

The logo for the Chilean Jack Mackerel Workshop is a dark blue rounded rectangle with a textured, wavy pattern. The text "Chilean Jack Mackerel Workshop" is centered in white, with "Chilean Jack Mackerel" on the top line and "Workshop" on the bottom line.

Catch per Unit Effort of Chilean Jack Mackerel (*Trachurus murphyi*) of the purse seine fishery off south-central Chile (32°10' – 40°10' S) 1981-2005

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Abstract

The CPUE standardization results of the purse-seine fleet operating in south-central Chile (32°10' – 40°10' S), reported by Caballero and Aranís (2005), were analyzed. Both CPUE and catch success were modeled through a Generalized Linear Model, in which the year, hold capacity, and month factors were the most representative in the explanation of variable. Catch success corresponds to the ratio between fishing trips with catches and the total trips fishing for jack mackerel, while in the CPUE the fishing trips with catches registers were considered as an effort measure.

When considering catch success as an availability measure, the CPUE ratio steadily increases in the last 8 years; this doesn't happen when considering catch success as an indirect efficiency or catchability measure. With the latter, the CPUE keeps a similar trend in the catch mean age, and decreases during the whole 90's. It is considered that catch success could reflect technological changes in the fleet, its efficiency and catchability; thus, it can be used as a correction factor of the CPUE signal of fishing trips with catches.

1. Introduction

The development of the jack mackerel fishery in south-center Chile (San Antonio - Valdivia) generated a steady increase of the purse-seine fleet between 1981 and 1997, reaching a 189-vessel top, which accumulated a 130 thousand m³ hold capacity. Further adjustment in the catches, produced by the stock reduction and new effort control measures, generated a strong

reduction of the fleet and a substitution for bigger, more efficient and more autonomous vessels (Figure 1).

Until the end of 1990, the fleet was constituted by minor vessels, with a hold capacity lesser than 450 m³ and displayed a considerable number of 1-day-average trips. However, an extension in the operation area of the fleet (Figure 2), and the entrance of bigger and better-equipped vessels led to less frequent but longer lasting trips. In 2005, the average hold capacity reached 1,200 m³ per vessel, and the trips reached a 3.2-day average length (Figure 3).

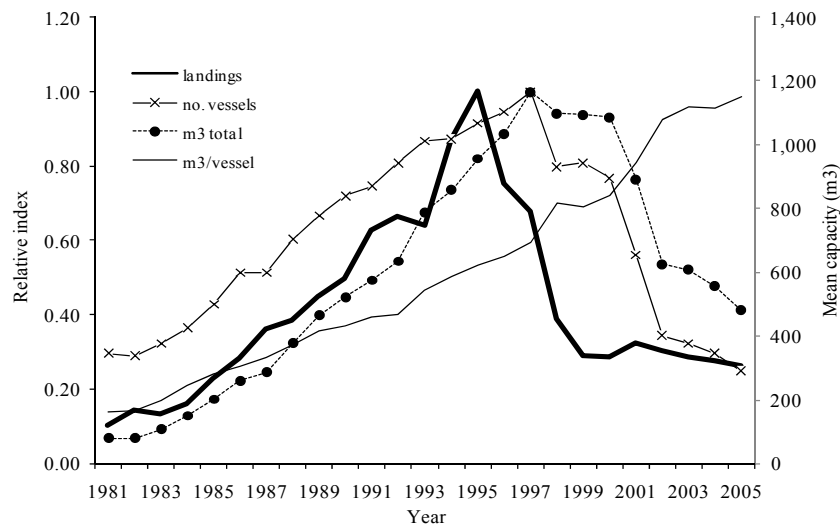
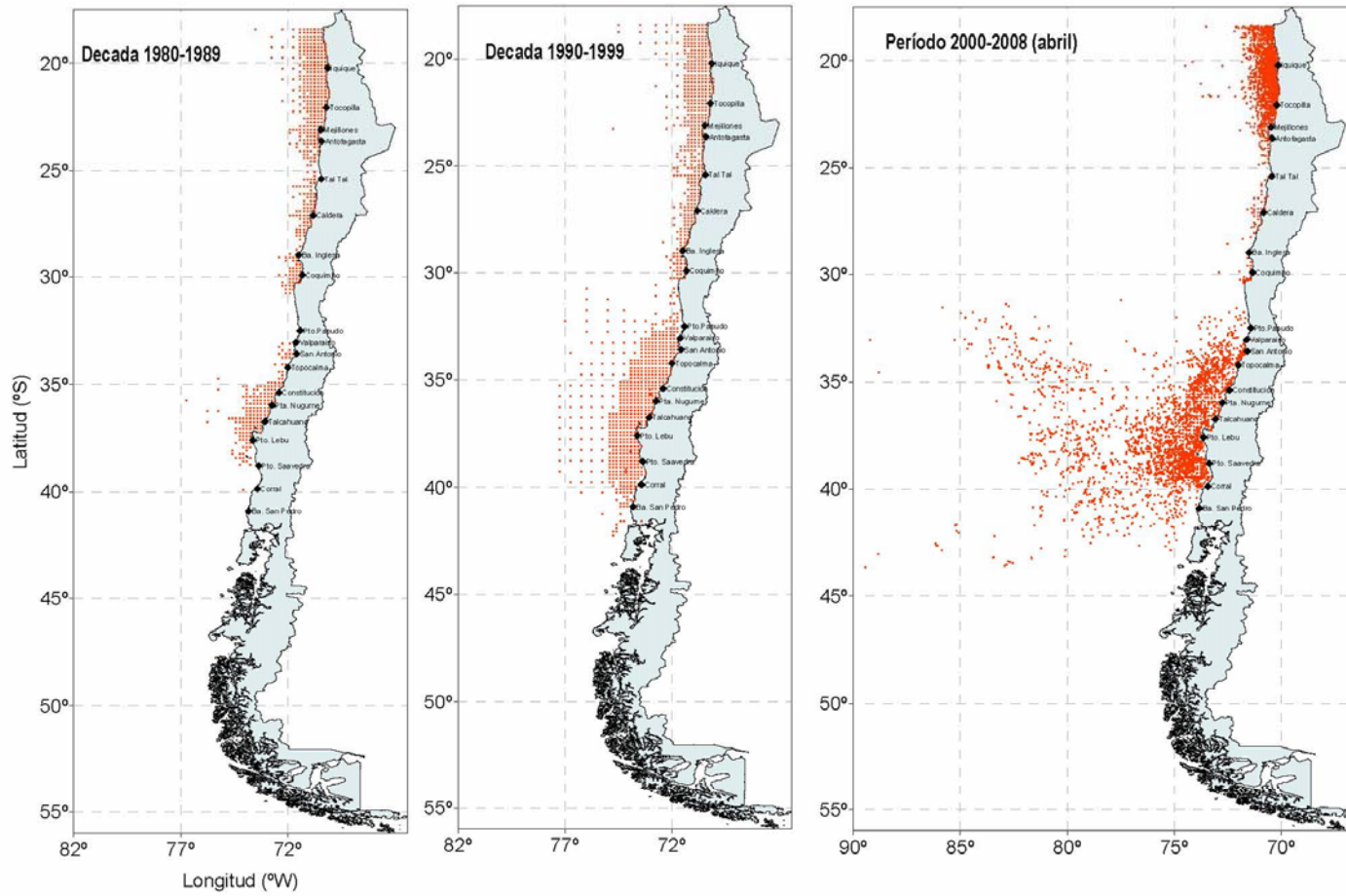


Figure 1. Relative evolution of the purse-seine fleet fishing for jack mackerel in the southern-central zone of Chile.



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Such changes have had an impact on the fishing power of the fleet, thus on the effort unit efficiency. In this document, the catch success is analyzed as an efficiency and/or catchability indicator: it is used to generate an abundance signal based on the tendency of the CPUE informed by Caballero and Aranis (2005).

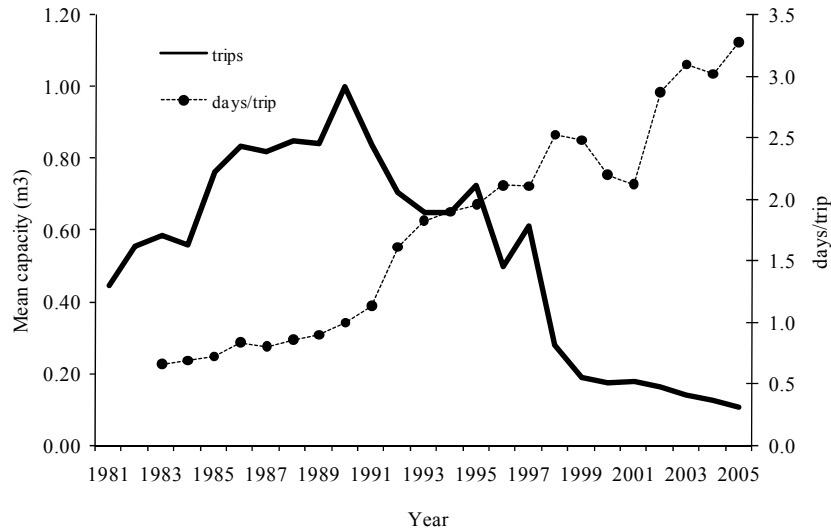


Figure 3. Evolution of the average hold capacity and the trips length of the purse-seine fleet fishing for jack mackerel in the southern-central zone.

2. Materials and Methods

Caballero and Aranis (2005) analyzed the daily registrations in the logbooks (IFOP) of the industrial purse-seine fleet fishing the center-south of Chile between 1981 and 2005. The study covered from the region V to the X, and was stratified in three macro-zones: San Antonio ($32^{\circ}10'00''$ - $34^{\circ}49'59''$ S); Talcahuano ($34^{\circ}50'00''$ - $38^{\circ}29'59''$ S); and Valdivia ($38^{\circ}30'00''$ - $41^{\circ}39'59''$ S). On the other side, the fleet was grouped in ten hold capacity strata: <250 m³; 250-350 m³; 350-500m³; 500-600 m³; 600-750 m³; 750-850 m³; 850-910 m³; 910-1100 m³; 1100-1500 m³ and 1500-1850 m³.

The CPUE is expressed as the quotient between the catch expressed in tons (t) and the effort, measured as trips with catch. For modeling the CPUE, Caballero and Aranis (op cit) considered factors like year (from 1981 through 2005), month (January to December), fishing zone, and hold range. The modeling was carried out through GLM (McCullagh and Nelder, 1989; Chambers and Hastie, 1992), using a gamma distribution for answer and a Log link function. This is

based on the proportionality found between the variance and the average of the CPUE (Stefansson, 1996). The CPUE with non-zero catch was modeled as:

$$\ln(CPUE)_{i,j,k,l} = \mu + \alpha_i + \beta_j + \gamma_k + t_l + \varepsilon_{i,j,k,l} \quad (1)$$

Where μ is the intercept, α_i is the year factor, β_j is the month factor, γ_k is the zone factor, t_l is the hold range factor, and $\varepsilon_{i,j,k,l}$ is the random error component. As a means to incorporate trips without catch, these authors independently modeled a catch success probability (p), which corresponds to the quotient between trips with non-zero catch and total trips fishing for jack mackerel. The model follows a binomial distribution and a “Logit” link function is used to relate p with the predictors.

$$\ln\left(\frac{p}{1-p}\right)_{i,j,k,l} = \mu' + \alpha'_i + \beta'_j + \gamma'_k + t'_l + \varepsilon'_{i,j,k,l} \quad (2)$$

Where μ' is the intercept; α'_i the year factor; β'_j the month factor; γ'_k the zone factor; t'_l the hold range factor; and $\varepsilon'_{i,j,k,l}$ the random error component. Thus, the annual value of the CPUE measured in tons/total trips corresponds to the product:

$$CPUE_i = \exp(\mu + \alpha_i + 0,5\sigma^2) \exp(\mu' + \alpha'_i + 0,5\sigma'^2) \quad (3)$$

Alternatively, if “ p ” is considered an efficiency indicator, then the annual value of the CPUE will correspond to the quotient:

$$CPUE_i = \frac{\exp(\mu + \alpha_i + 0,5\sigma^2)}{\exp(\mu' + \alpha'_i + 0,5\sigma'^2)} \quad (4)$$

The assumption is that the increase in the CPUE of the trips with catch could be influenced by changes in the fleet efficiency and the resource catchability, the latter indirectly represented by the catch success (p).

3. Results / Discussion

Both in the CPUE and catch success model, although statistically significant, the zone effect was not considered in the analysis due its low contribution to explaining the CPUE variability. The

variance analysis indicates that year and hold capacity are the factors that most explain the CPUE model variability, and that catch success is mainly explained by year and month effects (Table 1).

The results show that the CPUE shows a linear increase with the hold capacity (Figure 4a) and the monthly effects gather the well known seasonality of this fishery, showing a minimum from September through December (Figure 4b). On the other hand, the catch success model shows an inverted tendency to the landings, which is increasing since 1997 (figure 4c). The annual effect of the CPUE (figure 4d) shows a steady increase since 1997, supposedly caused by the previously mentioned efficiency increase.

Table 1

ANOVA of the GLM applied to the jack mackerel information, 1981-2005

Catch probability model (Binomial)

| | Df | Deviance | Resid. Df | Resid. Dev | F Value | Pr(F) |
|-------|----|----------|-----------|------------|---------|-------|
| NULL | | | 207,391 | 242,244 | | |
| year | 24 | 8,302 | 207,367 | 233,942 | 348 | 0 |
| m3 | 9 | 3,719 | 207,358 | 230,223 | 416 | 0 |
| month | 11 | 5,229 | 207,347 | 224,994 | 478 | 0 |

CPUE model (Gamma)

| | Df | Deviance | Resid. Df | Resid. Dev | F Value | Pr(F) |
|-------|----|----------|-----------|------------|---------|-------|
| NULL | | | 150,034 | 182,578 | | |
| year | 24 | 52,578 | 150,010 | 130,000 | 4,763 | 0 |
| m3 | 9 | 23,734 | 150,001 | 106,266 | 5,734 | 0 |
| month | 11 | 2,989 | 149,990 | 103,277 | 591 | 0 |

With this regard, during the maximum-catches-and-larger-fleet period (1990-1996), the efficiency could have diminished due to the technologic interference and the stock increase (Serra and Canales, 2007). For more recent years, the fishing effort of the fleet has significantly decreased, but it has improved its efficiency due to technologic upgrade and the management of the fishing operation.

Thus, the catch success tendency is contrary to an availability index if considering the remoteness of the fishing zone and the larger schools (Cordoba et al, 2005). It is expected at least a decrease of the availability for the last years. Thus, the “*p*” variable seems to more efficiently gather the tendencies in fleet efficiency that generate changes in catchability and, as such, it was considered to correct the CPUE reported by Caballero and Aranis (2005), which showed a steadily increasing tendency towards the last 8 years.

The corrected annual CPUE showed two periods associated to the changes in the operation area of the fleet and the resource. The first period increases between 1981 and 1992, corresponding to the development of the fishery where there was an increase of the fleet, and the fishing zones were mostly within the 50 nm. In the second period, 1993-2005, the operation of the fleet started to extend to 150 nm from the coast and from 2003 covers the zone beyond the 150 nm from the coast (Figure 5).

During the whole 1990 decade, the CPUE decreased and shows a similar tendency with the mean age of the catches. The explanation to this effect is the reduction in the mean age of the exploitable stock, which is reflected in the catches and is produced by the reduction of abundance of the bigger fishes (Serra and Canales, 2007) and with this, the decrease of the relative biomass reflected in the CPUE. Nonetheless, a reduction of the mean age of the catch can be observed after recruitment. Since 2001, both signals have shown a mild increase (Figure 6).

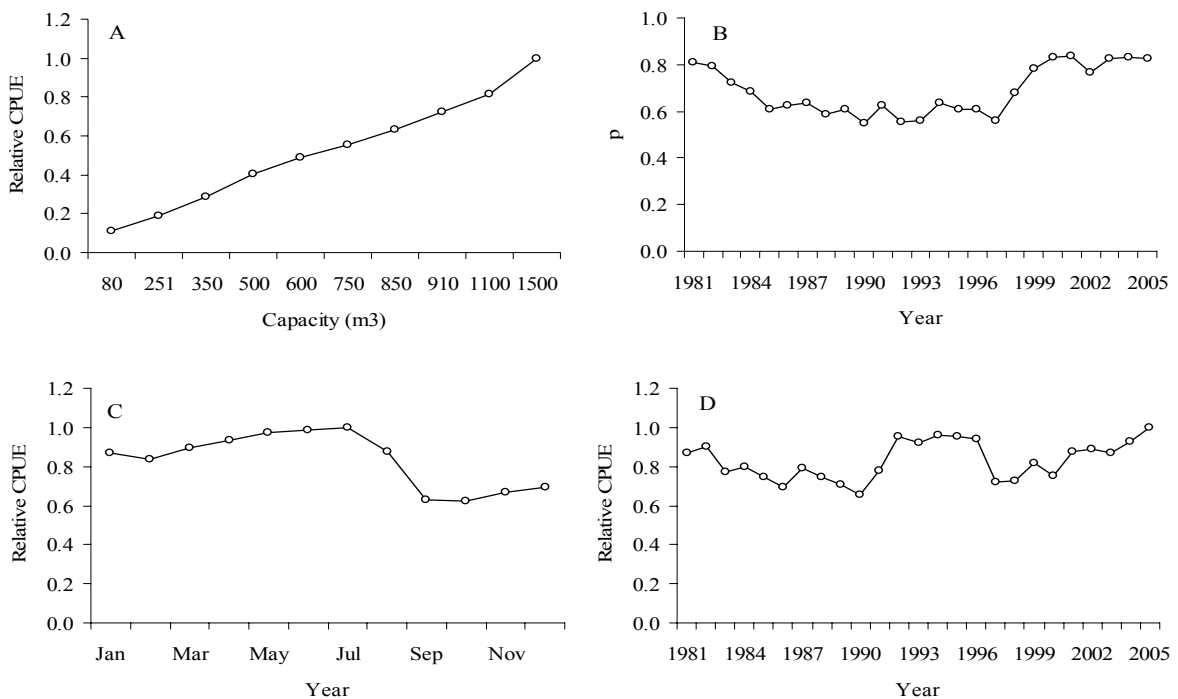


Figure 4 Main effects of the GLM model applied to the jack mackerel CPUE information. a) Hold capacity, b) Catch success, c) Month, d) Years.

An important assumption of the CPUE model is that fishing efficiency within a specific vessel category does not vary over time, which apparently has not happened in the jack mackerel fishery. The remoteness of the fishing zones caused higher efficiency of the fleet through the

substitution and entrance of larger vessels, plus better detection technologies. In fact, at the end of the 90's, most of the fleet was equipped with EK-60 echosounder (Sepulveda com. pers.) and with this the probability of finding should have significantly improved.

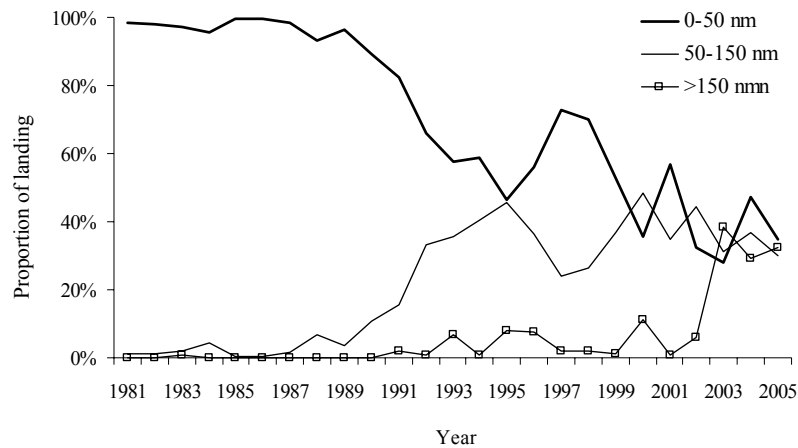


Figure 5 Annual proportion of jack mackerel catches according to distance from the coast.

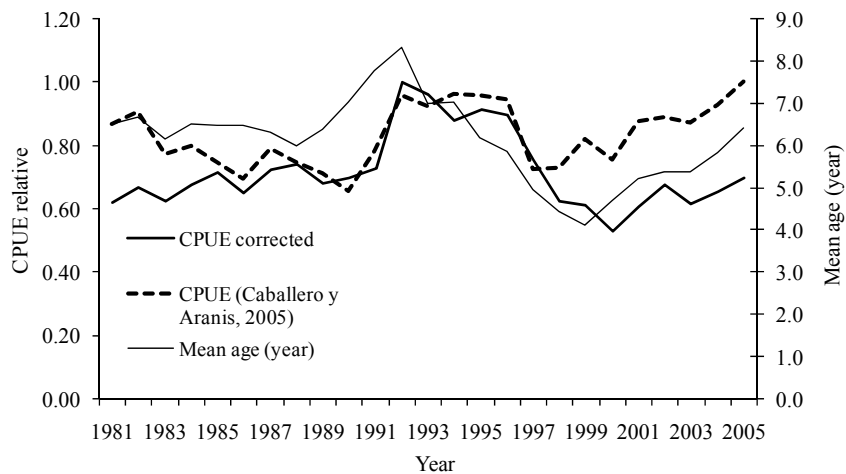


Figure 6 Evolution of the relative CPUE and mean age of the jack mackerel catches in the central-south area 1981-2005.

The most important problem in the jack mackerel CPUE standardization is the huge changes in the area covered by the fleet and the technological changes, which has not permitted an indirect gathering of the biomass changes. The resource has a high distribution and important migrating processes towards and from high seas caused by trophic and reproductive processes that make it difficult to interpret the CPUE.

In this document, an alternative interpretation to that of Caballero and Aranís (2005) is provided, assuming that modeling the catch probability is an indirect measure of the fleet efficiency, thus, the upward trend presented by the CPUE for the last years is corrected. Notwithstanding the foregoing, it must be considered that the period 1981-1991 correspond to the fishery development, and as such, the abundance CPUE signal may be disturbed by the coverage relation of the fleet vs. that of the resource during a mainly coastal operation period. On the other side, the establishment of the Maximum Allowable Catch limit per ship owner policy (MACL), could have had an effect on the CPUE which impact is quite difficult to define.

4. References

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