and Wyeth, M.R. 2009. Development of precautionary management strategies for the British Columbia sablefish (*Anoplopoma fimbria*) fishery. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/043. vi + 145 p.

Cox, S.P., and Kronlund, A.R. 2009. Evaluation of interim harvest strategies for sablefish (*Anoplopoma fimbria*) in British Columbia, Canada for 2008/09. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/042. vi + 82 p.

Wilkens, M.E. and M.W. Saunders (eds.). 1997. Biology and management of sablefish *Anoplopoma fimbria*. NOAA Tech. Report NMFS 130: 275p.

FOR MORE INFORMATION

Contact: A.R. Kronlund (Rob)
Marine Ecosystem and Aquaculture Division
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia V9T 6N7
Tel: 250-756-7108
Fax: 250-756-7053
E-Mail: Allen.Kronlund@dfo-mpo.gc.ca

This report is available from the:

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

Telephone: 250-756-7208
Fax: 250-756-7209
E-Mail: CSAP@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs

ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2011. Management procedures for the multi-gear sablefish (*Anoplopoma fimbria*) fishery in British Columbia, Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/025.