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Empirical survey-based harvest control rules in a transboundary small pelagic fishery under recruitment regime shifts: The case of the northern Chilean-southern Peruvian anchovy

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Abstract

The management of small pelagic fisheries is a complex task due to its large variability of both environmental and biological processes. This high variability can impact the reliability of stock assessment models and fishery management recommendations. When this occurs, management decisions should explore alternative control rules based on empirical abundance indices or pragmatic management procedures. In this paper, we examined the performance of a harvest control rule (HCR) for the Chilean fleet in the shared Chile-Peru anchovy (*Engraulis ringens*) fishery (16°S–24°S), which is one of the most important stocks in the Humboldt marine ecosystem in the Southeast Pacific. The HCR uses the annual changes in spawning biomass estimated by Daily Egg Production Method (DEPM) surveys in the waters off northern Chile. Analyses are carried out through operating models simulating population regime shifts under different uncertainty sources. The results show that despite the latent risk of overfishing caused both by recruitment variability and the lack of fisheries management coordination between two jurisdictions, the control of one of the parties' fishing mortality can enable the sustainability of the entire stock, provided the fishing effort of the other jurisdiction be remained at similar levels as in the last decade. The use of an HCR would avoid increases in fishing mortality and would facilitate B_{MSY} -based management goals. This research determined conditions under which the shared Chile-Peru anchovy fishery can be sustainable considering different sources of uncertainty of the biological-fishing system.

Introduction

Straddling fish stocks is a particular category of internationally shared fishery resources that involve exclusive economic zones (EEZs) and adjacent high seas. Despite the establishment of EEZs defined by the United Nations Convention on the Law of the Sea [1], the lack of cooperation between coastal states and distant water fishing states and entities has led to the overexploitation of several stocks in the world [2], [3]. The Humboldt Current is an eastern boundary upwelling ecosystem (EBUE) in the southeastern Pacific, producing more fish per unit of area than any other EBUE in the world ocean [4], [5]. In the Humboldt Current, anchovies (*Engraulis ringens*) are one of the most productive small pelagic fish, distributed from northern Peru to southern Chile [6], [7]. A transboundary fishery is located between southern Peru and northern Chile and is the second-largest fishery in FAO Region 87. after the

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north-central anchovy fishery [8], [9]. The average landings of the Peru-Chile-shared anchovy fishery have been nearly one million tons per year, accounting for approximately 6% of the world landings of small pelagic fish. In this region, the anchovy population is distributed within the first 60 nautical miles and constitutes a single shared stock between 16°S and 24°S [6], [7] (Fig. 1). The annual variability in spawning stock biomass, recruitment, fishing mortality, catch, daily egg production method (DEPM) survey estimates, and mean fish length are shown in Fig. 1.

In Chile and Peru, anchovy fishery management is performed based on catch quotas and fishing seasons with biological closures, although without the coordination between the management agencies of the two countries, which is a challenge for fishery management and a potential threat to the sustainability of the anchovy stock. Coordinated management is crucial when a fish population presents distinctive and dynamic characteristics, such as highly variable productivity, a short life cycle, and high sensitivity to environmental conditions. In the Humboldt Current Ecosystem, environmental variability occurs on an interannual scale and is also associated with the El Niño-Southern Oscillation [10], [11] at the interdecadal scale [6], [12], [13], [14], [15]. For anchovies, intraannual scale variability affects their distribution, availability, and reproduction [16], [17], including growth and spawning, and seasonal factors affect somatic conditions [18], whereas the interdecadal scale determines recruitment fluctuations [19], [20]. Significant sources of uncertainty for fisheries management of small pelagic fisheries include productivity changes and stock-recruitment relationships [21], [22] and the fact that these species are forage for multiple predators within the ecosystem [23], [24], [25]. Due to these factors, these small pelagic fisheries are subject to greater variability than other fisheries, and the maintenance of low-variability catches over time is extremely difficult [24]. One of the main scientific challenges is to assess fishing impacts, considering that the degree of population depletion and the natural variability of their populations are often confused [26]. The natural variability in population recruitment of small pelagic fish could lead to "stochastic depletion," even in the absence of fishing [22]. In this situation, regime shift-driven recruitment [27] is influenced by the environment through the carrying capacity of forage fish, individual productivity rate (recruits/spawners), or a combination of both [28]. Therefore, fishery strategies should be modified based on recorded environmental conditions for several years to change the biomass of reference used for fishery management [29].

In Peru, the fishing quotas for anchovies are based on a protocol considering the biomass estimated in acoustic surveys as the main information source, while in Chile, both the population diagnostic and fishing quota recommendations are based on estimations of an age-structured stock assessment model. The stock assessment model considers the Peru-Chile fishery as a single shared stock and uses data from both fisheries on a semiannual scale. The data consist of abundance indices from scientific surveys and length compositions from surveys and fisheries, together with estimated landings for the 1985–2018 period [30]. Despite the extensive time series of fisheries data, the available data show great irregularity and contradictory signals between them, making it difficult to interpret and generate uncertainty regarding the stock condition and the effectiveness of Chile's fisheries management strategy. In addition, there is evidence of changes in the biological traits of this species because of environmental variation [31], which may also have affected the growth parameters used in the stock assessment model. The daily egg production method (DEPM) surveys in Chile stand out [32], [33]; although they cover only the Chilean part of the fishery, their estimates attempt to track variations in the spawning population [34], [35] (Table 1). The Chilean DEPM surveys started in 1992 and have been carried out annually since 1999 (except in 2010) [33]. The survey design for estimating the daily egg production and number of fishing sets for daily specific fecundity varied slightly over the time series. The grid of stations varied in terms of extensions of the E-W transects and southern extension. The duration of the survey fluctuated between 17 and 44 days, overlapping between August and September during the spawning season. In general, the distance between stations was set equal to 5 nautical miles, and the distance between transects

stations was equal to 10 nautical miles, and the distance between transects was equal to 10 nautical miles. Since 2002, surveys have been performed using a regular grid of stations and transects of 5×10 nautical miles, and the spawning stock biomass estimates fluctuated between 300,000 and 1.2 million tons. It is important to note that there was a significant decrease in the biomass of these DEPM surveys in the last 5 years. (Fig. 1).

The assessment of population status can become uncertain due to misspecification of the abundance dynamic model, biological parameters, process error (e.g., recruitment dynamics), or observation errors involved in abundance indices and other data. Therefore, fishery management must find a robust way to control fishing pressure to achieve management objectives. Lack of information in data or data-driven model misspecification is not a justification for poor fisheries management. Managers need to develop pragmatic management strategies, regardless of the available data [36], that consider rules to control fishing intensity responsive to observed changes in some abundance indices [37].

Based on the multiple sources of uncertainty and the lack of coordination in fishery management between the two countries, this study aims to analyze the sustainability of the shared Chile-Peru stock if an empirical indicator-based harvest control rule (HCR) for the Chilean fishery is applied. A HCR is an algorithm through which stock assessment is translated into management advice in the form of a recommended biological catch [38] or current fishing effort correction. In this study, and as an empirical indicator, the HCR is based exclusively on the biomass of DEPM surveys in northern Chilean waters. The Chile-Peru-shared anchovy population was projected for 10 years, and HCR performance was evaluated under conditions of uncertainty, such as recruitment regime shifts (carrying capacity), changes in biological traits, variability in fleet selectivity, variations in the natural mortality rate, changes in biological reference points, and the operation of a fleet (Peru) regulated by another management procedure.

Section snippets

Materials and methods

The performance of empirical HCRs for the Chilean anchovy fishery was performed using operating models that simulated different states of populations under recruitment regimes and biological trait changes. In these simulations, the fishing mortality from the Peruvian fishery was randomly projected, whereas the Chilean fishery was controlled by a HCR (see Section 2.1). Biological reference points (BRPs), F_{MSY} , and B_{MSY} were assumed to be unknown to the fishery management agency. This study ...

Simulation of population variables

With a low recruitment regime and the Peruvian fishery fluctuating around its last 5-yr average fishing effort, projections indicate that if Chilean fishery management is based on a constant catch policy (HCR0.x) with reference catches larger than 300,000 tons per semester (HCR0.2 and HCR0.3), it would generate a reduction in spawning biomass below B_{MSY} and an increase in fishing mortality above F_{MSY} (Figs. 3a, 4a, 5). This increase would also produce an increase in variability in fishing ...

Discussion

Regardless of the type of exploitation strategy, recruitment regime, and biological parameters considered in the analyzed operating models, the results showed that alterations in these population variables could increase the adverse effects of anchovy fisheries, such as overfishing and overexploitation risks. One of the most significant consequences of recruitment regime shifts is biological reference point alterations, which are key parameters used to manage many fisheries. It was found that ...

CRediT authorship contribution Statement

Cristian M. Canales: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing – original draft, preparation, Writing – review & editing. **Luis A. Cubillos:** Conceptualization, Formal analysis, Writing – review & editing, ...

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References (72)

- A.M. Song *et al.*
[Transboundary research in fisheries](#)
Mar. Policy (2017)
- V. Montecino *et al.*
[The Humboldt current system: ecosystem components and processes, fisheries, and sediment studies](#)
Prog. Oceanogr. (2009)
- F.P. Chavez *et al.*
[A comparison of eastern boundary upwelling ecosystems](#)
Prog. Oceanogr. (2009)
- J. Alheit *et al.*
[Regime shifts in the Humboldt Current ecosystem](#)
Prog. Oceanogr. (2004)
- D. Pauly *et al.*
[Agreeing with FAO: comments on SOFIA 2018](#)
Mar. Policy (2019)
- E. Yáñez *et al.*
[Climate variability and pelagic fisheries in northern Chile](#)
Prog. Oceanogr. (2001)
- M. Niquen *et al.*
[Impact of El Niño events on pelagic fisheries in Peruvian waters](#)
Oceanogr. East. Pac. Vol. III (2004)
- Y. Xu *et al.*
[Environmental influences on the interannual variation and spatial distribution of Peruvian anchovy \(*Engraulis ringens*\) population dynamics from 1991 to 2007: a three-dimensional modeling study](#)
Ecol. Model. (2013)
- S.M. Cahuin *et al.*
[Climatic regimes and the recruitment rate of anchoveta, *Engraulis ringens*, off Peru](#)
Estuar., Coast. Shelf Sci. (2009)
- Y. Xu *et al.*
[Does spatial variation in environmental conditions affect recruitment? A study using a 3-D model of Peruvian anchovy](#)
Prog. Oceanogr. (2015)



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...According to the uncertainty of the direct estimates and to the speed in translating the estimates into management actions, the harvest strategy will have to be more or less conservative to cope with the uncertainties on the current and future biomasses: Timely use of the information can lead to empirical harvest rules (based on the output of the surveys) as it is the case of the management of anchovy and sardines in South Africa [26,27] which may respond to escapement policies, aiming at maximizing catches whenever the Spawning biomass at the end of the fishery remains above a threshold escapement limit (that warrants the normal productivity of the stock), as for the Barents sea capelin [46], or the Peruvian anchoveta [7,68]. However, if survey precision is poor, or if its use is lagged by 1 year, without a recruitment indicator to forecast the managed population, then the harvest strategy will have to be more conservative and precautionary [13,31,82,110]. For instance, management of Chilean sardine and anchovy [122] is precautionary by selecting a fishing mortality target corresponding to 60% spawning biomass per recruit; and for the management of the North Sea Sprat the fishing mortality corresponding to the escapement policy is capped by a maximum value to account for the unknown level of recruitment [102]....

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