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Research Article

Uncertain population dynamic and state variables of alfonsino (*Beryx splendens*)

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ABSTRACT. Alfonsino (*Beryx splendens*) is a species associated with seamounts, with an important fishery in Juan Fernandez archipelago, Chile (33º40'S, 79º00'W). Since 2004, this resource has been managed by catch quotas estimated from stock assessment models. The alfonsino model involves high levels of uncertainty for several reasons including a lack of knowledge of aspects of the population dynamics and poorly informative time-series that feed the proposed evaluation models. This work evaluated three hypotheses regarding population dynamics and their influence on the main state variables (biomass, recruitment) of the model using age-structured and dynamic biomass models. The hypotheses corresponded to de-recruitment of older individuals, non-linearity between standardized catch per unit effort, and population abundance as well as variations of the relative importance of length structures. According to the results, the depletion of the spawning biomass between 1998 and 2008 varied between 9 and 56%, depending on the combination of hypotheses used in the model. This indicates that state variables in alfonsino are not robust to the available information; rather, they depend strongly on the hypothesis of population dynamics. The discussion is focused on interpreting the causes of the changes in the state variables in light of a conceptual model for population dynamics in alfonsino and which pieces of information would be necessary to reduce the associated uncertainty.

Keywords: *Beryx splendens*, stock assessment, uncertainty, seamounts, population dynamics, southeastern Pacific, Chile.

Dinámica poblacional incierta y variables de estado en alfonsino (*Beryx splendens*)

RESUMEN. El alfonsino (*Beryx splendens*) es una especie asociada a montes submarinos. En Chile sustenta una importante pesquería en el archipiélago de Juan Fernández (33º40'S, 79º00'W). Desde el año 2004, este recurso es administrado a través de cuotas anuales de capturas, las cuales son estimadas desde un modelo de evaluación de stock. La modelación de la población de alfonsino se caracteriza por una alta incertidumbre, debido a diversas fuentes, como son desconocimiento de aspectos de su dinámica poblacional en concomitancia con series temporales débilmente informativas que sustentan los modelos de evaluación propuestos. En el presente trabajo fueron evaluadas tres hipótesis de dinámica poblacional y su influencia en las principales variables de estado del modelo (biomasa, reclutamiento) bajo un esquema edad-estructurado y otro de biomasa dinámica. Las hipótesis corresponden a des-reclutamiento de individuos longevos, no linealidad entre la captura por unidad de esfuerzo estandarizada y la abundancia poblacional; como también variaciones en la importancia relativa de las estructuras de longitud. Los resultados indican que el decaimiento de la biomasa desovante, entre 1998 y 2008, varió entre 9 y 56% dependiendo de la combinación de hipótesis de dinámica poblacional asumida en el modelo. Esto indica que las variables de estado en alfonsino no son robustas a la información disponible sino que dependen, fuertemente, de las hipótesis de dinámica poblacional. La discusión está enfocada en interpretar las causas de los cambios en las variables de estado a la luz de un modelo conceptual de dinámica poblacional en alfonsino y cuáles serían las piezas de información necesarias para reducir la incertidumbre asociada.

Palabras clave: *Beryx splendens*, evaluación de stocks, incertidumbre, montes submarinos, dinámica poblacional, Pacífico suroriental, Chile.

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INTRODUCTION

Alfonsino (*Beryx splendens*) is a benthic-demersal species inhabiting median latitudes throughout the world. Catches of this species have been reported in depths of between 25 and 1,240 m (Busakhin, 1982), however, it is generally found in depths of between 200 and 800 m over seamounts and the continental shelf. Their schools form dense aggregations, usually associated with rocky/sandy substrates. According to the literature, alfonsino is a species with unique spatial dynamics during its ontogeny. It is characterized by a long planktonic life (Mundy, 1990) before they migrate to the vegetative fraction of the population where individuals grow until they reach maturity. Mature individuals migrate to reproductive areas through current systems and meso-scale eddies (Alekseev *et al.*, 1986).

Landing records in Chile indicate the presence of this species principally over the seamounts located in the Juan Fernandez archipelago, and to a lesser extent in the Bajo O'Higgins area and the continental slope between 32° to 40°S (Fig. 1). The fishing fleet is composed of a few industrial trawling vessels which operate principally in depths of between 300 and 500 m. Although this species has been fished since 1989, its landings only started to be important from 1999 (around 700 ton), coinciding with the developing of the orange roughy (*Hoplostethus atlanticus*) fishery. During 2001, landings of alfonsino show a high increase (500%) with respect to previous years. Nowadays, this fishery has been declared as "fully exploited regime". This corresponds to a particular fishing regime established under the Chilean General Fishing Law on Fishing and Aquaculture that, in general, empowers the management authority to introduce an annual quota.

Stock assessment of deep-water species is considerable more complicated than that on shelf-based species (Large *et al.*, 2001). Knowledge of the primary biological processes such growth, feeding, maturation and fecundity is fragmentary at the best where knowledge is particularly poor in areas such recruitment and its variations, stock identity, fish migration and fish behaviour. Time series usually remains short for stock assessment purposes (frequently less than 5 years), age-disaggregated data are rare in deep-water fisheries and capture per unit of effort (CPUE) from commercial vessels is usually biased as index of abundance because most deep-water fish form dense spatially-aggregated schools (Morato *et al.*, 2006) and thus depletion reduces de size of the aggregation rather than fish density (Clark, 2001). Only in few cases, fishery-independent survey data for use in stock assessment is available, mostly because the prohibited costs involved and technical issues associated with prospecting deep-water fishes (Kloser, 1996). In fact, acoustic surveys of deep-water fishes need to account for bias associated with a dead zone close to the bottom within fish echoes are lost in the strong bottom signal (Simmonds & MacLennan, 2005) and also considers bias caused by the vertical migrations that usually occur as a diurnal rhythm.

The current knowledge of alfonsino in Chile is not as bad as in other deep-water fishes. Currently, basic biological knowledge about growth, natural mortality (Gili *et al.*, 2002) and maturation (Guerrero & Arana, 2009) is available. A routine sampling program was established in this fishery since 1999 by the Instituto de Fomento Pesquero (IFOP-Chile), which collects information regarding fishing logbooks and length structures. In addition, three acoustic surveys have been designed to evaluate the biomass of alfonsino in Juan Fernandez archipelago. With this information, a stock assessment program has been implemented on this fishery since 2004, but in all models implemented, a poor fitting of the data is reported. A poor goodness-of-fit of the models is mostly caused by the high interannual variability of length structures and abundance indices (Figs. 2 and 3). This situation has produced uncertainty on the exploitation status of alfonsino because the available information is not enough to verify the assumption of the models. This situation produces that the main state variables (biomass and recruitment) are not robust to the data but it is highly dependent on the underpinning population dynamic assumed.

Wiff (2010) indicated that the key issue in interpreting the data available is dealing with the particular ontogenetic behaviour of alfonsino. It seems that average sizes vary with depths where young and smaller individuals live in shallow waters and they move progressively to deeper waters when they became older and bigger This behaviour has been reported in alfonsino inhabiting other areas (Lehodey *et al.*, 1994) and it was first reported by Contreras &

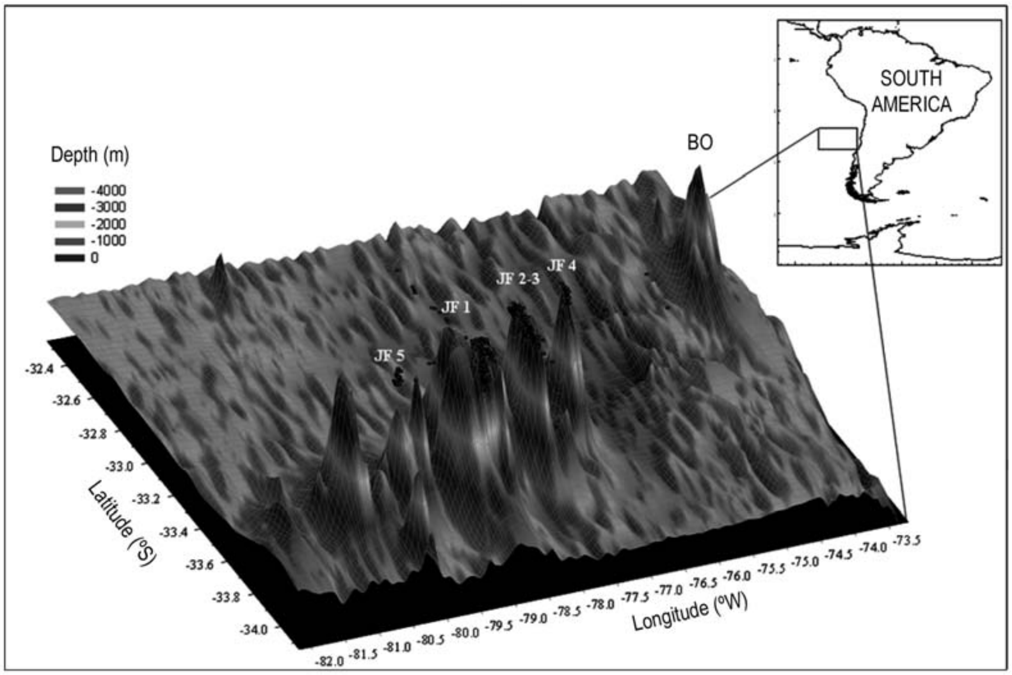

Figure 1. Fishing zone of alfonsino in Chile with emphasis in the Juan Fernández archipelago. Dots indicate the accumulated hauls with alfonsino. "JF1-JF5" indicates each specific name of the seamount in Juan Fernández. BO: indicates Bajo O'Higgins area.

Figura 1. Zona de pesca de alfonsino en Chile con énfasis en el área de Juan Fernández. Los puntos indican los lances acumulados de captura de alfonsino. "JF1-JF5" indica el nombre específico de cada uno de los montes del área de Juan Fernández. BO: indica el área del Bajo O'Higgins.

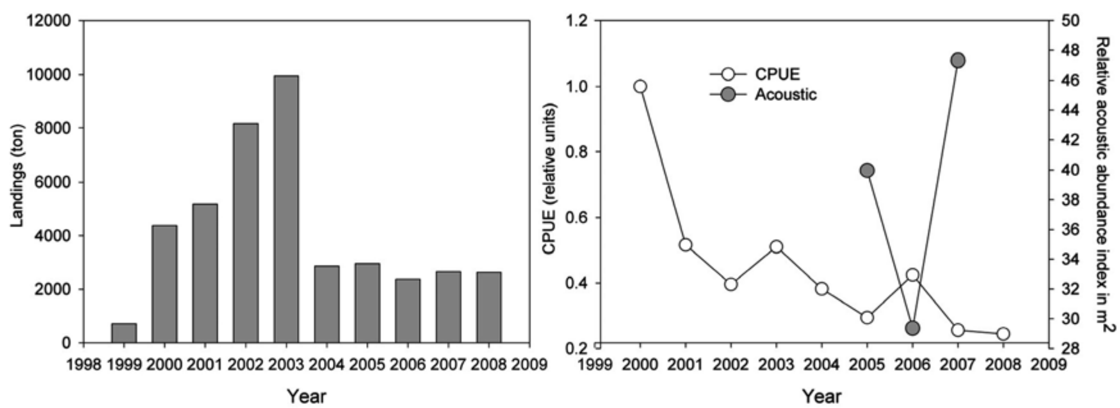

Figure 2. Landings and abundance indices of alfonsino used in the model.

Figura 2. Desembarques e índices de abundancia usados en el modelo.

Canales (2008) in Juan Fernandez. Wiff (2010) added that fishing operation has changed across time. The fishery started in 2000 operating in deep-waters (~550 m) catching large individuals (~40 cm FL). Then, fishing operations started progressively catching smaller individuals (~32 cm FL, year 2008) in shallower waters (~390 m). This particular fishing operation allows that different size/depth strata have been fished across years. The consequence of such a fishing process is that the basic assumptions of stock assessment modelling are not met and it may explain the lack of fit of the model to the observed data. Wiff (2010) simulated a population that mimic the life history and behaviour of alfonsino where different

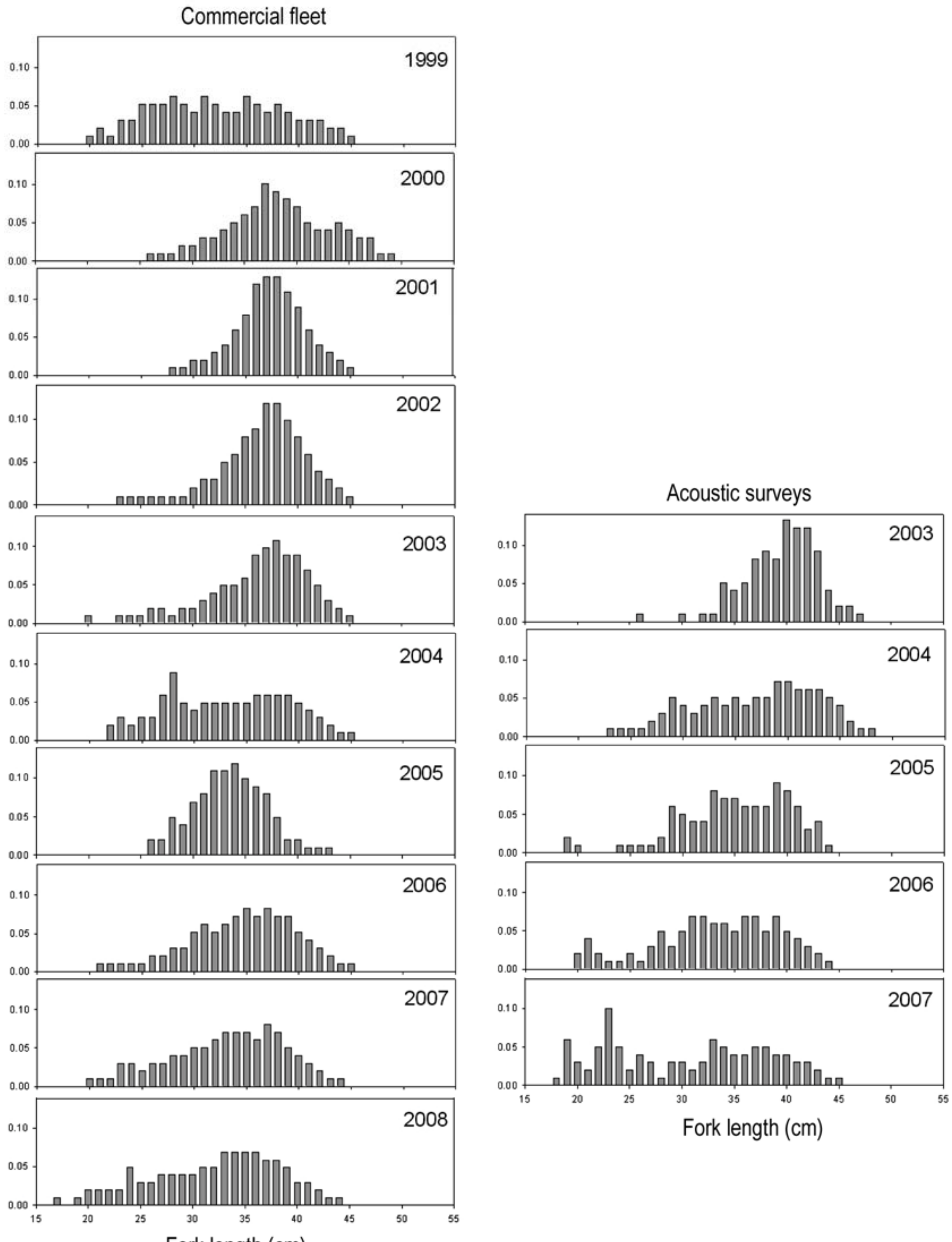

Figure 3. Length structures of alfonsino from commercial vessels and acoustic surveys used in the model.

Figura 3. Estructura de tallas en alfonsino usadas en el modelo y provenientes de la pesca comercial y cruceros acústicos.

length/ages and founded at different depths and were a fishery harvested in different age/length stratum across time. He reported that this particular fish and fishing behaviour explained the high variability of length structures and CPUE indices across time. He also suggested that three hypothesis regarding to population dynamics should be investigated (1) A de-recruitment to the fishing gear is expected in this fishery, where individuals older than 12 years are rarely caught being lifespan estimated in 19 year old (Gili *et al.*, 2002). Fishermen also reported high aggregation of bigger fish in deep-waters where trawling is difficult or impossible to perform (Gálvez *et al.*, 2009); (2) A non-linear relationship between the CPUE index and the abundance, process known as hyperdepletion/hyperestability. During the first years of the exploitation the CPUE time series decreases faster than abundance a process indicate as hyperdepletion, whereas in recent years a process of hyperstability is reported where abundance decreases faster than CPUE. (3) The length structures are non-informative in terms of population dynamics of alfonsino. In the theory of stock assessment, a time series of length structures is determined by the recruitment strength, somatic growth and age-dependent mortality. Taking into account these three hypotheses, the main objective of this work is to explore the causes underlying the lack of fitting of the model to the data and how the information should be incorporated in the model.

MATERIALS AND METODS

Available data

The information used corresponds to: (i) landings between 1998 and 2008; (ii) length structures from commercial catches reported by the monitoring program between 1999 and 2008 (for details see Gálvez *et al.*, 2009); (iii) length structures from acoustic surveys between 2003 and 2007 (Niklitschek *et al.*, 2006, 2007); (iv) a standardized CPUE time series between 2000 and 2008 (Wiff, 2010) and (v) biomass estimates from acoustic surveys for years 2005, 2006 and 2007 (Niklitschek *et al.*, 2006, 2007). Data used in the model is summarized in Figures 2 and 3.

This information is used to implement an age-structured model considering ages between 1 and 19 years and combined genders. Captures at age are not available in this fishery and thus, an age-at-length key is modelled using the growth parameters reported by Gili *et al.* (2002). The model considers the existence of one single stock inhabiting Juan Fernandez archipelago. A comparable acoustic index across time was available pooling together information from seamounts JF1 and JF2 (Fig. 1). The model optimization was implemented by minimizing the negative log-likelihood assuming multinomial error for length structures and log-normal error for the abundance indices.

A Schaefer's production model (Schaefer, 1954) was also implemented to analyse the consistency of state variables from the age-structured model. The production model used the standardized CPUE and acoustic time series as indices of abundance. The optimization was implemented by minimizing the negative log-likelihood assuming log-normal error for abundance indices.

Scenarios

To evaluate the sensitivity of the state variables, a total of 12 scenarios were evaluated by combining the three hypotheses about population dynamic explained in the introduction. In the case of age-structured model the assumptions evaluated were:

1. The information coming from length structures was evaluated modifying the sample size of the multinomial distribution in the likelihood function. Three sample sizes were evaluated for the length structures of commercial catches (ns) and from the acoustic surveys (na). The first scenario, evaluated the same sample size in both structures (ns = na = 20; Case A, Table 1). The second scenario considers as well the same sample size in both structures, but with a smaller sample sizes (ns = na = 10; Case B, Table 1) thus decreasing the relative importance of length structures in the total likelihood. Finally, it was evaluated the hypothesis that the length structures coming from commercial catches were more informative than those from acoustic surveys (ns = 10, na = 5; Case C, Table 2).

2. The hypothesis of de-recruitment was assessed by modifying the exploitation pattern allowing lower catch probability in older and bigger fish.

3. The assumption of hyperdepletion/hyperestability (hereafter named "linearity assumption") was incorporated modifying the linear assumption between CPUE and exploitable biomass according to the parameters reported in Wiff (2010).

The combination between these two exploitation patterns (2) and the two assumptions of linearity (2) conditioned a total of four scenarios to be evaluated by the age-structured model on each one of the sample size cases. A summary of these scenarios is found in Table 1. In order to compare state variables, each scenario was evaluated under a unique vector of initial parameters and the same coefficient of variation (CV = 0.3) on the abundance indices of CPUE and acoustic. In the case of the production model, it was only evaluated the assumption of linearity because this model does not considers length structures nor exploitation patterns.

Mathematical description of the models

Age-structured model

Let N = N(a,t) be the abundance and R = R(a,t) the recruitment at age a in the year t, thus the initial conditions of the model in 1998 (t = 1) are given by:

Table 1. Names of the cases and scenarios analysed. na and ns indicates the sample size of the length structures coming from the commercial catches and acoustic surveys, respectively. Linearity refers to the hypothesis of hyperdepletion/hyperstability of the CPUE. CV is the coefficient of variation used in the likelihood of the abundance indices.

Tabla 1. Nombre de los casos y escenarios analizados. na y ns indican el tamaño muestral de las estructuras de longitud provenientes de las capturas comerciales y de la acústica, respectivamente. Linealidad se refiere a la hipótesis de hiper-agotamiento/hiper-estabilidad de la CPUE. CV es el coeficiente de variación de la verosimilitud para los índices de abundancia.

Case	Scenarios	Sample size	Exploitation pattern	Linearity	CV
A	Base	ns = 20, na = 20	logistic	linear ($\lambda = 1$)	0.3
A	Sce 1	ns = 20, na = 20	logistic	linear ($\lambda \neq 1$)	0.3
A	Sce 2	ns = 20, na = 20	double normal	linear ($\lambda = 1$)	0.3
A	Sce 3	ns = 20, na = 20	double normal	linear ($\lambda \neq 1$)	0.3
B	Base	ns = 10, na = 10	logistic	linear ($\lambda = 1$)	0.3
B	Sce 1	ns = 10, na = 10	logistic	linear ($\lambda \neq 1$)	0.3
B	Sce 2	ns = 10, na = 10	double normal	linear ($\lambda = 1$)	0.3
B	Sce 3	ns = 10, na = 10	double normal	linear ($\lambda \neq 1$)	0.3
C	Base	ns = 10, na = 5	logistic	linear ($\lambda = 1$)	0.3
C	Sce 1	ns = 10, na = 5	logistic	linear ($\lambda \neq 1$)	0.3
C	Sce 2	ns = 10, na = 5	double normal	linear ($\lambda = 1$)	0.3
C	Sce 3	ns = 10, na = 5	double normal	linear ($\lambda \neq 1$)	0.3

$$N(a,1) = R(a,1) = R_0 \qquad a = a_{min} = 1$$
$$N(a,1) = R_0 \cdot e^{-M \cdot a} \qquad 1 < a < a_{max}$$
$$N(a,1) = \frac{R_0 \cdot e^{-M \cdot a}}{1-e^{-M \cdot a}} \qquad a = a_{max} = 19\ ,$$

where $R_0 = R(1,1)$ is the unexploited recruitment and M is the natural mortality rate assumed to be time and age invariant. If the total catch (C) is assumed to be known with no error and the fishing season takes place in a short period of time in the middle of the year, then the exploitation rate for the fully recruited ages ($u(t)$) can be defined as:

$$u(t) := \frac{C(t)}{e^{-0.5M} \sum_a S(a)N(a,t)w(a)}\ ,$$

where S is the exploitation pattern and w is the individual body mass of each age a. Thus, the exploitation rate at any specific age is $u(a,t) = S(a) \cdot u(t)$.

For the rest of the years included in the model (t = 1999…2008), the abundance at given age is given by:

$$N(1,t) := R_0 \cdot e^{\varepsilon_t} \qquad a = a_{min}$$
$$N(a,t) = N(a-1,t-1)e^{-M}\left[1-u(a-1,t-1)\right] \qquad a_{min} < a < a_{max}$$
$$N(a,t) = N(a-1,t-1)e^{-M}\left[1-u(a-1,t-1)\right] + N(a,t-1)e^{-M}\left[1-u(a,t-1)\right] \qquad a = a_{max}\ ,$$

where $\varepsilon_t \sim N(0,0.6)$ are the recruitment deviations.

The exploitation pattern at age was modelled by two functions. For the scenario where de-recruitment is not considers, the exploitation pattern is modelled by a logistic function:

$$S(a) := \frac{1}{1+\exp\left(\log(19)\left[\frac{\beta-a}{\alpha}\right]\right)}\ ,$$

where β and α are parameters. On the other hand, those scenarios considering de-recruitment, the exploitation pattern is modelled by a double normal distribution:

$$S(a) := \begin{cases} \exp\left[\frac{-(a-S_{full})^2}{v_l}\right] & a \leq S_{full} \\ \exp\left[\frac{-(a-S_{full})^2}{v_r}\right] & a > S_{full}\ , \end{cases}$$

defined by the age at maximum selectivity (S_{full}) and the right-hand side variance (v_r) and left-hand side variance (v_l). These three parameters give a high flexibility of the functional form adopted by the exploitation pattern.

To transform from modelled ages to lengths, the conditional probability of age given lengths was defined as follows:

$$P(l|a) := \frac{1}{\sqrt{2\pi(a)}} \exp\left[\frac{(l\text{-}l(a))^2}{2\sigma(a)}\right]$$

where l corresponds to a all possible lengths of a fish of age a and $l(a) := l_\infty (1\text{-}e^{-k(a\text{-}a_0)})$ defined as the mean length at age a, modelled by the von Bertalanffy growth function. The growth model requires knowledge about the asymptotic length (l_∞), the individual growth rate (k) and the theoretical age at length zero (a_0). These parameters are considered known by the model. The normal distribution of the length-at-age requires knowledge of the standard deviation of the length-at-age (σ(a)), defined here to be proportional to the mean length-at-age by $\sigma(a) := \eta / l(a)$, where η is the coefficient of variation of the length-at-age assumed as 0.2" and time and age invariant.

The observation model for CPUE is assumed to be proportional to the exploitable biomass in the middle of the year as:

$$CPUE(t) = q \cdot e^{-\frac{M}{2}} \left[\sum_a w(a)S(a)N(a,t)\right]^\lambda$$

where q is the catchability and λ is a parameter that models the non-linear behaviour between CPUE and exploitable biomass (Harley *et al.*, 2001). When $\lambda > 1$ the CPUE decreases faster than the abundance, process known as hyperdepletion. In addition, when $\lambda < 1$ the CPUE decreases slower than the abundance, process known as hyperestability. When $\lambda = 1$ there is a linear relationship between CPUE and abundance. According to Wiff (2010), for the period 2002-2003, $\lambda = 1.014$, indicating a light hyperdepletion, while for the period 2004-2008, $\lambda = 0.355$, indicating a moderate hyperstability.

The observation model for the acoustic index (I) is defined as:

$$I(t) = \kappa \cdot e^{-\frac{M}{2}} \left[\sum_a w(a)S(a)N(a,t)\right]$$

where κ is a scaling parameter relating the acoustic index and the exploitable biomass.

The likelihood function for the length structure from commercial catch is modelled by a multinomial distribution such:

$$\ln L(\theta|p_s) = -n_s \sum_a \sum_t p_s(l,t) \ln\left[\hat{p}_s(l,t)\right]$$

Where n_s is the simple size and p_s is the proportion of capture at length defined as $p_s(l,t) = C_s(l,t)/\sum_l C_s(l,t)$. In a similar manner, the likelihood for the size structure from acoustic surveys is defined by:

$$\ln L(\theta|p_s) = -n_s \sum_l \sum_t p_s(l,t) \ln\left[\hat{p}_s(l,t)\right]$$

where n_a is the sample size and p_a is the proportion of length as $p_a(l,t) = C_a(l,t) / \sum_l C_a(l,t)$.

For abundance indices, a log-normal likelihood function was implemented as:

$$\ln L(\theta|\gamma) = \frac{1}{2cv_\gamma^2} \sum_t \ln\left[\frac{\gamma(t)}{\hat{\gamma}(t)}\right]^2$$

where $\hat{\gamma}$ represents the estimates of abundance indices I and CPUE, while $cv_\gamma := cv_c = cv_I = 0.3$ are the coefficients of variation of the both indices, respectively.

The optimization was done minimizing the sum of the negative log-likelihood, which merges the error structure of the observed data given a parameter vector θ, by:

$$-\ln L(\theta|p_s,p_a,CPUE,I) = \ln L(\theta|p_s) + \ln L(\theta|p_a) + \ln L(\theta|CPUE) + \ln L(\theta|I)$$

Production model

The Schaefer model (Schaefer, 1954), was implemented to account of the global changes in biomass as:

$$B(t+1) := B(t) + rB(t)\left(1 - \frac{B(t)}{K}\right) - C(t)$$

where K is a parameter defining the carrying capacity and r is the intrinsic population growth rate. This model used CPUE and acoustic data as indices of abundance which observation models are:

$$CPUE(t) = qB(t)^\lambda$$

$$I(t) = \kappa B(t)$$

As the same as in the age-structured model, the likelihood function for the abundance indices correspond to a log-normal distributions, whith parameter vector θ = {B (1), K, r}.

RESULTS

In Figure 4 is shown the time series for spawning biomass and recruitment estimates by the age-structured model for the different scenarios and cases described in Table 1. When the sample size of the length structures increased (Case A, Table 1), recruitment estimates became different between scenarios, and when all scenarios are analysed, the bigger differences occurred between cases A and C (Fig. 4). This important variability in magnitude of

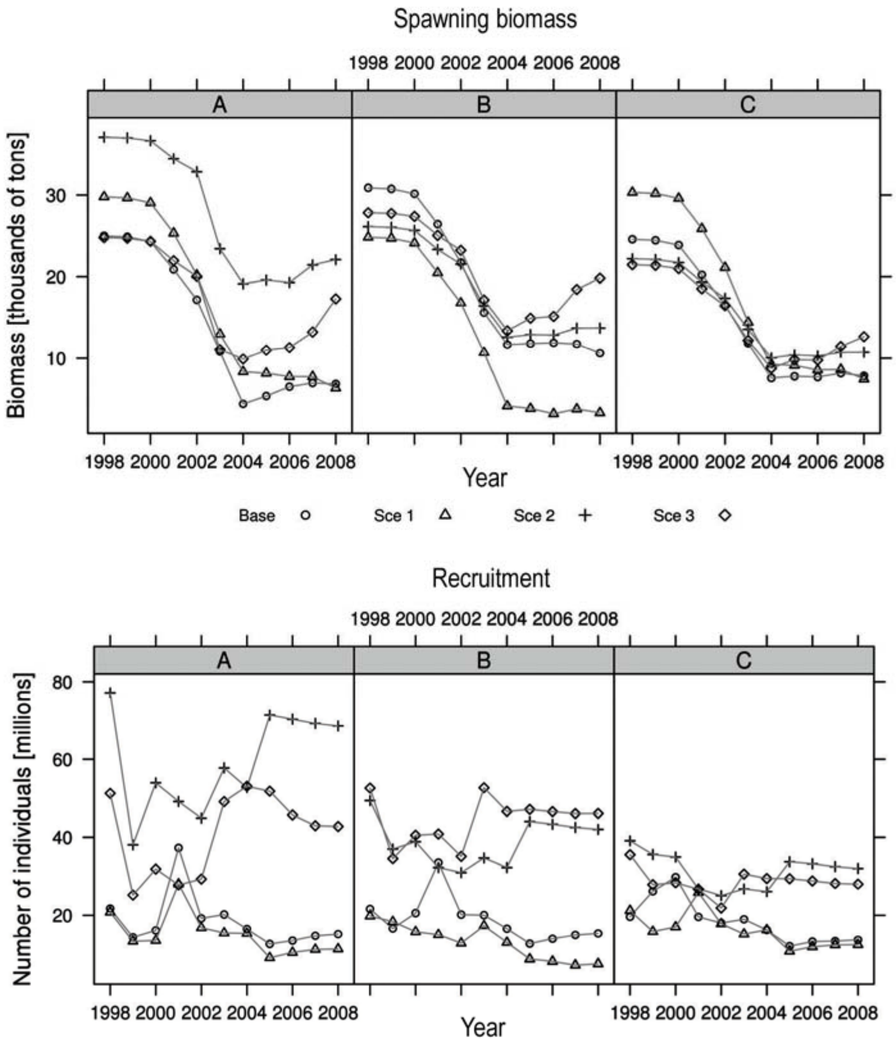

Figure 4. State variables of spawning biomass and recruitment for each case (A, B, C) and scenario analysed (in different symbols).

Figura 4. Variables de estado de la biomasa desovante y reclutamiento para cada uno de los casos (A, B, C) y escenarios analizados (en símbolos diferentes).

time series of recruitment among scenarios produced that estimates of abundance for case A were in average higher than those where sample size of length structure is smaller. When sample sizes of the length structure from acoustic surveys are small (Case C, Table 1), recruitment estimates are smaller and with lower interannual variability and lower biomass estimates in most of the scenarios (Fig. 4). This agreed with the theory, because the fitting of the length structures with the model (not shown here) at small sample size tends to be smother. When length structures estimates are smothering, the expected recruitment variability is low.

Scenarios incorporating non-linearity (Sce 1 and Sce 3) show biomass estimates lower than those scenarios that do not consider such effect (Base y Sce 2). In addition, when de-recruitment is assumed (Sce 2 and Sce 3), estimates of biomass and recruitment increased in comparison with the scenario assuming logistic exploitation pattern. This is consistent with Figure 5, because if we take the ratio between spawning biomass in 2008 and the unexploited spawning biomass (SB2008/SBo) as an indicator of status, those scenarios considering de-recruitment showed better status than those where exploitation pattern is logistic. Scenarios assuming non-linearity showed a worse status when logistic function is assumed (Fig. 5), but they do not show a clear behaviour when de-recruitment is assumed. In addition, recruitment estimates were less variable

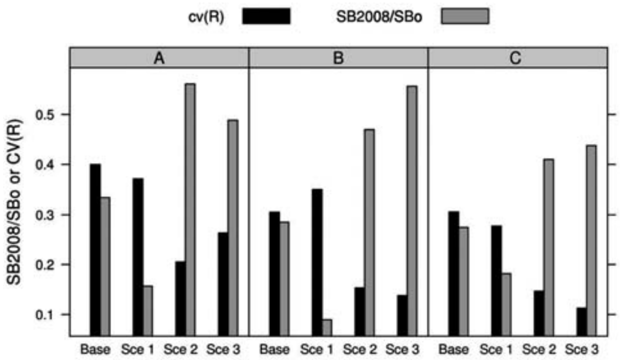

Figure 5. Simulation results of the different cases (A, B, C) and scenarios. CV(R) is the coefficient of variation of recruitment and SB2008/SBo is the ratio between spawning biomass of 2008 and the unexploited spawning biomass.

Figura 5. Resultados de las simulaciones para los distintos casos (A, B, C) y escenarios. CV(R) es el coeficiente de variación del reclutamiento, y SB2008/SBo es la razón de la biomasa desovante 2008 con respecto a la biomasa desovante virginal.

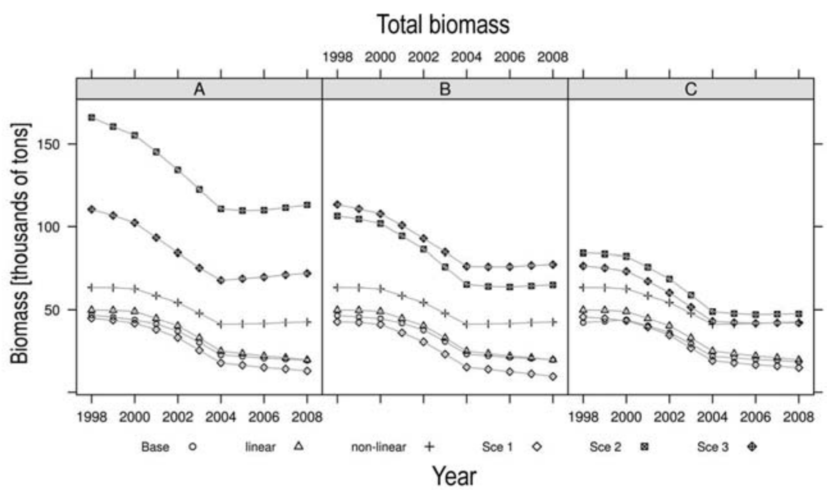

Figure 6. Total biomass comparison between age-structured and biomass dynamic model across cases (A, B, C) and scenarios.

Figura 6. Comparación de la biomasa total entre el modelo edad-estructurado y biomasa dinámica a través de los casos (A, B, C) y escenarios.

(lower CV(R)) for those scenarios assuming de-recruitment, and inside this scenario, the lower CV(R) is obtained in the case when non-linearity is considered (Fig. 5).

The Figure 6 showed a comparison of the total biomass coming from the age-structured model and those coming from the production model. Magnitudes and temporal changes of total biomass from the production model are similar to those from the age-structured model assuming logistic exploitation pattern. In addition, estimates from the age-structured model assuming de-recruitment tended to show higher biomass estimates than those from production model.

DISCUSSION

There are four key processes to understand the state variables under the modelling framework proposed. First, de-recruitment produces an increase in abundance and better population status, because adult individuals has lower catch probability and thus the model produces higher recruitments to account for the observed catches. This also caused an increase in spawning biomass because mature individuals de-recruit producing higher levels of abundance in older ages. Under the assumption of de-recruitment, the population status depends on individuals forming part of the population which de-recruit at older ages, but they have rarely been observed. Second, non-linearity between exploitable biomass and CPUE produces lower estimates of abundance because non-linearity conditioned a faster decrease in biomass related to the CPUE time series. According to the non-linear parameters used, the hyperstability is more important than hyper-depletion. Third, when sample size of the length structure increases, recruitments show high variability across years. This is caused for the high interannual variability showed by length structures in alfonsino which is principally a response of fishing dynamic. On the underlying theory of age-structured model, the interannual variations of the length structures depend on process such as recruitment, somatic growth and age-dependant mortality. In alfonsino, it has been observed that sizes are highly segregated across depth strata (Contreras & Canales, 2008). The particular fishing operation in alfonsino supposes that different length/depth strata have been exploited across years. The consequence of such fishing process does not allow meeting the basic assumption in stock assessment because length structure variations depend mostly on the fishing operation (Wiff, 2010). Therefore, a relative high sample size of the length structures produces high variability in recruitment to cope with the variability of length structures. One way to get useful information from length structure to be used in stock assessment is modelling the exploitation pattern as function of depth and time, and thus accounting for changes in length/depth strata across years. Fourth, biomass estimates from the age-structured model assuming de-recruitment are higher than those estimates from production models. This agreed with the theory, because the underlying assumption of a production model indicates that once individuals enter to the exploitation fraction of the population the availability to the fishing gear remains constant.

In exploited marine populations two interesting aspects are the current population state and its response to management decisions (Cooper *et al.*, 2003). These issues are usually addressed using stock assessment models that incorporate aspect of population dynamics and hypotheses related with processes. The existence of inadequate or biased data together with a non-robust model is highly relevant in resources management (Simmonds & Keltz, 2007). The quality of the information and the knowledge about life history and population dynamic influences the precision and bias of estimated parameters (Chen *et al.*, 2003; Booth & Quinn, 2006). In an ideal management scenario, a robust stock assessment model is available upon which consequences of different management actions are evaluated. Although the model used here is not robust to the data, in the sense that population depletion could be between 9 and 56%, the framework is informative in assessing how state variables behave under different population dynamic hypotheses. The selection of the most likely scenario for abundance in this fishery still remains as a challenger. This selection be based on the grounds of new research about the main lack of knowledge of the population dynamic of alfonsino. One way to explore these gaps of information is carrying out experiments to determine the stratification of lengths in depth which would be the principal cause of: i) de-recruitment of older and bigger fish, ii) the lack of population information of the length structures and iii) the existence of hyperstability on the CPUE caused by a changed in fished depth strata across time. An interesting experiment using vertical longlines was carry out by Lehodey *et al.* (1997) on the alfonsino inhabiting seamounts of New Caledonia determining the stratification length/ages in depth. A pilot study showed that alfonsino is likely to be fished with longline in Juan Fernandez (Arana & Vega, 2000) and thus an experiment such carried out by Lehodey *et al.* (1997) could allow determining a more precise relationship between length and depth, in addition with exploring the seabed not available for trawling, which will help to elucidate the existence of de-recruitment. At the current knowledge of population dynamics and taking into account the high level of inter-models uncertainty, the precautionary approach of FAO guidelines should be implemented. This means when scientific work is inconclusive but a course of actions has to be chosen, negative impact need to be avoided or minimized and management decision should ensure a low risk of drive the population to undesirable levels of abundance. Thus, a case with low sample size of length structures and scenarios considering non-linearity and where individuals are not allowing de-recruit should to be chosen to reduce to cost of our decision in the future. In this context scenario 1 in case B or C should be considered.

Age-based methods have rarely been used in deep-waters fishes because of a lack of reliable age estimates for most of the species (Large *et al.*, 2001). Usually, the only information available is short time series of catch and effort data from commercial fishery and thus the most commonly applied method of stock assessment has been depletion modelling using biomass production and DeLury models. In the present work, age-structured and biomass production models have been applied in alfonsino, because data is lengthy enough to apply either of these methods. Nevertheless, interpreting output from both models may not be as straightforward as in other self-based species. Biased indices of abundance and length structures repre-senting fishing dynamics rather than population process will preclude a rapid assessment of alfonsino in Juan Fernandez. The high vulnerability to fishing exploitation of fished inhabiting the seamounts, caused by demographic traits such long lifespan, late maturity and low fecundity (Morato *et al.*, 2006; Follesa *et al.*, 2011), highlight the need for application of precautionary approach in seamount species in Chile. This work contributes with a modelling frame-work in fisheries where data used in the models is non-informative and where the lack of knowledge in population dynamic has to be evaluated by hypotheses.

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