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SPATIAL AND TEMPORAL DISTRIBUTION, LENGHT COMPOSITION AND ENVIRONMENTAL RELATIONS OF THE YELLOWFIN TUNNA (*THUNNUS ALBACARES*) IN THE SOUTH WEST ATLANTIC.

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SUMMARY

The present work analyses information of captures, effort, length and sex composition of Thunnus albacares *collected by the Uruguayan Tuna Fleet National Onboard Program (PNOFA in Spanish) during the period 1998- 2007. It was only used data collected in the South West Atlantic, west of the longitude 20º W. In this area, a subzona of study was defined regarding the high amount of effort and captures done by the Uruguayan fleet. It comprises Uruguayan territorial waters and international adjacent waters. Size classes and spacial distribution is analyzed, as well as the proportion of subadutls and adults that occurred spacial and temporally and in function of the Sea Surface Temperature (SST).* T. albacares *captures were distributed in the total fishing zone, with higher number of captures in Uruguayan territorial waters, closed to the continental slope, which was more evident for the subadult class. The mean length registered for the whole studying period was 111,2 ± 16,7 cm (range: 52-180 cm) and a sexual composition of 1,3 males for each female. The maximum CPUE occurred in south latitudes between 35º and 37º for adults and subadults, reaching higher CPUE between 19º and 21ºC SST.*

RESUMEN

En el presente trabajo se utiliza la información obtenida por el Programa Nacional de Observadores de la Flota Atunera uruguaya (PNOFA) desde 1998 hasta el 2007, sobre captura, esfuerzo y composición de tallas y sexo de Thunnus albacares. *Se utilizaron únicamente los datos obtenidos en el Océano Atlántico Sur al oeste de los 20ºW. Dentro de esta área, se definió una subzona basado en el alto porcentaje de esfuerzo y capturas que realizo la flota, la cual comprende aguas uruguayas jurisdiccionales e internacionales adyacentes. Se analiza la distribución espacial y composición de tallas de las capturas y la proporción de subadultos y adultos espacial y temporalmente, y en función de la temperatura superficial del mar (SST). Las capturas de* T. albacares *estuvieron distribuidas en el total del área de pesca, con mayores capturas dentro de aguas jurisdiccionales uruguayas, en la zona cercana al talud continental, lo que se evidencia particularmente para los individuos subadultos. La talla media registrada para todo el período de estudio fue de 111,2 ± 16,7 cm (rango: 52-180 cm) y una composición sexual de 1,3 machos por cada hembra. Los valores máximos de CPUE ocurrieron a latitudes entre los 35º y los 37º de latitud sur, para subadultos y adultos, con valores máximos de CPUE entre los 19º y 21ºC SST.*

KEY WORDS

Yellowfin tuna, longline, Uruguay, SST, proportion adults

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1. Introduction

The yellowfin tuna (*Thunnus albacares*) is a cosmopolitan specie that occurred in the Atlantic Ocean as a unique stock (Anon. 2004; Fonteneau & Soubrier 1996; Bard & Scout 1992), distributing in the Western Atlantic from the south of Canada until north of Argentina (FAO Fisheries Department, 1994).

The juvenile yellowfin tunas more often distributes in equatorial regions, in coastal zones, while subadults and adults reach higher latitudes and more oceanic waters. In the Easter Atlantic 108,6 cm has been set as the first maturity length for males and 91,4 for females.

This specie shows a migratory cycle in the tropical Atlantic were four stages can be identified: i) concentration of schools in the eastern Atlantic (Gulf of Guinea and adjacent waters) for spawning, in the period January-March; ; ii) transatlantic migration from east to west between March and May; iii) concentration of schools in the west (Gulf of Mexico and southeast Caribbean) for spawning and feeding, between June and September; and (d) transatlantic migration from west to east between October and December (Hazin, 1993). In the West Atlantic in the south and southeast coast of Brazil, juvenile concentrations are observed next to shore and bigger individuals off the coast, in isolated schools (Costa *et al*. 2005). Zavala-Camin (1978) found that adults perform semester trophic migrations between equatorial zones and south and southeast of Brazil, in the periods of March-August and September-February.

Capturing sizes classes are found usually between 40 and 170 cm fork length (Anon, 2004) with a maximum size registered of 239 cm (International Game Fish Association 2001). According to Fonteneau (1992) in the Atlantic, many small yellowfin individuals (under 50 cm) are caught in the Eastern Atlantic, but they are rare in the west; the medium size individuals area caught in the east side, but they are predominant in the west; many large individuals (larger than 140 cm) are caught in the east, being scarce in the west.

Temperature range where *T. albacores* more often occurrs is between 18 to 31 ºC (Laevastu & Rosa, 1963), spending more than 90% of the time in waters with a uniform temperature higher than 22 ºC (Brill *et al*. 1999, Brill *et al*. 2005).

In the present work it is analyzed the information of captures, effort, length and sex composition of *Thunnus albacares* collected by the Uruguayan Tuna Fleet National Onboard Program (PNOFA in Spanish) (Mora & Domingo 2006) during the period 1998- 2007. As well, it is analyzed the proportion of subadutls and adults spacial and temporally and in function of the Sea Surface Temperature (SST).

2. Material and methods

For the present work data collected by the PNOFA in waters located west from 20ºW was used. In every fishing set, the following information was recorded: geographic position (latitude and longitude) and Sea Surface temperature (SST in ºC), both at the beginning of the set, number of individuals captured and effort (number of hooks). If possible, fork length (FL in cm) and sex information was used. Length information was analyzed using histograms and means per year and month.

It was analyzed the percentage of effort that the PNOFA covers of the total amount of effort performed by the whole Uruguayan longline fleet, using information from the fishing logbooks.

Individuals were divided in subadults and adults using 100 cm FL as maturity length (Albaret, 1977) for both sexes. For subadults and adults the nominal CPUE was calculated as number of individuals every 1000 hooks (ind/1000 hooks). CPUE was analyzed in function of the latitude and the SST, accumulating data per latitude and temperature grade.

Based on the concentration of effort and captures by the Uruguayan longline fleet, a subzone of analysis was defined, corresponding to Uruguayan territorial waters and international adjacent waters limited by the longitude 45º W and latitude 34 to 37º S (**Figure 1**).

2.1. Uruguayan territorial waters and international adjacent waters

For this area, detailed length analyses were carried out for the whole studying period, per year and per month. As well, it was analyzed the proportion of subadults and adults accumulated per month and the CPUE per month and accumulated per SST grade. For the spatial analysis of captures, the subzone was divided between the continental slope (from the 2000m isobath to the continental platform) and external waters (from 2000m isobath to deeper waters).

Spatial distribution of captures and effort was analyzed using software ESRI ArcMap 8.3.

3. Results

1.415 fishing sets were observed (corresponding to 2.826.259 hooks) out of a total of 8.053 sets and 9.428.890 hooks declared in the fishing logbooks. The percentage covered by the PNOFA was, in average, 31% of the total amount declared by the whole longline fleet in the period 1998-2007. A part from 1998, 2000, 2001 (cover: 9%, 3% y 6% respectively), it was always higher than 10%, reaching 42 and 80% in 2004 and 2007 (Figure 2). The PNOFA effort followed the spacial distribution of the whole fleet effort (Figure 1). *T. albacares* captures were distributed in the whole fishing area (Figure 3), with higher captures inside Uruguayan waters and international adjacent waters, between the 34 and 37ºS.

2.369 individuals were measured, observing a length mean for the whole studying period of 111,2 ± 16,7 cm FL (range: 52-180 cm). Figure 4A shows the length means per year; being the minimum FL mean recorded in 2002 (101,5 ± 15,4 cm) and maximum in 1998 (127,7 ± 8,9 cm). All year means were higher than 100 cm FL. Monthly, lower length means were recorded between May to August, with a minimum in August (99,0 ± 14,7 cm) and a maximum in December (144,5 ± 12,9 cm) (Figure 4B).

From the total of individuals measured, 1.141 were sexed, finding a sexual proportion of 1,3 males per female. Both sexes showed similar FL mean: 116,9 ±15,4 cm (rango: 65-180 cm) for males and 117,1 ± 14,0 cm. (rango: 65-162 cm) for females (Figure 5).

The spacial distribution of adults captures were seen in the whole fishing area. However, subadults' captures were distributed closer to the continental slope (Figure 6).

The higher CPUE values were observed between 35º and 37º S for both subadults and adults, reaching a maximum in 36º S (1,6 and 4,7 ind/ 1000 hooks for subadults and adults respectively), where also the higher effort is recorded. Despite the fact that between 29º to 33º S similar amount of effort is recorded as the observed between 35 to 37º S, CPUE values remind low.

Records of effort performed by the Uruguayan longline fleet were observed between 8º y 29 ºC of SST, with high concentration of effort between 19º y 24 ºC, observing *T. albacares* captures in the range of 12º C to 29 ºC. For both length classes CPUE was higher in the range of 19 to 21 ºC of SST, with maximum at 21 ºC (2,0 y 7,1 ind/ 1000 hooks for subadults and adults respectively) and minimum for both classes at SST higher than 25 ºC (**Figure 8**).

3.1. Uruguayan territorial waters and international adjacent waters

92% of the *T. albacares* captures occurred in Uruguayan territorial waters and international adjacent waters, reaching a CPUE of 5,7 ind/1000 hooks (4 times higher than the CPUE for the whole fishing area calculated in 1,4 ind/1000 hooks). The number of individuals captured on the continental slope (from the 2000m isobath to the continental platform) were higher than the recorded off this deep, recording 421 subadults and 1.147 adults for the first area and 75 and 455 for the second one (Figure 9).

It was recorded a length mean, for the whole studying period, of 110,2 ± 15,9 cm (range: 52-180 cm). Figure 10A shows FL means per year; corresponding the lower FL mean to 1999 (95,9 ± 15,2 cm, rango: 52-155 cm) and the higher to 1998 (127,7 ± 8,9 cm, rango: 75-151 cm). Monthly, for this subzone, similar means to the ones calculated for the whole fishing area were observed, recording as well lower mean values in the period May to August and a maximum mean in December (144,5 ± 12,9 cm) (**Figure 10B**).

For this subzone, sexual proportion was 1,2 males per female, being slightly lower than the proportion found for the whole fishing area. Males and females showed similar FL mean, being for males 115,8 ±14,7 cm (range: 65-180 cm) and for females 115,5 ± 12,5 cm (range: 65-151 cm) (**Figure 11**).

Subadults and adults proportion, monthly accumulated for the whole studying period, shows no clear tendencies, observing values close to 100% of adults in February, June and July, reaching 100% of adults in December. May and August presented proportion closed to 50% of subadults, being August the only month with more subadults captured in relation to adults (Figure 12). Spatially, subadults/adults proportion was 0,4 on the continental slope (from the 2000m isobath to the continental platform) and 0,2 off this zone.

Maximum CPUE values were recorded in March, follow by May and June. April was the month with lower CPUE, despite the high effort recorded (Figure 13). CPUE accumulated by SST grades, showed higher values in the range between 19 y 25º C, reaching maximum values for subadults and adults in 21 ºC (2,7 and 9,0 ind/1000 hooks for subadults and adults respectively) (**Figure 14**).

4. Discussion

PNOFA percentage cover was in most of the year higher than 10%, reaching a maximum of 80% in 2007, following the spacial distribution of the Uruguayan fleet operation. This means, that data collected by this Program is a good sample of the general effort and captures performed by the whole Uruguayan longline fleet. The high cover on 2007 is explained by the unusual low number of vessel that operated that year.

The information obtain of size classes distribution, males and females means and sexual proportion in 2007 was similar to the data recorded in previous years for the Uruguayan longline fleet (Domingo *et al.* 2008 a y b) and for Brazilian longline fleet that operated in the South West Atlantic (Costa *et la.*, 2005). The length range observed, with a mode between 100 and 140 cm FL, corresponding to subadults and adults individuals, which concord with data described by Fonteneau (1992), who stands that medium size classes (between 50 and 140 cm FL) predominate in the West Atlantic. Few larger individuals were recorded being only 0,04 % of the total of individuals measured.

For the whole fishing area, a wider SST range was recorder (12 ºC to 29 ºC) for *T. albacares* captures in relation to the range reported by Laevastu & Rosa (1963) being 18 ºC to 31 ºC, showing higher CPUE values between 19 to 21ºC.

4.1. Uruguayan territorial waters and international adjacent waters

For subadults and adults it was observed elevated captures on the continental slope zone, which coincided with data recorded for other target species, such us swordfish (Domingo et al. 2007; Mora et al. 1991; Mora 1988; Rios *et al.* 1986), as well as bycatched species (Jiménez & Domingo 2007; Domingo *et al.* 2006). The high productivity of this area is given by the confluence of the cold Malvinas current and the warm Brazilian current, together with the Rio de la Plata discharge. In this zone, a thermohalin front is formed; know as Subtropical Brazil-Malvinas confluence, with elevated food availability that sustains high trophic levels such us tunas, swordfish and big mammals (Acha *et al*, 2004; Olson, 2002; Passadore *et al*. 2004, 2007). It is due to this characteristic, that a high amount of fishing effort is recorded in this area.

Inside this subzone of analysis, size range histograms and FL boxplots were similar to the obtained for the whole fishing area. Length means values were usually higher than 100cm FL for every year meaning that the Uruguayan longline fleets captures mostly adults individuals. This can be explained by the spacial distribution of the size classes, as well as the selectivity of the fishing art (Costa *et al.*, 2005). In the last 3 years, a small increment of the capturing means is observed.

In the South West Atlantic, Costa *et al.* (2005) found higher proportion of adults during the period from August to April; observing an increment of the amount of juveniles during the period from May to July, probably caused by the adults migration to Venezuelan Caribbean to reproduce, during August and September. In the present work it was not evidenced any clear seasonality in the proportion of subadults/adults, related to the migratory periods proposed by other authors (Costa *et al*. 2005; Zavala-

Camin, 1978). In Uruguayan waters an increase on subadults captures was observed in May and August and a decreased in the cold months of June and July and in the summer season.

Previous work published by Zagaglia *et al.* (2004) showed that *T. albacares* captures are not directly related to the SST. Still, for this work, data shows that the higher CPUE values are found for SST ranging from 19 to 21 ^{o}C. In particular 21 ^{o}C seems to be an important capturing SS temperature for this specie in areas close to the continental slope.

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Figures

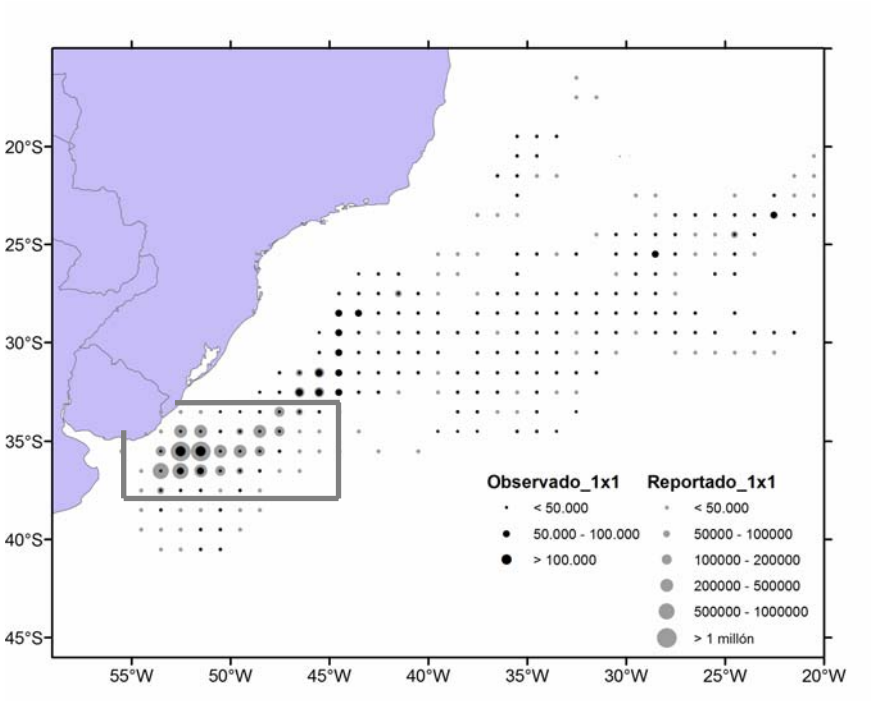


Figure 1. Effort observed by the PNOFA (black dots) and the effort declared in the logbooks by the Uruguayan longline fleet (gray dots), for the period 1998-2007, integrated in 1º x 1º areas. In the gray square is indicated the subzona that comprises Uruguayan territorial waters and international adjacent waters.

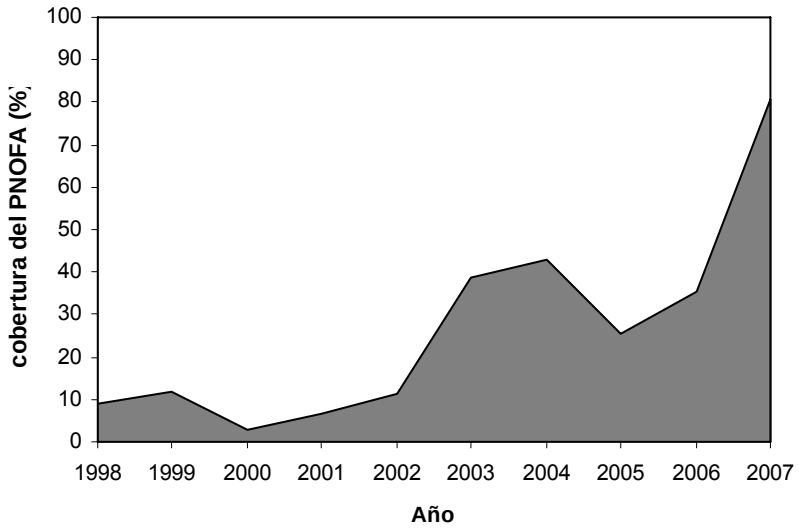


Figure 2. Annual percentage of the effort covered by the PNOFA, in relation to the effort declared by the Uruguayan longline fleet.

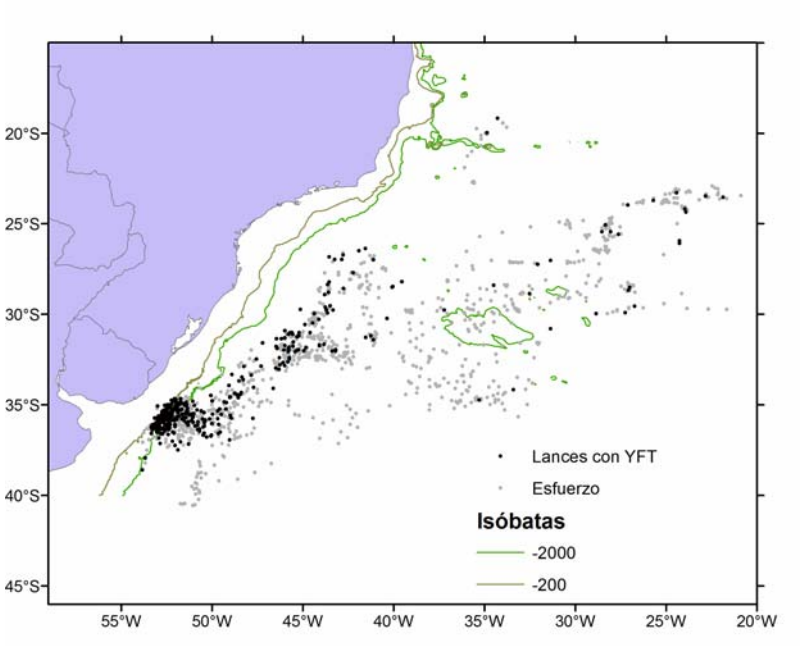


Figure 3. Sets with *T. albacares* captures (black dots) and total amount of sets (gray) accumulated for the whole studying period (1998-2007).

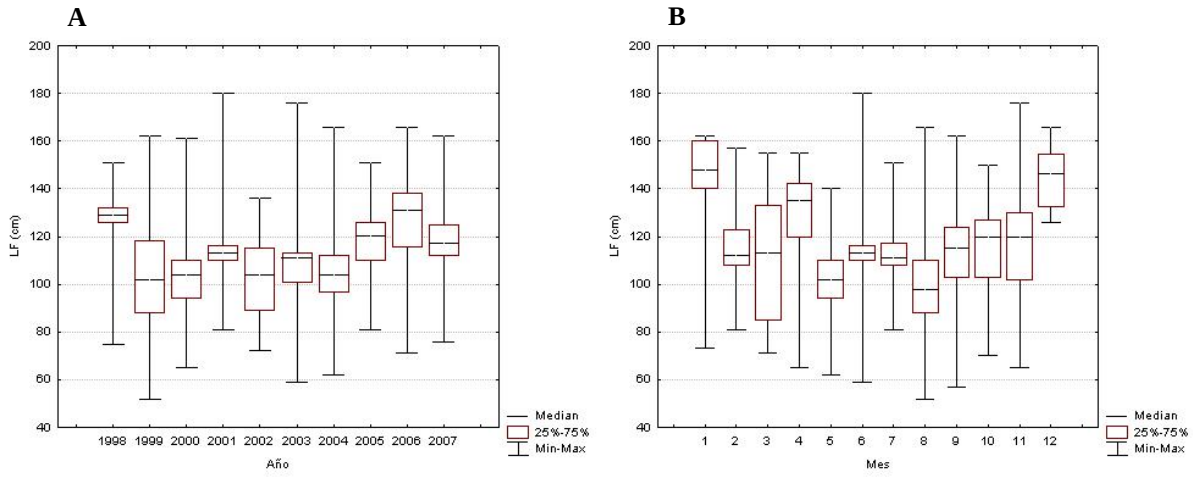


Figure 4. Boxplots (median, first and third quartile, minimum and maximum) of FL in cm, accumulated per year **(A)** and month **(B)** for the whole fishing area.

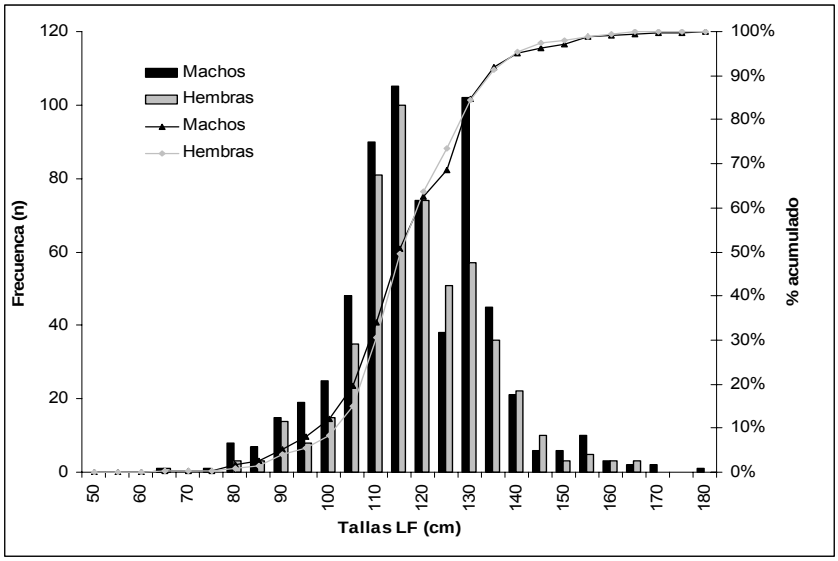


Figure 5. Size classes of males (machos) and females (hembras) frequency histogram (classes range = 5 cm FL) and accumulated percentage per sex, for the whole fishing area.

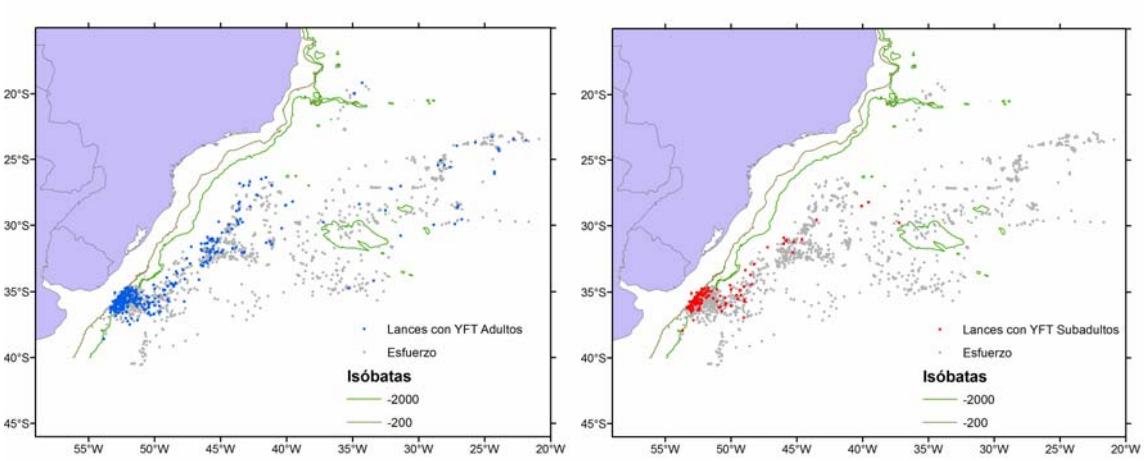


Figure 6. Sets with *T. albacares* captures and total amount of sets (gray) accumulated for the whole studying period (1998-2007), for adults (blue dots) and subadults (red dots).

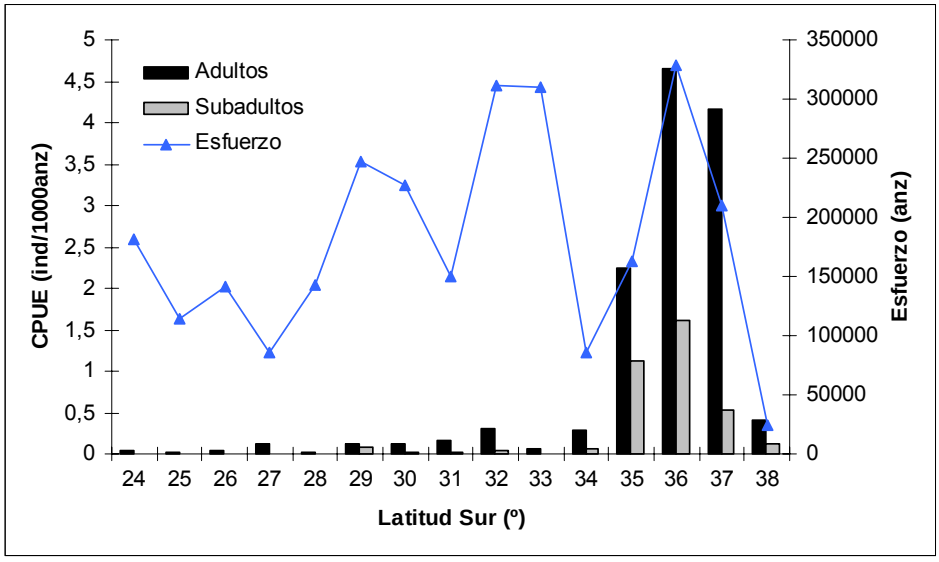


Figure 7. CPUE of subadults and adults and effort, accumulated per latitude grade, for the whole fishing area.

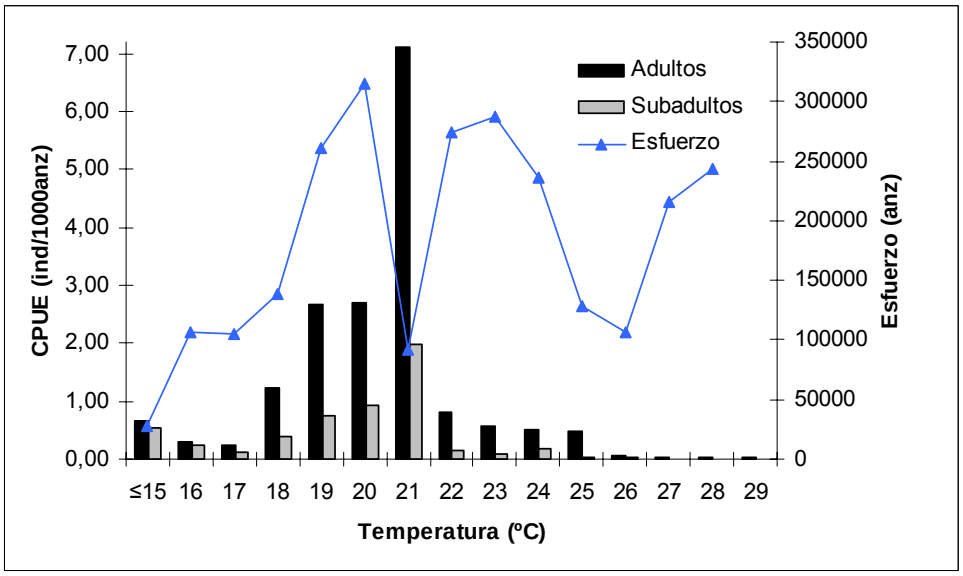


Figure 8. CPUE of subadults and adults and effort accumulated per SST grade for the whole fishing area.

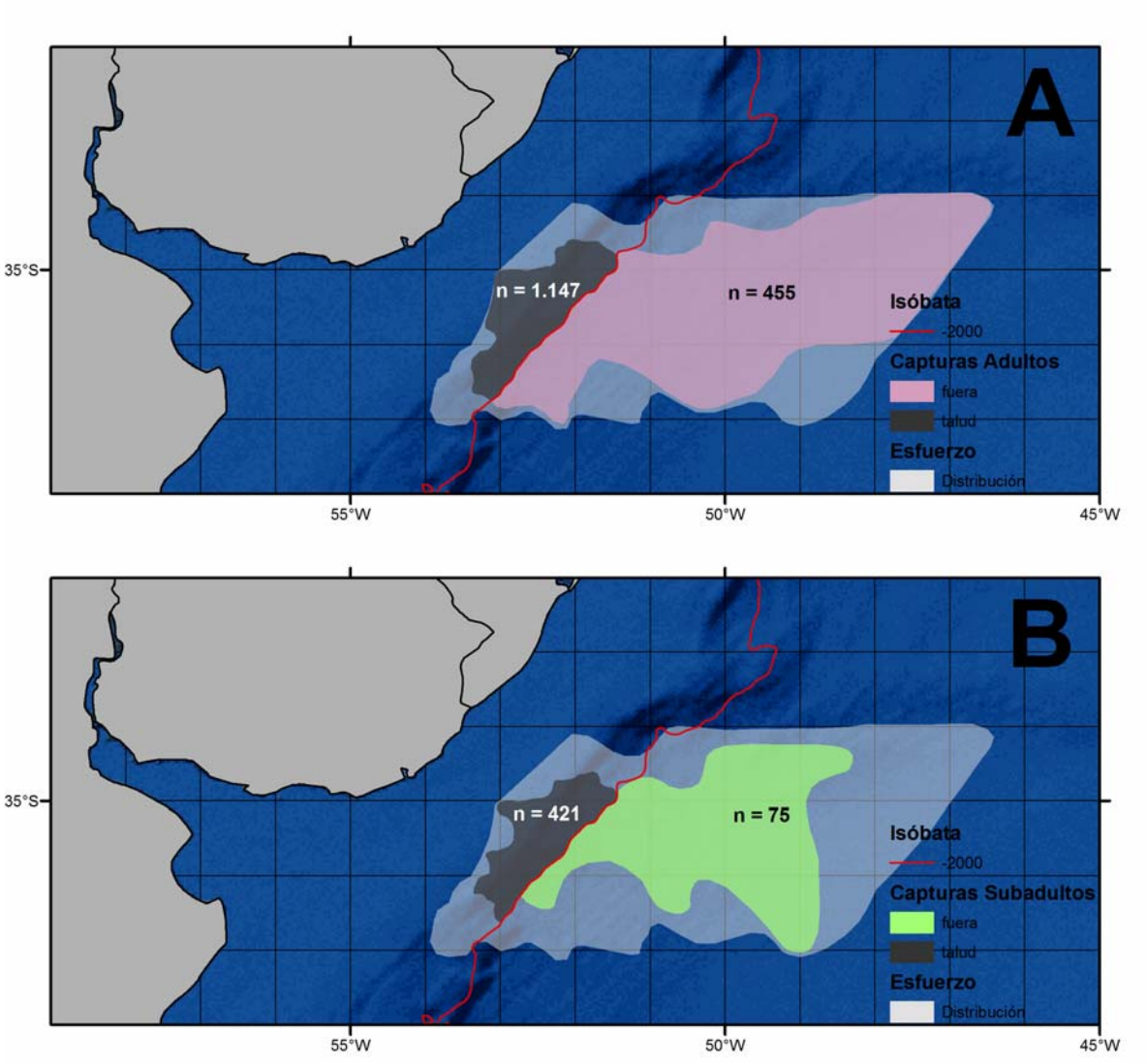


Figure 9. Spacial distribution of the *T. albacares* captures and effort (light gray in A and B) in Uruguayan territorial waters and international adjacent waters, accumulated for the whole studying period. **(A)** adults (dark gray and light pink) and **(B)** subadults (dark gray and light green).

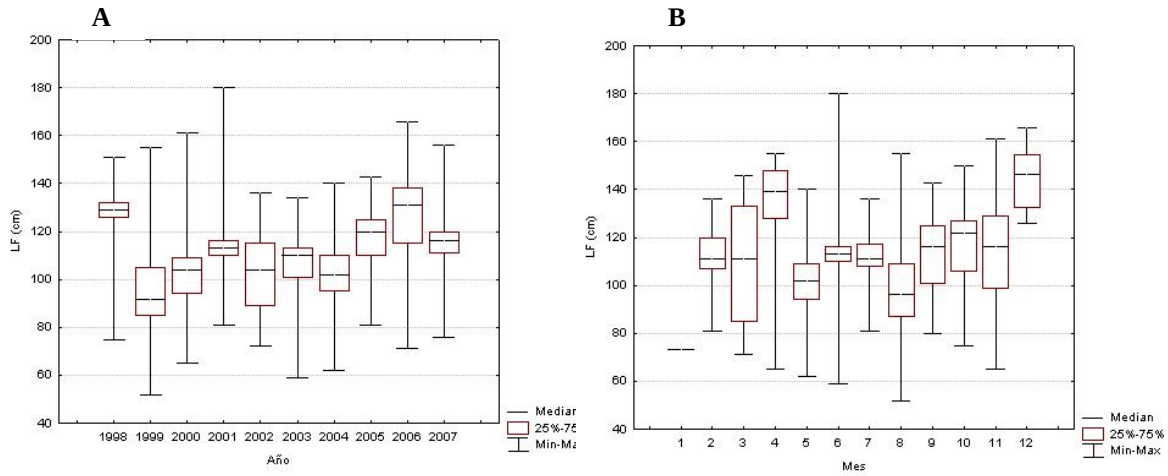


Figure 10. Boxplots (median, first and third quartile, minimum and maximum) of FL in cm, accumulated per year **(A)** and month **(B)** for Uruguayan territorial waters and international adjacent waters. In B January is excluded for not having enough measurement for the analysis.

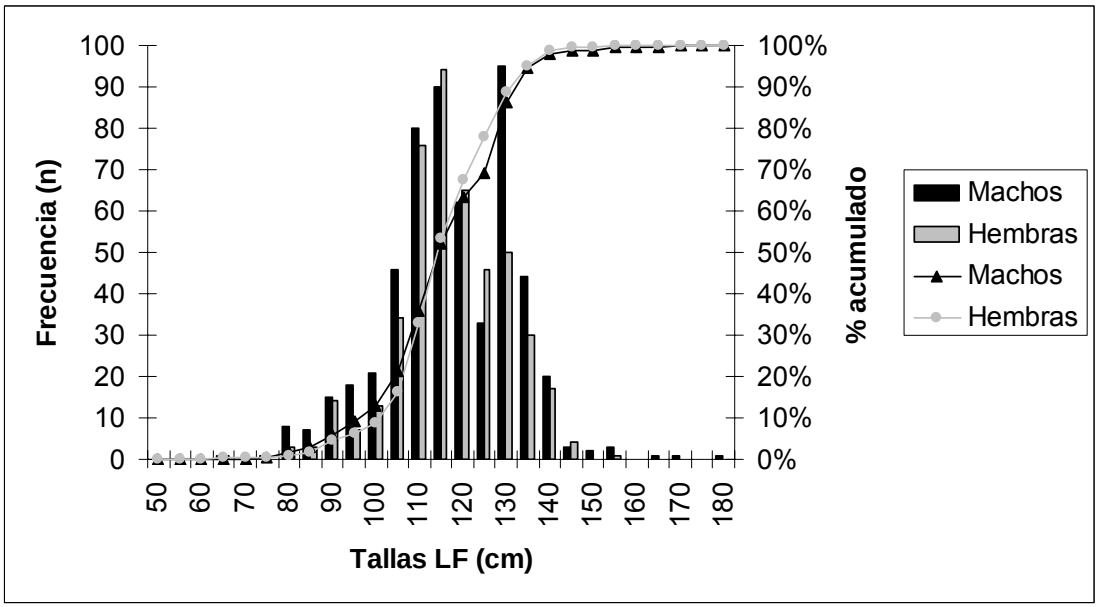


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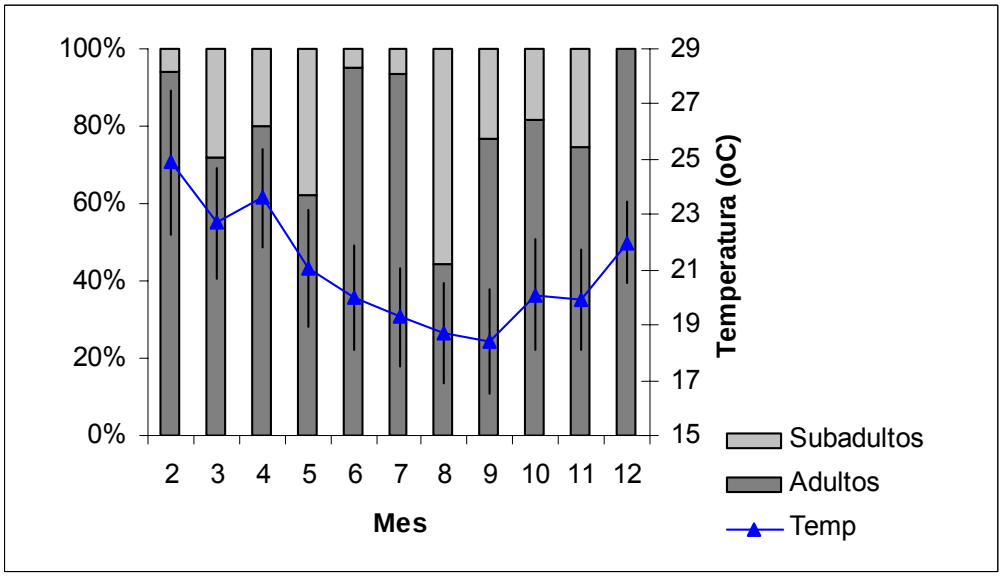


Figure 12. Subadults and adults' proportion (%) and SST mean and SD (Temp) accumulated per month, for Uruguayan territorial waters and international adjacent waters. January is excluded for not having enough individuals measured.

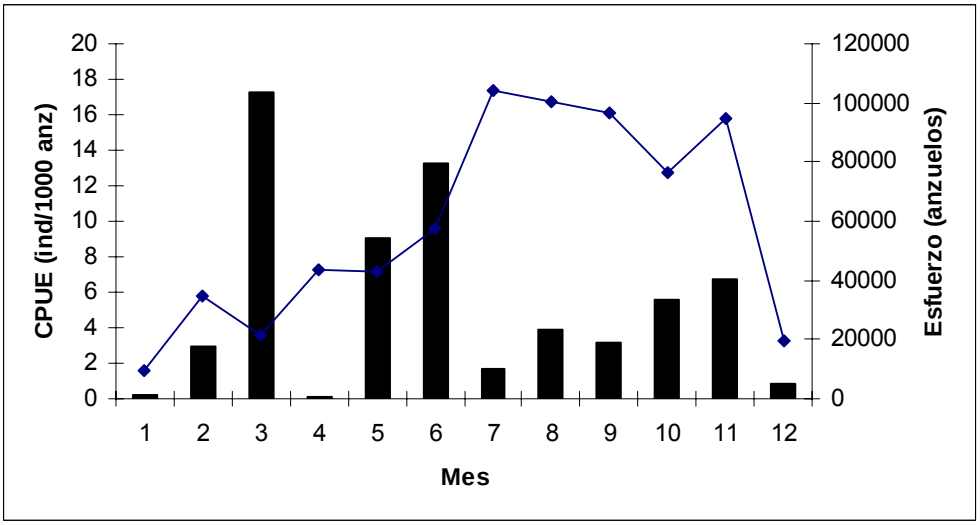


Figure 13. CPUE of *T. albacares* and effort per month for Uruguayan territorial waters and international adjacent waters for the period 1998-2007.

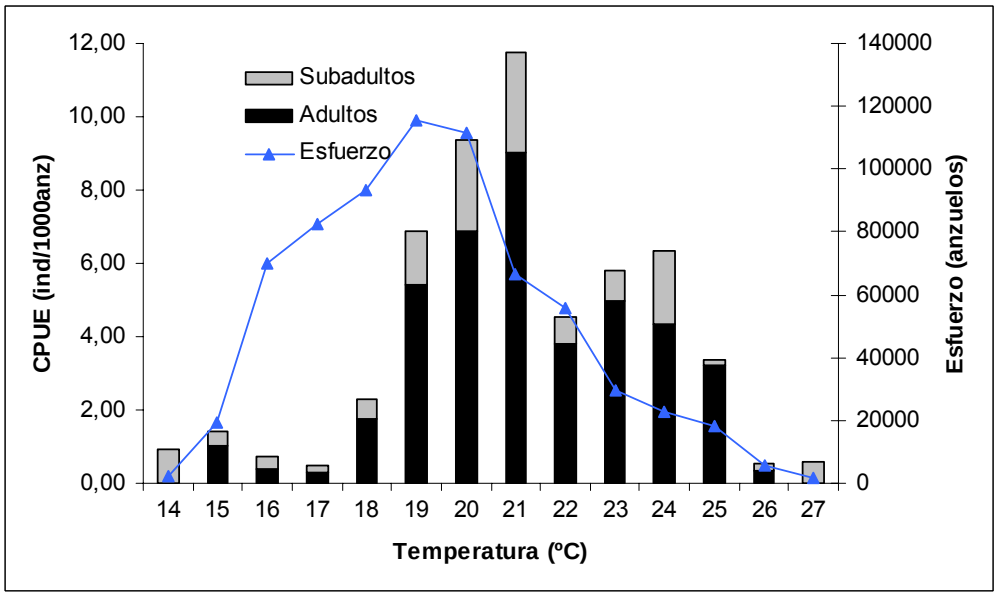


Figure 14. CPUE of subadults and adults and effort accumulated per SST grade, for Uruguayan territorial waters and international adjacent waters.