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## Effort Creep in the JM south central fleet in Chile

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*Republic of Chile*

# Working document: Effort creep in the Jack Mackerel central-southern fleet in Chile: preliminary analysis and proposed alternative.

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## Abstract

The central-southern fleet for the jack mackerel fishery in Chile has experienced technological changes over time, which may not be reflected by other variables already considered in the CPUE standardization process. To account for these changes the SPRFMO Scientific Committee agreed to apply a factor of 1% per year to correct the CPUE abundance indexes of Jack Mackerel for the chilean and peruvian fleets. However, there are concerns over the technical implications of a fixed rate, and the exploration of alternative efficiency correction factors was recommended. In this study we compiled and organized available qualitative and quantitative information related to technological, operative and normative changes in the Chilean central-southern fleet, and an informed effort creep time series was developed. The proposed correction is composed of time-varying blocks of efficiency factors, providing an alternative for the correction of effort or CPUE. We discuss the benefits and limitations of this approach, and propose next steps for adjusting and improving its reliability.

## Background

Undocumented increases in fishing effort, or "effort creep" describes the situation where the catch efficiency of fishing vessels increases over time (Ye and Dennis 2009). Fishing effort can be difficult to quantify directly because it is a composite metric made up of many different components including but not limited to: vessel length, engine power, fishing technologies (for example, bird radar, remote oceanographic sensing, etc.) echo sounders, helicopters), and skipper/crew experience (Pilling et al., 2016).

The effectiveness of effort grows under technological change, even though the nominal units of effort (e.g. days out-at-sea, number of sets) may remain constant (Squires et al. 2016). Effort creep can be thought of as a dimensionless change in catchability (q) or a dimensionless change in some aspect of nominal effort (Palomares and Pauly, 2019). In this sense, if effort creep has been estimated, it can be used to correct the abundance index (e.g. CPUE) either to the effort series or directly to the index series.

For the central-southern jack mackerel fishery in Chile, the fleet has experienced technological changes over time, which may not be reflected by other variables already considered in the CPUE standardization process. Among others, changes include improvements in detection equipment, captain experience, and real-time information systems. On the other hand, fleet efficiency can be limited by other factors, such as process plants production bottlenecks, and the reduction of available fishing area (e.g. first 5 miles restriction).

During the Jack Mackerel Benchmark Workshop in 2022, the SPRFMO Scientific Committee agreed to apply a factor of 1% per year to correct the CPUE abundance indexes of Jack Mackerel for the chilean and peruvian fleets. In the report of the SC10 meeting (Jack Mackerel Technical Annex), the SPRFMO-SC made recommendations on the current correction for effort creep applied to the jack mackerel CPUE series are highlighted. The Committee expressed concerns that the fixed annual rate of 1% currently implemented would be unrealistic over a long period and lacks technical foundations. It suggests the application of correction blocks or periods, which would be delimited by changes in fishing, either for administrative, operational or technological reasons. The impact of effort creep is likely to be minimal over the short term, but could grow more pronounced over time, and additional steps would be required in order to provide a more long-term solution to this problem.

Objectives

1) Review the information available on changes in the increase in fishing efficiency ("effort creep") and request from SSPA and INPESCA the information available in this regard (dates of changes in detection equipment, changes in size and composition of the fleet, etc.).
2) Analyze different methods to include efficiency changes in the correction of the abundance index based on the CPUE of the central-south zone, among them, a fixed factor for the complete series (currently in use in the SPRFMO-PS), fixed factors by blocks of years or variable factors per year.

## Methodology

In order to have a well-founded basis for the elaboration of correction factors for the CPUE series, this study compiled and organized all the available qualitative and quantitative information related to changes in the jack mackerel fishing fleet, and that could imply increases not documented in the efficiency of fishing. With this information, periods of development of the fishery were defined, whose time limits were defined by significant changes in the administration, regulation and/or in the technological tools of the fishing fleet.

### Information considered for the definition of efficiency periods

- Qualitative information on the history of pelagic fisheries in Chile (Aranis, pers. comm.)
- National and international laws and regulations that regulate jack mackerel fishing.
- Historical changes in the technology and capacity of the jack mackerel fishing fleet (Sepúlveda et al. pers. comm.)

The information available on changes in the increase in fishing efficiency (“effort creep”) was reviewed and the information available to SSPA and INPESCA was provided in this regard (dates of changes in detection equipment, changes in size and composition of the fleet, etc.). Different methods of including efficiency changes in the correction of the abundance index based on the CPUE of the central-south zone will be analyzed, among them, a fixed factor for the complete series (currently in use in the RFMO-PS), factors fixed for blocks of years or variable factors per year.

In a next stage, we collected metrics from different predictors that would be associated with changes in fleet efficiency, according to previous studies (Marchal et al. 2006). This information was collected through surveys aimed at industry experts and users. In particular, this tool allows the collection of information on changes in fishing gear, experience of boat captains, increases in hold capacity, changes in school detection technology, increases in crew and captain expertise, as well as regulatory or market limitations. With this information we can develop specific efficiency factors, each with an associated period of operation or occurrence. Median dates, as provided by industry users through a survey, were used to determine the initial and final years of occurrence of each efficiency factor. The change in the annual efficiency of the fleet (EC) is calculated as the sum of all the efficiency factors (FE) operating in the year:

$$EC_t = \sum FE_{i,t}$$

Where ECt corresponds to the efficiency factor in year t, FEi,t corresponds to the efficiency factors operating in year t. It provides a series of annual fleet efficiency changes, or effort creep, which can be used for effort or CPUE correction.

The effective CPUE for each year can be calculated below (Palomares and Pauly, 2019):

$$ECPUE_t = CPUE_t \times (1 - EC_t)^{t-y}$$

Where y corresponds to the first year of the series and t is the year to be calculated. This equation can be applied to the standardized CPUE, or an adapted version can be used to correct for the effort time series before CPUE standardization, in either sets or days-at-sea (Palomares and Pauly, 2019). We applied this correction to the Chile CPUE index time series from SC-10.

We compare the CPUE index time series with and without effort creep, as well as the agreed constant 1% correction. In addition, we use the model estimate of biomass for the 3 respective indexes to compare the impact of the corrected CPUE series. We use the latest available JJM model configuration to estimate jack mackerel biomass, per the SC-10 assessment in 2022.

## Results

The review of the history of the fishery, its regulations and meetings with industry experts and administrators, were used to map the major changes in terms of technological improvements, as well as normative and productive limitations for the Jack Mackerel central-southern fishery. The milestones, and corresponding periods, for the different factors that were identified and considered in the evaluation of technological improvement in the jack mackerel central-southern fleet are:

- Ship refrigeration (1995-2010)
- Fleet reduction (1998-2023)
- Redirection of captures to consumption (1998-2023)
- Delivery of satellite information to ships (2000-2023)
- Satellite Positioning System (2001-2023)
- Sonar renovation (2005-2020)
- Renewal of fishing gear (2010-2020)

These technological milestones were assumed to be constant and occurring continuously during their respective period of impact. The only exception was the one associated with the fleet reduction, which was divided in two periods, which were divided in two periods and were estimated from the slope of the relationship of number of boats and time (years). All other efficiency factors, were assigned values relative to the "fleet reduction" factor, according to input provided by jack mackerel fishery researchers and administrators (Sepulveda, com. pers). The results of this process are summarized in Table 1.

The efficiency factors, representing the different technological improvements and which are summed across each time step, translate into a dynamic behavior of efficiency (Figure 1). The estimated creep time series, or "informed EC", exhibits important variability during the study period, ranging between 0% and 4.5%. The corrected CPUE shows marked differences from the original CPUE as well as the corrected with the 1% fixed rate (Figure 2 and Table 2).

The biomass estimated with the JJM model exhibits differences between the CPUE index corrected with ECinf, and both the original CPUE index and the CPUE corrected with the constant 1% EC rate (Figure 3). The differences between indexes are negligible for most of the period, but they become more evident during the last 5 years of the series.

**Table 1.** Summary of technological milestones considered in the effort creep analysis.

| Starting Year* | Milestone | Effect on efficiency | Direction of effect | Annual effect (%) | Period of effect | Source |
|---|---|---|---|---|---|---|
| 2000 | The Satellite Positioning System comes into operation | Limitation of available fishing areas | Negative | -0.5% | 18 | Industry users, Subpesca, Inpesca |
| 2004 | Program promotion begins to direct catches towards direct consumption | Limitation of warehouse capacity by direct consumption processing plants | Negative | -1.0% | 19 | Industry users, Inpesca |
| 2004 | Fleet refrigeration capacity is developed | Allows to increase the capture storage time | Positive | 0.5% | 15 | Industry users, Inpesca |
| 2003 | Fishing gear is renewed | New nets made of lighter material increase fishing efficiency | Positive | 1.0% | 15 | Industry users, Inpesca |
| 1998 | Fleet reduction (period I): the best captains and crew are retained. | Retention of more experienced captains increases the average efficiency of the fleet | Positive | 3% | 8 | Inpesca, Sernapesca, IFOP |
| 2006 | Fleet reduction (period II): the best captains and crew are retained. | Retention of more experienced captains increases the average efficiency of the fleet | Positive | 0.5% | 17 | Inpesca, Sernapesca, IFOP |
| 2003 | New sonar technology of greater range and capacity | Multi-frequency system allows for better and easier detection of shoals and species. | Positive | 1% | 17 | Industry users, Inpesca |
| 2006 | Implementation of Inpesca satellite information system to vessels | Environmental information delivered on real-time improves effectiveness of fishing. | Positive | 0.5% | 17 | Industry users, Inpesca |

*Estimated dates are approximated, with uncertainty, according to expert survey.

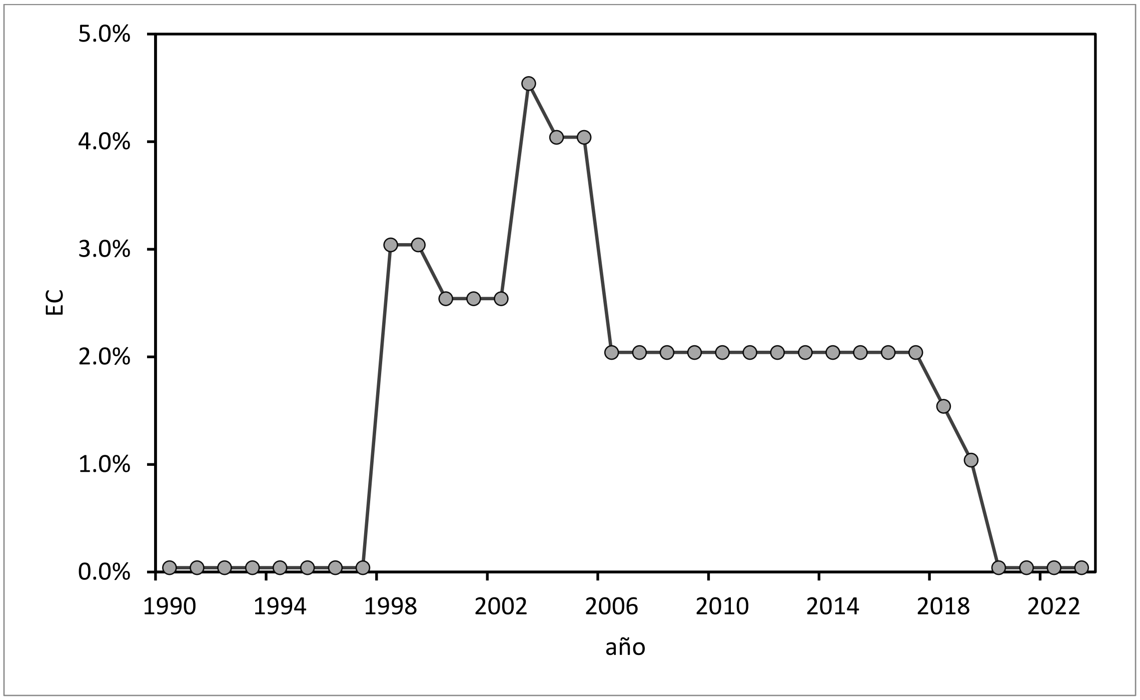


Figure 1. Informed effort creep time series developed for the jack mackerel central-southern fleet.

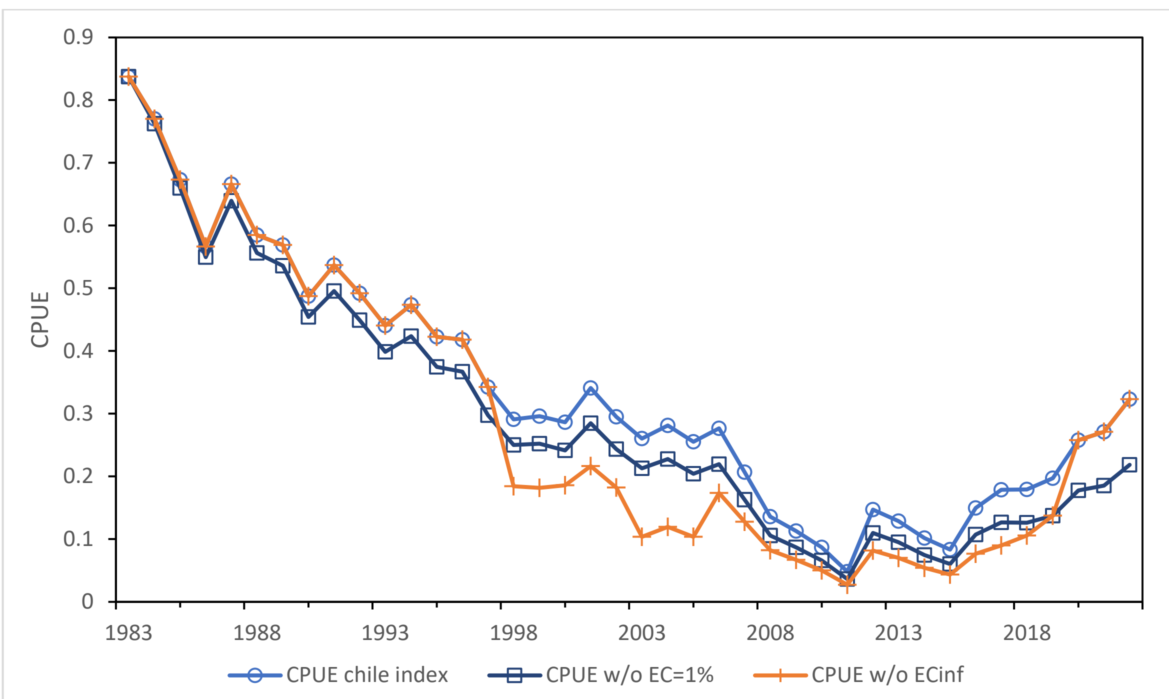


Figure 2. Chile CPUE index, and corrected series with constant EC= 1% and with the informed EC.

**Table 2.** Abundance index for the CS Chilean fleet, and corrected indexes with informed effort creep (ECinf) and with 1% fixed effort creep rate.

| **Year** | Chile Index | Corrected Index ($EC_{inf}$) | Corrected Index ($EC_{1\%}$) |
|---|---|---|---|
| **1983** | 0.8374 | 0.8374 | 0.8374 |
| 1984 | 0.7701 | 0.7701 | 0.7624 |
| 1985 | 0.6732 | 0.6732 | 0.6598 |
| 1986 | 0.5665 | 0.5665 | 0.5497 |
| 1987 | 0.6659 | 0.6659 | 0.6397 |
| 1988 | 0.5848 | 0.5848 | 0.5562 |
| 1989 | 0.5692 | 0.5692 | 0.5358 |
| 1990 | 0.4873 | 0.4873 | 0.4542 |
| 1991 | 0.5372 | 0.5372 | 0.4957 |
| 1992 | 0.4918 | 0.4918 | 0.4493 |
| 1993 | 0.4406 | 0.4406 | 0.3985 |
| 1994 | 0.4735 | 0.4735 | 0.4239 |
| 1995 | 0.4228 | 0.4228 | 0.3748 |
| 1996 | 0.4180 | 0.4180 | 0.3668 |
| 1997 | 0.3427 | 0.3427 | 0.2977 |
| 1998 | 0.2909 | 0.1842 | 0.2502 |
| 1999 | 0.2963 | 0.1820 | 0.2523 |
| 2000 | 0.2862 | 0.1861 | 0.2413 |
| 2001 | 0.3412 | 0.2163 | 0.2847 |
| 2002 | 0.2949 | 0.1823 | 0.2437 |
| 2003 | 0.2602 | 0.1036 | 0.2128 |
| 2004 | 0.2811 | 0.1193 | 0.2277 |
| 2005 | 0.2550 | 0.1039 | 0.2044 |
| 2006 | 0.2765 | 0.1737 | 0.2194 |
| 2007 | 0.2070 | 0.1275 | 0.1627 |
| 2008 | 0.1360 | 0.0821 | 0.1058 |
| 2009 | 0.1129 | 0.0668 | 0.0869 |
| 2010 | 0.0868 | 0.0503 | 0.0662 |
| 2011 | 0.0481 | 0.0273 | 0.0363 |
| 2012 | 0.1469 | 0.0818 | 0.1098 |
| 2013 | 0.1288 | 0.0702 | 0.0953 |
| 2014 | 0.1016 | 0.0543 | 0.0744 |
| 2015 | 0.0834 | 0.0437 | 0.0605 |
| 2016 | 0.1498 | 0.0769 | 0.1075 |
| 2017 | 0.1785 | 0.0898 | 0.1268 |
| 2018 | 0.1794 | 0.1057 | 0.1262 |
| 2019 | 0.1972 | 0.1374 | 0.1374 |
| 2020 | 0.2576 | 0.2576 | 0.1776 |
| 2021 | 0.2713 | 0.2713 | 0.1852 |
| 2022 | 0.3234 | 0.3234 | 0.2185 |

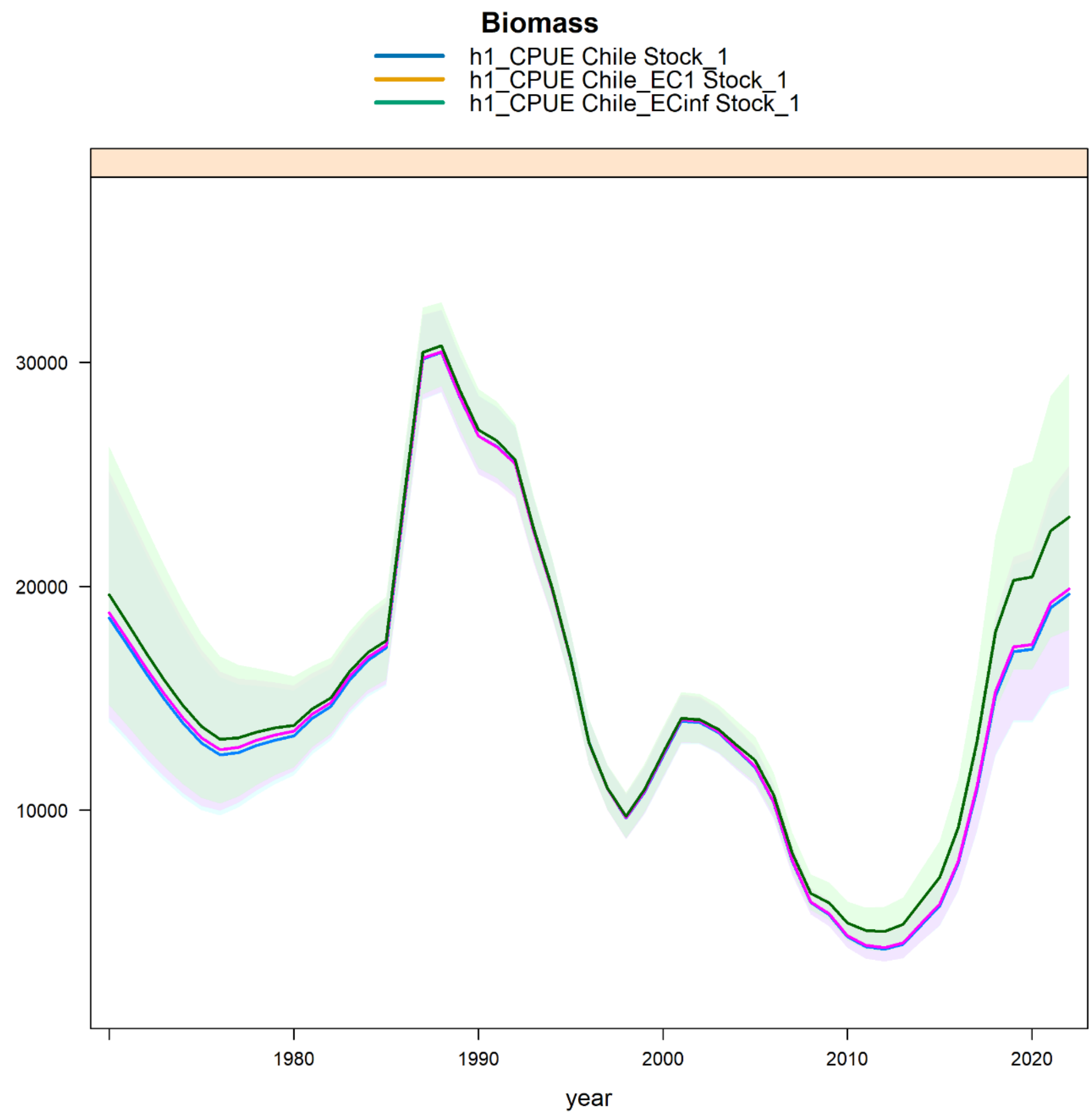


Figure 3. Output biomass (model 1.02) with Chile CPUE index (blue line), corrected CPUE with EC=1% (purple line) and corrected CPUE with informed EC (green line).

## Discussion

We present an alternative effort creep time series for the Chile CPUE index, developed with preliminary information from industry experts, as an alternative to the fixed 1% value agreed for the Chilean and peruvian fleets. The effort creep proposed here is based on time blocks created according to the use of technological changes experienced by the central-southern fleet of jack mackerel over the last three decades. Efficiency was predominantly estimated to be positive across the study period, with some factors limiting fleet efficiency. Limiting factors were mainly associated with normative changes (e.g. spatial restrictions), as well as holding capacity of processing plants. The results provided with the current JJM model show that using a more realistic and informed correction could have significant impact on estimated biomass. Further research should be conducted into effort creep factors and their effect over the CPUE index order to provide the required technical support.

The magnitudes of this informed EC are in line with recent studies of fleet efficiency changes in other fisheries. In a recent synthesis study, the authors estimated EC for more than 50 pelagic and demersal fisheries (Palomares and Pauly, 2019), with values ranging between a 0.5% and 20% (average 3.4%) annual increase in effort efficiency. For the pelagic artisanal fishery in Peru, another study corrected CPUE time series showed a steeper drop in CPUE than that calculated with nominal effort. This greater effective effort had a negative impact on the conditions of the resource and of the fishermen over time (De la Puente et al. 2020).

Our results are limited by the approach used to determine the values that were assigned to the efficiency factors. Also, we are limited by the scale of the data, since we do not have a correction factor per haul or vessel. Therefore, the proposed correction is on an annual scale. Additionally, there are data limitations and uncertainty associated with the magnitude of the effect of technological improvement and the duration of the effect on fleet efficiency.

In order to address the limitations of this approach, we are currently working on analyzing fleet data obtained by an extended industry expert survey conducted during July of 2023, destined for fishers, captains and fishing company owners of the central-southern fleet. This data will allow us to improve scores based on expert opinion, provided by jack mackerel industry sources in Chile. Further, we will implement GLM models to include the updated efficiency factors and test their impact over the standardized CPUE index.

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