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Biological reference points (BRP project) for Chilean Fisheries: The case of Jack mackerel

Cristian Canales

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Cristian Canales (cristian.canales@ifop.cl)

Summary

The main results obtained after three workshops carried out in Chile (2013-2014) in order to estimate the Biological Reference Points for all Chilean fisheries and particularly for the jack mackerel fishery are summarized. A preliminary value of steepness of stock-recruit relationship in h=0.67 was estimated. The biomass depletion ratio at MSY was estimated in 35%, while F_{msy} was calculated in 0.24. This value is close to natural mortality rate (M=0.23) and F45%BPRwasproposed as proxy. The spawning biomass at MSY was estimated in 5.9 million tons with the current biomass 60% lower. Nevertheless, the fishing mortality in 2013 was estimated below F_{msy} and this should allow the population recovery in the medium term. This document is intended to be a contribution to the work of the SPRFMO-Scientific Committee which, under the mandate of the Commission, shall determine the BRP for the jack mackerel fishery.

1. Introduction

In order to estimate the Biological Reference Points (BRP) of the 24 main fisheries in Chile, IFOP has been carrying out a project requested by the Undersecretariat for Fisheries and Aquaculture and funded by the Undersecretariat of Economy. It is expected that the results will be a relevant support for the fisheries management. In 2013, a new Fishery Act was put in practice where MSY was defined as target for all fisheries and it is expected that, at the end of 2014, these BRP can be adopted by the Scientific Committees.

A total of eight experts were contracted for this task and three workshops (December 2013, April and August 2014) were carried out in order to reach the main objectives. In each workshop, the members of Chile's Scientific Committee were invited to attend and be part of the discussion. The international experts invited were Dr. Carmen Fernandez (ICES, Spain), Dr. Mike Sissenwine (USA), Dr. William Clark (USA), Dr. Martin Dorn (NOAA, USA), Dr. Malcolm Haddon (CSIRO, Australia), Dr. Neil Klaer (CSIRO, Australia), Dr. Matthew Dunn (NIWA, New Zealand), and Dr. Shijie Zhou (CSIRO, Australia).The local experts were those scientists that work in stock assessments and mainly those that form part of the Stock Assessment Department at IFOP.

At the 1st Workshop, different methodologies to estimate biomass and fishing mortality at MSY were discussed and proposed. These approaches depend on the data quality and type of assessment model used. In this sense, the fisheries were categorized in tiers detailed as follows:

Tier 1- Stocks for which there is an age- or length-structured assessment model (e.g., Statistical Catch at Age type models) that provides usable estimates of current abundance. Within this tier, two distinct situations are common:

- 1a. MSY reference points (F_{msy} and B_{msy}) and the reference point BLIM can be reliably estimated (or otherwise specified) from parameters estimated within the assessment model.

- 1b. Proxies for the reference points in 1a are chosen. The selection of these proxies should take account of uncertainty in the assessment model and the degree of resilience (or lack thereof) of the species. In this Tier, a level of 45% virginal biomass per recruit (BPR_0) was proposed as proxy of MSY.

Tier 2- Stocks for which there is a biomass dynamics model (also known as surplus-production or stock-production model) or an empirical approach based on catch and relative abundance data. Other relevant data may also be used.

Tier 3- Stocks for which there is insufficient data allowing application of a population dynamics model. Empirical approaches based primarily on catch data (with no relative abundance data), life history traits, and/or survey data shall be used.

Considering the characteristics of available information and the model used to assess the jack mackerel stock, this fishery was categorized in Tier 1a. This situation implies that steepness in stock-recruitment relationship can be estimated from the stock assessment and also its variables related to MSY. Complementarily, variables related to Tier 1b were also estimated.

In theSecond Workshop, and in accordance with the proposed methodology, the MSY variables (or its proxies) were calculated for all fisheries. In the Third Workshop, the exploitation diagrams were generated for all fisheries and some variables as F_{lim} and B_{lim}, are calculated considering a value of 50% B_{msy} as a general proposal. The project is not yet finished and further discussion will be necessary.

2. Materials and methods

- *Steepness estimation*

A Beverton-Holt stock recruitment relationship for jack mackerel has been proposed. The steepness (h) in this function was estimated by running the JJM several times as steepness values were proposed as candidates. In this sense, a likelihood profile was generated and the evaluated steepness range was 0.4-0.8 with step of 0.1. The likelihood function value was recorded for each scenario.The final steepness was selected from the scenario with the minimal likelihood value.

The “model 0.4” considered in the meeting of SC1-SPRFMO 2013 (La Jolla, USA) was used as base case for all purposes. This model represents the situation that was used in 2012 but updated to 2013 (model 7c).

- *Equilibrium analysis and MSY’s calculation*

In order to calculate the spawning biomass depletion ratio(d_{msy}) necessary to obtain MSY (SSB_{msy}) and its fishing mortality value (Fmsy), an equilibrium analysis was carried out. This analysis considered the steepness (h) based on a Beverton-Holt S/R model, the fishery selectivity, and biological parameters (natural mortality, maturity and weight-at age). The F_{msy} corresponds to fishing mortality of individuals fully recruited; this and other variables related to MSY were obtained when the production curve per recruit reaches its maximum value (YPR_{msy}). The following are the estimators used:

(i) Virginal spawning biomass:

$$SSB_0 = BPR_0 * R_0$$

(ii) Spawning biomass (SSB) at MSY:

$$SSB_{msy} = d_{msy} * SSB_0 * R_0$$

where $R_0$is estimated in stock assessment given a steepness value and BPR_0 is the biomass per recruit without fishing (F=0) estimated in 1.21 kg.

(iii) Fishing mortality target:F_{msy}

- *Depletion index and exploitation diagram.*

The ratio between the Spawning Biomass (SSB) in each year and SSB_0 was defined as depletion index. Considering the estimates of SSB_{msy} and F_{msy} per year, an exploitation diagram B-F was done due to important changes in selectivity that occurred in the fishery's history (Fig 1).The main biological parameters are summarized in Table 1 and natural mortality rate is M=0.23.

Table 1
Weight and maturity at age of jack mackerel

	Age (yrs)											
	1	2	3	4	5	6	7	8	9	10	11	12
weight (kg)	0.05	0.09	0.13	0.20	0.26	0.33	0.42	0.53	0.68	0.84	1.07	1.46
maturity	0.07	0.31	0.73	0.94	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00

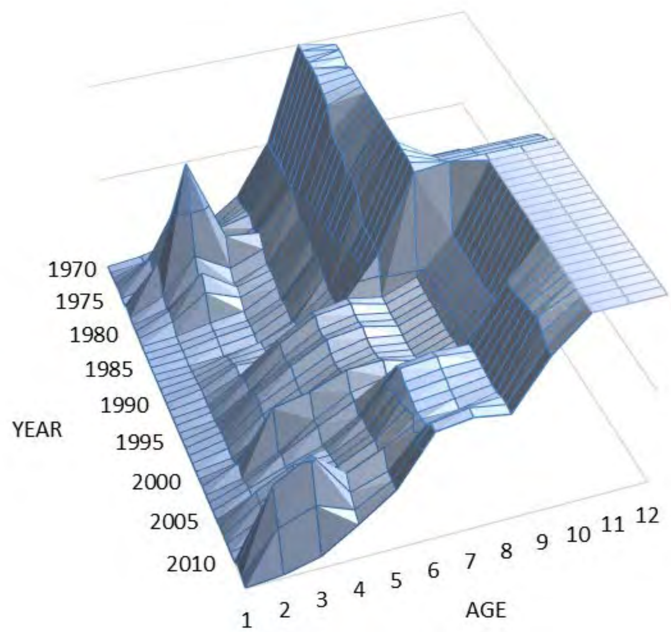

Figure 1. Fishery selectivity of jack mackerel per age and year 1970-2013.

3. Results

The steepness was estimated at around h=0.67 and corresponds to the value when likelihood profile is minimum (Fig 2). In this sense, the main component that determines the curvature is “rec_like”, which represents the deviation measure of recruitments in respect of the stock-recruitment model (Table 2).There is an improvement in the model fit to the age composition of catches (lower likelihood) when the steepness is increased, while the other components seem to be less informative.

As mentioned above, important changes occurred in selectivity mainly in the mid-1980’s, when the fishery located off center-south Chile started to gain significance. This situation generated a big change in main variables related to MSY as F_{msy} and SSB_{msy}/SSBo (Fig. 3, 4). The F_{msy} is around 0.25 but its slight declination through the years is related to the selectivity’s orientation to catch the youngest fish (Fig. 1, 3). Nevertheless, the rate between SSB_{msy}/SSBo seems to be robust since 1986, indicating that depletion of virginal spawning biomass to reach the SSB_{msy} is around 35%-36% (Fig 3). This biomass depletion rate value corresponds to the point where yield is maximum (Fig. 4), but as said before, this can vary depending on selectivity changes.

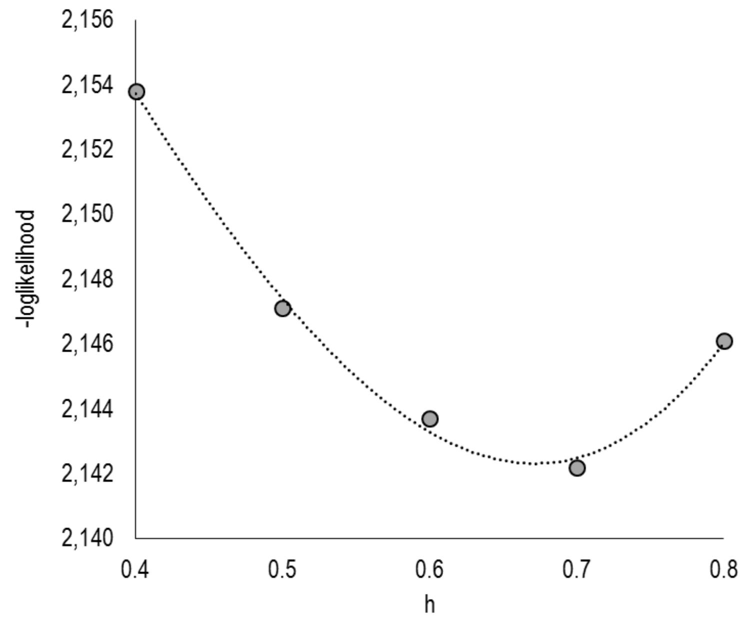

Figure 2. Steepness likelihood profile for jack mackerel

Table 2.

Relative variation in likelihood components for each steepness scenario. Values represent the difference in respect to minimum for each row. Hot colors represent low values.

h	0.4	0.5	0.6	0.7	0.8
catch_like	0.00	0.10	0.00	0.10	0.10
age_like_fsh	20.70	17.60	14.70	5.80	0.00
length_like_fsh	0.00	0.50	1.10	2.00	2.30
sel_like_fsh	0.20	0.30	0.40	0.20	0.00
ind_like	0.00	0.40	0.70	0.70	0.60
age_like_ind	0.00	0.20	0.30	0.40	0.50
sel_like_ind	0.00	0.00	0.10	0.10	0.10
rec_like	6.30	1.60	0.00	7.50	14.50
post_priors_indq	0.60	0.40	0.30	0.10	0.00
total	10.90	4.20	0.70	0.00	1.20

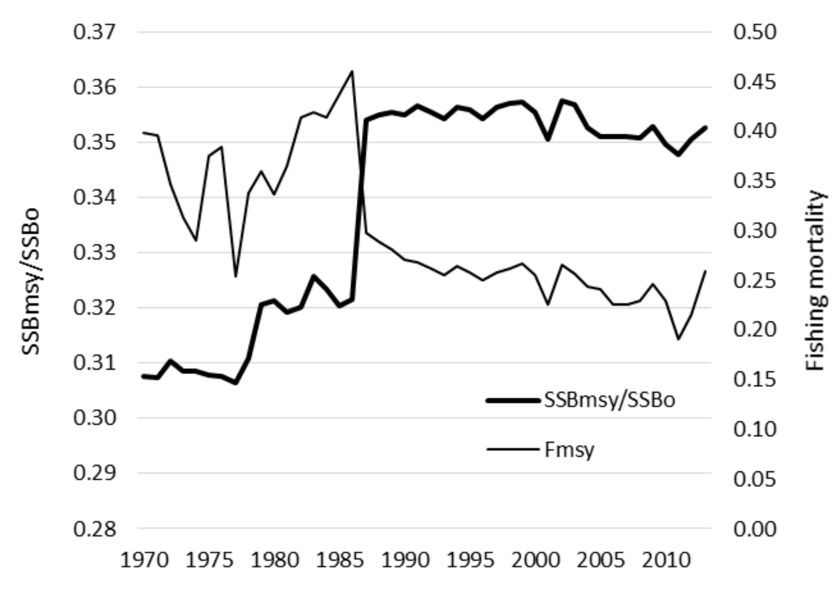

Figure 3. Fishing mortality and virginal biomass depletion at MSY for jack mackerel 1970-2013.

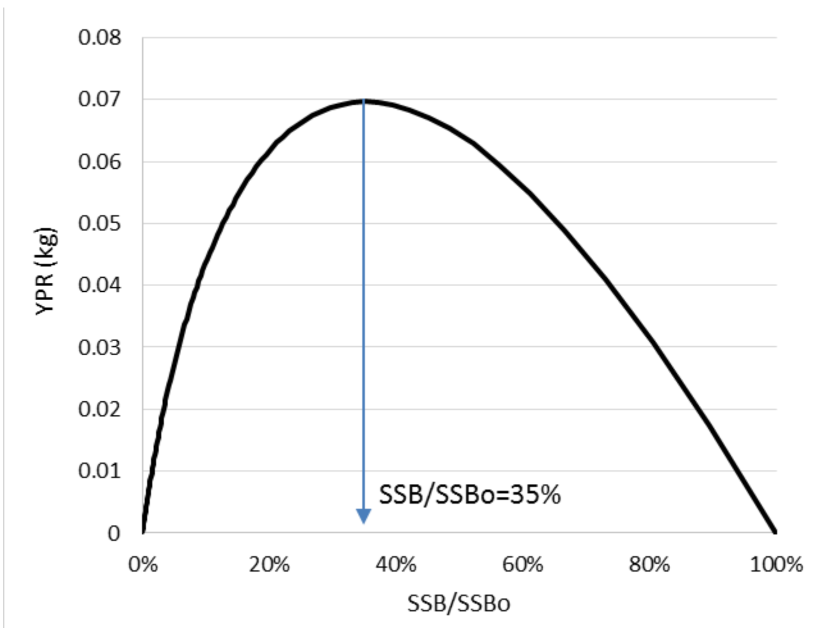

Figure 4. Example of production curve of jack mackerel considering the selectivity in 2013. The maximum value corresponds to MSY.

The MSY variables of jack mackerel are based on an average selectivity 1990-2013, and indicate that F_{msy} = 0.245 and B_{msy}=5.9 million tons. A complementary analysis based on Tier 1b indicated that F45BPR% = 0.23, value that is very similar to F_{msy}.

Based on these results and the biomass and fishing mortality history, the exploitation diagram B-F indicate that jack mackerel is in an overexploited/overfished condition (current condition of jack mackerel is overexploited) and its biomass is 60% lower than SSB_{msy} (SSB/SSB_{msy}=0.39). A similar conclusion is reached under Tier 1b (Fig 5, 6). However, the fishing mortality has declined and reached a value below F_{msy}, which should allow the stock recovery in the medium term. (Fig 5, 6).

Table 3.

Biological Reference Points for jack mackerel.

B_{msy}/Bo	0.354
F_{msy}	0.247
B_{msy} (000' t)	5941

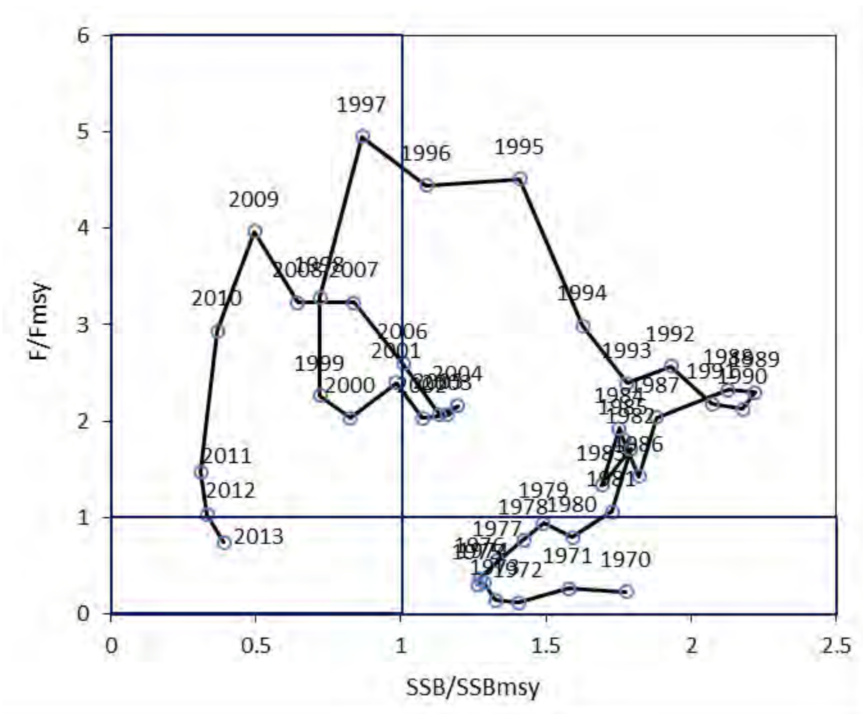

Figure 5. B-F exploitation diagram of jack mackerel based on h=0.67

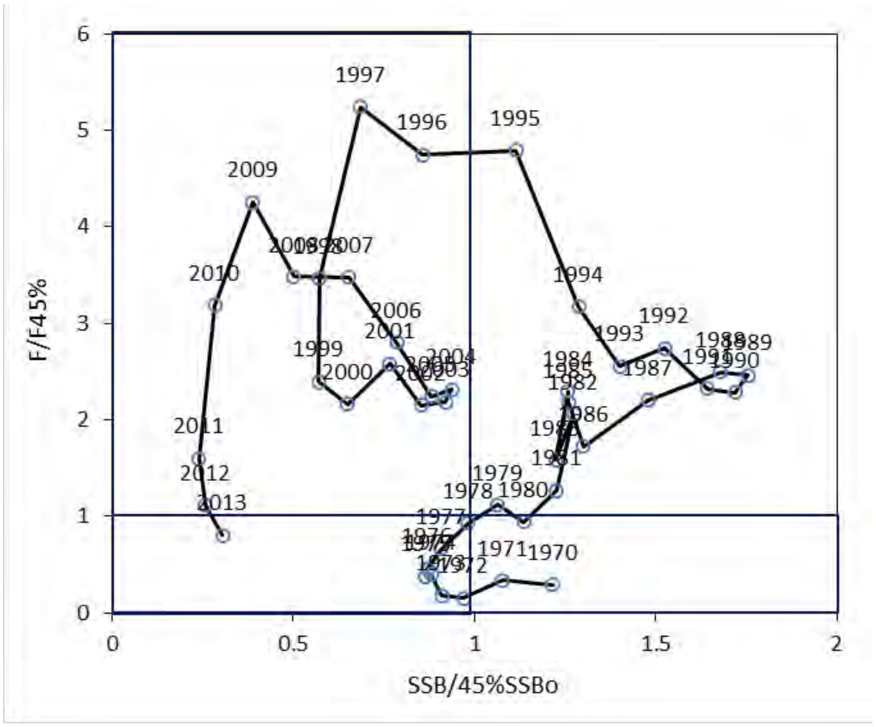

Figure 6. B-F exploitation diagram of jack mackerel based on F45%BPR as proxy F_{msy} (Tier1b)

4. Conclusions

The Biological Reference Points for jack mackerel indicate that the stock depletion rate of virginal population to reach B_{msy} is around 35%. This conclusion comes from the steepness analysis that provided an estimation h=0.67.However, this estimation may need further analysis considering its dependence with the error assumption of S-R relationship and of the final model that will be used as base case. The fishing mortality at MSY (F_{msy}) was estimated in 0.24 and has shown a slight declining trend regarding the increase of the exploitation of youngest fish in recent years. This value results close to natural mortality and the criterion based on F45%BPR (Tier 1b).The spawning biomass at MSY was estimated in 5.9 million tons and the current biomass is 60% lower. Nevertheless, the current fishing mortality is below $F_{msy,}$ a situation that should allow the recovery of the jack mackerel population in the medium term.

5. References

M. Sissenwine, C. Fernandez, Clark, W., Dorn, M., Haddon M., Klaer N., Zhou S., 2013. Review of biological reference points in domestic fisheries. 1th Workshop Report, December 2013.Instituto de Fomento Pesquero, Chile: 44 pp.

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