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Stock Assessment of North Pacific Blue Shark (*Prionace glauca*) Using a Catch Based Method[1]

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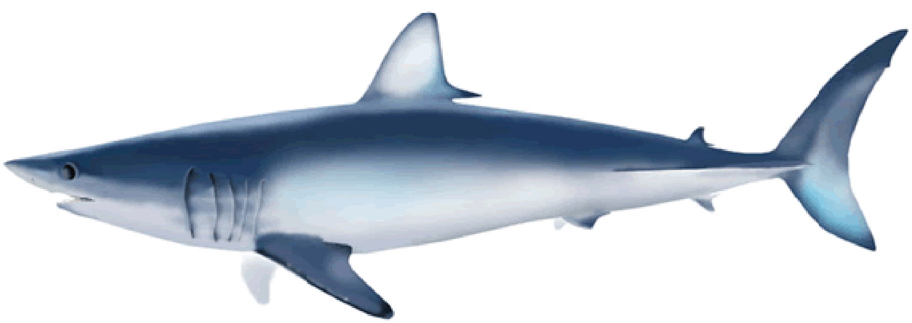

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Abstract

In this study I use a catch-based method (i.e. CMSY) to investigate the productivity and historical harvest rates of the north Pacific blue shark. We use the catch data available for the last ISC blue shark stock assessment, conducted in 2014. The CMSY posterior median estimate for the current (2011) stock biomass was 816,048 mt, while the posterior median estimate for the maximum sustainable yield (MSY) was 75,718 mt. The median ratio of the 2011 biomass to that at MSY (B_{2011}/B_{MSY}) was 1.52. The posterior median for the ratio of fishing mortality rate in 2011 to that at MSY (F_{2011}/F_{MSY}) was 0.35. The median estimate for maximum population increase (*r*) was 0.28. In the present study CMSY estimates for *r* and *K* were different to those obtained in the 2014 BSP2 stock assessment JEJL_Ref. However, the estimates for management quantities were similar. Results suggest that historical catch is within the estimated limits of the capacity of the blue shark stock to replace the amount of biomass harvested.

Introduction

Fisheries have been defined as data-poor if information is insufficient to produce a defensible quantitative stock assessment, meaning that the best scientific information available is inadequate for determining reference points or current stock status relative to such reference points. It is often difficult to bring data-poor fisheries into alignment with legislative requirements concerning estimation of reference points and relative stock status. In the United States, for example, the Magnuson-Stevens Act requires fisheries to be managed on the basis of MSY. Shortcomings in data provide an incentive for the development of assessment methods that have lower data requirements than those currently in use.

Data-poor situations are generally the norm when assessing risk of overfishing for chondrichthyan populations. This group of fish is often taken as bycatch in many fisheries around the world and their biology is poorly understood.

The blue shark (*Prionace glauca*) is an oceanic species found worldwide in temperate and tropical waters. It is the most abundant pelagic shark, and large numbers are caught by global fisheries, especially as bycatch on longline and gill net fisheries. Of all the pelagic sharks, it is the most well-studied, especially the north Pacific population for which we have information on growth, reproduction, and stock structure. Its widespread distribution, high initial abundance, and moderate productivity have given the blue shark the reputation of being resilient to fishing pressure.

The management of blue shark stocks in the north Pacific Ocean is under the responsibility of the Western and Central Pacific Fisheries Commission (WCPFC). Currently, the International Scientific Committee for Tuna and Tuna-like Species (acronym?) is tasked with providing scientific information and advice to the WCPFC on northern Pacific species, including blue sharks. In 2014, ISC carried out a stock assessment for the north Pacific blue shark using two stock assessment approaches: i) a Bayesian surplus production model (BSP2); and ii) an integrated age-structured model (Stock synthesis). The accepted assessment reference-cases indicated that the current fishing mortality rates for the blue shark in the north Pacific are sustainable. Although the general conclusion of the assessment was that the stock was not overfished, the results were interpreted with considerable caution due to data deficiencies and the sensitivity of the assessment results to changes in the parameterization of the low-fecundity stock recruitment function.

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Both stock assessment approaches used to assess the status of the north Pacific blue shark population rely heavily on the time-series of historical catches. Consequently, the credibility of these stock assessments hinges on the quality of the catch data inputted. A time-series of catches can be viewed as a sequence of yields produced by the available biomass with a given productivity. If two of the three variables (yield, biomass, and productivity) are known, then the third can be estimated.

To further explore the north Pacific blue shark stock depletion and productivity, here we conduct a stock assessment for this stock using a data-poor approach developed by Froese et al. (2016), hereafter referred as CMSY. The method is based on classical biomass dynamic models, it requires only catch history, without the need for fishing effort or CPUE. **The analyses presented here are not proposed as a definitive stock assessment procedure, but they can yield useful information for more complex stock assessment models.**

Materials and Methods

Description of the method

Typical production models, such as the one by Schaefer (1954), use time series of catch and abundance to estimate productivity. Instead, the CMSY method uses catch and productivity to estimate biomass, exploitation rate, MSY, and related fisheries reference points from catch data and resilience of the species. Assuming population dynamics from a Schaefer Model, a Monte-Carlo algorithm is used to evaluate various combinations of parameters r and K, drawn from probable distributions, which are subsequently filtered to obtain a distribution of 'viable' r-K pairs. A parameter pair is considered 'viable' if the corresponding biomass trajectories are compatible with the observed catches in the sense that predicted biomass does not become negative, and is compatible with prior estimates of relative biomass ranges for the beginning and the end of the respective time series.

CMSY can incorporate three uniform prior ranges for B/K at the beginning and end of the time series, and optionally also in an intermediate year. Wrong priors resulting from the default rules, such as setting initial biomass to medium when instead the stock was still lightly exploited or already severely depleted at the beginning of the time series can lead to erroneous conclusions regarding the current stock status. Thus, the results of this study refer to a scenario where I assumed to not have made gross errors in setting broad prior biomass ranges.

Input catch and priors

Fishery data from ISC member nations and observers were compiled, shared, and reviewed through a series of working papers which were presented and discussed at intercessional meetings of the WG held between 2012 and 2013. Catches were extracted from databases of landings, vessel logbooks and observer records. When catch data were unavailable, catch was estimated using independently derived standardized catch per effort information, often applying assumptions on the species compositions of the catch, to transform effort data into catch. Only a single time-series of catch estimates was used in the 2014 stock assessments and it is provided in Figure 1. This series included the working groups' best estimates for discard mortality.

The biological plausible range for r was based on classification of resilience as provided in FishBase (Froese et al. 2000; Froese and Pauly 2015). I used a low resilience range ($0.05 < r < 0.5$), which is in

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close agreement with the value for the *r* prior used in the 2014 BSP stock assessment (*r* = 0.34). The range of initial depletion levels was 0.3 – 0.8, while for intermediate and final depletions were 0.1 – 0.6 and 0.2 – 0.8, respectively.

Results

Figure 2 shows the graphical output of the CMSY method as applied to the north Pacific blue shark. The catch-based model outputs a probabilistic estimation of the maximum sustainable yield, and the most probable *r-k* pairs. Figure 2A show the estimated MSY (median and upper-lower confidence intervals) together with historical catches of the north Pacific blue shark stock. In this figure, catches are much lower than the estimated MSY median for the past two decades. The most probable value for *r* was 0.28 with lower and upper boundaries of 0.161 and 0.477, respectively (Figure 2B). Figure 2C displays CMSY output showing catch relative to MSY (Catch/MSY) over biomass relative to unexploited stock size (B/K). Most points fall below the equilibrium curve, which indicate that catches were consistently less than surplus production throughout the time series, which allowed the stock to increase.

CMSY stock assessment statistics are shown in Table 4, along with the median estimates from the 2014 BSP stock assessment reference case JEJL. The CMSY posterior median estimate for the current (2011) stock biomass was 816,048 mt (95% CI 363,210 – 902,704 mt). Posterior median estimates for the maximum sustainable yield (MSY) was 75,718 mt (95% CI 53,173 – 110,060 mt). The median ratio of the 2011 biomass to that at MSY (B_{2011}/B_{MSY}) was approximately 1.52 (95% CI 0.676 – 1.680). The posterior median of the 2011 abundance relative to its unfished stock size (B_{2011}/K) was 0.760 (95% CI 0.338 – 0.840). The posterior median for the ratio of fishing mortality rate in 2011 to that at MSY (F_{2011}/F_{MSY}) was 0.35 (95% CI 0.318 – 0.791). The median estimate for *r* was 0.28 (95% CI 0.161 – 0.477).

The median estimate and 95% confidence limits for the historical stock dynamics are plotted in Figure 3. The degree of stock depletion and overfishing was illustrated using a “Kobe plot”. The stock biomass of north Pacific blue shark in the final year of the assessment was above the biomass at the maximum sustainable yield (B_{MSY}), and the fishing rate well below that at F_{MSY} in 1971. The historical trajectories of stock status revealed that north Pacific blue shark had experienced some levels of depletion and overfishing in previous years showing that the trajectories moved through the orange (overfishing), red (overfished and overfishing) and yellow (overfished) zones in sequence in the Kobe plot. In the last two decades, the stock condition returned into the Kobe green zone and stock biomass has remained above BMSY with fishing mortality below FMSY. However, 95% CI for B/BMSY in 2011 extended to the yellow zone (Figure 4).

Sensitivity runs

In order to investigate if the catch increase observed in the mid 1970s could bias the MSY estimates, we tried the CMSY method using an alternative data series starting in 1985, and compared the resulting parameters with those estimated using the complete catch time-series and the 2014 BSP stock assessment. The CMSY model using catch time-series starting at 1985 would produce median estimates for MSY higher than those obtained using the complete time-series, and from the 2014 BSP2 stock assessment JEJL_Ref. The median estimate for *r* (0.28) was the same obtained when the complete catch time-series was used, and slightly lower than the one obtained in the 2014 BSP2 stock assessment JEJL_Ref.

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Discussion

Data-poor methods as the one used here allow a very simple estimation of the status of fish stocks. However, the key question is how well this method compares with the estimates yielded by full stock assessments. In the paper by Froese et al. (2016), a comparison using 128 stocks evaluated how different the CMSY estimates for MSY, *r*, and *K* were from those obtained using a Bayesian state-space implementation of the Schaefer production model. Their results showed that for 76% of the stocks the estimates were not significantly different. In the present study CMSY estimates for *r* and *K* were different to those obtained in the 2014 BSP2 stock assessment JEJL_Ref. However, the estimates for management quantities were similar.

The CMSY has a number of assumptions that need to be respected in order for this model to produce credible results. These include estimates of resilience to bind the intrinsic rate of increase (*r*), relative biomass depletion at the start and end of the time series, range of carrying capacity (K), and limits on biomass. These assumptions make assessing developing fisheries or very lightly fished stocks that have not gone through overexploitation phases, even harder. In these cases, the time series of catches would contain very little information about productivity of the stock (Martell and Froese, 2013).

Final considerations

One of the top priorities of the Shark Working Group should be to decide how much faith to place in the available catch time-series. If we assume that the catch data is reliable and the CMSY model structure is appropriate, the data-poor stock assessment presented here is telling us that it is quite improbable that the stock is in bad condition.

Literature cited

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Table 1. Comparison of model results of the two CMSY models and the 2014 BSP2 reference case JEJL – medians (drawn from the posterior distributions) of key biological parameters and reference points.

	Median		
	CMSY (1971- 2011)	CMSY (1985-2011)	2014 BSP (JEJL_Ref)
K	1,073,116	1,181,863	806,000
r	0.28	0.28	0.41
MSY	75,718	83,392	76,000
B_{2011}	816,048	897,107	622,000
F_{2011}/F_{MSY}	0.35	0.31	0.32
B_{2011}/B_{MSY}	1.52	1.51	1.65

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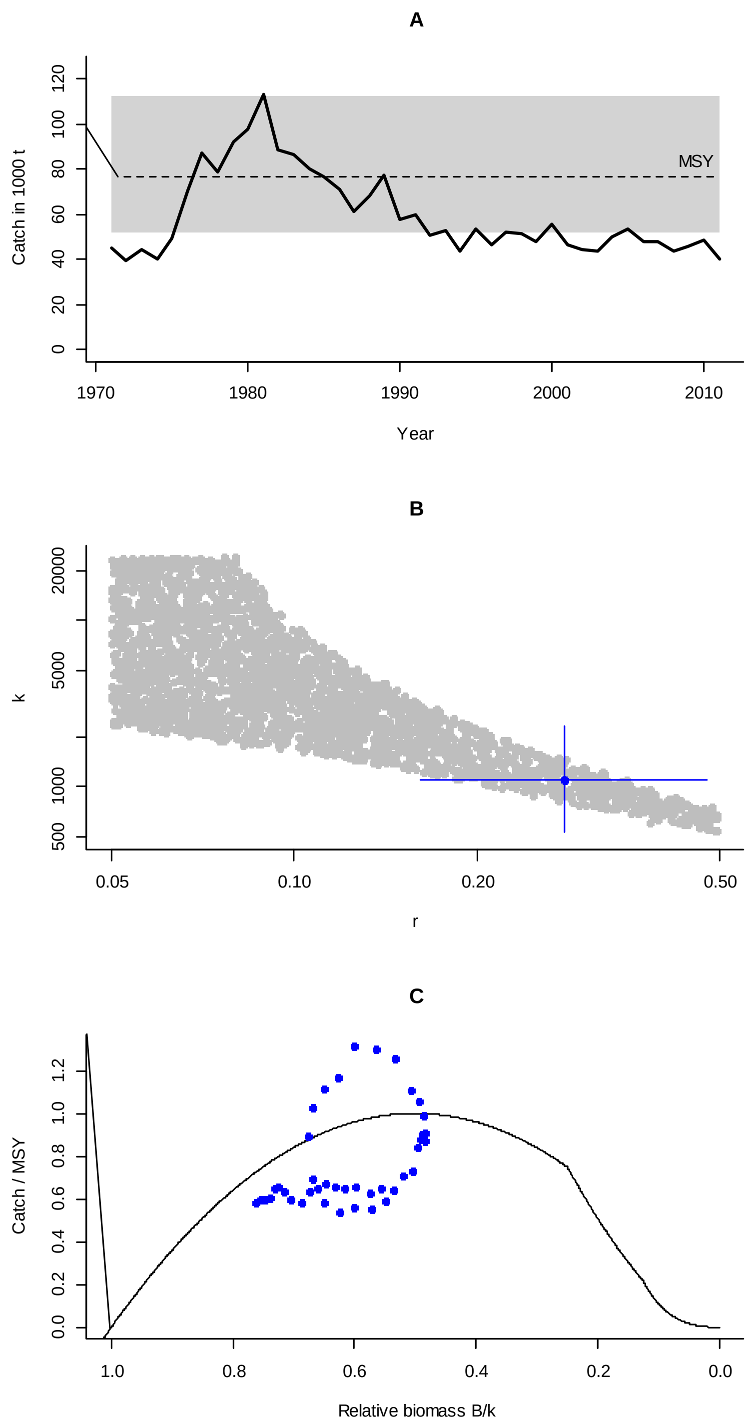

Figure 2. Graphical output of the CMSY method as applied to the north Pacific blue shark. A) Shows the estimated MSY (median and upper-lower confidence intervals) together with historical catches of the north Pacific blue shark stock. B) The most probable *r-k* pair is marked by the black cross, with indication of approximate 95% confidence limits. C) Catch relative to MSY over biomass relative to unexploited stock size.

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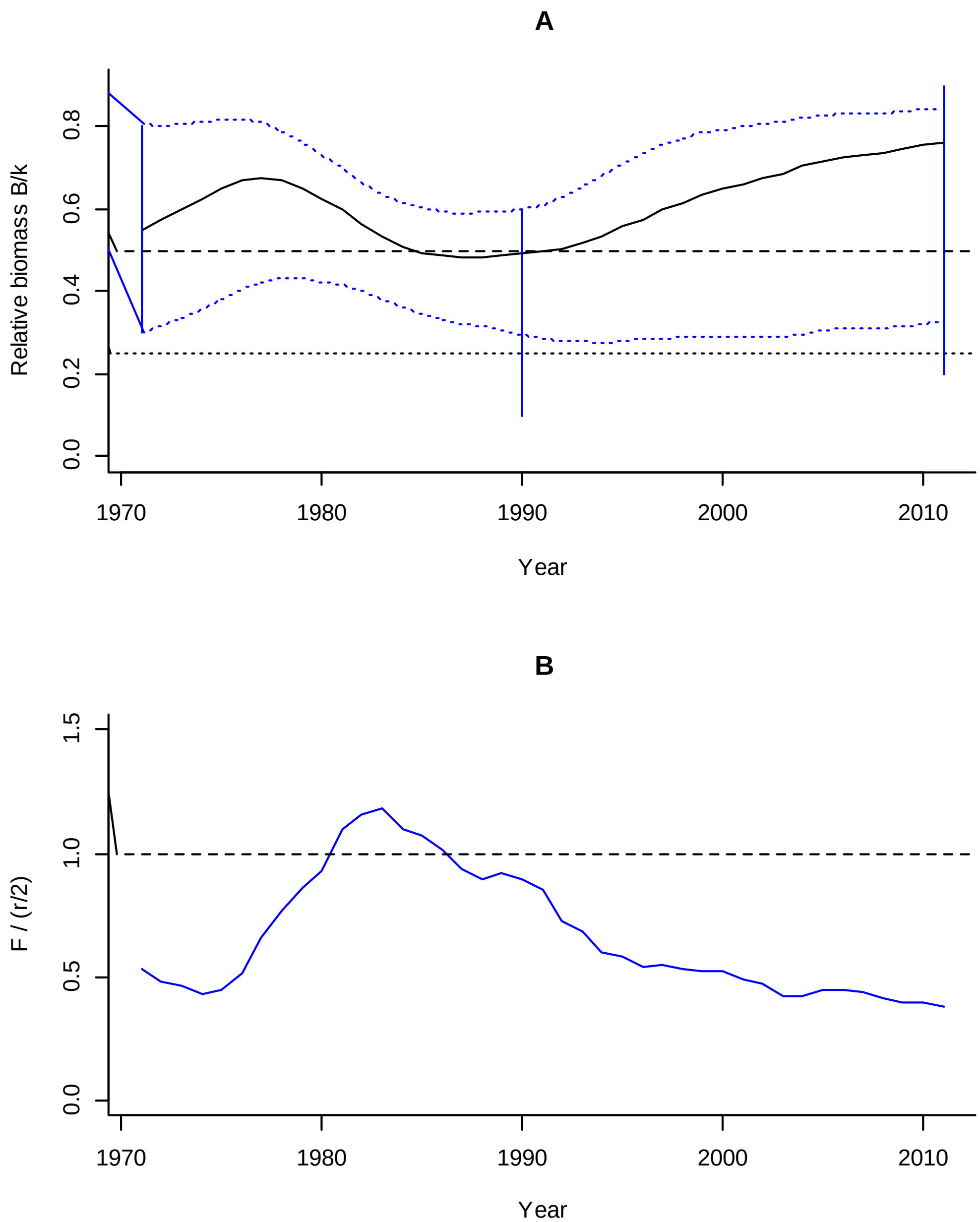

Figure 3. A) CMSY predictions of relative biomass *B*/*k* (solid black line) with 2.5th and 95th percentiles (dotted blue lines). The vertical blue lines indicate the prior estimates of biomass. The horizontal dotted black lines emphasize BMSY = 0.5 *k* and 0.5 BMSY = 0.25 *k*. B) Time series of exploitation rate (solid blue line).

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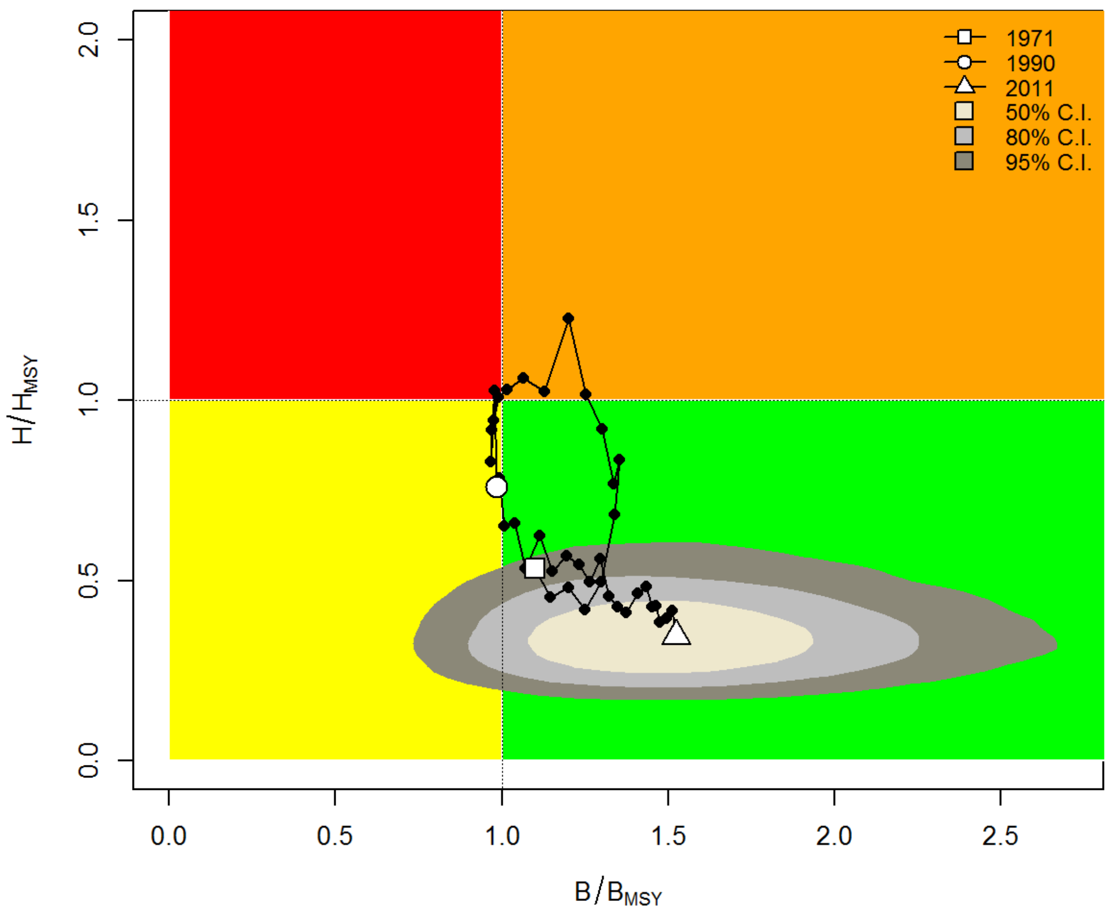

Figure 4. Kobe plot for the CMSY blue shark stock assessment. The plot illustrates degrees of stock depletion (horizontal axis) and over-fishing (vertical axis). Colors represent the magnitude of risk of stock collapse green (safe) to red (high risk). The solid white square indicates the median estimate in 1971, while the solid white triangle indicates the median in 2011. The 50, 80, and 95% CI for the 2011 estimate are also provided.

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