



South Pacific Regional Fisheries Management Organisation

1st Meeting of the Scientific Committee

La Jolla, United States of America, 21-27 October 2013

SC-01-06

Impact of using different weight-at-age by fleet in the Jack mackerel stock assessment

Cristian Canales

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Cristian Canales – IFOP – Chile

Abstract

In order to assess the impact of using differentiated mean weights by fleet in the stock assessment, a sensitivity analysis was conducted. The results show that when putting together Peru's and Chile's mean weight series, the spawning biomass is 12% lower than that obtained when only Chile's weights are considered. This causes a slight further reduction of the stock with respect to the base scenario.

When including Peru's mean weight, its catches are represented by a lower number of fish; therefore, the impact of exploitation on the young fraction of fish is considerably lower. Thus, the catches in the north of Chile -constituting less than 10% of the catch of Peru-Ecuador- represent the same level of fishing mortality.

Additionally, the analysis showed a great impact on the stock projection; that is, due to the apparent low impact of the Farnorth fleet on fishing mortality, future catch and biomass forecasts turn out to be significantly higher than the base case.

Finally, the use of mean weights split by fleet or survey may be ideal for stock assessments, yet, due to the great impact of Peru's mean weights based on a growth model and the significant differences registered at a same age, it is rather recommended that said weights are validated before being considered in the stock assessment.

1. Introduction

The need for regulation measures in this area of the Pacific led to a negotiation for the establishment of a regional fisheries management organization, convened by Chile, Australia and New Zealand in 2006. The South Pacific Fisheries Regional Management Organization (SPRFMO) was established in 2013, aiming at setting the basis for the sustainable exploitation of resources, particularly jack mackerel, since its biomass is currently depressed. The medium-term objective of the Organization is to rebuild the population of this species.

One of the most relevant working groups is the Jack Mackerel Stock Assessment Working Group; it provides the best available information for stock assessment. In the 2012 Science Working Group meeting (SGW-SPRFMO), held in Lima, particularly at the Jack Mackerel Subgroup (JMSG) session, a discussion took place regarding the mean weight-at-age that shall be used in stock assessments. This discussion was based on the fact that, until then, only the average weight of the Chilean center-south fleet was considered as the single information matrix for the four fleets exploiting this resource. It was argued that Peru's information enabled a matrix of mean weights at age particular for its fleet and levels of abundance, and as such it was included in the stock assessment.

However, differences with Chile's weight matrix are a relevant effect caused mainly by differences of age and growth function; this aspect has not been properly evaluated. Peru's information shows that jack mackerel lives less and weighs more than a jack mackerel of the same age captured off Chile (**Figure 1**). It is important to note that average weight at age allows to convert the number of individuals into biomass either to measure population or to estimate catches. Thus, the effect can be seen at a fishing mortality level as, for a given catch in weight, the Peruvian fleet would remove a lower number of individuals, as compared to the Chilean fleet. Accordingly, a comparative analysis of the impact of considering these discrepancies in fishing mortality of estimated fleets of the stock assessment was conducted.

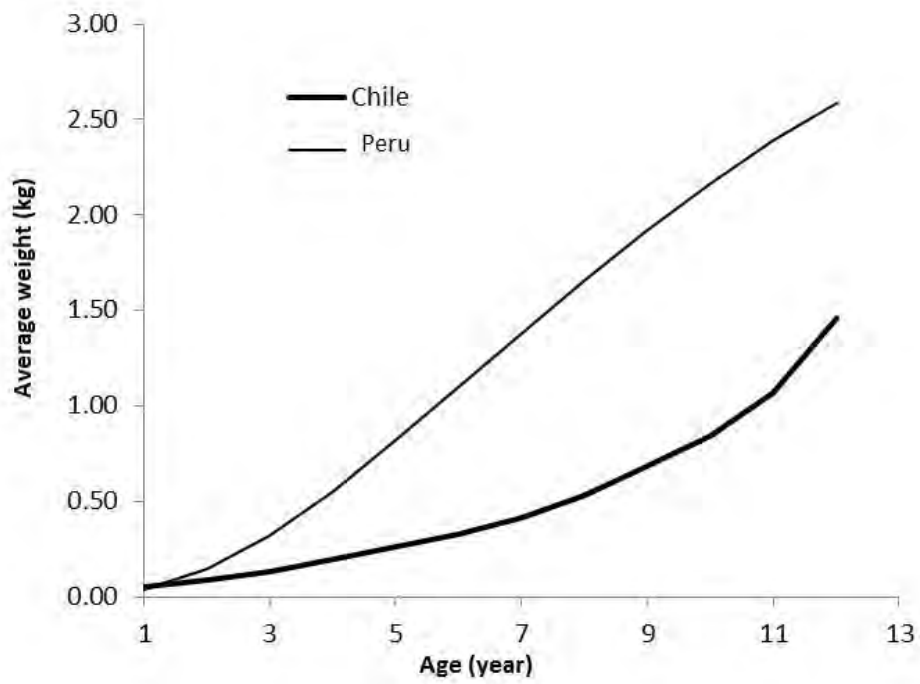


Figure 1 Average weight of the jack mackerel of central-south Chile and in Peru.

2. Materials and Methods

Data used correspond to results obtained in the last joint stock assessment conducted by the JMSG-SWG of the 11th SPRFMO Scientific Meeting updated in 2012. Two scenarios of stock assessment were considered as the main methodology:

- S1: model with a single matrix of mean weight at age (only mean weights at age of the Chilean fleet).
- S2: model with two matrices of mean weight at age (Peru and Chile).

Mean weight at age is directly related to the adjustment of indexes of relative abundance and catch series by fleet within the model. The second scenario implies that Peru's landings series within its EEZ, its CPUE series and its acoustic biomass consider Peru's mean weight. The remaining series adjust to Chile's mean weight. Stock assessment includes 9 series of abundance indexes and 4 landings series (**Table 1**). Notwithstanding the foregoing, it is important to say that the population's mean weight at age used to estimate the biomass within the model of stock assessment corresponds to the average derived from the weight matrix of central-south Chile (**Figure 1**). The JJM model is implemented on ADMB¹ (Fournier *et al*, 2012) and used for the SPRFMO JMSG.

Table 1.

Series of jack mackerel abundance indexes and landings. The number of data series is indicated in brackets.

Index	Country
CPUE (5)	Chile, China, Peru, EU and Russia.
Acoustic (3)	Chile central-south, north Chile, Peru.
MDPH (1)	Central south Chile.
Catches per fleet (4)	Northern Chile, central-south Chile, Peru-Ecuador, International off Chile and outside the EEZ.

Performance of one or another scenario was conducted on the basis of the following variables:

- Likelihood components

Inclusion of mean weights of Peruvian catches is evaluated to see if it improves the adjustment of the model to the abundance and landings indexes.

- Biomass and reduction of the reproductive potential

¹ <http://www.admb-project.org/>

Biomass and reduction of the reproductive potential should have certain, although lower, impact due to the negative correlation between recruitments and fishing mortality.

- Total fishing mortality and mortality per fleet

Fishing mortality should be affected significantly as, at same landing level, a higher individual mean weight implies a lower number of fish captured, therefore, a lower fishing mortality.

- Total selectivity and selectivity per fleet

Selectivity should vary if the decrease in fishing mortality affects some age segment in a particular manner.

- Spawning biomass projection

As a result of the changes in selectivity, future expectations of biomass against current catch levels should vary. Population projection was conducted considering a S/R Beverton-Holt model which is integrated in the JJM stock assessment model.

3. Results

3.1 Model's fit

The fit of the model to the information did not show significant improvements when scenario S2 was considered. Variation on total likelihood (partial) decreased 1% mainly because of a relative improvement in the fitting of the abundance indexes reducing its likelihood value in 3% (**Table 2**). In terms of spawning biomass and reduction of the reproductive potential, the use of Peru's mean weights (S2) leads to a 12% and 10% reduction, respectively, compared to considering only Chile's mean weights (S1).

Table 2

Log-likelihood per type of information and assessment scenario

	S1	S2	Variation
Prop age catch	629	622	-1%
Prop length catch	466	470	1%
Abundance indexes	605	590	-3%
Prop age indexes	133	132	-1%
Total (partial)	1834	1815	-1%
SB (2012) thousand tons	2143	1889	-12%
RPR	18%	16%	-10%

1. State variables

The use of differentiated mean weights for Peru's fleet and indexes (S2) leads to a decrease in the scale of the recruitments (**Figure 2**). This is clear at the spawning biomass level with a reduction both at the beginning and at the end of the series (**Figure 3**). As mentioned before, scenario S2 produces a 12% reduction in the spawning biomass estimate of the most recent year.

Notwithstanding the foregoing, important effects, particularly on the Farnorth fleet, are observed at average fishing mortality level (all ages). As a result of this higher weight at the same age (S2), fishing mortality is now lower than half of the values obtained in scenario S1 and similar to Chile's northern fleet (**Figure 4**). This has a significant impact on the structure of the fishing mortality level of the most recent year by age, where scenario S2 indicates that the fishing mortality level of age groups of 2 and 3 years is significantly lower than S1 (**Figure 5**), as a result of the considerable reduction in the scale of fishing mortality by ages that the Farnorth fleet is experiencing (**Figure 6**).

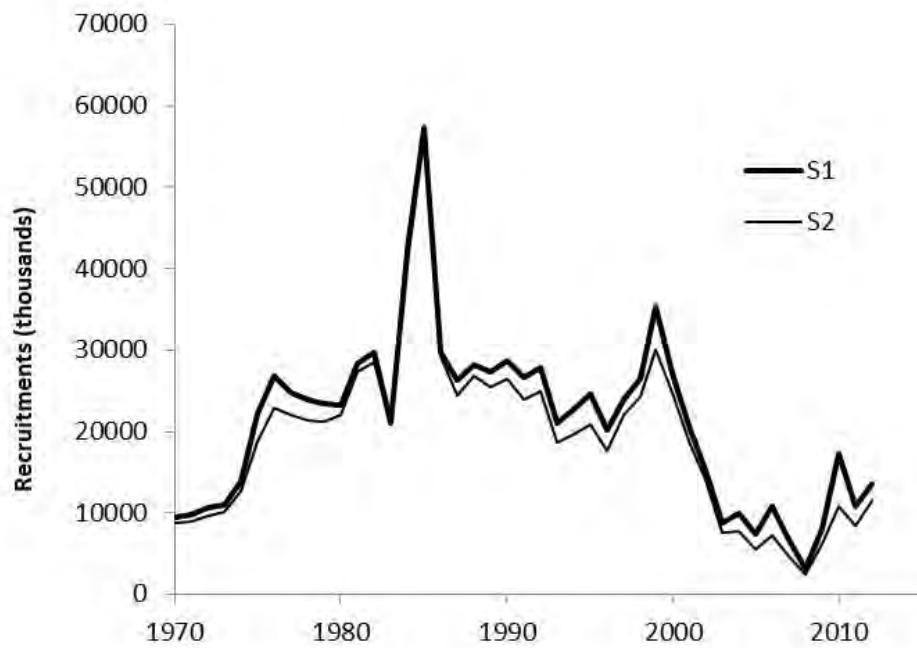


Figure 2 Jack mackerel recruitments according to assessment scenario

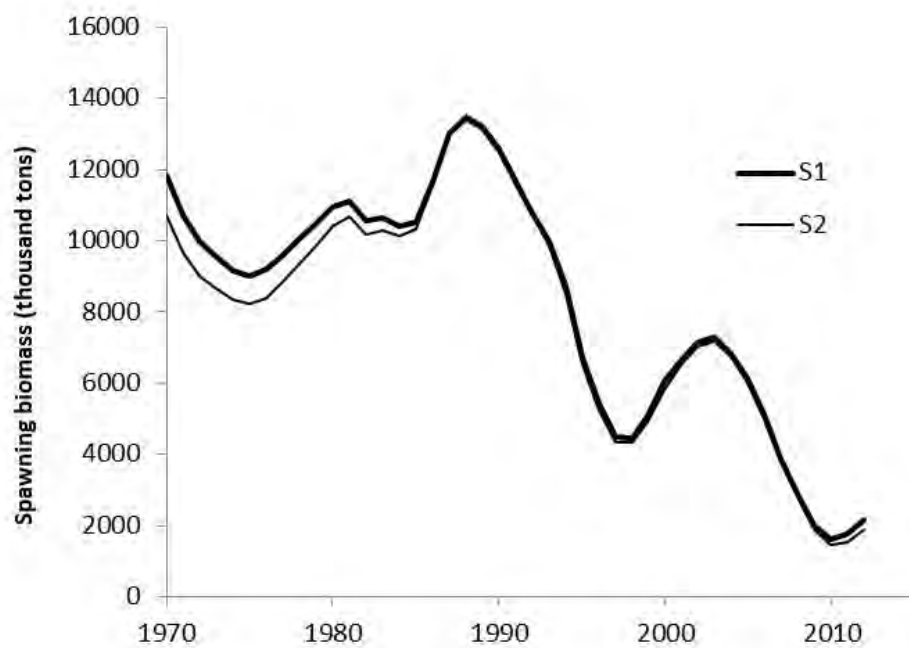


Figure 3 Jack mackerel spawning biomass according to assessment scenario

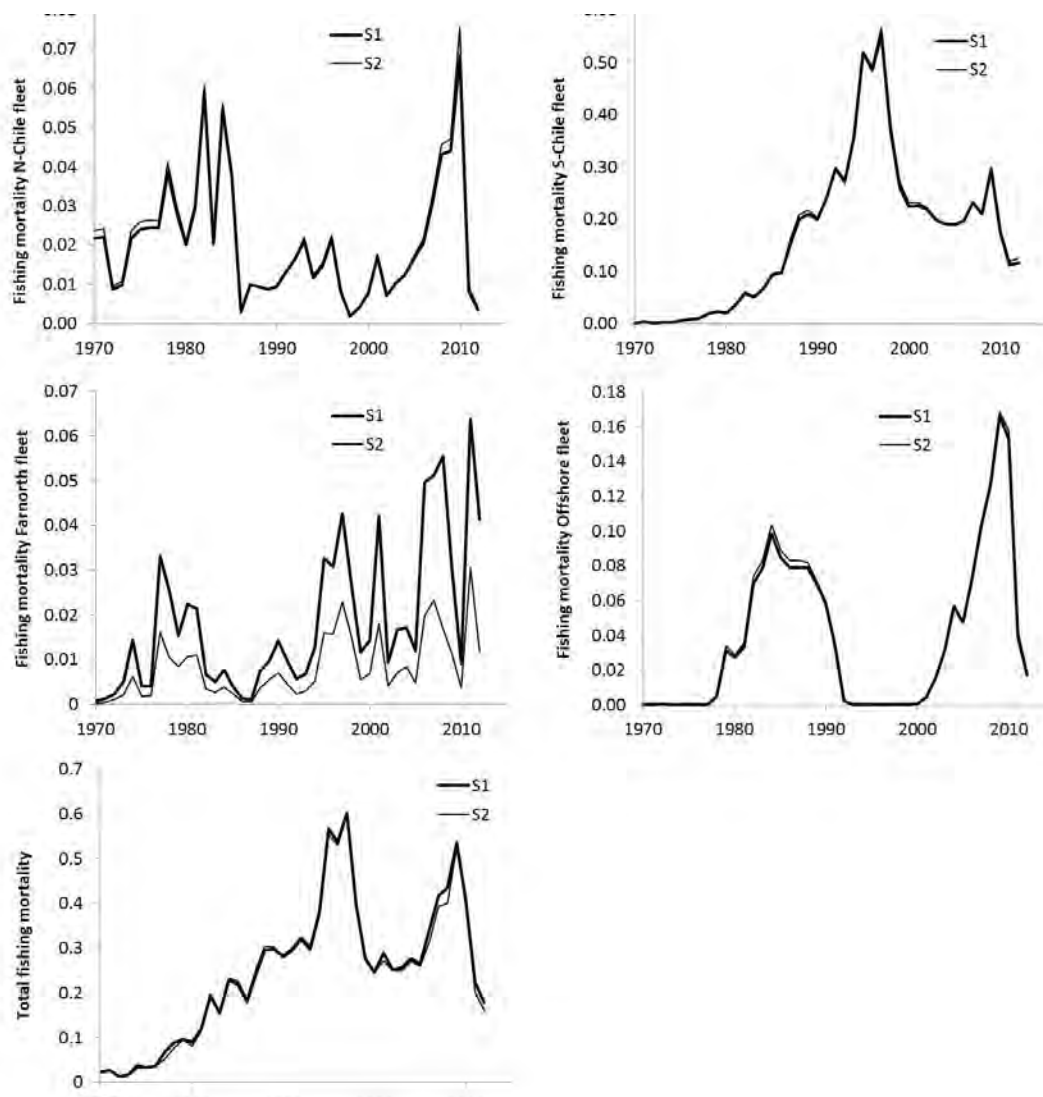


Figure 4 Average annual fishing mortality per fleet and total, according to assessment scenario.

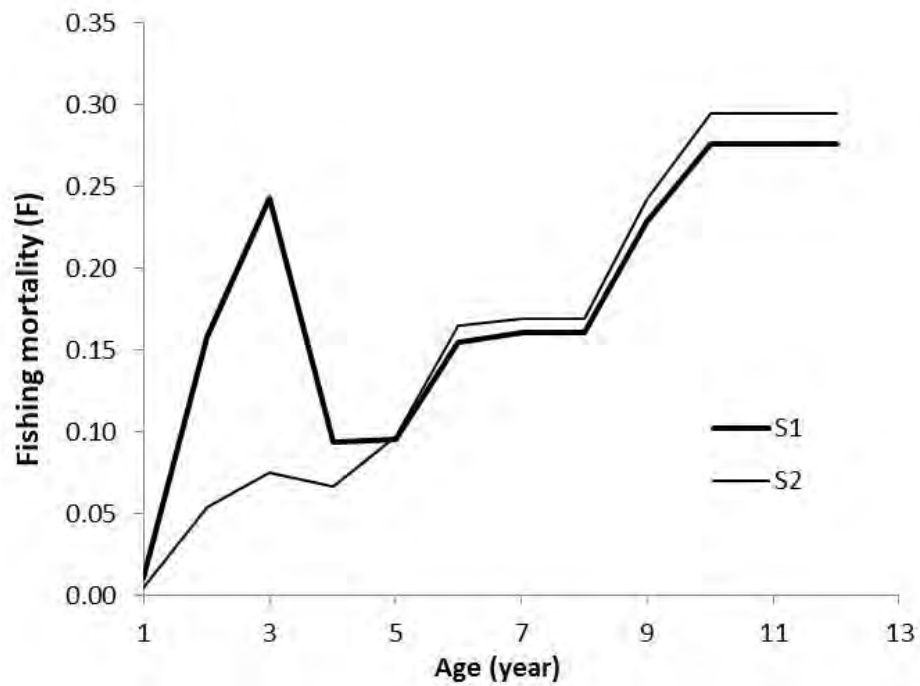


Figure 5 Total fishing mortality at age of 2012 jack mackerel according to assessment scenario.

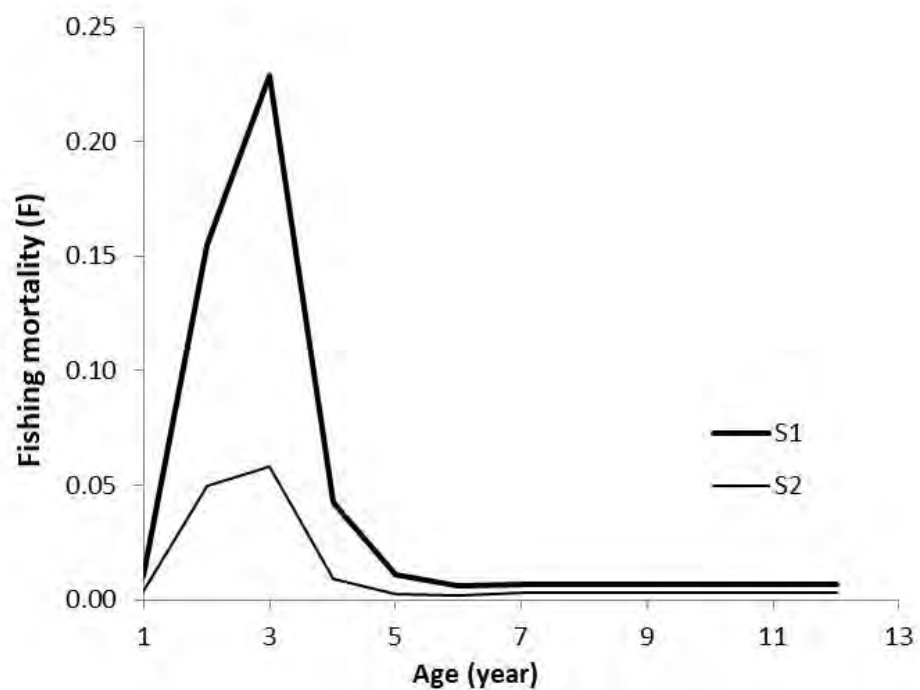


Figure 6 Jack mackerel fishing mortality at age, Farnorth fleet, 2012, according to assessment scenario.

2. Projections of biomass and catch

A low level of fishing mortality on groups of younger fish (2 and 3 years) leads to a greater recovery of the spawning stock. In fact, **Figure 7** shows that projecting the population 10 years ahead under the current levels of fishing mortality with scenario S2, the recovery is much greater and reaches 3 times the estimated biomass for 2012, compared to the 2.2 times recovery reached by scenario S1 in the same time period. This also has an impact on the catch expectations, as catches that would be obtained by the end of the period are slightly over 1.1 million tons with scenario S2 compared to 900 thousand tons obtained with scenario S1 (**Figure 8**).

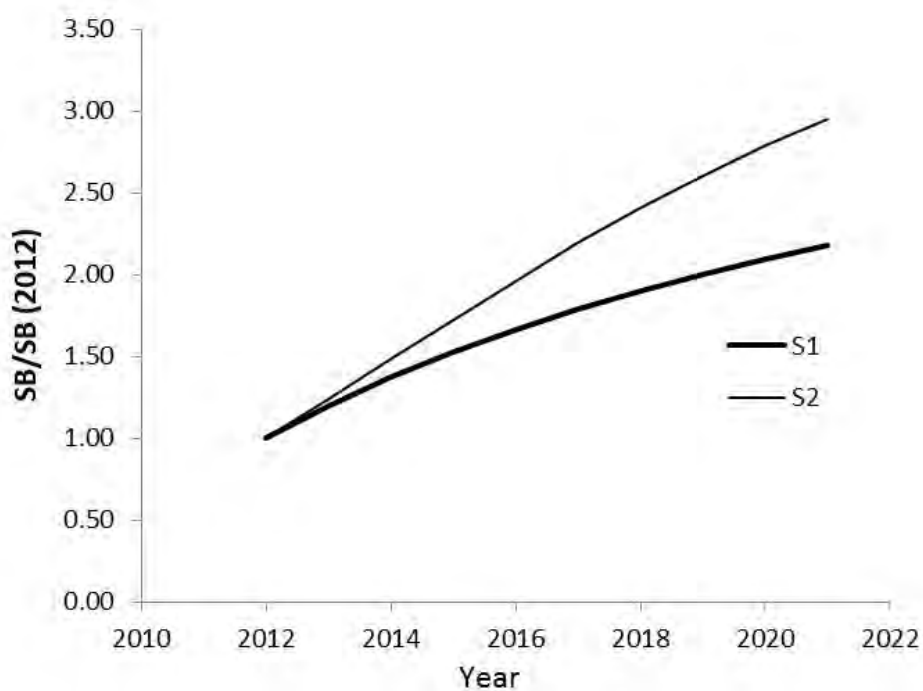


Figure 7 Jack mackerel spawning biomass projected 10 years forward for two assessment scenarios.

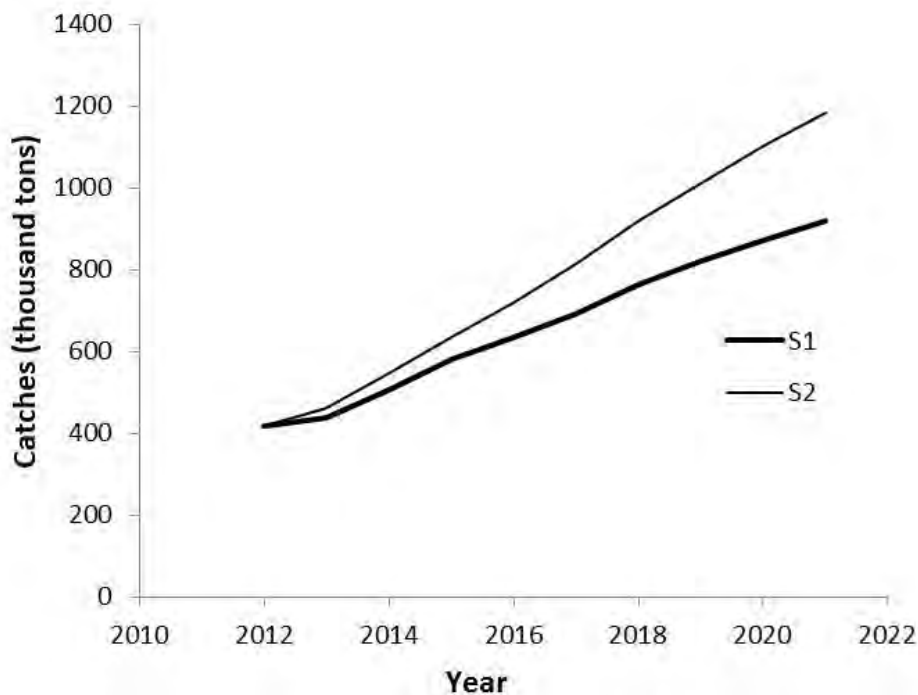


Figure 8 Jack mackerel catches projected 10 years forward for two assessment scenarios.

4. Discussion

The analysis of mean weights differentiated by fleets has a great impact at a biomass and catch projection level and, to a lesser extent, at the level of the spawning biomass and stock reduction estimates. In fact, when putting together Peru's and Chile's mean-weight series, a spawning biomass is obtained, which is 12% lower than the one obtained when only considering Chile's weights. This also causes a slight further reduction of the population with respect to the base scenario (S1).

This work showed that the inclusion of Peru's mean weight leads to the representation of their catches by a lower number of fish, therefore, the impact that the exploitation has on the fraction of fish younger than 4 years is significantly lower than the base scenario, even similar to the one of northern Chile. That is, the catches in the north of Chile -constituting less than 10% of the catch of Peru-Ecuador- represent the same level of fishing mortality just for the effect referred to the average weight at age. This has a considerable effect on the total exploitation pattern of the fishery and as such, it shall have an impact on the estimation of Biological Reference Points.

At the same time, this situation has a great impact on the population projection and catch level, since a low impact made by the Farnorth fleet on fishing mortality of young fish (as a result of a higher mean weight at age) will make the future biomass and catch expectations significantly higher than those where only Chile's weight are considered.

Mean weights of fleets and surveys shall ideally be considered separately, in order to incorporate implicitly the data variability of the different fleets or fishing zones of the fishery. However, there is still no process of validation of Peru's growth function or at the level of average weights. This situation is not supported by otolith reading but by the direct application of the growth model to the weight-length relation by year: This means that Peru's growth model shall be at least validated before being considered in the stock assessment.

5. References

- Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optim.Methods Softw.* 27:233-249.
- SWG-11, JMSG report, 2012. Report of the Jack Mackerel Subgroup. Annex SWG-03. In: Report of the 11th Science Working Group, Lima, Perú, 2012.