SPATIAL AND TEMPORAL DISTRIBUTION, SIZE AND SEX COMPOSITION OF THE YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE SOUTHWEST ATLANTIC OCEAN

Andrés Domingo[1], Mariana Rios[1], Maite Pons[1]

SUMMARY

The present study analyses information on captures, effort, size and sex composition of Thunnus albacares *collected by the Uruguayan Observers Program of the Tuna Fleet (PNOFA) for the period 1998- 2007. Only data collected in the South West Atlantic, west of 20º W were used. The spatial and temporal distribution and size and sex composition of the captures was analyzed, as well as the proportion of subadults and adults in relation to spatial and temporal factors and to the sea surface temperature (SST).* T. albacares was *captured throughout the whole fishing area, with larger captures, especially of subadults, in Uruguayan territorial waters close to the continental slope. The mean length recorded for the whole period of study was 111,2 cm ± 16,7 cm (range: 52 cm-180 cm). The male:female ratio was 1,3:1. The higher CPUE was recorded between 35ºS and 37ºS, reaching its maximum under a SST of 19ºC to 21ºC.*

RÉSUMÉ

La présente étude analyse les informations sur les captures, l'effort, la composition par taille et par sexe du Thunnus albacares *collectées par le Programme national d'observateurs de la flottille thonière uruguayenne (PNOFA) pour la période 1998-2007. Seules les données collectées dans l'Atlantique Sud-Ouest, à l'ouest de 20º W, ont été utilisées. La distribution spatio-temporelle et la composition par taille et par sexe des captures ont été analysées ainsi que la proportion des sous-adultes et des adultes par rapport aux facteurs spatio-temporels et à la température de la mer en surface (SST). Le* T. albacares *était capturé dans toute la zone de pêche, avec de plus fortes captures, notamment de sous-adultes, dans les eaux territoriales de l'Uruguay près du plateau continental. La taille moyenne enregistrée pour toute la période à l'étude s'élevait à 111,2 cm ± 16,7 cm (gamme: 52 cm-180 cm). Le ratio de mâle:femelle était de 1,3:1. La CPUE la plus élevée a été enregistrée entre 35ºS et 37ºS, atteignant son maximum dans une SST de 19ºC à 21ºC.*

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 2007, sobre captura, esfuerzo y composición por tallas y sexo de Thunnus albacares. *Se utilizaron únicamente los datos obtenidos en el océano Atlántico sur, al Oeste de los 20ºW. Se analiza la distribución espaciotemporal y la composición por tallas y sexo de las capturas, así como la proporción de subadultos y adultos, en función de factores espaciotemporales y de la temperatura superficial del agua (TSA). Las capturas de* T. albacares *estuvieron distribuidas en el total del área de pesca, con mayores capturas, especialmente de subadultos, dentro de aguas jurisdiccionales uruguayas, en la zona cercana al talud continental. La talla media registrada para todo el período de estudio fue de 111,2 cm ± 16,7 cm (rango: 52 cm -180 cm) y la composición sexual de 1,3 machos por cada hembra. Los valores más altos de CPUE se registraron entre los 35º y los 37º de latitud sur, alcanzando sus valores máximos entre los 19ºC y 21ºC TSA.*

KEY WORDS

Yellowfin tuna, distribution, longline, Uruguay, SST

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1. Introduction

The yellowfin tuna (*Thunnus albacares*) is a cosmopolitan species that occurs in the Atlantic Ocean as a single stock (Anon. 2004; Fonteneau & Soubrier 1996; Bard & Scout 1992). In the West, it is distributed from the south of Canada up to the north of Argentina (FAO Fisheries Department, 1994).

Juveniles are more often distributed in coastal equatorial waters, while subadults and adults reach higher latitudes and more oceanic waters.

The migratory pattern of this species in the tropical Atlantic comprises four stages: 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 (iv) transatlantic migration from West to East between October and December (Hazin, 1993).

In the West Atlantic, juvenile concentrations can observed next to shore on the South and Southeast coast of Brazil from March to October, while larger individuals can be seen further off, in isolated schools (Costa *et al*. 2005). Zavala-Camin (1978) found that adults perform semestral trophic migrations between equatorial zones and the South and Southeast of Brazil, in the periods of March-August and September-February.

Usually, captures consist mainly of specimens measuring between 40 and 170 cm fork length (FL) (Anon, 2004) with a maximum recorded size of 239 cm (International Game Fish Association 2001). According to Fonteneau (1992), in the eastern Atlantic the main captures consist of individuals below 50 cm or over 140 cms while in the West medium size individuals (between 50 and 140) are the most frequently captured.

T. albacares occurs more often with SST ranging from 18ºC to 31ºC (Laevastu & Rosa, 1963), spending more than 90% of the time in waters with a uniform temperature over than 22 ºC (Brill *et al*. 1999, Brill *et al*. 2005).

In the present study we analyze the information on captures, effort, length and sex composition of *T. albacares* collected by the Uruguayan Tuna Fleet National Observers Program (PNOFA) (Mora & Domingo 2006) for the period 1998- 2007. We also analyze the proportion of subadults and adults spatially and temporally and in function of the SST.

2. Material and methods

For the present study we used data collected by the PNOFA west of 20^{o}W. At the beginning of every fishing set the latitude, longitude and SST in ºC were recorded. In addition, we recorded the number of individuals captured and the effort in number of hooks and, where possible, FL in cm and sex. On the basis of the size information obtained we made histograms and determined mean sizes per year and per month.

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

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

For this area, we analyzed the proportion of subadults and adults by month for the period of study. The CPUE was analyzed per month and accumulated per SST grade. For the spatial analysis of captures, the subzone was divided into the continental slope (from the 2000m isobath to the continental platform) and outer waters (from 2000m isobath to deeper waters).

The spatial distribution of captures and effort were analyzed using ESRI ArcMap 8.3 software.

3. Results

A total of 1.415 fishing sets, comprising 2.826.259 hooks, were observed out of 8.053 sets and 9.428.890 hooks declared in the fishing logbooks. The average percentage of sets monitored by the PNOFA was 31% of the total number declared by the longline fleet for the period 1998-2007. Except for 1998, 2000 and 2001 (with a

coverage of 9%, 3% y 6% respectively), such percentage was over 10%, reaching 42% and 80% in 2004 and 2007, respectively (**Figure 2**). The effort of the PNOFA was homogeneously distributed in relation to the effort of the fleet (**Figure 1**). *T. albacares* was captured throughout the whole fishing area (**Figure 3**), with larger captures in Uruguayan and adjacent international waters, on the continental slope, between the 34ºS and 37ºS.

A total of 2.369 individuals were measured. The length mean recorded for the period of study was 111,2 cm ± 16,7 cm FL (range: 52 cm -180 cm). **Figure 4A** shows the length means per year: the minimum FL mean was recorded in 2002 (101,5 cm ± 15,4 cm) and the maximum in 1998 (127,7 cm ± 8,9 cm). The means for all years were over 100 cm FL. The monthly analysis showed lower length means between May and August, with a minimum of 99,0 cm ± 14,7 cm in August and a maximum of 144,5 cm ± 12,9 cm in December (**Figure 4B**).

Out of the total of individuals measured, 1.141 were sexed. The male:female ratio was 1,3:1. Both sexes showed a similar FL mean: 116,9 cm ±15,4 cm (range: 65 cm -180 cm) for males and 117,1 cm ± 14,0 cm. (range: 65 cm -162 cm) for females (**Figure 5**).

While adults were captured throughout the whole fishing area, subadults were more often captured close to the continental slope (**Figure 6**).

The higher CPUE values were recorded between 35ºS and 37ºS for both subadults and adults, reaching a maximum at 36ºS (1,6 and 4,7 ind/1000 hooks for subadults and adults respectively), this being the latitude where the highest effort was recorded. Despite the fact that the effort between 35ºS and 37ºS and between 29ºS and 33ºS, was similar, CPUE values in the latter area were much lower (**Figure 7**).

The fleet operated within a SST range of 8ºC and 29ºC, with a higher effort as from 19ºC. *T. albacares* was captured with SST in the range of 12º C to 29 ºC. For both subadults and adults the CPUE was higher in the SST range of 19ºC to 21ºC, with a maximum at 21ºC (2,0 and 7,1 ind/ 1000 hooks for subadults and adults respectively) and a minimum for both stages when the SST was over 25ºC (**Figure 8**).

Ninety-two percent of the captures of *T. albacares* occurred in Uruguayan territorial waters and adjacent international waters, reaching a CPUE of 5,7 ind/1000 hooks, that is 4 times higher than the CPUE for the whole fishing area, which is calculated in 1,4 ind/1000 hooks. The number of individuals captured on the continental slope was higher than that recorded off this depth: 421 subadults and 1.147 adults, and 75 subadults and 455 adults, respectively (**Figure 9**).

The length mean recorded for the period of study was 110,2 cm ± 15,9 cm (range: 52 cm -180 cm). **Figure 10A** shows FL means per year: the lowest was recorded in 1999 (95,9 cm ± 15,2 cm, range: 52 cm -155 cm) and the highest in 1998 (127,7 cm ± 8,9 cm, range: 75 cm -151 cm). The lowest mean value was recorded in August (99,0 cm ± 14,7cm) and the maximum in December (144,5 cm ± 12,9 cm) (**Figure 10B**).

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

The proportion of subadults and adults, accumulated monthly for the whole period, shows no clear tendencies. Values close to 100% of adults were observed in February, June and July, reaching 100% of adults in December. May and August presented a proportion close to 50% of subadults, August being the only month when the captures of subadults exceeded those of adults (**Figure 12**).

Maximum CPUE values were recorded in March, followed 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 and 25º C, reaching maximum values for subadults and adults at 21ºC (2,7 and 9,0 ind/1000 hooks, respectively) (**Figure 14**).

4. Discussion

The length range observed, with a mode between 100 cm and 140 cm FL, corresponding to subadults and adults, agrees with Fonteneau (1992), who states that medium size classes (between 50 and 140 cm FL) predominate in the West Atlantic. Few larger individuals were recorded, representing only 0,04 % of the individuals measured.

The SST range whithin which *T. albacares* was captured in the whole fishing area (12ºC to 29ºC), was wider than the range reported by Laevastu & Rosa (1963) (18ºC to 31ºC). Higher CPUE values were recorded between 19 to 21ºC.

For both subadults and adults the captures were abundant on the continental slope, which agrees with data recorded for other target species, such as swordfish (Domingo *et al*. 2007; Mora *et al*. 1991; Mora 1988; Rios *et al*. 1986), as well as for bycatch species (Jiménez & Domingo 2007; Domingo *et al*. 2006). The high productivity of this area is due to the confluence of the cold Malvinas current, the warm Brazilian current and the Rio de la Plata discharge. The two currents form a thermohalin front, known as Subtropical Brazil-Malvinas confluence. The abundance of food sustains high trophic levels such as tunas, swordfish and big mammals (Acha *et al*, 2004; Olson, 2002; Passadore *et al*. 2004, 2007) that causes the Uruguayan fleet to concentrate its effort in the area.

Within the subzone of analysis, size range histograms and FL boxplots were similar to those obtained for the whole fishing area. Length mean values usually exceeded 100 cm FL for every year, which would mean that the Uruguayan longline fleet captures mostly adults. This can be explained by the spatial distribution of the size classes, as well as by the selectivity of the fishing gear (Costa *et al.*, 2005). In the past 3 years, a small increase of the size means was observed.

In the South West Atlantic, Costa *et al*. (2005) found a higher proportion of adults during the period August–April, while observing an increment in the amount of juveniles during the period May-July, probably caused by the adults migrating to the Venezuelan Caribbean to reproduce in August and September. In the present study no clear seasonality in the proportion of subadults/adults, related to the migratory periods proposed by other authors (Costa *et al*. 2005; Zavala-Camin, 1978) was evident. In Uruguayan waters, an increase on subadult captures was observed in May and August and a decrease in the cold months of June and July and in the summer.

Previous studies published by Zagaglia *et al*. (2004) suggest that the captures of *T. albacares* are not directly related to the SST. Still, this study shows that this species would have preference for a SST range of 19^{o}C to 21^{o}C.

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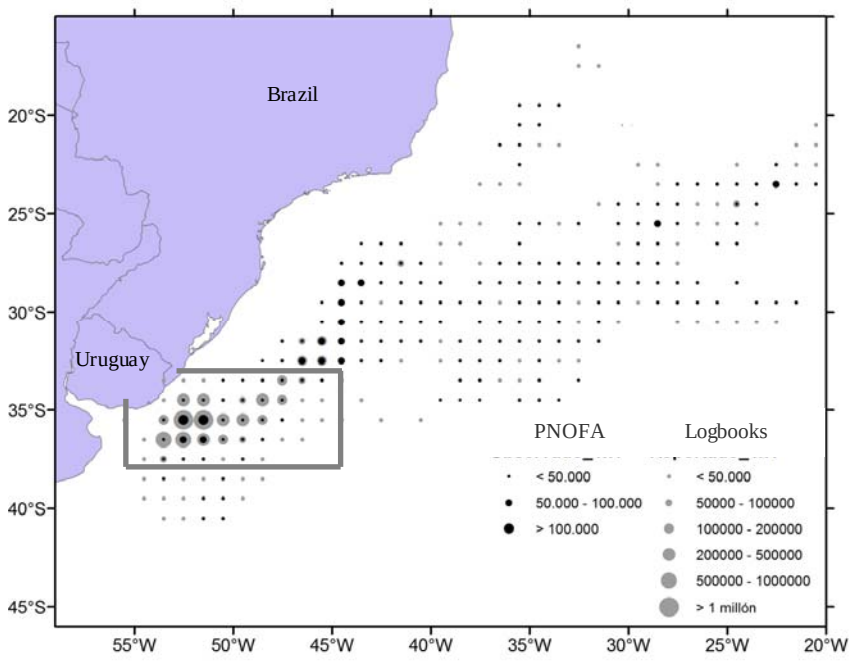


Figure 1. Effort observed by the PNOFA (black dots) and the effort declared in the logbooks by the Uruguayan longline fleet (gray dots), for the period 1998-2007, integrated in 1º x 1º areas. In the gray square is indicated the subzona that comprises Uruguayan territorial waters and international adjacent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

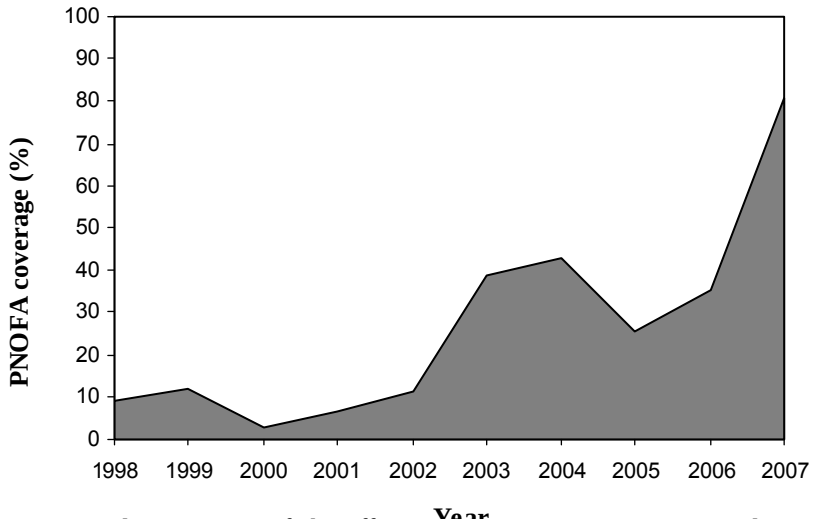


Figure 2. Annual percentage of the effort PNOFA, in relation to the effort declared by the Uruguayan longline fleet.

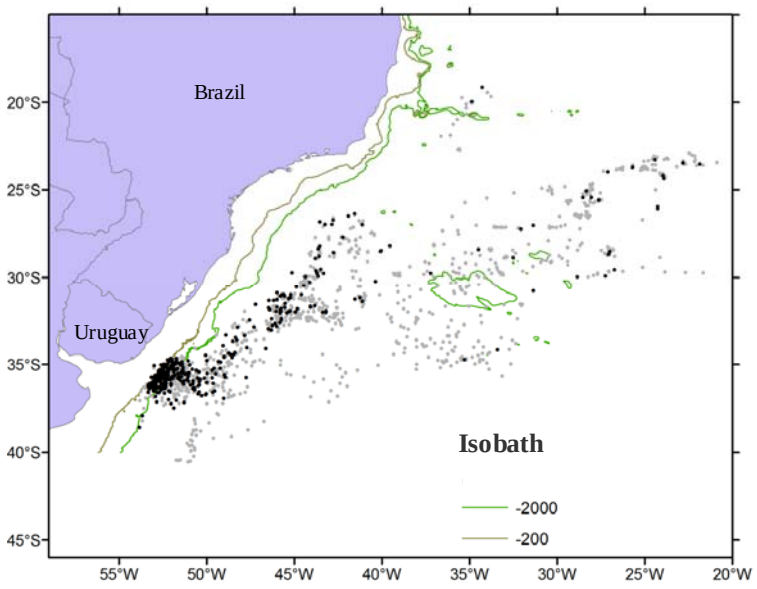


Figure 3. Sets with *T. albacares* captures (black dots) and total amount of sets (gray) accumulated for the whole studying period (1998-2007).

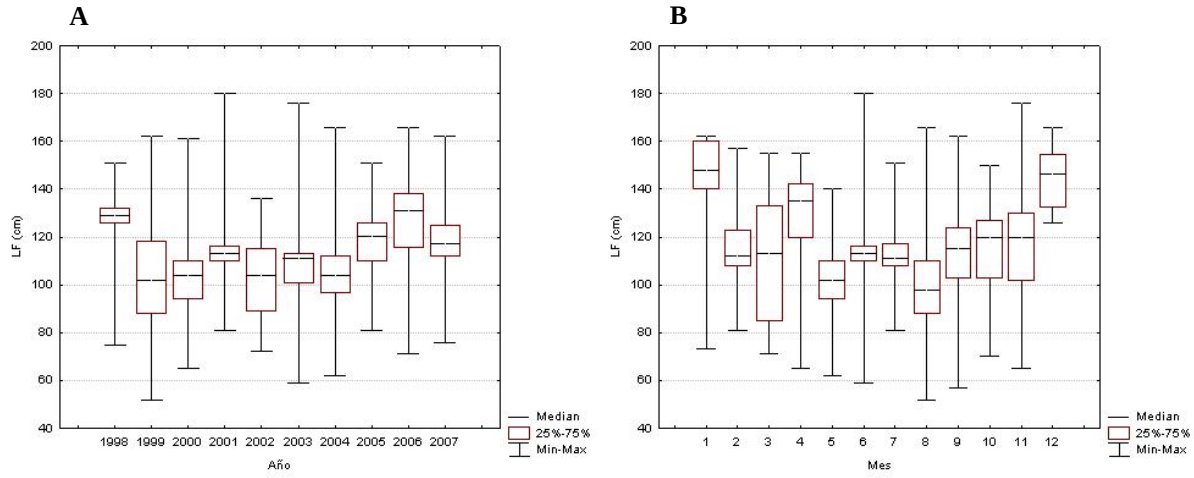


Figure 4. Boxplots (median, first and third quartile, minimum and maximum) of FL in cm, accumulated per year **(A)** and month **(B)** for the whole fishing area.

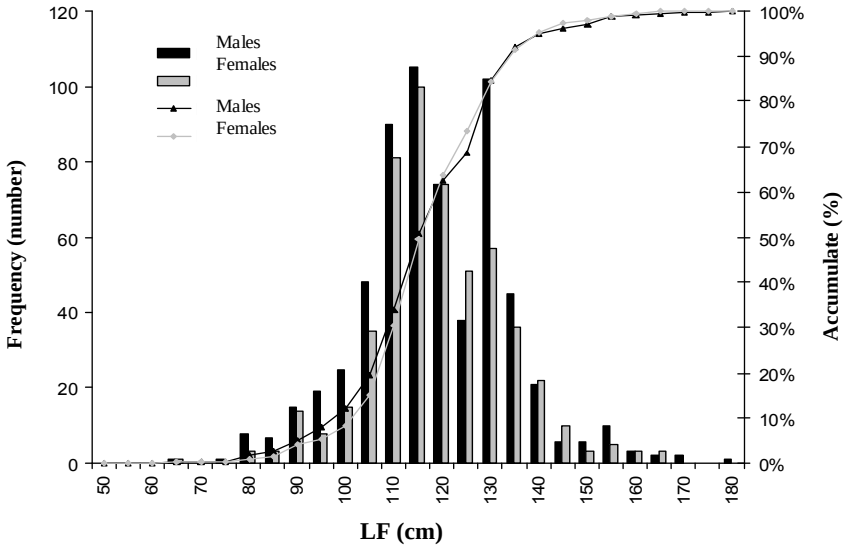


Figure 5. Size classes of males and females frequency histogram (classes range = 5 cm FL) and accumulated percentage per sex, for the whole fishing area.

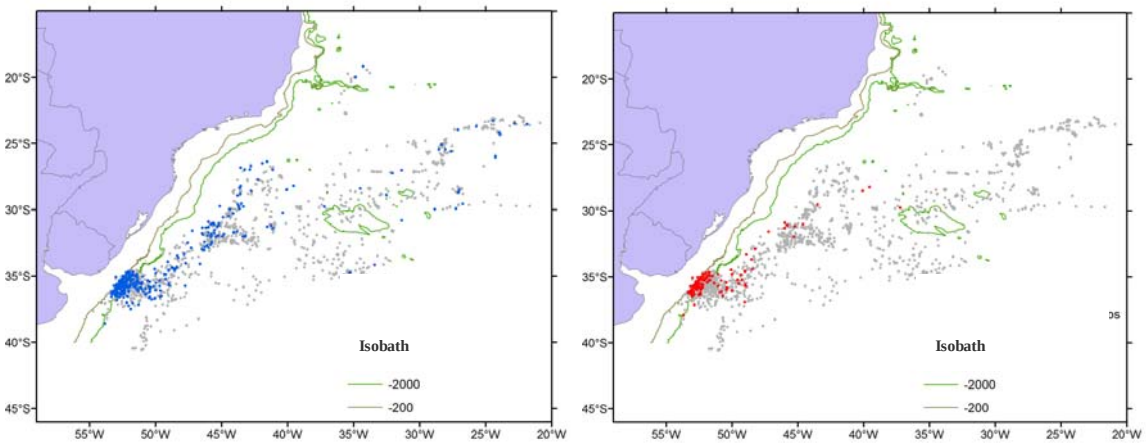


Figure 6. Sets with *T. albacares* captures and total amount of sets (gray) accumulated for the whole studying period (1998-2007), for adults (blue dots) and subadults (red dots).

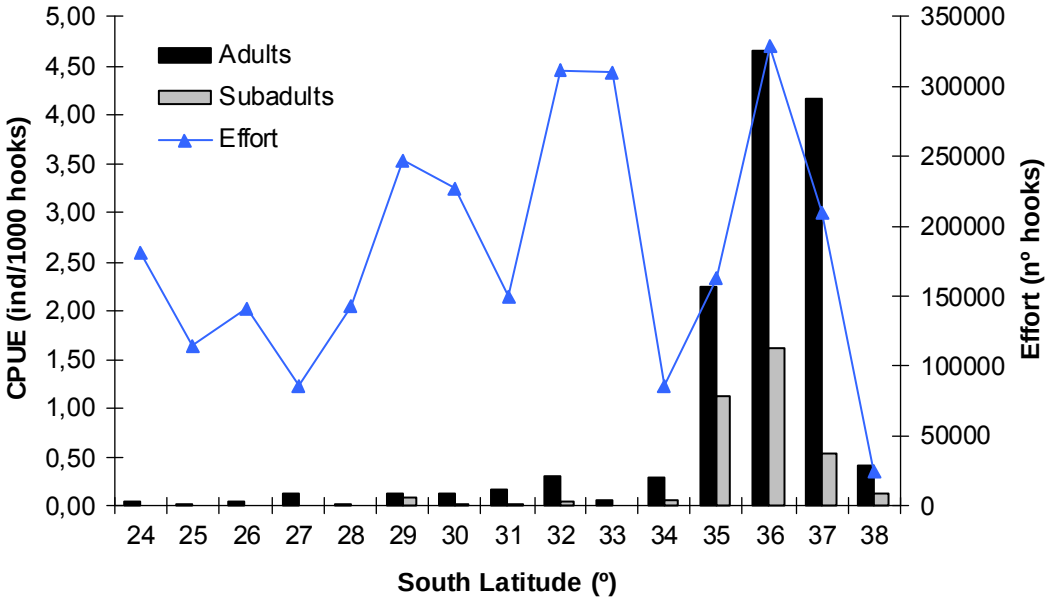


Figure 7. CPUE of subadults and adults and effort, accumulated per latitude grade, for the whole fishing area.

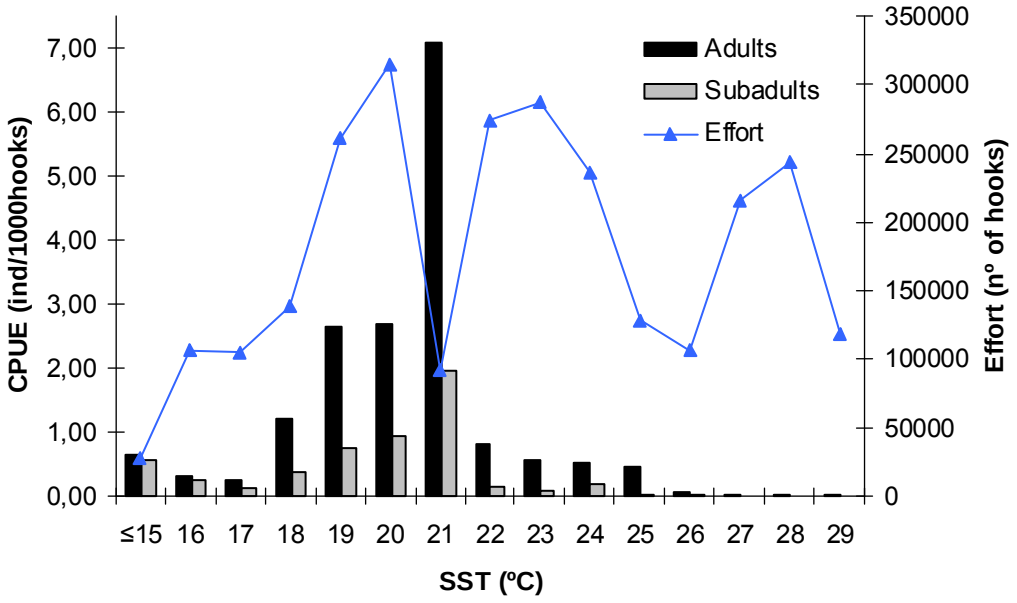


Figure 8. CPUE of subadults and adults and effort accumulated per SST grade for the whole fishing area.

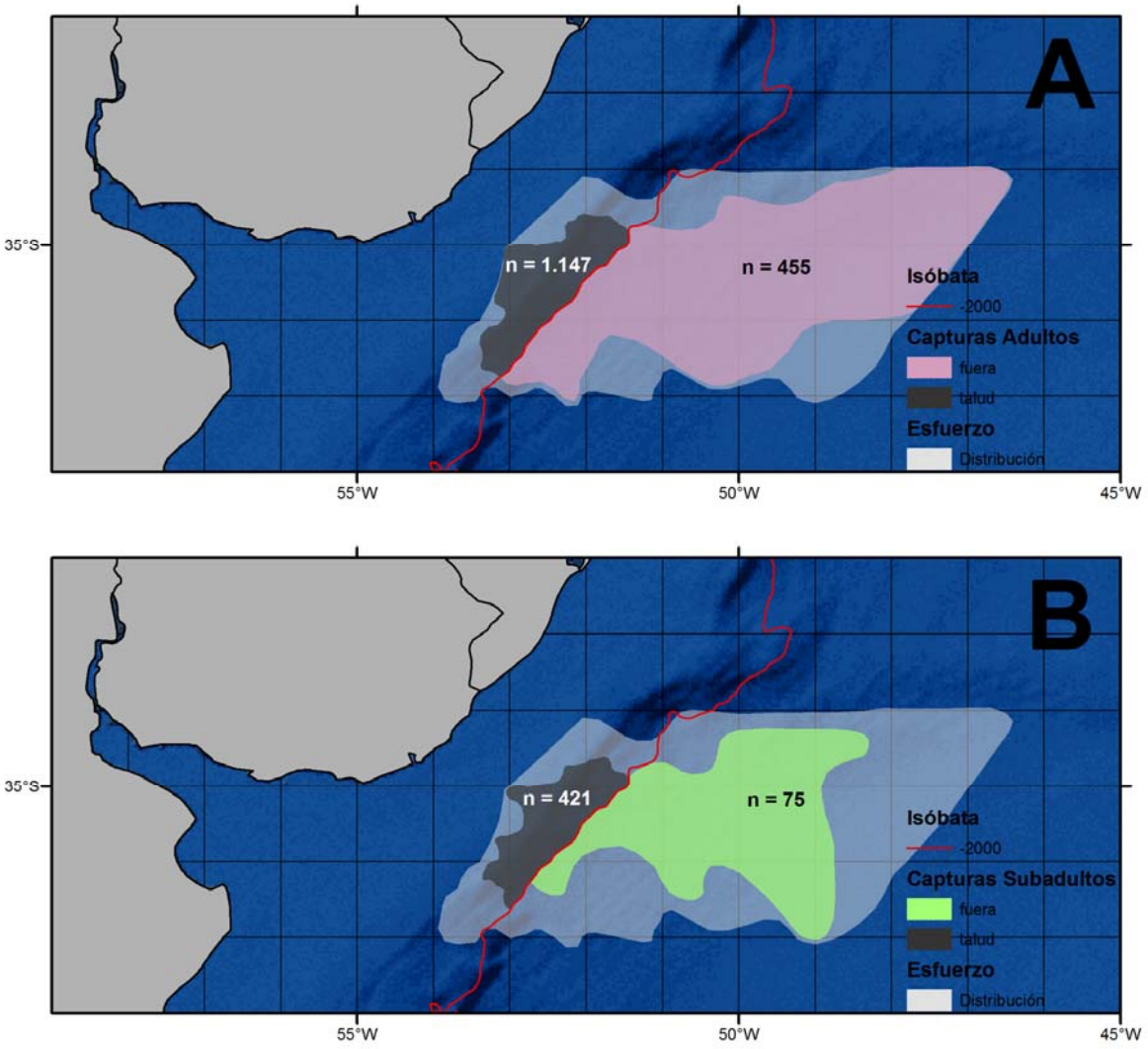


Figure 9. Spatial distribution of the *T. albacares* captures and effort (light gray in A and B) in Uruguayan territorial waters and international adjacent waters, accumulated for the whole studying period. **(A)** adults (dark gray and light pink) and **(B)** subadults (dark gray and light green).

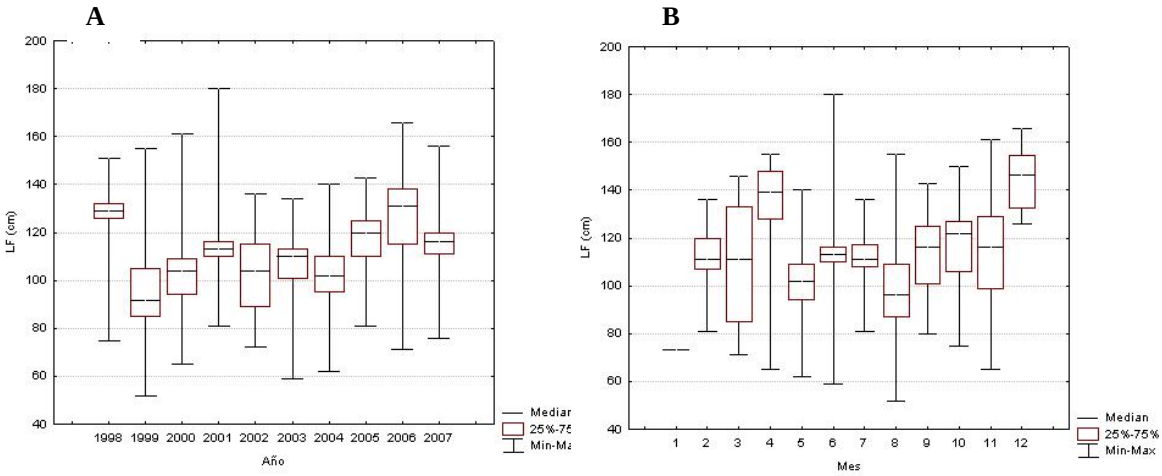


Figure 10. Boxplots (median, first and third quartile, minimum and maximum) of FL in cm, accumulated per year **(A)** and month **(B)** for Uruguayan territorial waters and international adjacent waters. In B January is excluded for not having enough measurement for the analysis.

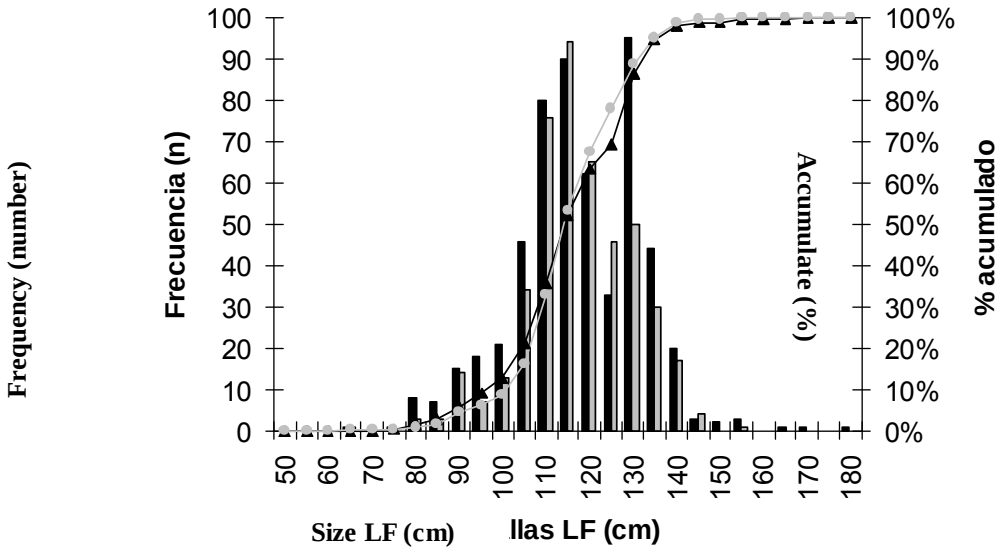


Figure 11. Size classes of males (in black) and females (grey) frequency histogram (classes range = 5 cm FL) and accumulated percentage per sex, for Uruguayan territorial waters and international adjacent waters.

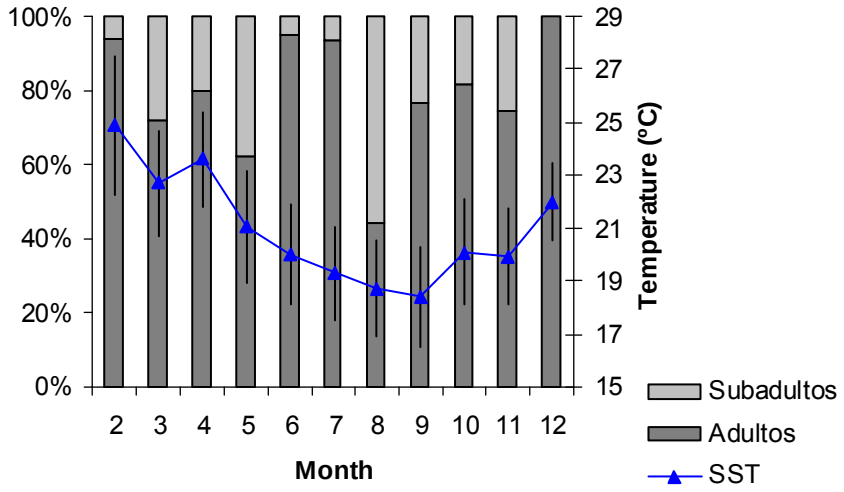


Figure 12. Subadults and adults' proportion (%) and SST mean and SD accumulated per month, for Uruguayan territorial waters and international adjacent waters. January is excluded for not having enough individuals measured.

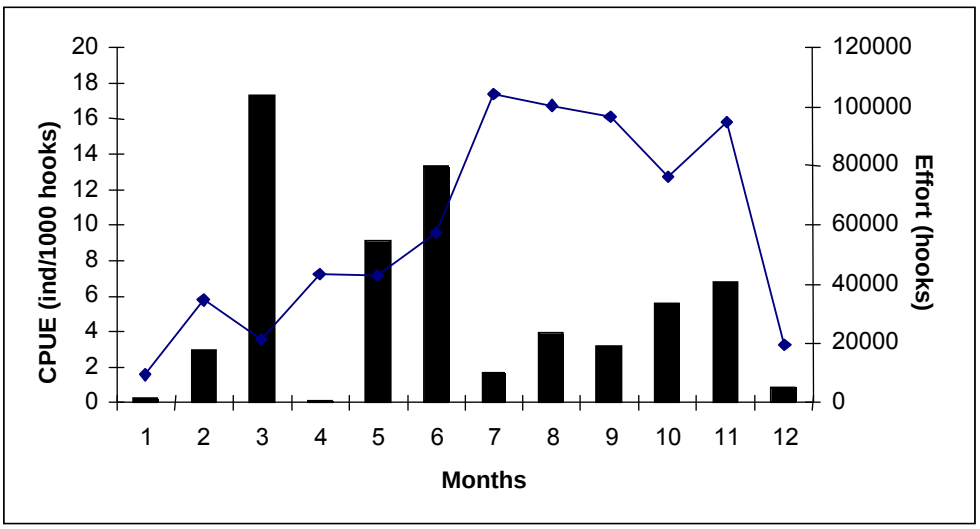


Figure 13. CPUE of *T. albacares* and effort per month for Uruguayan territorial waters and international adjacent waters for the period 1998-2007.

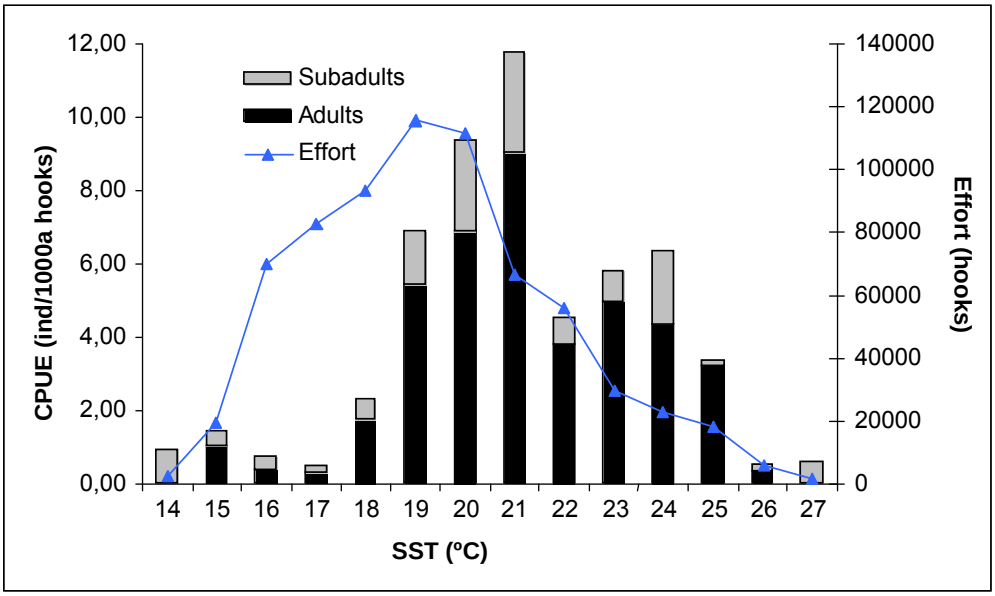


Figure 14. CPUE of subadults and adults and effort accumulated per SST grade, for Uruguayan territorial waters and international adjacent waters.