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Science / Sciences

Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2014/028

STOCK ASSESSMENT FOR SILVERGRAY ROCKFISH (*SEBASTES BREVISPINIS*) ALONG THE PACIFIC COAST OF CANADA

Image: Silvergray Rockfish (Sebastes brevispinis). Credit: Terri Bonnet, Fisheries and Oceans Canada (DFO).

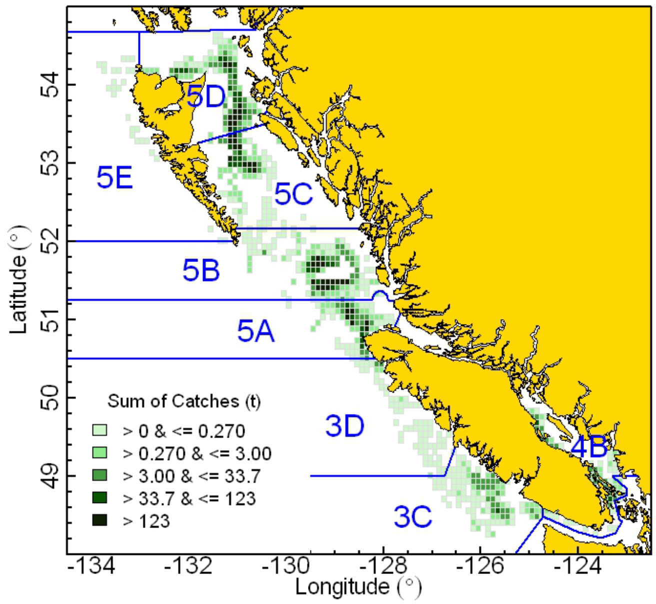

Figure 1. Total Silvergray Rockfish catches (t) from trawl fisheries summed over 1996 and 2012 in grid cells 0.100 longitude by 0.075 latitude (approximately 58.6 km^2). The Pacific Marine Fisheries Commission major areas are outlined by blue lines. This stock assessment for Silvergray Rockfish was coastwide and included all areas shown here except for 4B.

Context

Harvest advice for Silvergray Rockfish was required to determine if current harvest levels are sustainable and compliant with Fisheries and Oceans Canada "Fishery Decision-Making Framework Incorporating The Precautionary Approach".

This Science Advisory Report is from the Regional Peer Review meeting on 'Assessments of British Columbia Rock Sole and Silvergray Rockfish Stocks', held on November 20-22, 2013. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule *as they become available.*

SUMMARY

- Silvergray Rockfish (*Sebastes brevispinis*) is a commercially important species of rockfish that has supported a domestic trawl fishery since 1940, with periods of heavy fishing in the mid-1960s and during 1985-1995.
- All areas of Canada's Pacific coast, excluding waters between Vancouver Island and the British Columbia mainland, were assessed as a single stock using an annual two-sex catch-at-age model, implemented in a Bayesian framework to quantify uncertainty of estimated quantities.
- The spawning biomass (mature females only) at the beginning of 2014 (B_{2014}) is estimated to be 0.56 (0.41–0.70) of unfished spawning biomass (B_0); numbers denote median (and 5-95 percentiles) of the Bayesian results. Also, B_{2014} is estimated to be 2.04 (1.22–3.00) of the equilibrium biomass at maximum sustainable yield, B_{MSY}.
- Two periods of high recruitment, 1982-1984 and 2000–2001, were estimated for this stock. Increased catch followed the large recruitment of 1982-1984, but not the large recruitment of 2000-2001.
- Decision tables are presented using the provisional reference points from the Fisheries and Oceans Canada *Sustainable Fisheries Framework* Precautionary Approach, namely a limit reference point (LRP) of $0.4B_{\mathrm{MSY}}$ and upper stock reference (USR) point of $0.8B_{\mathrm{MSY}}$.
- Advice to management is presented in the form of decision tables using ten-year projections for a range of constant catch strategies up to 3,000 t/year, where t is tonnes; the mean annual coastwide catch was 1,408 t from 2008-2012. The probability of remaining above the LRP at the beginning of 2024 is estimated to be at least 0.99 for all catch strategies tested. The probability of remaining above the USR at the beginning of 2024 is estimated to be at least 0.89 for all catch strategies tested. Stock sizes are predicted to likely decrease at catch levels of at least 1,750 t/year. The probability that the exploitation rate at the beginning of 2024 will be below that associated with MSY at equilibrium is at least 0.56 for all catch strategies tested.
- Catches at levels of 1,500 t/year, slightly above recent mean catch levels, essentially predict no change in stock size over the next 10 years, with the stock remaining well above the USR.

INTRODUCTION

Silvergray Rockfish (*Sebastes brevispinis)* is a long-lived, commercially important species of rockfish found along the rim of the North Pacific Ocean. It had an annual coastwide total allowable catch (TAC) of 1,433 t in 2013, which has been the status quo since 2006. The mean annual coastwide catch was 1,408 t from 2008-2012. The trawl fishery and hook and line fishery are allocated 1,267 t and 166 t of the TAC, respectively.

Silvergray Rockfish are presently managed in four Management Units (MUs) consisting of groupings of the Groundfish Management Areas (GMAs) that are used by the Fisheries and Oceans Canada (DFO) Groundfish Management Unit to set TACs (Figure 1). Reporting from the GMAs has only been available since 1996, and there is presently no procedure to alter historical landings to conform to these boundaries. The four MUs were not assessed separately here. Instead, the Silvergray Rockfish population was aggregated into a single coastwide stock after investigating the available growth functions and abundance trends for each MU and concluding that they were all very similar. As well, there was a nearly continuous distribution of catch along the coast (see Figure 1). Participants of the Regional Peer Review meeting agreed that, based on these observations, a coastwide assessment was acceptable, but recommended continuing the separation of the TAC into MUs as a precautionary measure, with Area 3CD receiving the lowest TAC.

Coastwide, 98% of the commercial captures of Silvergray Rockfish were recorded in the depth range 82-388 m.

ASSESSMENT

This report summarises the key results from a quantitative stock assessment for coastwide Silvergray Rockfish. An annual two-sex, catch-at-age model was applied and tuned to: six series of fishery-independent trawl survey data, annual estimates of commercial catch since 1940, and age composition data from the commercial fishery and from four of the six survey series. The stock was assumed to be at an unfished equilibrium in 1940.

The model estimated stock-recruitment parameters, natural mortality (independently for females and males), catchability coefficients for the survey series, selectivity parameters for the commercial fishery and those survey series for which age data were available, and a time series of recruitment deviations from the predicted stock-recruitment function.

The model was used to estimate the past and present vulnerable biomass (the biomass that is vulnerable to capture by the fishery), spawning stock biomass (mature females only) and population age structure. Estimated parameters were projected forward to equilibrium under a range of exploitation rates to calculate maximum sustainable yield (MSY) and associated reference points. Ten-year projections were performed over a range of constant catches to estimate probabilities of the spawning biomass being greater than the reference points at each level of catch. All calculations were made using the Bayesian Markov Chain Monte Carlo (MCMC) method to quantify the uncertainty associated with parameter estimation. This approach yielded 1,000 MCMC samples from the Bayesian posterior distribution. Estimates of various quantities were calculated from these samples, and are presented here as median values (with 5-95% percentiles). Results presented as probability statements were also calculated using the 1,000 MCMC samples. Uncertainty associated with some data sets and model assumptions was explored through sensitivity runs, some of which were also investigated using the MCMC procedure.

Advice to managers is presented as a set of decision tables that provide probabilities of exceeding reference points in 2019 and 2024, over a range of constant catch levels applied without feedback control.

Figure 2 shows the time series of the median estimate of female spawning biomass in year *t* relative to that in 1940 (B_t/B_0), median exploitation rate, and the reconstructed historical catches. Figure 3 shows the median estimates and 90% credibility intervals for B_t/B_0, together with the reference points (that are described below). The results show that the biomass dropped by about 50% between 1965 to 1990, beginning with the onset of foreign fishing and continuing with a high level of domestic catches up to the mid-1990s. Catches were then reduced and biomass stabilized or possibly increased slightly to the present. Estimates of quantities of interest are given in Table 1. In particular, the estimate for B_{2014}/B_0, the ratio of coastwide female spawning biomass at the start of 2014 (B_{2014}) to that for unfished conditions in 1940 (B_0), was 0.56 (0.41-0.70).

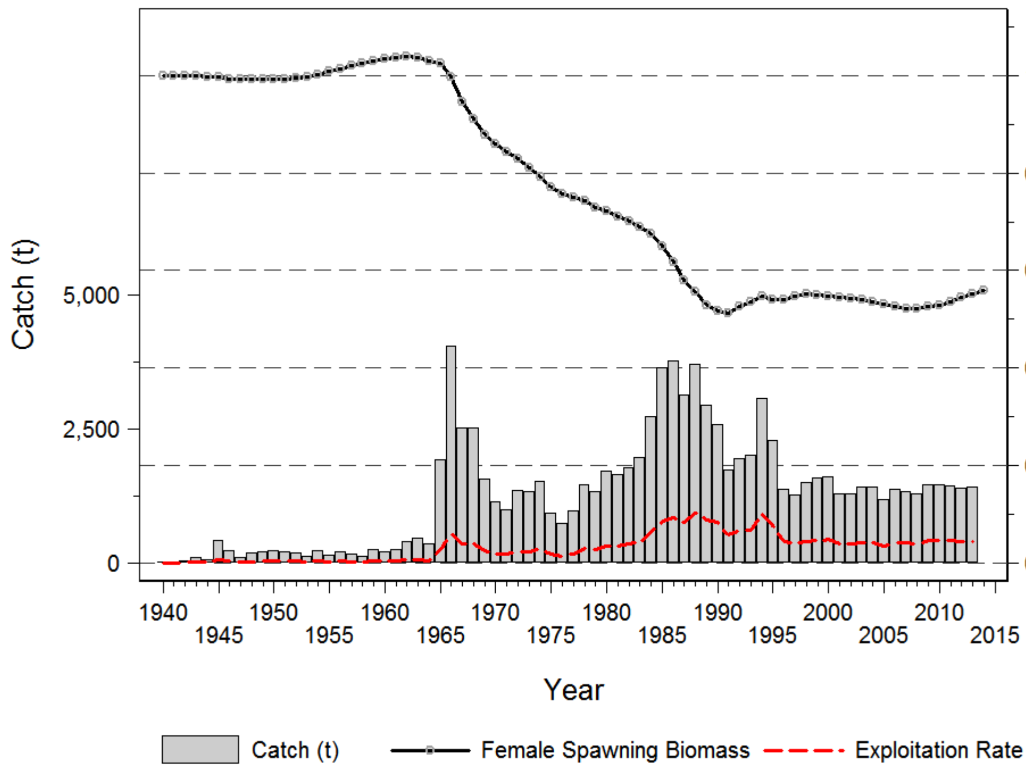

Figure 2. Annual commercial catch (vertical bars, relative to left-hand axis) and median estimates for Bt/B0 (female spawning biomass in year t relative to that in 1940) and exploitation rate ut (ratio of total catch to the vulnerable biomass in the middle of the year) both relative to the right-hand axis

The years 1982 and 1983 had approximately double the long-term average age-1 recruitment. There was not any subsequent increase in spawning biomass (Figures 3 and 4), probably due to the relatively high levels of removals in the years up to the mid-1990s. There have been one or two years of good recruitment in the early 2000s. The estimated annual exploitation rate (ratio of total catch to the vulnerable biomass in the middle of the year) ranged from 0.08 to 0.10 from 1985 to 1990 due to high catch levels, and then peaked again at 0.10 in 1994 (Figure 2). Exploitation rates dropped quickly with the reduction of catch levels associated with the introduction of TACs in the mid-1990s and have remained near 0.04 since 1996. The exploitation rate for 2013, u_{2013}, is estimated to be 0.04 (0.03-0.07) (Table 1).

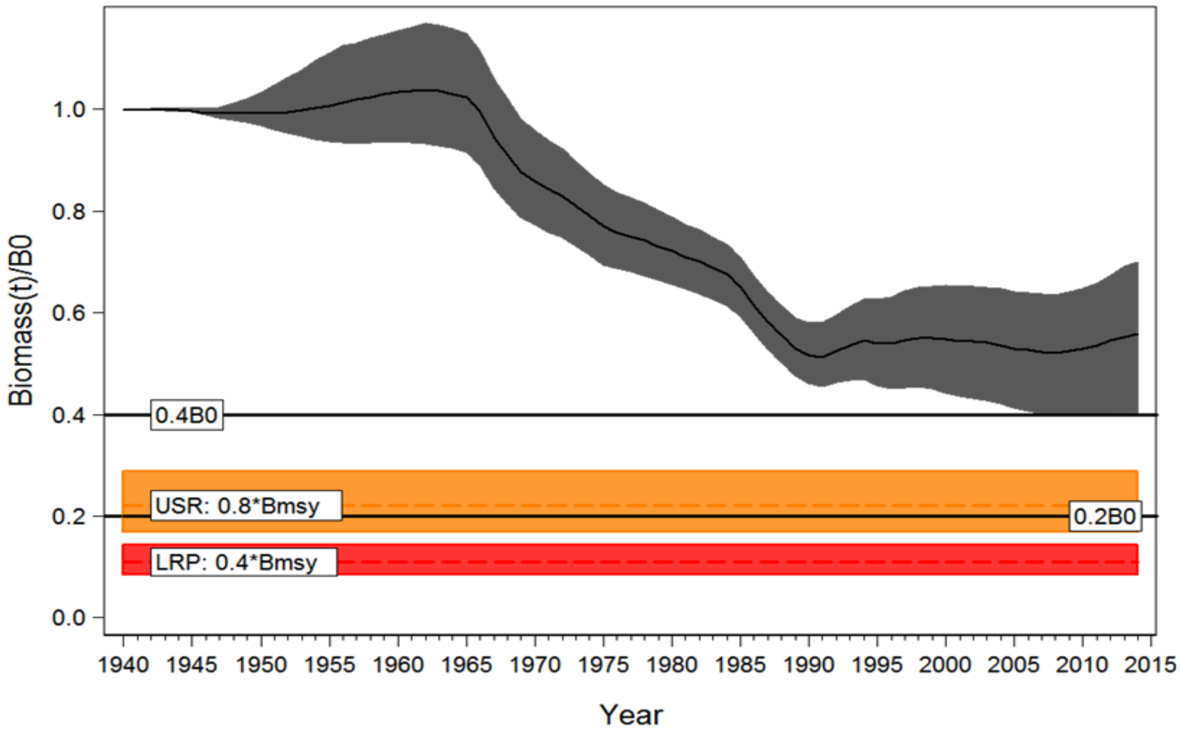

Figure 3. Median estimates and 90% credibility intervals for Bt/B0 (female spawning biomass in year t relative to that in 1940) for Silvergray Rockfish (black line and grey fill). Also shown are median estimates and 90% credibility intervals for the MSY-based reference points (LRP: Limit Reference Point = 0.4BMSY; USR: Upper Stock Reference Point = 0.8BMSY) relative to B0. The B0-based reference points 0.2B0 and 0.4B0 are shown as solid horizontal black lines.

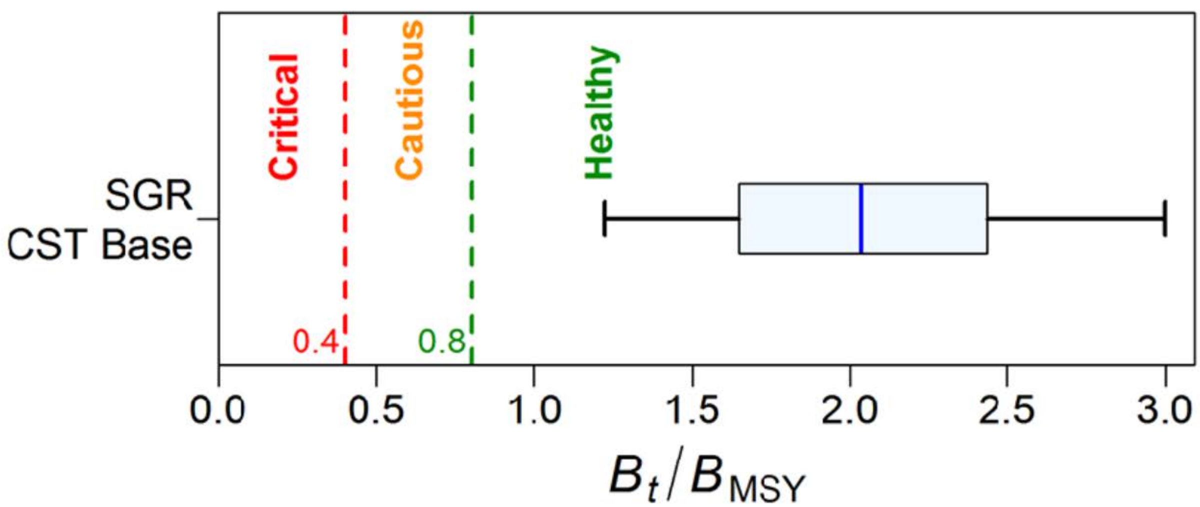

Figure 4. Current status of the coastwide Canadian Silvergray Rockfish stock relative to the DFO Precautionary Approach provisional reference points of 0.4B_{MSY} and 0.8B_{MSY}. The value of B_t/B_{MSY} uses t=2014. Boxplots show the 5, 25, 50, 75 and 95 percentiles from the MCMC results.

Table 1. The 5th, 50th and 95th quantiles from the MCMC results for quantities of importance. Definitions are: B_0: unfished equilibrium spawning biomass (mature females), V_0: unfished equilibrium vulnerable biomass (males plus females), B_{2014}: spawning female biomass at the start of 2014, V_{2014}: vulnerable biomass in the middle of 2014, u_{2013}: exploitation rate (ratio of total catch to vulnerable biomass) in the middle of 2013, equilibrium spawning biomass at maximum sustainable yield (MSY), u_{MSY}: equilibrium exploitation rate at MSY. All biomass values and MSY are in tonnes. For reference, the average coastwide catch over the last five years (2008-2012) is 1,408 t.

Model derived quantities:

	Quantiles		
	0.05	0.50	0.95
B_0	30,135	35,387	41,926
V_0	60,849	69,565	81,206
B_{2014}	12,669	19,803	28,070
V_{2014}	20,759	32,832	47,679
B_{2014} / B_0	0.405	0.559	0.698
V_{2014} / V_0	0.334	0.474	0.601
u_{2013}	0.030	0.044	0.068

MSY-based derived quantities:

	Quantiles		
	0.05	0.50	0.95
B_{MSY}	7,089	9,718	13,717
$0.4B_{MSY}$	2,836	3,887	5,487
$0.8B_{MSY}$	5,671	7,774	10,974
B_{2014} / B_{MSY}	1.223	2.035	2.997
B_{MSY}/B_0	0.210	0.277	0.360
MSY	1,299	1,998	2,688
u_{MSY}	0.064	0.145	0.300
u_{2013}/u_{MSY}	0.127	0.298	0.883

The estimated MSY is 1,998 (1,299–2,688) t, compared to the average catch over the last five years (2008–2012) of 1,408 t. Estimates of MSY-based quantities are given in Table 1. In particular, the estimated value of B2014/BMSY, where BMSY is the equilibrium spawning biomass that would support the MSY, is 2.04 (1.22–3.00).

Reference Points

Figure 4 shows the stock status relative to the provisional DFO (2009) limit and upper stock reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$. These reference points specify the critical, cautious and healthy zones in the DFO Fishery Decision-making Framework (DFO 2009). The stock at the beginning of 2014 is estimated to be above both the limit and the upper stock reference points with probability 1.00.

A second component of the provisional harvest rule of DFO (2009) concerns the relationship of the exploitation rate relative to that associated with MSY under equilibrium conditions (u_{MSY}). The rule specifies that the exploitation rate should not exceed u_{MSY} when the stock is in the healthy zone. Catch should be reduced when in the cautious zone, and be kept to the lowest level possible when in the critical zone. The estimated ratio of u_{2013}/u_{MSY}, which the harvest rule specifies should be ≤1, is 0.30 (0.13–0.88) (Table 1). The probability that the current exploitation rate is below that associated with MSY is $P(u_{2013}<u_{MSY})=0.96$. The coastwide stock is estimated to have been in the healthy zone since the start of fishing in 1940 (based on median values). The median exploitation rate has never been greater than u_{MSY}.

Additional reference points relative to B_0, the equilibrium unfished spawning biomass in 1940, are presented (Figure 3). These are reference points used in other management jurisdictions and include $0.2B_0$, the level used as a “soft-limit” in New Zealand, and $0.4B_0$, a level used as a “target” in New Zealand and the United States for low productivity stocks. A “soft limit” is a level below which management action is mandatory and a “target” is a desirable level where the stock can hover, spending as much time below as above that level. The stock at the beginning of 2014 is estimated to be above the “soft limit” with probability $P(B_{2014} > 0.2B_0) = 1.00$; the stock at the beginning of 2014 is estimated to be above the “target” with probability $P(B_{2014} > 0.4B_0) = 0.96$.

Projection Results and Decision Tables

Projections starting with the biomass at the beginning of 2014 were made over a range of constant catch levels (0-3,000 t in 250 t increments). Projections were made for 10 years, a time frame considered adequate for long-term advice, but short enough for the projected recruitments to be primarily based on individuals spawned before 2004 (and therefore explicitly estimated by the model). Few Silvergray recruit to the commercial fishery before age 10.

Decision tables (Table 2) give the probabilities of the spawning biomass exceeding the LRP and USR in each projected year for each catch level. Note that catches are held constant without feedback control, so there is no consequent reduction of the exploitation rate in the projections if a stock drops into the cautious or critical zones.

As an example of how to read the tables, the estimated probability that the stock is in the provisional healthy zone in 2024 under a constant catch strategy of 3,000 t is 0.89 (corresponding to row ‘3000’ and column ‘$P(B_{2024} > 0.8B_{MSY})$’ of Table 2).

With a constant catch of 1,500 t, which is above the average recent catch of 1,408 t, the probabilities of the stock remaining above the critical zone, $P(B_t > 0.4B_{MSY})$, or in the healthy zone, $P(B_t > 0.8B_{MSY})$, remain at 0.99 or above by the end of the ten-year projection period (row ‘1500’ in second half of Table 2). With a constant catch of 1,500 t, the probability that the stock at the beginning of 2024 will be above the “soft limit” is $P(B_{2024} > 0.2B_0) = 1.00$ and that it will be above the “target” is $P(B_{2014} > 0.4B_0) = 0.94$. Stock size is also expected to remain around the current level under catches of 1,500 t/year, with the probability $P(B_{2024} > B_{2014}) = 0.53$.

Sources of Uncertainty

Uncertainty in the estimated parameters and quantities is explicitly addressed using a Bayesian approach, but reflects only the specified model and weights assigned to the various data components. Results from sensitivity runs (not shown here) do not differ greatly from the base run.

Ecosystem Considerations

In 2012, measures were introduced to reduce and manage the bycatch of corals and sponges by the British Columbia groundfish bottom trawl fishery. These measures were developed jointly by industry and environmental non-governmental organisations, and include: limiting the footprint of groundfish bottom trawl activities, establishing a combined bycatch conservation limit for corals and sponges, and establishing an encounter protocol for individual trawl tows when the combined coral and sponge catch exceeds 20 kg. These measures have been incorporated into DFO's Pacific Region Groundfish Integrated Fisheries Management Plan (March 28, 2012, version 2.1).

The fishery is also subject to the following management measures: 100% at-sea monitoring, 100% dockside monitoring, individual vessel accountability for all retained and released catch, individual transferable quotas and reallocation of these quotas between vessels and fisheries to cover catch of non-directed species (see aforementioned Management Plan).

Table 2. Decision tables for seven reference points for projections to 2019 (5 years) and to 2024 (10 years) over a range of constant annual catch strategies (in metric tonnes) for the coastwide Silvergray Rockfish stock. Values are the probabilities of the spawning biomass (mature females) at the start of projection year t being greater than the reference point for the given annual catch strategy. The probabilities are the proportion of the MCMC samples for which B_t is greater than the respective reference point. For reference, the average catch over the last five years (2008-2012) is 1,408 t.

5 year projections (to 2019):

Catch	$P(B_{2019} > 0.4B_{MSY})$	$P(B_{2019} > 0.8B_{MSY})$	$P(B_{2019} > B_{MSY})$	$P(B_{2019} > B_{2014})$	$P(u_{2019} > u_{MSY})$	$P(B_{2019} > 0.2B_0)$	$P(B_{2019} > 0.4B_0)$
0	1.00	1.00	1.00	1.00	0.00	1.00	0.99
250	1.00	1.00	0.99	1.00	0.00	1.00	0.99
500	1.00	1.00	0.99	0.99	0.00	1.00	0.99
750	1.00	1.00	0.99	0.95	0.00	1.00	0.98
1000	1.00	1.00	0.99	0.87	0.01	1.00	0.97
1250	1.00	1.00	0.99	0.71	0.02	1.00	0.96
1500	1.00	0.99	0.98	0.52	0.04	1.00	0.95
1750	1.00	0.99	0.98	0.36	0.07	1.00	0.93
2000	1.00	0.99	0.97	0.22	0.11	1.00	0.90
2250	1.00	0.99	0.96	0.12	0.16	1.00	0.86
2500	1.00	0.98	0.95	0.07	0.22	1.00	0.83
2750	1.00	0.98	0.94	0.04	0.28	1.00	0.79
3000	1.00	0.97	0.92	0.02	0.33	0.99	0.76

10 year projections (to 2024):

Catch	$P(B_{2024} > 0.4B_{MSY})$	$P(B_{2024} > 0.8B_{MSY})$	$P(B_{2024} > B_{MSY})$	$P(B_{2024} > B_{2014})$	$P(u_{2024} > u_{MSY})$	$P(B_{2024} > 0.2B_0)$	$P(B_{2024} > 0.4B_0)$
0	1.00	1.00	1.00	1.00	0.00	1.00	1.00
250	1.00	1.00	1.00	1.00	0.00	1.00	1.00
500	1.00	1.00	1.00	0.99	0.00	1.00	0.99
750	1.00	1.00	0.99	0.95	0.00	1.00	0.99
1000	1.00	1.00	0.99	0.86	0.01	1.00	0.98
1250	1.00	1.00	0.98	0.72	0.02	1.00	0.97
1500	1.00	0.99	0.98	0.54	0.04	1.00	0.94
1750	1.00	0.99	0.97	0.37	0.08	1.00	0.90
2000	1.00	0.98	0.95	0.22	0.14	1.00	0.84
2250	1.00	0.98	0.92	0.13	0.21	0.99	0.77
2500	0.99	0.96	0.89	0.08	0.28	0.98	0.69
2750	0.99	0.93	0.85	0.05	0.36	0.97	0.62
3000	0.99	0.89	0.80	0.02	0.44	0.95	0.53

CONCLUSIONS AND ADVICE

This assessment depicts a slow-growing, low-productivity stock that has experienced commercial fishing by foreign and domestic fleets in the past. Exploitation rates have been low since the 1990s and the stock is estimated, with very high probability, to be in the DFO provisional healthy zone both now and in ten years at harvest levels up to 3,000t/year (which is over twice recent average catches).

Advice to management is provided in the form of decision tables. The tables assume the model to be valid and also assume no future management intervention if stock status changes.

Catches in the commercial groundfish fisheries are presently well recorded by virtue of independent at-sea monitoring of the fishery. Such data, together with ongoing results from surveys, give confidence that future assessments can continue to monitor this stock and that action can be taken if required.

SOURCES OF INFORMATION

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DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach

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