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EXTENDED ABSTRACT

Application of ARIMA models on the Pacific Halibut CPUE Historical Series (1998-2016): Detection of legislative changes?

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INTRODUCTION

Ensuring the sustainability of the fisheries resources, through the establishment of a maximum fishing effort applicable to a defined area during a determined period maintaining the rate of renewal of the stable population, is a factor of vital importance in the exploitation of demersal species (Norse et al. 2012).

A clear example of a regulated exploitation of a demersal fish resource is the halibut fishery (*Hippoglossus stenolepis*, Schmidt 1904), one of the most important fisheries in the Pacific and whose management is handled by the International Pacific Halibut Commission (IPHC). Halibut fishery has a marked seasonal character, fishing starting at the end of May and ending at the beginning of September.

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Despite the economic importance of the halibut fishery, few mathematical models have been applied to its management. The primary objective of this study was to assess the ability model of behaviour of the Pacific Halibut CPUE (catch per unit effort) using univariate linear techniques, Auto Regressive Integrated Moving Average (ARIMA) models applied from 1998 to 2016 with a period of aggregation of the data in seven calendar days.

To do so, we analysed the general characteristics of halibut fishing time series, using the ARIMA models to identify the effects that may have interfered in the general pattern of the series, as well as establishing the sources of errors in the models themselves.

METHODS

The data on Pacific halibut catches were retrieved from the IPHC database (http://www.iphc.int/). These include daily catches during the fishing season (May to September) between 1998 and 2016 in the IPHC Regulatory Areas corresponding to the Bering Sea and Gulf of Alaska.

The CPUE was calculated using data of legal catches (whose size is greater than or equal to 32 inches) in kilograms (kg) divided by the addition of seven days.

The development of the ARIMA models was carried out following the Box and Jenkins methodology (1976). The best model will be the one with a high coefficient of determination (r^2), average relative variance (ARV) coefficient of efficiency (E_2) and persistence (PI) and a low root mean square (RMSE), mean absolute error (MAE), standard error of prediction (%SEP), Akaike information criterion (AIC) and Bayesian information criterion (BIC).

RESULTS

The ARIMA (111) $(011)^{13}$ and ARIMA (111) $(111)^{13}$ were the best models to describe the CPUE series according to the criteria described above, with similar values in the error sources (Figure 1).

From 1998 to 2016, the CPUE showed a clearly negative trend and a marked seasonal character (Figure 1). However, two different periods have been observed during this time frame. The negative trend started to smoothen around 200, which led to the observation of two different periods: the first covers nine years (1998-2007) and the second eight years (2008-2016). The existence of both periods could be corroborated statistically with the Kruskal-Wallis nonparametric test of multiple intra- and inter-annual comparisons.

Within the first period, the maximum CPUE was 180.1 kg/fishing day in August 1998 and the minimum 10.4 kg/fishing day in May 2007, this corresponding to a significant (94%) decrease in CPUE between these years (Kruskal-Wallis test: $p_{1998\text{-}2007} < 0.05$). In the second period, the maximum CPUE was 126.4 kg/fishing day in August 2009 and the minimum 19.6 kg/fishing day in August 2016. This decrease (by 86%) was not significant (Kruskal-Wallis test: $p_{2008\text{-}2016} > 0.05$). In brief, the halibut CPUE progressively decreased from 1998 to the 2007 minimum (10.4 kg/day), after which it showed a slight recovery until 2009, with a peak of 126.4 kg/fishing day, subsequently falling to the levels observed in 2016 (19.6 kg/fishing day).

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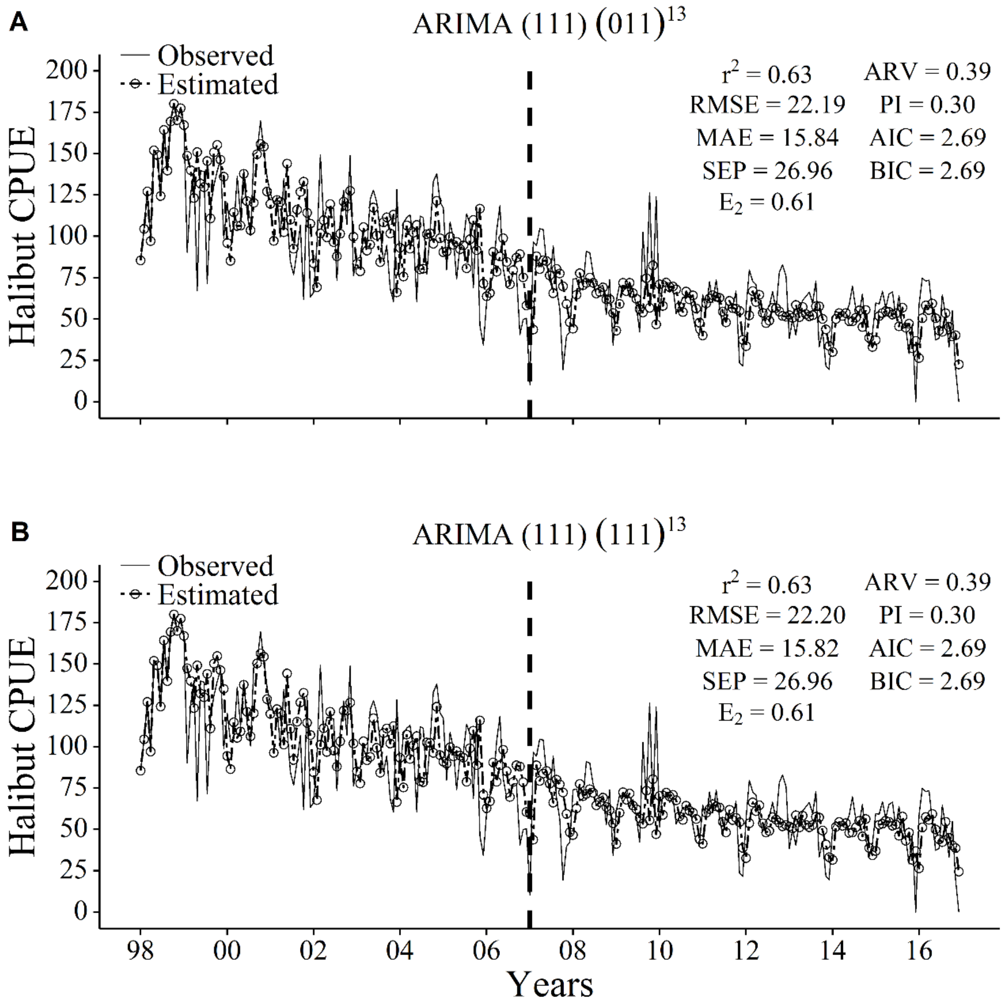

FIGURE 1. (A) CPUE observed and estimated variation of the ARIMA model 111 (011)13 calibrated with a procedure of minimization of the sum of squared residuals in the independent validation phase. (B) CPUE observed and estimated variation of the ARIMA model 111 (111)13 calibrated with a procedure of minimization of the sum of squared residuals in the independent validation phase. The dashed line indicates the year in which the trend in the CPUE changed.

DISCUSSION

The results of this study indicate that if the catch rates remain similar to those observed in recent years, this fishery may collapse in the near future.

In this fishery, catches have fallen by about 85% over the last two decades. Stewart and Martell (2014) reported that the halibut stock decreased rapidly from the end of the 1990s until 2011, as a consequence of the notable reduction in recruitment that occurred from 1980 to 1990. In relation to this, these authors indicated that the reproductive biomass would decrease in 2015, this resulting in the long-term in a decrease in catch rates. The findings of the present study are consistent with these conclusions and are based on estimates provided by the ARIMA models.

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Both the efficiency of the halibut fishery and its legal framework have been improving since the early 1990s (Gilroy et al. 2011). These advances in the fishing industry led to changes that are directly reflected in fishing, for example, decreases or increases in total catches, in the effort, fleet size, etc. With the application of the ARIMA models, an approach to these historical changes has been possible. In the period 2008-2016 the CPUE decreasing trend softened showing significant differences in the behaviour of the CPUE when compared with 1998-2007. This is because there are differences in the patterns when both periods are compared.

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