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Science Advisory Report 2016/016

STOCK ASSESSMENT OF THE COASTWIDE POPULATION OF SHORTSPINE THORNYHEAD (*SEBASTOLOBUS ALASCANUS*) FOR BRITISH COLUMBIA, CANADA IN 2015

Shortspine Thornyhead (Sebastolobus alascanus). Credit: Fisheries and Oceans Canada (DFO).

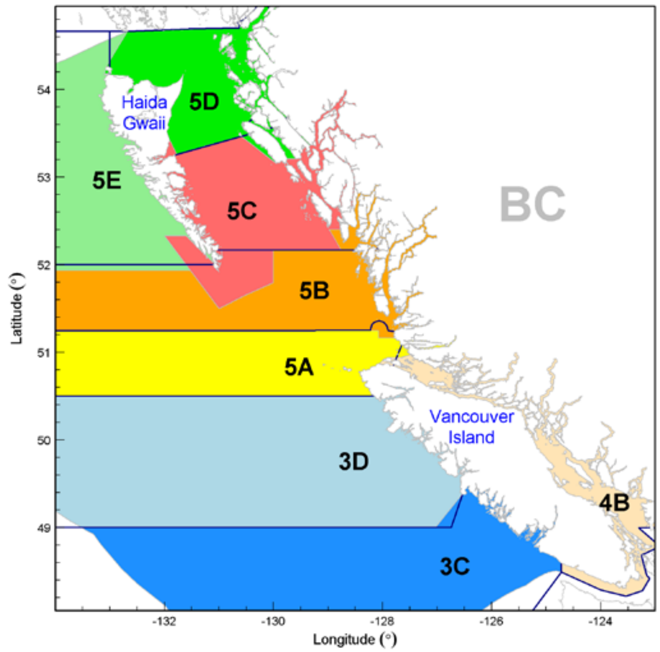

Figure 1. Pacific Marine Fisheries Commission major areas (outlined by blue). Groundfish Management Unit areas for Shortspine Thornyhead (excluding 4B where the species rarely occurs) are shaded in seven colours and differ slightly from the Pacific Marine Fisheries Commission areas.

Context:

Shortspine Thornyhead (Sebastolobus alascanus) was caught in small amounts by the commercial trawl fishery up to the late-1980s (<100 t), followed by a large increase in catch by the mid-1990s (max = 958 t). Species separation with its congener S. altivelis (Longspine Thornyhead) did not occur in catch records until 1996 with the introduction of 100% observer coverage. An annual coastwide total allowable catch (TAC) limit was first set in 1997 (748 t) and is currently 771 t. A quantitative population dynamics model has not previously been used to assess this species. The Fisheries Management Branch of Fisheries and Oceans Canada (DFO) requested that the Shortspine Thornyhead coastwide stock be assessed relative to reference points that are consistent with the DFO Precautionary Approach (DFO 2009), and that probabilistic decision tables be produced that forecast the effect of a range of fixed annual harvest levels on stock status.

This Science Advisory Report is from the December 10-11 and 18, 2015 regional peer review on Shortspine Thornyhead (Sebastolobus alascanus) Stock Assessment for the Pacific Coast of Canada in 2015. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- Shortspine Thornyhead was caught in amounts less than 100 t by the commercial trawl fishery up to the late 1980s, followed by increasing catches into the 1990s, when catches reached 958 t. Although there is some directed fishing on this species, it is most often caught along with other groundfish species in the commercial trawl fishery. Species separation with its congener *S. altivelis* (Longspine Thornyhead) did not occur in catch records until 1996 with the introduction of 100% observer coverage.
- The coastwide stock was assessed using a delay-difference model fit to five fishery-independent surveys, a catch per unit of effort (CPUE) time series derived from commercial catch and effort data, and an annual time series of mean weights derived from unsorted commercial catch samples.
- A model-averaged decision table is presented using the provisional reference points from Fisheries and Oceans Canada's [Fishery Decision-making Framework incorporating the Precautionary Approach](): a limit reference point (LRP) of $0.4B_{MSY}$, an upper stock reference (USR) of $0.8B_{MSY}$, and a reference harvest rate of u_{MSY}. The decision table provides estimates of stock status and harvest rates that result from three-year projections at a range of constant annual catches from 0 to 1000 t.
- The estimated stock biomass trajectory has remained above the estimates of the stock status reference points throughout the history of the fishery. Estimated current stock status (beginning year biomass in 2016) has a 0.97 probability of being above the USR and a 1.0 probability of being above the LRP. The probability that u_{2015} exceeded u_{MSY} is 0.72.
- The stock is expected to decline if annual harvests of 600 t/year (the 2010-2014 average catch) are removed in each of the next three years. The probability that the stock will stay above the USR at the end of the next three years is 0.76. The probability that the stock will remain above the LRP after three years is 0.88.
- An assumption of the analysis is that Shortspine Thornyhead is a single coastwide stock. Therefore, harvest advice on a smaller scale is not provided. Advice at a smaller spatial scale would require definition of spatially specific objectives for the stock and fishery.
- Uncertainties associated with growth, natural mortality, and knife-edge selectivity were bounded by adopting a model average approach across a range of hypotheses for these assumptions. There is a contradiction in the model data, with the annual mean weight index showing an increasing trend, while biomass indices show no trend. Additionally, it is not known if the lack of large, old fish in the data is a sampling issue or a feature of the BC Shortspine Thornyhead population.

INTRODUCTION

Biology and Distribution

Shortspine Thornyhead (*Sebastolobus alascanus*) is distributed from the Sea of Japan, through the Aleutian Islands and along the west coast of North America to Baja California at depths ranging to 1570 m. Maximum age is thought be ~100 years, while the maximum observed length in BC is 89 cm. Shortspine Thornyhead likely spawns between March and May in the oxygen minimum zone (600-1000 m), and eggs are released in gelatinous masses that float to the surface. Larvae and juveniles spend just over one year in the pelagic zone before settling into the benthic zone at ~100 m depth on the continental shelf. As individuals get older and larger, they migrate into deeper water. Adult Shortspine Thornyhead eat fish, shellfish and amphipods. At depths greater than 600 m, Shortspine Thornyhead is known to prey on the smaller, but more abundant, congener Longspine Thornyhead.

The BC coastwide stock of Shortspine Thornyhead applies to the combined Pacific Fisheries Management Commission (PMFC) major areas 3CD (west coast Vancouver Island), 5AB (Queen Charlotte Sound), 5CD (Hecate Strait and Dixon Entrance), and 5E (west coast Haida Gwaii) (Figure 1).

Fishery

Shortspine Thornyhead is encountered by both trawl and hook and line gears in BC's integrated groundfish fishery, but is primarily caught in the groundfish bottom trawl fishery (average [1996–2014] percentage=91% trawl), most often as non-directed catch taken in conjunction with other commercial species (Figure 2). In trawls that captured at least one Shortspine Thornyhead between 134 m and 1032 m coastwide, three species occur in greater proportions than do Shortspine Thornyhead – Arrowtooth Flounder (*Atheresthes stomias*), Pacific Ocean Perch (*Sebastes alutus*), and Dover Sole (*Microstomus pacificus*) (Figure 2). Discard levels for Shortspine Thornyhead are low, averaging below 5% of total catches between 1996–2014.

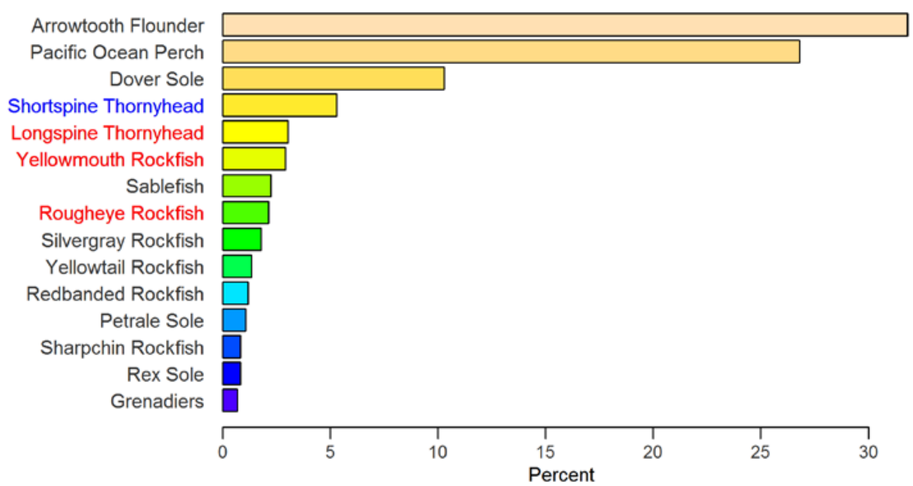

Figure 2. Distribution of catch weights for important finfish species in bottom tows that caught at least one Shortspine Thornyhead. Coastwide tows were selected over a depth range between 134 and 1032 m and over the period February 1996 to September 2015. Relative concurrence is expressed as a percentage by species of the total catch weight summed over all finfish species in the data set. Shortspine Thornyhead is indicated in blue on the y-axis; other species of interest to the Species At Risk Act are indicated in red.

Annual TACs for this species were introduced in 1997 and fluctuated around ~730-770 t/y up to 2001, when a coastwide total allowable catch (TAC) of 771 t was established. This TAC is allocated between the trawl (95.4%) and the hook and line sectors (4.6%). The latter allocation is subdivided between the Outside ZN (2.27%) and Halibut (2.33%) fisheries. In 2006, the Groundfish Hook and Line Sub Committee (GHLSC) agreed to set aside 5% of the ZN allocation for research purposes (~1 t/y) each year going forward. In 2013, the Groundfish Trawl industry likewise agreed to account for unavoidable mortality during groundfish trawl multi-species surveys by setting aside about 1.7 t per year.

Fishing for this species in the trawl fishery has been subject to the following management measures: 100% dockside monitoring (since 1994); 100% at-sea monitoring (since 1996); individual vessel accountability for all retained and released catch, and individual transferable quotas (since 1997); and reallocation of quotas between vessels and fisheries to cover catch of non-directed species (DFO 2015). 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 organizations, and include limiting the footprint of groundfish bottom trawl activities (DFO 2015). These measures reduced the contribution of Shortspine Thornyhead catch from outside the footprint from 10.7% of total catch over the period 1996 to 2012 to 0.7% in the period 2012 to 2015.

ASSESSMENT

The modelling approach uses a delay-difference model previously developed to assess Pacific Cod (*Gadus macrocephalus*) by Forrest et al. (2015). Five fishery-independent bottom trawl surveys were used to describe the relative abundance of Shortspine Thornyhead over time in the stock assessment model. These surveys span a period from 1980 to 2015, which is the same period included in the delay-difference stock assessment model. The five trawl surveys are

- US National Marine Fisheries Service (NMFS) Triennial (1980-2001), covering the lower half of Vancouver Island;
- WCVI Synoptic (2004-2014), covering the west coast of Vancouver Island;
- QCS Synoptic (2003-2015), covering all of Queen Charlotte Sound;
- HS Synoptic (2005-2015), covering all of Hecate Strait and extending into Dixon Entrance and across the top of Graham Island;
- WCHG Synoptic (2006-2012), covering the west coast of Graham Island in Haida Gwaii and western part of Dixon Entrance.

Commercial catch and effort data (CPUE) were used to generate an annual index series of abundance for Shortspine Thornyhead. This was done to add a long-term continuous abundance series for use in this data-poor model. This index series was assumed to track biomass with the expectation that it would be relatively unaffected by economic considerations, given that the majority of Shortspine Thornyhead catches are non-targeted and that the smaller specialized target fishery is characterized by long indiscriminate tows.

Two growth functions were developed for this stock assessment in recognition of the uncertainty associated with ageing this species. One growth function (designated DFO) was derived from about 700 age/length pairs taken from BC research survey samples. These ages were obtained using a “break and burn” otolith preparation method that is considered less reliable than the preferred “thin-section” preparation method. However, a small study was provided that compared 60 otoliths which were prepared using both methods, with no statistical difference demonstrated between the methods. A larger sample size would be needed to detect a real difference. A second growth function (designated NMFS) was developed from a published growth model used in a stock assessment for a Shortspine Thornyhead stock located off the west coast of the US mainland (Taylor and Stephens 2013). The ages used in this growth model were also determined using the “break and burn” methodology, but the available data included older and larger specimens than those observed from BC waters. A composite model was adopted for the assessment that incorporated both growth functions, with the NMFS model representing published analyses that indicate Shortspine Thornyhead are slow growing and old while the DFO growth model was based on the available Shortspine Thornyhead length and age data from BC that had few old or large specimens.

The length-weight relationships from the DFO and NMFS data sets are almost identical, indicating that Shortspine Thornyhead have equivalent weight at length from both regions. However, the growth equations and estimated Walford parameters describe much larger fish above age ~26 years in the NMFS growth model compared to the DFO growth model (Figure 3).

The median total length across annual cumulative frequency distributions from unsorted fishery samples taken from the BC fishery estimated the length at knife-edge selectivity to the fishery to be 29 cm. This length was converted to an age consistent with each adopted growth model because the age of knife-edged selectivity is a key assumption of a delay-difference model, resulting in age estimates of 16 years for the DFO growth model and 21 years for the NMFS growth model. Given the uncertainty associated with the age at knife-edge recruitment selectivity, illustrated by the difference in the age estimates at the same size from the two growth models, sensitivity tests were included for the NMFS growth model where the age of knife-edged selectivity was set to 13 and 16 years, corresponding to lengths of 21 cm and 24 cm, respectively.

Annual mean weights are used in delay-difference models as absolute estimates of population mean weight; the time series of mean weights provide information for estimating recruitment deviations. An additive General Linear Model (GLM) was fit to observed Shortspine Thornyhead fish weights (estimated from lengths) sampled from unsorted commercial catch samples to estimate a series of annual mean weights. The GLM model corrected for trends due to depth, longitude, latitude and month of capture for each sample. The geometric mean of the observed annual mean weights (0.395 kg/fish) was used to scale the index of standardized mean weights.

Three values of natural mortality (0.03, 0.06, 0.08) were evaluated in this stock assessment to reflect the difficulty of ageing Shortspine Thornyhead, the absence of older fish observed from BC waters compared to US waters, and values published in the literature. While the literature suggested that the instantaneous rate of natural mortality, M, should be around 0.03 to 0.06, ages obtained from fish sampled in BC included few old females (maximum age=95), with the majority of the observed ages being younger (mean age 19 years, n=1144). These data suggested an M=0.08 based on Hoenig's method.

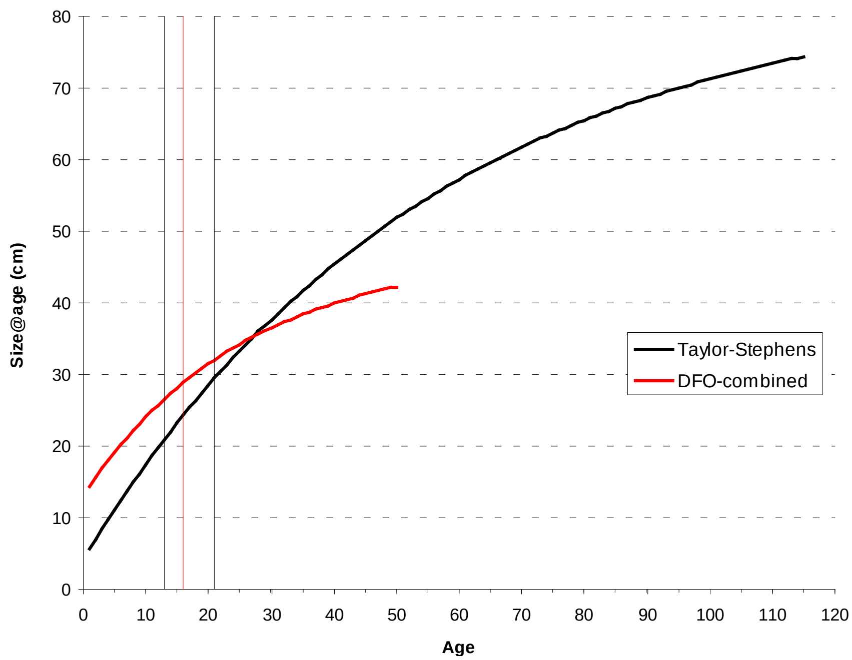

Figure 3. Growth curves contrasting DFO and NMFS (Taylor and Stephens 2013) growth of Shortspine Thornyhead. DFO growth: L_∞=47.257cm, K=0.0385, t_0=-8.456; NMFS growth: L_∞= 84.99cm, K= 0.0178, t_0=-2.88. Vertical lines indicate ages {13, 16, 21} years corresponding to NMFS lengths of {21, 24, 29} cm, respectively. Note that age 16 y corresponds to DFO length 29 cm.

Reference Points

The Fisheries and Oceans Canada Fishery Decision-making Framework incorporating the Precautionary Approach (PA, DFO 2009), requires stock status to be characterized using the best available reference points, defaulting to a provisional limit reference point of $0.4B_{MSY}$ and an upper stock reference point of $0.8B_{\mathrm{MSY}}$, where B_{MSY} is the estimated long-term equilibrium biomass when the stock is fished at the exploitation rate (u_{MSY}) that results in maximum sustainable yield (MSY). Stocks are considered to be in the “critical” zone when $B_t < 0.4B_{\mathrm{MSY}}$, in the “cautious” zone when $0.4B_{\mathrm{MSY}} < B_t < 0.8B_{\mathrm{MSY}}$, and in the “healthy” zone when $B_t > 0.8B_{\mathrm{MSY}}$. The reference points adopted for this assessment are: LRP = $0.4B_{\mathrm{MSY}}$, USR = $0.8B_{\mathrm{MSY}}$, and reference harvest rate u_{MSY}.

Model Results

Advice to fishery managers is based on twelve model scenarios (Table 1) that reflect uncertainty in fish growth (two growth functions), natural mortality (three values) and the age of knife-edged selectivity (three estimates). An approximation to the Bayes posterior probability distribution was calculated for each of the twelve models using the Markov Chain Monte Carlo (MCMC) method. These results were pooled and averaged, with each model weighted equally, to produce the advice to fishery managers.

Table 1. Twelve scenario options adopted for model averaging. DFO growth: L_∞=47.257cm, K=0.0385, t0=-8.456; NMFS growth: L_∞= 84.99cm, K= 0.0178, t0=-2.88. Each scenario contributes 1000 MCMC samples.

Scenario	Growth	*M*	*k*-len (cm)	*k*-age (y)
1	DFO	0.03	29	16
2	DFO	0.06	29	16
3	DFO	0.08	29	16
4	NMFS	0.03	29	21
5	NMFS	0.03	24	16
6	NMFS	0.03	21	13
7	NMFS	0.06	29	21
8	NMFS	0.06	24	16
9	NMFS	0.06	21	13
10	NMFS	0.08	29	21
11	NMFS	0.08	24	16
12	NMFS	0.08	21	13

The model averaged biomass depletion (B_t/B_0, Figure 4) suggests that the stock has remained above the upper stock reference $0.8B_{MSY}$ since 1980, with a probability of 0.0078 that it dropped below $0.4B_{MSY}$ in 1999. Since then, the stock increased to levels well above both reference points, coinciding with a decrease in catches in the early 2000s. Current stock status, estimated for the model average scenario and represented as B_{2016}/B_{MSY}, sits above the USR (Figure 5). Current stock status is also shown in Figure 5 for each of the 12 contributing scenarios, but is not part of the advice. The probability that current stock status lies above the USR (in the DFO "healthy zone") is 0.98. The median B_{2016}/B_{MSY} = 1.85 (0.93-4.16), where values in parentheses represent the 5th and 95th percentiles.

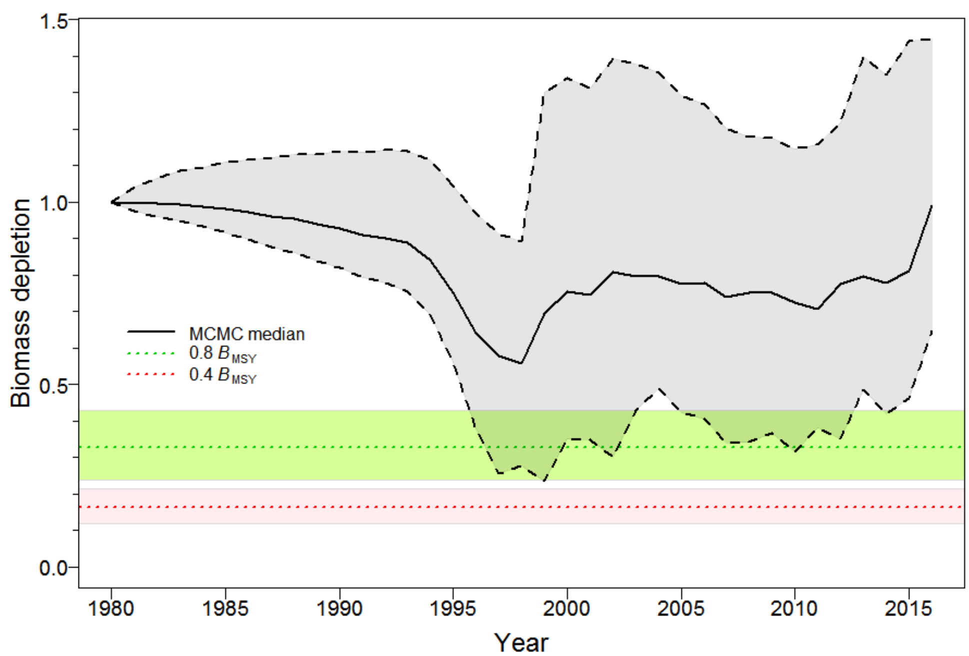

Figure 4. Median estimates (solid black line) and 90% credibility intervals (black dashed lines, grey fill) for the model average B_t/B_0 (biomass in year t relative to that in 1980) for Shortspine Thornyhead. Also shown are the MSY-based reference points (Limit Reference Point, LRP = $0.4B_{MSY}$ shown as a red band and line; Upper Stock Reference, USR = $0.8B_{MSY}$ shown as a green band and line) relative to B_0.

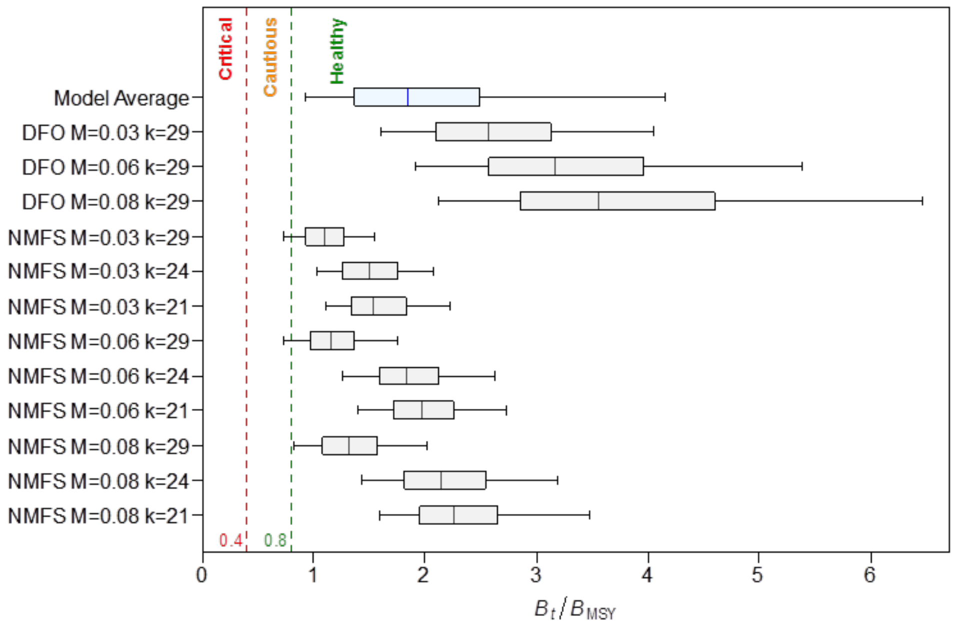

Figure 5. Current status of the coastwide BC Shortspine Thornyhead stock relative to the DFO Precautionary Approach provisional reference points of 0.4B_{MSY} and 0.8B_{MSY}. The value of B_t/B_{MSY} uses t=2016. Boxplots show the 5, 25, 50, 75 and 95 percentiles from the MCMC results. The model average (top boxplot in blue) summarizes the 12 scenarios represented in the grey boxplots below the model average (see Table 1 for scenario definitions). DFO = Canadian Fisheries and Oceans; NMFS = US National Marine Fisheries Service; M = natural mortality (y^{-1}); k = length (cm) at knife-edge selectivity.

Harvest Advice

A decision table of probabilities (Table 2), based on the model averaged scenario, forms the basis of the advice to managers. Note that the probabilities in this table for 2016 cannot change because the 2015 catch has already been taken. The probability that the estimated biomass in 2016, B_{2016}, is greater than the estimated upper stock reference is 0.98, and B_{2016} is always greater than the limit reference point. The estimated harvest rate u_{2015} has a probability of 0.72 of being greater than the estimated harvest rate at maximum sustainable yield.

The coastwide average level of total removals in the last five years (2010-2014) is 572 t, which is similar to the constant catch policy of 600 t is listed in Table 2. Three-year projections indicate that annual catches of 200 t or greater will cause the stock to decline from current levels. At 600 t, the probability that biomass in 2019 is greater than the upper stock reference point, P(B_{2019} > 0.8B_{MSY}), is 0.76 and P(B_{2019} > 0.4B_{MSY}) is 0.88. At fixed annual catches of 600 t, the probability that the harvest rate will exceed the harvest rate at maximum sustainable yield, u_{MSY}, is 0.84.

Table 2. Model-average decision table for three reference points – the upper stock reference point $0.8B_{MSY}$, the limit reference point $0.4B_{MSY}$, and the harvest rate at maximum sustainable yield u_{MSY} – for end-year biomass B_{2016} and mid-year harvest rate u_{2015} and their respective 3-year projections for a range of constant catch strategies (in tonnes). Each value is the probability that current or projected biomass or harvest rate is greater than the indicated reference point. The probabilities are the proportion of the 12 pooled MCMC samples for which $B_t > 0.8B_{MSY}$, $B_t > 0.4B_{MSY}$, and $u_t > u_{MSY}$. For reference, the average catch over the last 5 years (2010-2014) is 572 t.

TAC	$P(B_{2016} > 0.8B_{MSY})$	$P(B_{2019} > 0.8B_{MSY})$	$P(B_{2016} > 0.4B_{MSY})$	$P(B_{2019} > 0.4B_{MSY})$	$P(u_{2015} > u_{MSY})$	$P(u_{2018} > u_{MSY})$
0	0.9792	0.9964	1	1	0.72	0
100	0.9792	0.9867	1	1	0.72	0.1412
200	0.9792	0.9604	1	0.9998	0.72	0.4002
300	0.9792	0.9158	1	0.9963	0.72	0.5630
400	0.9792	0.8571	1	0.9799	0.72	0.6884
500	0.9792	0.8043	1	0.9388	0.72	0.7758
600	0.9792	0.7605	1	0.8795	0.72	0.8370
700	0.9792	0.7245	1	0.8259	0.72	0.8816
800	0.9792	0.6874	1	0.7849	0.72	0.9135
900	0.9792	0.6463	1	0.7570	0.72	0.9346
1000	0.9792	0.6025	1	0.7318	0.72	0.9526

Sources of Uncertainty

Uncertainty due to growth, natural mortality, and the age of knife-edged selectivity was evaluated by selecting 12 model scenarios for inclusion in the final averaged model. These included growth (options DFO vs. NMFS), natural mortality with three options (M = 0.03, 0.06, 0.08) for both growth functions, and size at knife-edge selectivity – one option for DFO growth

(k = 29 cm) and three options for NMFS growth (k = 29, 24, 21 cm). There is a contradiction in the model data, with annual mean weight increasing from the late 1990s/early 2000s while the available biomass indices show no trend. These issues lead to the observation that the estimates of stock status relative to reference points should be taken as a guide rather than as definitive. The stock has maintained its size over the period covered by this stock assessment (Figure 4), i.e., productivity has been adequate to balance historic removals. However, the stock assessment projections indicate that that recent catches will reduce the biomass over the next three years once the information from biomass indices are no longer available. This immediate drop indicates that stock abundance has been maintained in the past through good recruitment generated by the model or that the adopted growth models are biased low. For these reasons, the three year projections presented in Table 2 should be considered less reliable than the stock reconstruction presented in Figure 4.

Available BC Shortspine Thornyhead biological sampling data does not contain many large or old fish. This was notable because the stock assessments for this species both to the north and to the south of BC used growth functions and assumed a natural mortality (M) value that implied that the species lived longer and grew larger than appeared to be the case in BC waters. This difference is reflected in the published data. For instance, Figure 25 of Taylor & Stephens (2013) shows a much larger proportion of the commercial trawl catch comprising Shortspine Thornyhead greater than 50 cm compared to the equivalent proportion from the BC trawl fishery. There was disagreement regarding the cause of the paucity of large or old Shortspine Thornyhead specimens in BC samples. One hypothesis was that the anomaly was most likely a sampling issue, with the fishery and research surveys operating in regions where the preponderance of large, old Shortspine Thornyhead was small. Others noted that a large proportion of the length observations were from random trawl surveys, several of which went to very deep depths specifically to sample *Sebastolobus*.

CONCLUSIONS

The average of the 12 model scenarios (described in Table 1) was used to develop the advice for this coastwide Shortspine Thornyhead stock assessment. This advice is presented in Table 2, plotted in Figure 4 and in the uppermost box plot in Figure 5, and can be summarized as follows:

- the stock trajectory has remained well above the DFO precautionary reference points (USR and LRP) throughout the history of the fishery;
- current stock status (beginning year biomass in 2016) has a 0.98 probability of being above the USR and a 1.0 probability of being above the LRP. The probability that u_{2015} exceeded u_{MSY} is 0.72
- the stock is projected to decline at catch levels greater than 200 t/year over the next three years. Stock status at the end of the three year projection period under a catch level equivalent to the 2010-2014 average catch (600 t/year) has a probability of 0.76 of being above the USR and a probability of 0.88 of being above the LRP. The probability of being above u_{MSY} is 0.84;
- advice for catch levels other than 600 t/year can be found in the Table 2 decision table which provides probabilities for catch levels ranging from 0 to 1000 t/year.

This assessment considers Shortspine Thornyhead to be a single stock and does not provide harvest advice on a smaller scale. Further exploration of the utility and potential for more spatially explicit management advice is recommended.

Given the uncertainty in growth, natural mortality, and the age of knife-edged selectivity in this assessment, improvements in biological sampling and aging of Shortspine Thornyhead are recommended before an updated assessment is conducted. The development and application of an ageing protocol for Shortspine Thornyhead may provide improved estimates of age and associated ageing error, while length stratified biological samples would ensure that future age samples represent the full size range of Shortspine Thornyhead in BC.

SOURCES OF INFORMATION

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