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Canadian Science Advisory Secretariat
Pacific Region **Science Advisory Report 2017/043**

PACIFIC OCEAN PERCH (*SEBASTES ALUTUS*) STOCK ASSESSMENT FOR QUEEN CHARLOTTE SOUND, BRITISH COLUMBIA IN 2017

Photo. Pacific Ocean Perch (Sebastes alutus). Credit: Schon Acheson, Fisheries and Oceans Canada (DFO).

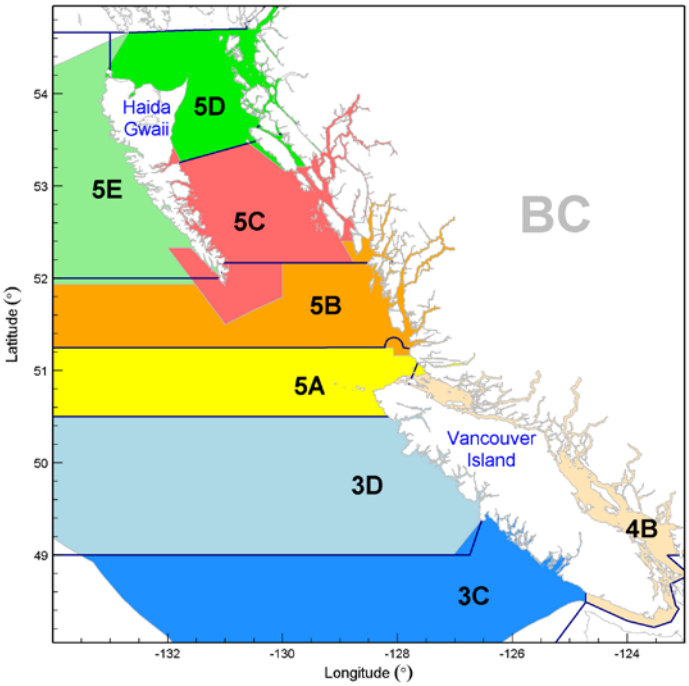

Figure 1. Pacific Marine Fisheries Commission major areas (outlined by blue lines). This assessment covers areas 5A, 5B and 5C, and 5E south of 52°20' (the red area to the west of the southern part of Haida Gwaii), known collectively as 5ABC. The 5E portion was not included in the previous assessment in 2010. Groundfish Management Unit areas for Pacific Ocean Perch are shaded in seven colours and differ slightly from the Pacific Marine Fisheries Commission areas.

Context

Pacific Ocean Perch (POP, Sebastes alutus) is a commercially important species of rockfish that inhabits the marine canyons along the coast of British Columbia. Of the current annual Total Allowable Catch (TAC) of rockfish on the west coast of Canada, POP has the second largest single-species quota after Yellowtail Rockfish (S. flavidus). Key results from the stock assessment for area 5ABC at the start of 2017 (the first assessment since 2010) are reported here. Harvest advice is required to determine if current harvest levels are sustainable and compliant with DFO's Decision-making Framework Incorporating the Precautionary Approach.

This Science Advisory Report is from the Regional Peer Review meeting on Stock Assessment for Pacific Ocean Perch (Sebastes alutus) in Queen Charlotte Sound, British Columbia in 2017, held on June 1-2, 2017. The full stock assessment (Research Document) and Proceedings from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule when available.

SUMMARY

- Pacific Ocean Perch (POP) is a commercially important species of rockfish that has supported a domestic trawl fishery for decades, and was heavily fished by foreign fleets from the mid-1960s to 1977. The stock in Queen Charlotte Sound (5ABC) is the largest of the three POP stocks assessed on the British Columbia coast.
- The stock in area 5ABC was assessed using a single fishery, annual two-sex catch-at-age model, implemented in a Bayesian framework to quantify uncertainty of estimated quantities.
- An update to the 2010 assessment approach was followed, which included the removal of the Queen Charlotte Sound (QCS) shrimp survey series. The QCS shrimp survey series may be evaluated for applicability in future groundfish assessments as well.
- The median (and 5 and 95 percentiles of the Bayesian results) spawning biomass (mature females only) at the beginning of 2017 (B_{2017}) is estimated to be 0.27 (0.18-0.42) of unfished spawning biomass (B_0). Also, B_{2017} is estimated to be 1.03 (0.54-1.96) of the equilibrium spawning biomass at maximum sustainable yield, B_{MSY}.
- Advice to management is presented in the form of decision tables using the provisional reference points from the Fisheries and Oceans Canada *Sustainable Fisheries Framework* Precautionary Approach, namely a limit reference point of $0.4B_{MSY}$ and upper reference point of $0.8B_{MSY}$. The decision tables provide five-year projections across a range of constant catches.
- At current catch levels, there is an estimated 0.99 probability that $B_{2017} > 0.4B_{MSY}$, and a 0.74 probability that $B_{2017} > 0.8B_{MSY}$, (i.e. of being in the healthy zone). The probability that the exploitation rate in 2016 was below that associated with MSY is 0.75. Constant catches at levels slightly above the mean of recent catches indicate that there will be slight declines in the probabilities of the spawning biomass being above the reference points at the end of five years.
- A suite of climatic and environmental indicators were investigated to identify potential ecosystem influences on recruitment. The methods used to develop and evaluate the indicators are suitable for identifying ecosystem influences on recruitment, and could be explored with other species. At present, no link between the indicators and Pacific Ocean Perch recruitment could be detected, consequently ecosystem influences were not incorporated into the model or advice to management.
- It is recommended that the next assessment occur in 2022, with three new indices available from the QCS synoptic trawl survey and five years of ageing and catch data. No appropriate indicators for this stock could be recommended that would trigger an assessment earlier than scheduled. Advice for the interim years is explicitly included in the decision tables.
- Recommended future work includes the investigation of alternative reference points due to the sensitivity of B_{MSY} based reference points, and the development of informative priors on survey catchability (q).

INTRODUCTION

Pacific Ocean Perch (*Sebastes alutus*, POP) is a long-lived, commercially important species of rockfish found along the rim of the North Pacific Ocean. It supports the second largest rockfish fishery in British Columbia with an annual coastwide total allowable catch (TAC) of 5,192 t (metric tonnes) in 2016, after a progressive 3-year reduction of 258 t/y in 5ABCD (based on the 2010 assessment for Queen Charlotte Sound; DFO 2011, and Edwards et al. 2012). The mean annual coastwide catch was about 4,200 t from 2012-2016. The 5ABC trawl fishery is the

largest of the three BC POP fisheries, with a mean annual catch of 2,400 t over the period 2012-2016. The trawl fishery is allocated 99.98% of the coastwide POP TAC, with the remainder allocated to the hook and line fishery.

The Pacific Marine Fisheries Commission (PMFC) major areas used in stock assessments are similar to the groundfish management areas (GMAs) used by the Fisheries and Oceans Canada (DFO) Groundfish Management Unit (GMU) to set TACs (Figure 1). Exact GMU area boundaries were not used in the assessment because reporting from them has only been available since 1996 and there is no available procedure to alter historical landings to conform to these boundaries. Therefore, areas refer to PMFC areas unless otherwise specified.

The TAC for GMU area 5ABC has been 3231 t since 2013. For area 5ABC, 98% of the commercial captures of POP are made in the depth range 96-416 m.

ASSESSMENT

This report summarises the key results from the 2017 quantitative stock assessment for the 5ABC stock of POP. A single fishery, annual two-sex, catch-at-age model was tuned to fishery-independent trawl survey data (from historical survey data and the ongoing Queen Charlotte Sound synpotic trawl survey), annual estimates of commercial trawl catch since 1940, and age composition data from the commercial fishery and from survey series. The main change from this base case with the equivalent run in the 2010 assessment is the exclusion of the Queen Charlotte Sound (QCS) shrimp survey, due to its limited depth and spatial coverage: only half the depth range of POP and only partial coverage of Queen Charlotte Sound. This survey was also redundant with the QCS synoptic survey, which was designed to monitor a range of groundfish species, including POP. Seven sensitivity analyses (including the addition of QCS shrimp survey data) were conducted to explore sensitivity to the assumptions of the base case.

The model estimates stock-recruitment parameters, natural mortality (independently for females and males), catchability coefficients for the survey series, and selectivity parameters for the commercial fishery and the two survey series.

The model reconstructs the time series of vulnerable biomass (total of male and female biomass that is vulnerable to capture by the fishery) and spawning stock biomass (mature females only), given the model assumptions. Estimated parameters are then used to calculate maximum sustainable yield (MSY) and reference points. Five-year projections are performed for a fixed range of constant catches to estimate probabilities of the spawning biomass being greater than the reference points. All calculations are made using the Bayesian Markov Chain Monte Carlo (MCMC) method to quantify the uncertainty associated with parameter estimation. This search procedure yielded 1,000 MCMC samples from the posterior distributions for estimated parameters. Estimates of various quantities are calculated from these samples, and are presented as the median (with 5-95% quantiles to specify uncertainty). Calculated probabilities are also based on the MCMC posterior distributions. Uncertainty associated with some data sets and model assumptions was explored through sensitivity runs.

Advice to managers is presented as a set of decision tables that provide probabilities of exceeding reference points ($0.4B_{MSY}$; $0.8B_{MSY}$) for 2017 through 2022 for a range of constant catch levels.

Figure 2 shows the posterior distributions of the estimated annual vulnerable biomass, together with the historical catches. Figure 3 compares the trajectories of the estimated medians of vulnerable and spawning (mature females only) biomasses relative to their unfished values. These results demonstrate a slow decline in biomass from 1940 to 1960, followed by an increasing biomass caused by fish entering the population after a large recruitment event in 1953 (Figure 4). Heavy fishing pressure by foreign fleets (Figure 5) from 1965-77 caused a

decline in biomass. The decline then continued into the 1980s due to increased fishing pressure from the domestic Canadian trawl fleet (after the foreign fleet left) and a lack of large recruitment events for most of the 1960s and 1970s (Figure 4). Another good recruitment year in 1977 sustained an increase in spawning biomass from the late 1980s until 1994, after which the biomass declined until 2005. Since then, spawning biomass has remained fairly constant, coincident with a reduction in catch levels from the mid-2000s.

There have been two large POP recruitment events in areas 5ABC with recruitment well above the long-term average (Figure 4). These events occurred near 1953 and 1977 (as 1-yr old fish); with each of these events resulting in increases in the estimated spawning and vulnerable biomasses (Figure 3) as these fish matured or became old enough for capture by the fishery.

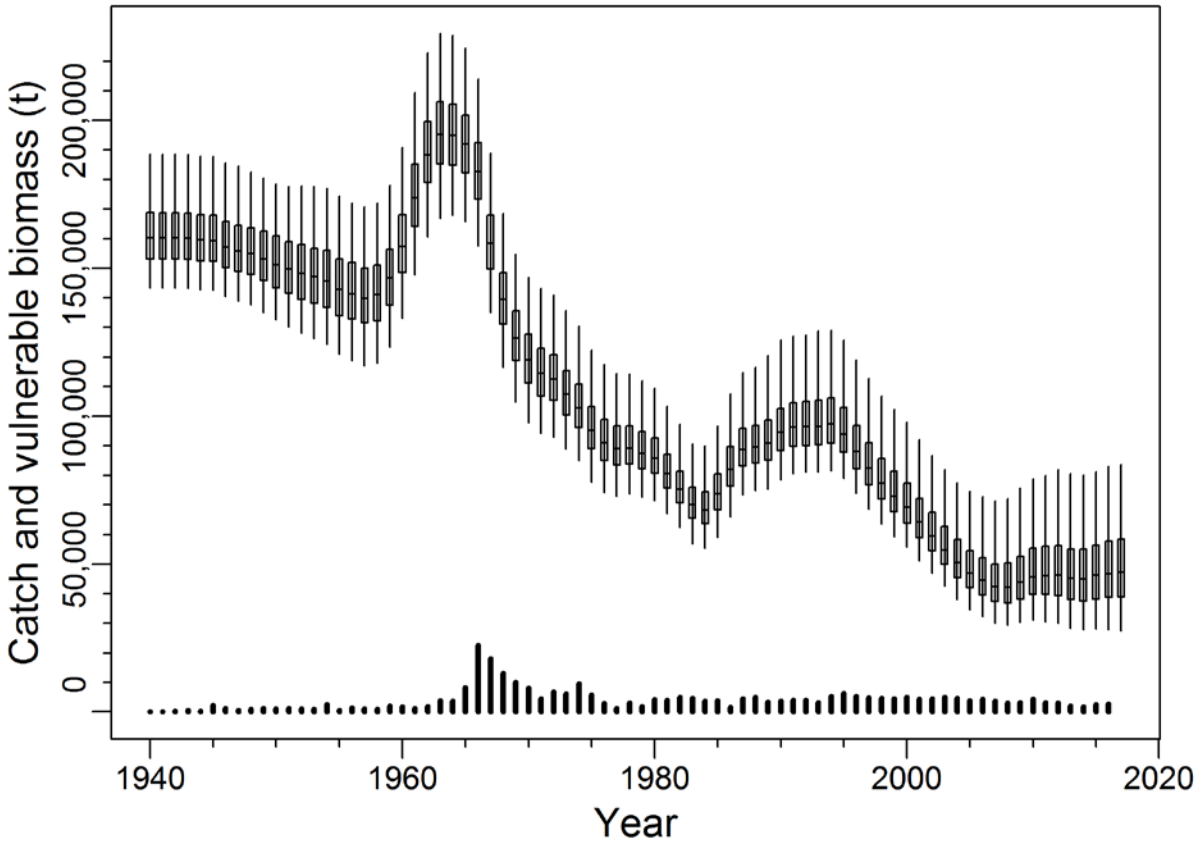

Figure 2. Annual commercial catch (vertical bars) and vulnerable biomass (boxplots showing 2.5, 25, 50, 75 and 97.5 percentiles of the MCMC results).

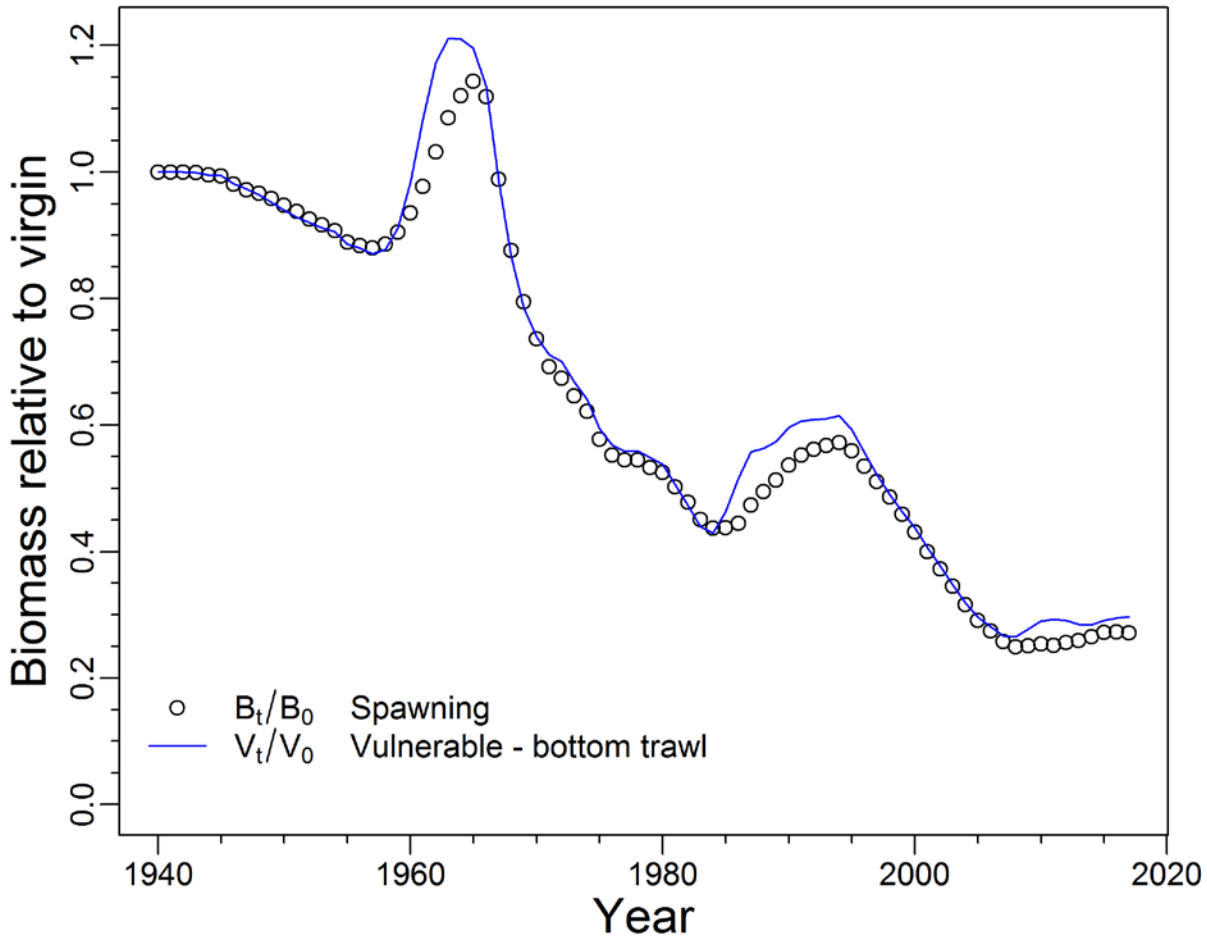

Figure 3. Trajectories of spawning and vulnerable biomass relative to unfished equilibrium levels, B_t / B_0 and V_t / V_0 respectively, shown as MCMC medians.

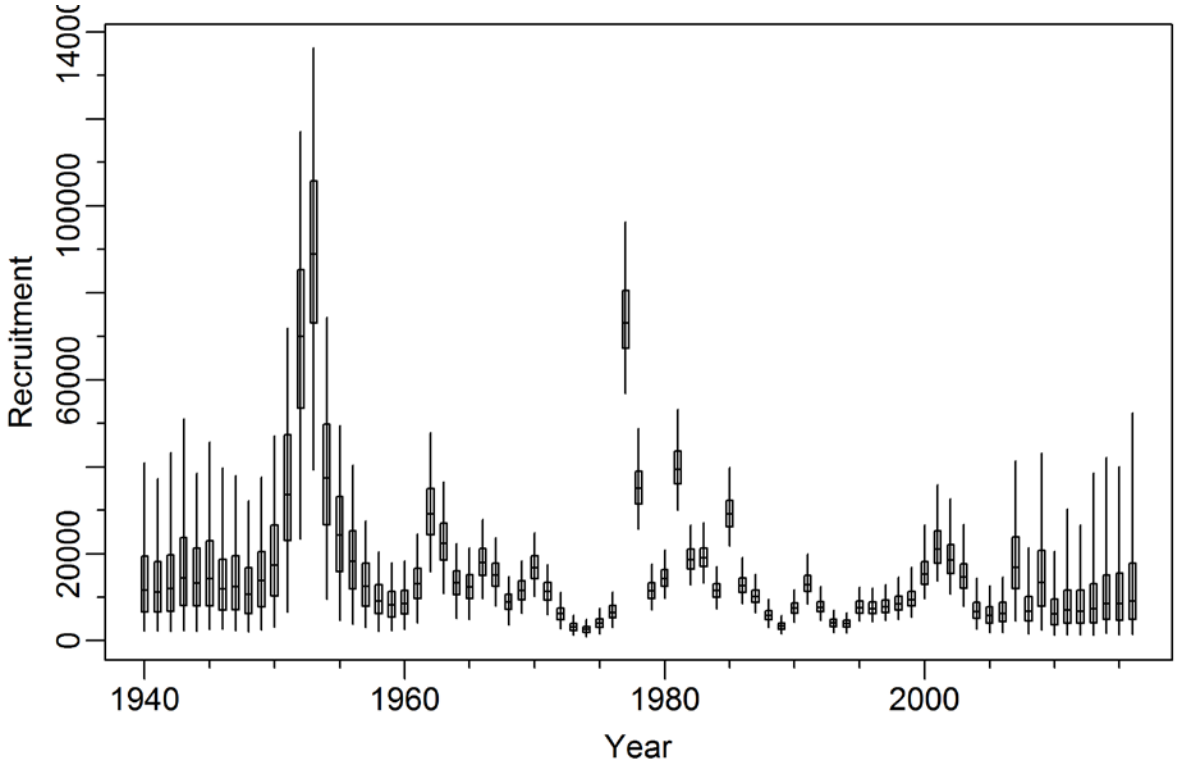

Figure 4. Marginal posterior distribution of recruitment (in 1000's of age 1 fish) for each year. Boxplots give the 2.5, 25, 50, 75 and 97.5 percentiles from the MCMC results.

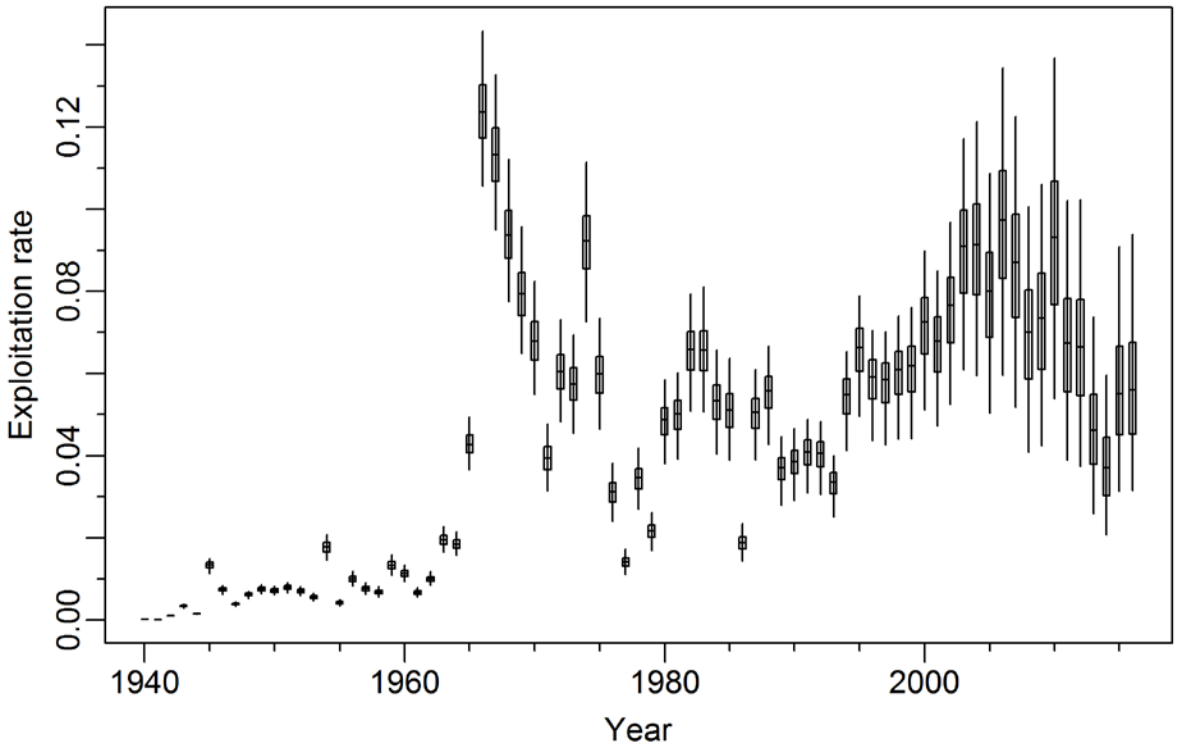

Figure 5. Marginal posterior distributions of annual exploitation rate by year. Boxplots give the 2.5, 25, 50, 75 and 97.5 percentiles from the MCMC results.

The estimated annual exploitation rate (ratio of total catch to the vulnerable biomass in the middle of the year) peaked in the mid-1960s (Figure 5) due to the large foreign catches, and then peaked again in 2007 due to increased domestic exploitation combined with lowered vulnerable biomass levels. Exploitation rates have declined since TAC reductions were put in place, beginning in 2006 (by 700 t) and in 2011-13 (by 774 t). Estimated 2016 exploitation rate, u_{2016}, is 0.056 (0.033-0.085, Table 1).

Table 1. The 5th, 50th and 95th percentiles of the MCMC results. Definitions are: B_0 – unfished equilibrium spawning biomass (mature females), V_0 – unfished equilibrium vulnerable biomass (males and females), B_{2017} – spawning female biomass at the start of 2017, V_{2017} – vulnerable biomass in the middle of 2017, u_{2016} – exploitation rate (ratio of total catch to vulnerable biomass) in the middle of 2016, u_{max} – maximum exploitation rate from 1940-2016, B_{MSY} – equilibrium spawning biomass at MSY (maximum sustainable yield), u_{MSY} – equilibrium exploitation rate at MSY, V_{MSY} – equilibrium vulnerable biomass at MSY. All biomass values (and MSY) are in tonnes. For reference, the average catch over the last five years (2012-2016) is 2397 t.

	Area 5ABC		
Quantity▼	5%	50%	95%
B_0	81,005	89,993	103,214
V_0	144,968	160,337	182,826
B_{2017}	15,312	24,302	40,768
V_{2017}	29,990	47,272	79,451
B_{2017}/B_0	0.177	0.271	0.417
V_{2017}/V_0	0.195	0.297	0.45
u_{2016}	0.033	0.056	0.085
u_{max}	0.108	0.124	0.142
$0.4B_{MSY}$	6,297	9,647	13,908
$0.8B_{MSY}$	12,594	19,293	27,817
B_{MSY}	15,743	24,116	34,771
B_{MSY}/B_0	0.183	0.269	0.362
B_{2017}/B_{MSY}	0.537	1.029	1.964
MSY	2,539	3,843	5,255
u_{MSY}	0.039	0.08	0.148
u_{2016}/u_{MSY}	0.292	0.684	1.798
V_{MSY}	33,785	47,982	66,674
V_{MSY}/V_0	0.218	0.301	0.382

The estimated ratio of current spawning biomass (B_{2017}) to equilibrium unfished biomass B_0, is 0.27 (0.18-0.42). The estimated median MSY is 3,843 t (2,539-5,255 t), compared to the average catch over the last five years (2012-2016) of 2,397 t (Table 1). The estimated value of B_{2017}/B_{MSY}, where B_{MSY} is the equilibrium spawning biomass that would support the MSY, is 1.03 (0.54-1.96).

Reference Points

Figure 6 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 define the critical, cautious and healthy zones. The spawning biomass at the beginning of 2017 is estimated to be above the limit reference point with probability $P(B_{2017} > 0.4B_{MSY}) = 0.99$, and above the upper stock reference point with probability $P(B_{2017} > 0.8B_{MSY}) = 0.74$. These probabilities are higher than those estimated for beginning year biomass in 2011 for the equivalent model from the previous assessment (DFO, 2011) due to changes in some model assumptions, and the principal change of removing data from the QC Sound shrimp survey. The current model estimates that the biomass has remained relatively constant since 2010 (Figure 2).

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. Catches 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_{2016}/u_{MSY}, which the harvest rule specifies should be ≤1, is 0.68 (0.29-1.8). The probability that the current exploitation rate is below that associated with MSY is P($u_{2016} < u_{MSY}$) = 0.75.

The stock is estimated to have been in the healthy zone (above $0.8B_{MSY}$) since the start of fishing in 1940 (based on median values). The median exploitation rate has been greater than u_{MSY} for a total of 9 years (1966 – 1968, 1974, 2003, 2004, 2006, 2007, 2010), and has been less than u_{MSY} since 2010.

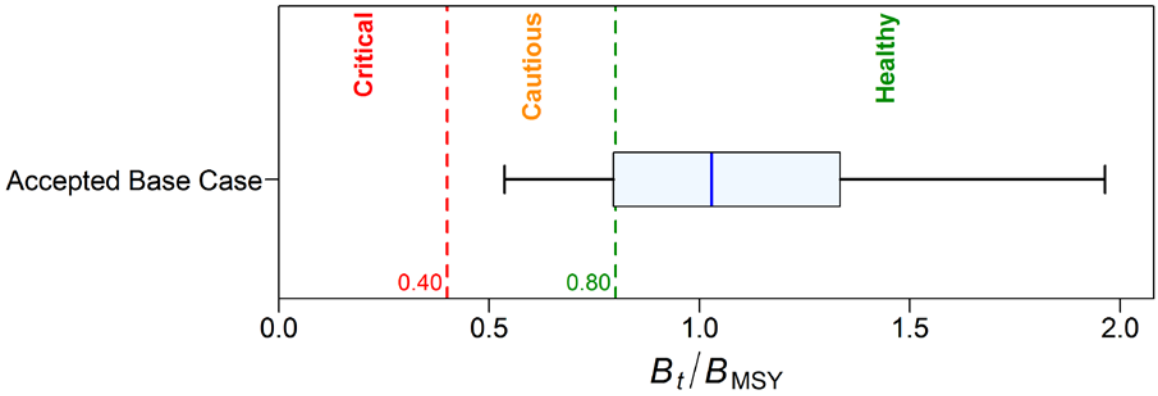

Figure 6. Current status of the 5ABC POP stock relative to the DFO Precautionary Approach provisional reference points of $0.4B_{MSY}$ and $0.8B_{MSY}$. The probability that B_{2017} lies in the critical zone is 0.01, in the cautious zone is 0.25, and in the healthy zone is 0.74. Boxplots show the 5, 25, 50, 75 and 95 percentiles from the MCMC results.

Projection Results and Decision Tables

Five-year projections, starting with the biomass at the beginning of 2017, were made over a range of constant catch levels (0-5,000 t in 250 t increments). This time frame was considered adequate for long-term advice and short enough for projections to be mainly based on individuals spawned before 2013 (and therefore explicitly estimated by the model. Decision tables (Table 2) give the probabilities of the spawning biomass exceeding the reference points in each projected year for each catch level. Note these tables assume that catches are held constant, so there is no consequent reduction of the exploitation rate in the projections if a stock reaches 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 at the start of 2020 under a constant catch strategy of 1,000 t is P(B2017 > 0.8BMSY) = 0.79 (corresponding ‘1000’ row and ‘2020' column in bottom half of Table 2).

With a constant catch of 2,500 t, which is above the average recent catch of 2,397 t, the probabilities of the stock remaining above the critical zone, P($B_t > 0.4B_{MSY}$), or in the healthy zone, P($B_t > 0.8B_{MSY}$), five years from now are 0.97 and 0.71, respectively (row=‘2500', column=’2022’, Table 2).

Table 2. Decision tables concerning the reference points $0.4B_{MSY}$ and $0.8B_{MSY}$ for five-year projections for a range of constant annual catch strategies (in tonnes). 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 (2012-2016) is 2,397 t.

A)	$P(B_t > 0.4B_{MSY})$					
Annual catch	Current	Projection year				
strategy (t)	2017	2018	2019	2020	2021	2022
0	0.99	1.00	1.00	1.00	1.00	1.00
250	0.99	0.99	1.00	1.00	1.00	1.00
500	0.99	0.99	1.00	1.00	1.00	1.00
750	0.99	0.99	1.00	1.00	1.00	1.00
1000	0.99	0.99	0.99	1.00	1.00	1.00
1250	0.99	0.99	0.99	0.99	0.99	0.99
1500	0.99	0.99	0.99	0.99	0.99	0.99
1750	0.99	0.99	0.99	0.99	0.99	0.99
2000	0.99	0.99	0.99	0.99	0.99	0.99
2250	0.99	0.99	0.99	0.99	0.99	0.98
2500	0.99	0.99	0.99	0.99	0.98	0.97
2750	0.99	0.99	0.99	0.98	0.98	0.97
3000	0.99	0.99	0.99	0.98	0.97	0.96
3250	0.99	0.99	0.99	0.98	0.96	0.95
3500	0.99	0.99	0.98	0.97	0.95	0.94
3750	0.99	0.99	0.98	0.96	0.95	0.92
4000	0.99	0.99	0.98	0.96	0.94	0.91
4250	0.99	0.99	0.98	0.95	0.93	0.90
4500	0.99	0.99	0.97	0.95	0.91	0.87
4750	0.99	0.98	0.97	0.94	0.90	0.85
5000	0.99	0.98	0.96	0.94	0.89	0.82

B)	$P(B_t > 0.8B_{MSY})$					
Annual catch	Current	Projection year				
strategy (t)	2017	2018	2019	2020	2021	2022
0	0.74	0.78	0.80	0.83	0.85	0.87
250	0.74	0.78	0.80	0.82	0.84	0.85
500	0.74	0.78	0.79	0.81	0.83	0.84
750	0.74	0.77	0.79	0.80	0.81	0.82
1000	0.74	0.77	0.78	0.79	0.80	0.81
1250	0.74	0.76	0.77	0.78	0.79	0.79
1500	0.74	0.76	0.76	0.78	0.78	0.78
1750	0.74	0.75	0.76	0.77	0.77	0.77
2000	0.74	0.75	0.75	0.75	0.75	0.74
2250	0.74	0.74	0.74	0.73	0.73	0.72
2500	0.74	0.74	0.73	0.72	0.71	0.71
2750	0.74	0.73	0.71	0.71	0.70	0.68
3000	0.74	0.72	0.70	0.69	0.67	0.66
3250	0.74	0.72	0.69	0.67	0.65	0.63
3500	0.74	0.71	0.68	0.66	0.63	0.60
3750	0.74	0.70	0.67	0.64	0.61	0.58
4000	0.74	0.69	0.67	0.63	0.59	0.56
4250	0.74	0.69	0.65	0.61	0.58	0.54
4500	0.74	0.68	0.64	0.60	0.55	0.51
4750	0.74	0.68	0.63	0.59	0.53	0.48
5000	0.74	0.67	0.62	0.57	0.51	0.46

Sources of Uncertainty

Uncertainty in the estimated parameters is explicitly addressed using a Bayesian approach, with credibility intervals and probabilities provided for all quantities of interest. These intervals and probabilities are only valid for the specified model using the weights assigned to the various data components. Other uncertainties were explored through the sensitivity runs, which investigated alternative assumptions to the base case run. MSY-based reference points are also considered uncertain because they may not be constant over time.

Ecosystem Considerations

A Bayesian method was developed to investigate a suite of climatic and environmental indicators for potential ecosystem influences on recruitment, using the recruitment estimates from the previous assessment. However, none of the indicators were reliable predictors of recruitment. Ecosystem influences were not used in the modelling or advice to management.

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 Plans.

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).

Other considerations

It is recommended that the next assessment occur in 2022, with three new indices available from the Queen Charlotte Sound synoptic survey, along with five years of ageing and catch data. No appropriate indicators are recommended that could be used to trigger an assessment earlier than scheduled during the interim years. The most suitable potential indicator, the Queen Charlotte Sound synoptic survey, provides biannual estimates of relative biomass with error and likely requires at least two observations to trigger a new assessment. In addition, there needs to be at least 6-8 months lead time to allow for the reading of new ageing structures necessary for any new assessment. A CPUE indicator would not be informative because POP catch rates will be influenced by harvester behaviour, market pressures, and other species encountered in the fishery and is unlikely to reflect the underlying biomass levels. Advice for interim years is explicitly included in the decision tables.

CONCLUSIONS AND ADVICE

The assessment depicts a slow-growing, low-productivity stock, which has experienced heavy commercial fishing by foreign and domestic fleets. Exploitation rates have since declined and the stock is estimated to have a 0.74 probability of being in the healthy zone at the start of 2017.

Advice to management is provided in the form of decision tables. The tables assume the model to be valid and no future management interventions would occur if stock status changes for each level of constant catch.

SOURCES OF INFORMATION

This Science Advisory Report is from the Regional Peer Review meeting on Stock Assessment for Pacific Ocean Perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia in 2017, held on June 1-2, 2017. Additional publications from this process (Proceedings and Research Document) will be posted the on Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2011. Stock assessment for Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia in 2010. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/017.

Edwards, A.M., P.J. Starr, and R. Haigh. 2012. Stock assessment for Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound, British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/111. viii + 172 p.

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