Collect. Vol. Sci. Pap. ICCAT, 81(3), SCRS/2024/156: 1-16 (2024)

THUNNUS ALALUNGA (BONATERRE 1788) REPRODUCTIVE BIOLOGY STUDY IN SOUTH ATLANTIC

P. Travassos[1], P. Souza[1], M.L.G. de Araújo[1], M. Rêgo[2], J. Evêncio.[2], L.G. Cardoso[3], W. West, S. Kerwath[4], A. Domingo[5], R. Forselledo[5], N-J Su[6], F. Santana[7], C. Jagger[8]

SUMMARY

Information on reproduction biology for South Atlantic Thunnus alalunga *is limited. Samples were collected and analyzed to study the reproductive biology of fish caught by the fleets of the countries collaborating in this research. The range of FL was 76-125 cm. The histological criteria used to assess the maturity status indicate that reproductive activity occurred in 63.6% of the mature individuals analyzed, 30.2% of adults were in regressing phase and only 2.8% of individuals were classified immature phase. The range of the number of rings in the spine sections analyzed was 6 to 9 rings. After reviewing the maturation stages of some specimens, the L50 was estimated again, resulting in 88.0 cm FL for males and 89.7 cm for females. Batch fecundity ranged from 0.14 to 1.7 million oocytes. It is estimated that* T. alalunga *spawns in the tropical south-west Atlantic between austral spring and summer.*

RÉSUMÉ

Les informations sur la biologie de la reproduction du Thunnus alalunga de l'Atlantique Sud sont limitées. Des échantillons ont été collectés et analysés afin d'étudier la biologie de la reproduction des poissons capturés par les flottilles des pays collaborant à cette recherche. La fourchette de la longueur à la fourche (FL) était comprise entre 76 et 125 cm. Les critères histologiques utilisés pour évaluer le statut de maturité indiquent que l'activité reproductrice a eu lieu chez 63,6 % des spécimens matures analysés, 30,2% des adultes étaient en phase de régression et seulement 2,8% des spécimens étaient classés en phase immature. Le nombre d'anneaux dans les sections de l'épine analysées était compris entre 6 et 9 anneaux. Après avoir revu les stades de maturation de certains spécimens, la L50 a été estimée à nouveau, ce qui a donné 88,0 cm FL pour les mâles et 89,7 cm pour les femelles. La fécondité moyenne par acte de ponte était comprise entre 0,14 et 1,7 million d'ovocytes. Il est estimé que T. alalunga se reproduit dans l'Atlantique tropical sud-ouest entre le printemps et l'été austral.

RESUMEN

La información sobre la biología reproductiva para el Thunnus alalunga *del Atlántico sur es limitada. Se recogieron y analizaron muestras para estudiar la biología reproductiva de los peces capturados por flotas de países que colaboran en esta investigación. El rango de FL era de 76-125 cm. Los criterios histológicos utilizados para evaluar el estado de madurez indican que la actividad reproductora se produjo en el 63,6 % de los ejemplares maduros analizados, el 30,2 % de los adultos se encontraban en fase de regresión y sólo el 2,8 % de los ejemplares se*

[1] Laboratório de Ecologia Marinha, Universidade Federal Rural de Recife, Rua Dom Manoel de Medeiros, s/n. CEP 52.171-900, Recife-PE, Brazil (Corresponding author);

[2] Laboratório de Morfologia Animal, Universidade Federal Rural de Recife, Rua Dom Manoel de Medeiros, s/n. CEP 52.171-900, Recife-PE, Brazil;

[3] Laboratório de Recursos Pesqueiros Demersais e Cefalópodes, Fundação Universidade Federal de Rio Grande, Av. Itália, Km 8, CEP 96.901-200

[4] Department of Forestry, Fisheries, and the Environment, South Africa

[5] Dirección Nacional de Recursos Acuáticos (DINARA), Constituyente 1497, 11200, Montevideo, Uruguay

[6] Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, 2, Pei-Ning Road, Keelung City, 20224 Taiwan

[7] Universidade Federal Rural de Recife, Unidade Acadêmica de Serra Talhada (UAST), Av. Gregório Ferraz Nogueira, s/n - Serra Talhada, PE, 56909-535

[8] National Marine Information and Research Centre, Ministry of Fisheries and Marine Resources, 1 Strand Street, P.O.Box 912, Swakopmund, Namibia.

clasificaron en fase inmadura. El rango del número de anillos en las secciones de espinas analizadas fue de 6 a 9 anillos. Tras revisar las etapas de madurez de algunos ejemplares, se volvió a estimar la L50, teniendo como resultado 88,0 cm FL para los machos y 89,7 cm para las hembras. La fecundidad por lotes osciló entre 0,14 y 1,7 millones de ovocitos. Se estima que el T. alalunga *desova en el Atlántico tropical suroccidental entre la primavera y el verano austral.*

KEYWORDS

Reproduction, albacore, maturation size, longline

1. Introduction

Thunnus alalunga (Bonnaterre, 1788) is a species that can be found in all oceans, as well as the Mediterranean Sea (Colette & Nauen,1983). In the Atlantic Ocean, albacore is found at latitudes ranging from 45ºN to 45ºS and, as a temperate water species, it is more abundant in colder waters, ranging from 16° to 20°C. These small temperature ranges can act as a barrier to albacore movements, separating populations as it occurs in the Atlantic Ocean (Penney et al., 1998). For this and other reasons, the International Commission for the Conservation of Atlantic Tuna (ICCAT) considers three populations of this species in the Atlantic Ocean: North Atlantic, South Atlantic, and Mediterranean.

In the South Atlantic the species migrates between the latitudes of 5ºS and 40ºS, moving between feeding and breeding areas. This migration is influenced by temperature, which is a fundamental factor in determining the species' catch period in the tropic waters of the South Atlantic, which basically affects adult fish (Colette & Nauen,1983; Dhurmeea *et al.*, 2016). Albacore form separate groups based on the spatio-temporal distribution of the stages of their life cycle, with marked effects on their fisheries (Coimbra, 1999). Travassos (1999) proposed a westward migratory reproductive circuit based on catch composition and sea surface temperature data in the South Atlantic. Adult individuals of albacore tuna are highly concentrated between 5ºS and 25ºS during the southern spring/summer seasons, where spawned individuals were observed along the Brazilian coast Pedrosa, 2011).

Although it is currently assumed that the first maturity of Atlantic albacore occurs at 90 cm and 5 years of age (Bard, 1981), information on the reproductive biology of *Thunnus alalunga* in the South Atlantic is still necessary. Some stock assessment models benefit from reproductive parameters such as size and age at first maturity, gonad index, fecundity and others, improving the accuracy of catch limit estimates.

This report presents the recent progress made in the continuation of the study on the reproductive biology of albacore tuna in the South Atlantic. It highlights the acquisition of new samples obtained from the Chinese Taipei fleet (n = 161), as well as the ongoing processing of samples (n = 39) collected by the fleet operating in the Northeast region of Brazil.

In addition, 86 new samples were received from the Chinese Taipei fleet and are currently being processed for further analysis

2. Material and Methods

During the period of execution of this contract, new samples were collected, complementing those obtained by Brazil (July/2021 to October/2023) and Chinese Taipei (November-December/2021). These new samples were collected by the partner countries as follows: Brazil (n = 40), Chinese Taipei (n = 161), South Africa (n = 80) and Namibia (n = 60). Only those from Brazil and Chinese Taipei were analysed and their results included in this report. The samples from South Africa arrived in Brazil in mid-July (São Paulo airport) but were retained by the Brazilian sanitary authority and not released for lack of the required document. The samples from Namibia are ready to be shipped to Brazil but are awaiting documentation to fulfil the export/import requirements between the two countries. Samples collected in periods prior to the project and provided by Brazil (2005-2010), Uruguay (2013-2016) and South Africa (2012-2018) were included in the analyses (**Figure 1; Table 1**).

The methodology adopted from the beginning of the research was followed, as detailed below.

Each albacore tuna specimen was measured for FL and weight, and its gonads were extracted for macro and microscopic analysis. In the laboratory, the gonads were individually weighed (±0.1 g) after thawing. After testing the data's normality, the fork length frequency distribution for the 5.0 cm size class was drawn up for each fleet individually.

Each individual gonad was staged according to the macroscopic and microscopic characteristics (Brown-Peterson et al., 2011; Schaefer, 2003; Gálvez and Castillo, 2015). For the estimation of the size at 50% sexual maturity for males and females, all fish in the immature and development maturation stage were classified as immature (0), and all fish developing, capable to reproduce, active and regressing were classified as mature (1). The binomial 0 and 1 fit the logistic equation to estimate the length at which 50 % of the population reaches sexual maturity.

$$P = \frac{e^{\,(a+b*FL)}}{1+e^{(a+b*FL)}}$$

Where: P - is the probability that an individual is mature in a specific length, and a and b are parameters of the model.

L50 was estimated as $L50 = \frac{-a}{b}$.

To identify the presence of maturational stages by size class, frequency distributions of maturational stages by size class were made for the samples from Brazil fleet, China Taipei flee and Uruguay fleet.

The fecundity was estimated according to Hunter et al. (1985), because the species has indeterminate fecundity, and spawning occurs in batches. For each batch, fecundity was calculated by counting the hydrated oocytes. Three sub-samples (0.5 g) were taken from the median portion of seven ovaries in different months and dissected to counting hydrated oocyte.

The monthly average gonad index GI was calculated for male and female albacores caught by the Brazilian and Chinese Taipei longline fleets in the South Atlantic using the given formula: GI = (GW/FL3)× 104, where GI is gonadal index; GW is gonad weight (g), FL is fork length.

For age assessment, eighty-seven spines were sampled. Each spine was measured, and a piece removed above the condyle between 5 and 20% of the length of the spine. This piece was embedded in polyester resin and cut in a metal saw for further reading (counting and measuring the distance from the nucleus to each ring) under a stereoscopic microscope at 20x magnification. In addition, ten individuals were sampled to obtain sagittal otoliths to identify age rings of the first few years of life, as the central vascular zone of the spine obscures early age rings.

3. Results and discussion

3.1 Size and sex ratio

During the study period, a total of 873 specimens were sampled: Brazil/Recife fleet, n = 165; Brazil/Rio Grande fleet, n = 52; China Taipei fleet, n = 301; Uruguay fleet, n = 55 (historical data); and South Africa fleet, n = 300 (historical data). Out of this total, 869 individuals were sexed. Among all the albacore specimens sampled, males (n = 554; 63.8%) predominated over females (n = 315; 36.2%), resulting in a sex ratio of 1.8M: 1F (a significant difference at the 5% level; $\chi^2 = 7.5$; GL = 1; $p = 0.0006$).

The males exhibited a larger fork length (FL) than the females, ranging from 70 to 125 cm ($\bar{x} = 102.5 \pm 8.6$) and 60 to 112 cm ($\bar{x} = 99.1 \pm 8.7$), respectively. The highest frequency of FL occurred in the 100–105 cm FL class for both sexes, considering the catches from all fleets. Statistical differences were observed in the length class distribution between sexes (Mann-Whitney: U = 68; $p = 0.39$) (**Figure 2**).

The furcal length CF ranged from 81.0 to 125.0 cm, considering all the specimens caught by the Brazilian fleet: Recife, Rio Grande. The lowest length range was observed for Rio Grande (81.0-110.0), with an average value of 96.5 cm. Statistically, the sex ratio for the individuals caught by the Recife and Rio Grande fleet differed from what was expected (2.8M:1F; $\chi2$ = 22.9; 2.3M:1F; $\chi2$ = 14.8), while for the catches made in Chinese Taipei and Uruguay no statistical difference was observed in the sex ratio (1.4M:1F; $\chi2$ = 2.9 and 1.1M:1F; $\chi2$ = 1.6, respectively). Unlike the previous results, where the minimum catch length for the China Taipei fleet was 99.0 cm CF, the recently analyzed data showed that the smallest individuals CF = 60 cm were caught by this fleet.

The smallest individuals were caught by Chinese Taipei fleet, there was a minimum of 60.0 cm and a maximum of 111.0 cm CF ($\bar{x}$ = 98.8 cm CF), Uruguayan fleet, with a minimum CF value of 76.0 cm and a maximum of 115.0 cm ($\bar{x}$ = 96.3 cm CF) and African fleet, with a minimum CF value of 63.0 cm and a maximum of 119.0 cm ($\bar{x}$ = 87.3 cm CF) (**Table 1**). The South African fleet caught a wider range of individuals than the Uruguayan fleet, including the smallest ones (**Table 1 and Figure 2**). The mode of the size distribution for the South African sample was in the 80-85 class, while for the Uruguayan sample it was in the 95-9100 class. Despite the temporal variation in data collection, there was a noticeable latitudinal variation in the sizes of the species (**Figure 3**).

The average length found in this study for the samples collected in the western tropical zone of the South Atlantic is similar to the value found by Pedrosa (2011) (**Table 1**). Compared with previous data from South Africa and Uruguay (Travassos et al., 2022), the observed differences reflect the migratory movement of the albacore in the South Atlantic Ocean, as demonstrated by Coimbra (1999). According to Farley et al (2014), the migratory pattern of the albacore creates a latitudinal gradient in size. As a result, the average size of fish caught increases with decreasing latitude.

3.2 Maturity assessment

The study used two hundred and ninety-eight (n = 298) and two hundred and ninety-six (n = 296) individuals for macroscopically (Figures 4 and 5) and microscopically/ histological (Figures 6 and 7) analyses to determine maturation stages, respectively. Based on the degree of turgidity, shape, color, and cells development stages five maturation phases were established for females and males: Immature (Im), Developing (Dv), Capable of reproduction (CR), Active (At) and Regression (Re).

Based on the monthly distribution of the frequency of maturation stages, of the total number of individuals classified as immature (*n* = 28), 92.9% were caught by the Chinese Taipei fleet, and 7.1% by the Rio Grande fleet, considering that of the total number of individuals classified as immature, n = 16 were observed in the catches received and made in 2024.

Only 7.7% of the individuals were classified as immature females (Im), sampled in the months of March, April, May, and July. For males, 5.5% were immature (Im) and were sampled in February, March, April, May, and July. As for the developing individuals (Dv), 20.8% were females and 16.7% males, with the highest percentage of individuals in these stages found in the months of January, February, March, June, July, and August. For the stage capable of reproduction (CR), 20.8% of females and 17.5 of males were observed in November, December. The highest percentages of active individuals (At) (18.2% females, 35.3% males) were observed in September, October, November, December, and January. Individuals classified as regressing (Re) (12.7% females and 25.1% males) were observed in January, February (**Figure 8**).

The largest female and the largest male classified as immature had CF of 92 cm, respectively, both sampled in Chinese Taipei fleet. The smallest immature females had a FL of 60 cm, while the smallest immature male had a FL of 75 cm, both caught off the Chinese Taipei fleet.

The assessment of maturation stages according to fleet-location revealed that at higher latitudes there is a predominance of immature individuals, observed only in the south of Brazil, Chinese Taipei and Uruguay, totaling 64%. There were no individuals classified as Immature (Im) in the north of Brazil/NE. Individuals in the Developing (Dv) stage were observed for all fleets and locations, with a predominance for the south of Brazil (Rio Grande – 58.8%) and Uruguay (47.8 %). As latitude decreases, the percentage of stages indicating reproductive activity becomes more significant of Brazil/NE (11.8% CR and 32.6% Act) and Chinese Taipei fleet (24.2% CR and 24.6% Act) and Regressing (Re) (Brazil/NE: 49.2% and Chinese Taipei: 23.9% fleet), especially at latitudes between 20ºS and 23ºS (**Figure 9**).

In this context, the species breeds in low latitudes after its migratory journey to tropical areas in the western South Atlantic. The greater number of young and developing individuals found in higher latitudes aligns with the study conducted by Travassos et al. (in preparation). The study suggests that the younger members of the species remain in the subtropical and temperate zones on both sides of the South Atlantic Ocean, while the adults carry out their reproductive migration to warm tropical waters and then return to high latitudes of cold waters.

3.3 Size of first maturation $L_{(50)}$

Considering the samples acquired and analyzed by the Chinese Taipei fleet, 16 individuals classified as immature were added, contributing to a more accurate estimation of the L50. Consequently, the size at first maturity (L50) was re-estimated based on a review of the previously established maturation stages for both males and females. The L50 for females was determined to be 89.7 cm FL (confidence interval: 86.1–91.5 cm), while for males it was 88.0 cm FL (confidence interval: 86.8–90.5 cm). The L95 was 94.0 cm for both females and males. However, to obtain a more accurate and precise L50, it is necessary to include smaller individuals, making it essential to analyze samples from Namibia and South Africa.

The relationship between the maturity ratio for females and males by length class revealed that there were no statistical differences between the maturity curves, so only one ogive can represent the species' first maturity value (**Figure 10**). These figures are much lower than those previously estimated in the last report and close to those previously estimated by Bard (1981), which estimated values of 94 cm FL for males and 90 cm for females. These differences may possibly be associated with mistakes in the classification of fish in the developing stage that were classified as immature.

3.4 Type of spawning, fecundity, and gonadal index

The histological analyses of the ovaries for *T. alalunga* reveal an asynchronous development of the oocytes, in which the formation of a single group of oocytes was not observed, i.e. there is no dominant oocyte population present. The ovaries are marked by the presence of primary growing oocytes in the 154├247 class (primary growing oocytes), observed at all stages of development. In the developing stage (Dv), it was possible to observe the formation of batches of oocytes between classes 247├360 and 360├463 (oocytes in alveolar cortex and primary vitellogenesis, respectively). The capable of reproducing (CR) phase is marked by the presence of batches of oocytes between the classes: 463├566 (secondary vitellogenesis) and 566├669 (tertiary vitellogenesis). In the active (At) spawning phase, oocytes were observed in classes of 669├978 and 978├1081, a group of oocytes classified as germinal vesicle migration and hydrated oocytes, respectively. In the regression (Re) phase, a batch of remaining atresic oocytes was observed that were not released during the spawning season.

This behavior in the displacement of oocyte classes during the maturation process indicates that the South Atlantic albacore spawns in batches, of the synchronous type in more than two groups, as it has more than two batches of oocytes that increase synchronously in diameter until the spawning period (**Figure 11**).

For the fecundity estimate, there was no new analysis, and the values already presented are considered here. The average weight of the ovaries used for estimating fecundity was 328.1 g (±164.6 std. dev.), while the fork length of the females ranged from 97.7 to 109.0 cm. The batch fecundity varied from 0.08 to 1.46 million oocytes, and the frequency of hydrated oocytes per 0.5 g batch ranged from 176 to 398. Based on the initial findings, the data shows a high correlation ($r^2 = 0.9621$) between fecundity and gonad weight (**Figure 12**). In this study, individuals caught at latitudes 23º to 25 º S had higher batch fecundity than those caught at latitudes 6º to 9º S (**Figure 13**).

The batch fecundity of *T. alalunga* in this study is comparable to the estimates made by Chen (2010) for albacore in the North Pacific Ocean, which ranged from 0.17 to 1.66 million oocytes. The range of fecundity values estimated by Pedrosa (2011) for albacore caught on Brazil's northeast-southeast coast (0.5 to 1.2 million oocytes) was in small latitude range than observed in this study. The differences in these estimates may be due to spatiotemporal variations of reproductive parameters, which have been previously identified in other oceans, caused by the migratory pattern of the species (Farley et al., 2014).

According to the data provided, it appears that albacore tend to spawn during the spring and austral summer seasons. This hypothesis is substantiated by the fluctuations in the monthly GI of mature females and males (**Figure 14**). The average GI was at its peak between September ($\bar{x}$ = 0,32±0,07♀; $\bar{x}$ = 0,12±0,02♂), October ($\bar{x}$ = 0,33±0,09♀; $\bar{x}$ = 0,17±0,03♂), and November ($\bar{x}$ = 0,43±0,01♀; $\bar{x}$ = 0,24±0,02♂). During this period, the catches revealed a mix of development females, mature females in regression, and only a small number of females in active stage. The male data also exhibited comparable findings, with the GI increasing from September through

November, but decreasing from February to June (**Figure 14**). There were no active males identified during (January to April) in the samples. These findings are consistent with the results of Farley et (2013) for the South Pacific Ocean.

3.5 Age

To date, a total of two hundred and eighty-eight (288) dorsal fin spines of *Thunnus alalunga* have been collected from September to July 2024, from fish caught by the Brazilian and Chinese Taipei fleets, measuring between 91 and 125 cm FL. Of this total, a small portion was blocked (25), analysed (18) and cleaned spines (63) with the rest in the process of being cleaned.

Preliminary results of the age-ring readings have been carried out (**Figure 15**). Individuals ranging from 91 to 114 cm FL were studied to measure their spines, and two readings were taken. The count of age rings varied between 3 and 6, and the Index of Average Percentage Error (IAPE) (Beamish & Fournier, 1981) was 3.6%. This IAPE is far below the accepted error margin of 10%, proving the accuracy of the ring count between two readers. The highest IAPE was for the age class with three rings (5.7%), which could be related to the presence of age rings in vascularized areas. In smaller individuals, age rings could be counted in areas that fall under vascularization in larger individuals, which could lead to similar ring counts in individuals of different sizes. A *T. alalunga* specimen measuring 91 cm FL had four rings, while another measuring 103 cm FL had the same number of rings. However, the rings in the latter were not visible in the vascularization area, suggesting that they were six and seven years old, respectively, considering three rings being present on average in the vascularized area. New analyses will be made with new spines. However, it is necessary to collect smaller fish to estimate the species' initial growth ages.

Eight (80) otoliths were also collected so far from fish caught by the Brazilian longline fleet based in Recife, measuring more than 95 cm FL. These otoliths have been processed and stored for analyses, which should begin soon.

4. General comments

The most important result generated during this contract were the new estimate of the L50 of males and females of the species, which carried out based on a review of the previously established maturation stages by sex. Thus, the L50 for females was 89.7 cm FL (confidence interval 86.1 - 91.5) and 88.0 cm FL for males (confidence interval 86.8 - 90.5). These results are still preliminary and further analysis with new samples will be carried out.

Unfortunately, it was not possible to analyse samples from the south-eastern area of the South Atlantic (Namibia and South Africa) as planned. Although the samples from South Africa were collected and sent to Brazil for analysis, they were held up by the sanitary surveillance authority at São Paulo airport. But new samples are being collected and will be sent by colleagues from South Africa next year. In the case of Namibia, the samples were collected and new ones are being collected, but just as with the South African samples, they will only be sent to Brazil under the next contract in 2025. This is due to the requirements of the Brazilian sanitary authority and the bureaucracy involved in importing biological samples. The process to obtain the necessary authorisation is well advanced and by the next contract we will be able to make these imports without any problems. Despite this, new samples have been collected by Brazil and Chinese Taipei and analyses will continue. Last week, for example, we received more samples (around 100) from Chinese Taipei in Recife for analysis.

5. Acknowledgment

We would like to thank ICCAT for the financial support for this research. We also thank the SCRS for recognizing the importance of this work and for encouraging us to continue generating results to subsidize science-based management measures.

This work was conducted within the ICCAT Albacore Year Programme (ALBYP).

6. Research Team

6.1 List of Cooperating members

- Brazil

  FADURPE - Fundação Apolônio Salles de Desenvolvimento Educacional
  Executive Secretary: Fernando Freire (secretarioexecutivo@fadurpe.com.br)
  Rua Monsenhor Silva, 45, Madalena. Recife – PE, CEP:50610-360, Fone: (81) 4141 1113
  Fax: (81) 3033 6070

  Project coordinator: Paulo Travassos (paulo.travassos@ufrpe.br)
  Departamento de Pesca e Aquicultura Universidade Federal Rural de Recife
  R. Dom Manoel de Medeiros, s/n, Dois Irmãos, Recife – PE CEP 54172-900
  Phone: + 55 81 33206511 (Marine Ecology Lab/UFRPE); +55 81 998344271

- Uruguay
  Dirección Nacional de Recursos Acuáticos – DINARA Ministerio de Ganadería, Agricultura y Pesca
  Dirección: Constituyente 1476
  Teléfonos: (+598) 2413 8030

- Chinese Taipei
  Department of Environmental Biology and Fisheries Science, National Taiwan Ocean
  University Address: No. 2, Pei-Ning Road, Keelung City, 20224 Taiwan
  Phone: +886-2-24622192#5046

- South Africa
  Department of Forestry, Fisheries and the Environment Forestrust Building, Foreshore, Cape
  Town, South Africa. Phone: +27 82 6607985

- Namibia
  National Maribe Information and Research Centre
  Ministry of Fisheries and Marine Resources
  1 Strand Street
  PO Box 912, Swakopmund, Namibia

6.2. Supporting Scientists

- Brazil: Paulo Travassos (paulo.travassos@ufrpe.br), Mariana Rego(mari_rego03@hotmail.com), Maria Lúcia Goes de Araújo (malugaraujo@gmail.com), Joaquim Evêncio Neto (joaquim.evenciont@ufrpe.br), Guelson Silva (guelson@ufersa.edu.br), Francisco Marcante (framarsantana@yahoo.com.br), Luís Gustavo Cardoso (cardosolg15@gmail.com).

- Uruguay: Andrés Domingo (dimanchester@gmail.com), Rodrigo Forselledo (rforselledo@gmail.com).

- Chinese-Taipei: Nan-Jay Su (nanjay@ntou.edu.tw).

- South Africa: Sven Kerwath (skerwath@dffe.gov.za), Wendy West (wmwest@dffe.gov.za).

- Namibia: Charmaine Jagger (Charmaine.jagger@mfmr.gov.na)

References

Albacora Tuna Species Group. 2021. Report of the Intersessional Meeting of the Albacore Species Group Including the Mediterranean Albacore Stock Assessment. https://www.iccat.int/Documents/Meetings/Docs/2021/REPORTS/2021_ALB_ENG.pdf

Arrizabalaga, H., Costas, E., Juste, J., González-Garcés, A., Nieto, B., & López-Rodas, V. (2004). Population structure of albacore Thunnus alalunga inferred from blood groups and tag-recapture analyses. *Marine Ecology Progress Series*, *282*, 245-252.

Bard, F.X. 1981. Le thon germon (*Thunnus alalunga*) de l'Ocean Alantique. De la dynamique des populations à la strategie demographique. These de Doctorat d'etat. Université de Paris. 333 p.

Beamish, R.J. and Fourier, D.A. 198). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fish and Aquatic Science*, 982-983.

Brown-Peterson, N. J., Wyanski, D. M., Saborido- Rey, F., Macewicz, B. J., Lowerre-Barbieri, S. K. 2011. A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 3(1), p.52-70.

Chen, K.-S.; Shimose, T.; Tanabe, T., Chen, C.-Y. and Hsu, C.-C. 2012. Age and growth of albacore *Thunnus alalunga* in the North Pacific Ocean. *Journal of Fish Biology*, 80: 2328-2344.

Coimbra, M.R.M. 1999. Proposed Movements of albacores, *Thunnus alalunga*, in the South Atlantic Ocean. SCRS/1998/040 Col.Vol. Sci.Pap. ICCAT, 49 (4): 97-136.

Collette B, Nauen C. FAO species catalogue, Vol 2. Scombrids of the world: an annotated and illus- trated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish Synop 1983; No. 125(2),137 p.

Dhurmeea, Z., Zudaire, I., Chassot, E., Cedras, M., Nikolic, N., Bourjea, J., ... & Bodin, N. 2016. Reproductive biology of albacore tuna (Thunnus alalunga) in the Western Indian Ocean. PLoS One, 11(12), e0168605.

Farley, J. H., Williams, A. J., Hoyle, S. D., Davies, C. R., & Nicol, S. J. 2013. Reproductive dynamics and potential annual fecundity of South Pacific albacore tuna (*Thunnus alalunga*). PLoS One, 8(4), e60577.

Farley, J. H., Hoyle, S. D., Eveson, J. P., Williams, A. J., Davies, C. R., & Nicol, S. J. 2014. Maturity ogives for South Pacific albacore tuna (*Thunnus alalunga*) that account for spatial and seasonal variation in the distributions of mature and immature fish. PloS one, 9(1), e83017.

Gálvez M.A., Castillo J. 2015. Escala de Maturez Gonadal de Bonito Sarda *Chiliensis chiliensis* (Cuvier, 1832). Bol Inst Mar Perú. 30(1-2): 29-39 p.

Pedrosa, V. B. Reprodução da albacora branca *Thunns alalunga* (Bonnaterre, 1788) capturada pela frota brasileira Espinheleira no Oceano Atlântico Sudoeste. 2011. 50 f. Dissertação (Programa de Pós-Graduação em Recursos Pesqueiros e Aquicultura) - Universidade Federal Rural de Recife, Recife.

Penney, A.J., S-Y. Yeh, C-L. Kuo and R. W. Leslie. 1998. Relationships between albacore (Thunnus alalunga) stocks in the southern Atlantic and Indian Oceans. Proceedings of the ICCAT Tuna Symposium (Beckett, J.E. ed.), vol 1, 2 61-271.

Saber S, de Urbina JO, Go´ mez-Vives MJ, Mac´ıas D. 2015. Some aspects of the reproductive biology of alba- core Thunnus alalunga from the western Mediterranean Sea. J Mar Biol. Assoc UK; 95: 1705– 1715.

Schaefer KM. Reproductive biology of tunas. In: Block BA and Stevens ED, editors. Fish Physiology, Vol. 19. San Diego, CA: Academic Press; 2003. pp. 225–270.

Senina, I. N., Lehodey, P., Hampton, J., & Sibert, J. 2020. Quantitative modelling of the spatial dynamics of South Pacific and Atlantic albacore tuna populations. *Deep Sea Research Part II: Topical Studies in Oceanography*, *175*, 104667.

Travassos P. 1999, Anomalies thermiques et pêche du germon (Thunnus alalunga) dans l'Atlantique Tropical Sud-Ouest. Col.Vol. Sci. Pap. ICCAT, 49 (4), 324-338.

Travassos, P., Araújo, M.L.G., Rêgo, M. Evêncio, J.; Cardoso, L.G.; Domingos, A.; Su, N.J; Sanatana, F. 2022. *Thunnus alalunga* (Bonnaterre 1788) Reproductive Biology Study in South Atlantic. Scientific document presented at SCRS/ICCAT in September 2022.

Table 1. Fork length range and sex ratio of *Thunnus alalunga* obtained from this study and preterit data from Brazil, China Taipei, South Africa, and Uruguay.

Country/Fleet	Fork Length Range (Avg± Std)	Sex ratio ♂:♀	Year
Brazil	81 - 125 (101.0±8.1)	2.6♂:1.0♀ (χ^2, p=0.19)	2021 - 2024
Brazil/NE	91 – 125 (106,9±5,3)	2.8♂:1♀ ($\chi 2$ = 22,9*; p<0.001)	2021 – 2024
Brazil/RGS	(81 – 111) (96,3±7,9)	2.3♂:1♀* ($\chi 2$ = 14.8; p<0.001)	2021
China Taipei	60-111 (98.8±9.1)	1.4♂:1.0♀ (χ^2 = 2.9 p=0.08)	2021
South Africa	63 - 119 (87.1±10.4)	2.2♂:1.0♀* (χ^2 = 14.3 p=0.27)	2012 - 2018
Uruguay	76 - 115 (96.5±87.9)	1♂:1.0♀ (χ^2 = 1.6 p=0.00)	2013 - 2016

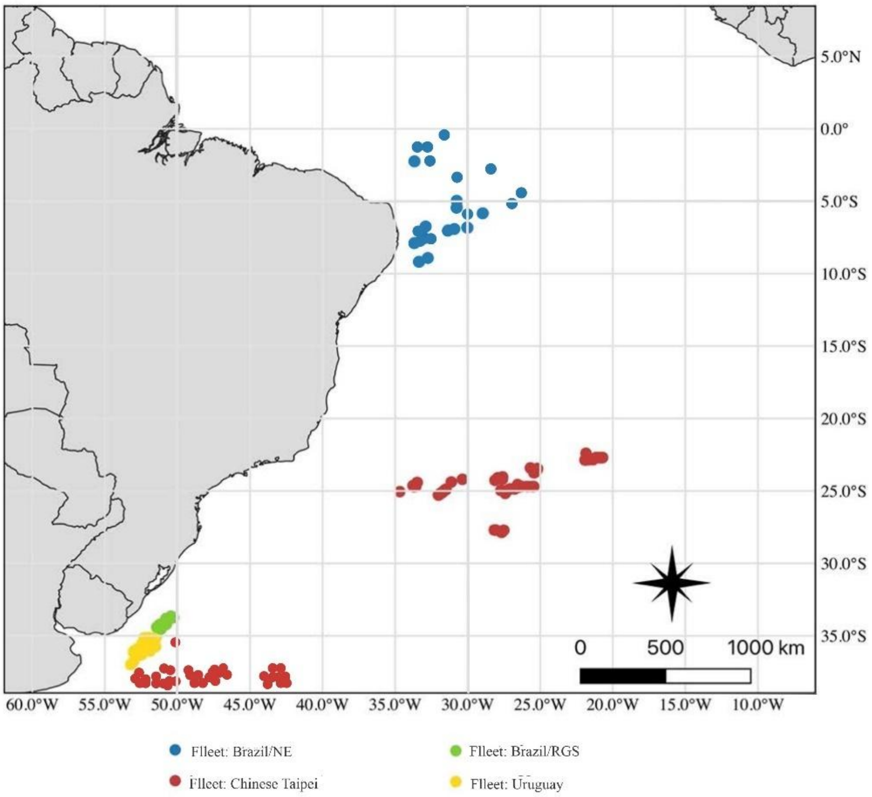

Figure 1. Major catch areas of *Thunnus alalunga* in the South Atlantic Ocean caught by longline fleet from Brazil-NE (●), Brazil-Rio Grande (●), China Taipei fleet (●), and Uruguay (●).

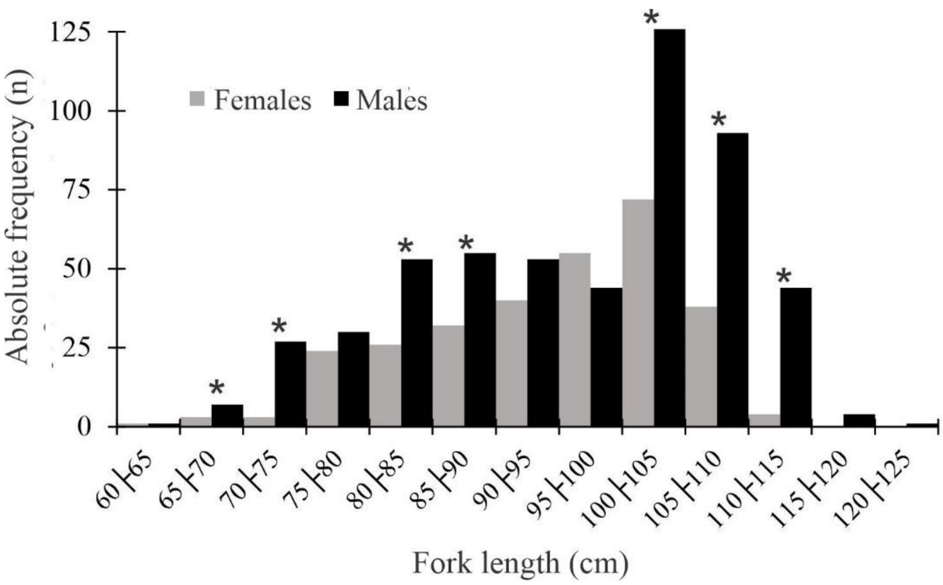

Figure 2. Absolute frequency distribution by length class for male and female *Thunnus alalunga* caught by pelagic longline fleets operating in the South Atlantic between May 2012 and 2024. *Indicates statistically significant differences.

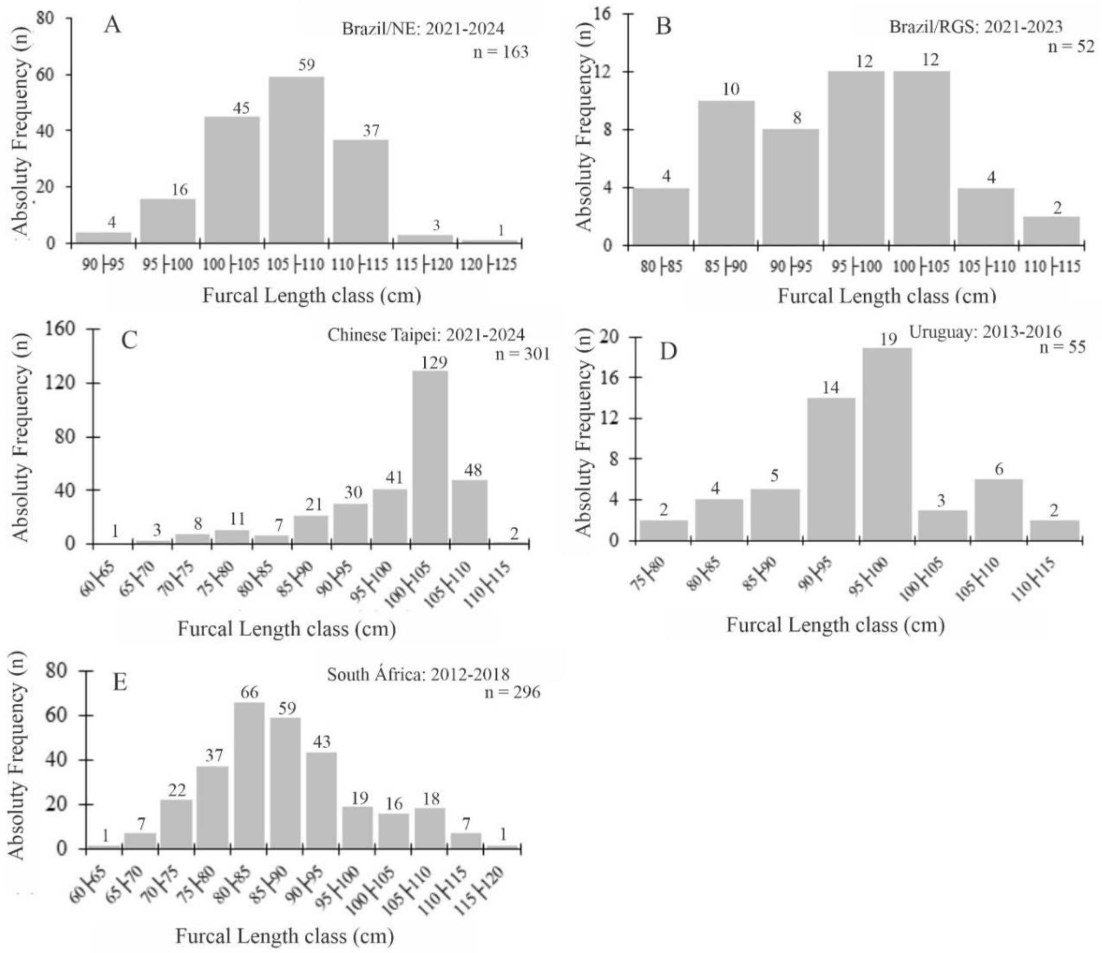

Figure 3. Frequency distribution of lengths of *Thunnus alalunga* caught by the industrial pelagic longline fleet A – Brazil/Nordeste (NE) n=163; B - Brazil/Rio Grande (RS), n=52 (2021-2023); C – Chinese Taipei fleet, n=301; D- Uruguay, n =55; E – South Africa, n=296 (preterit data).

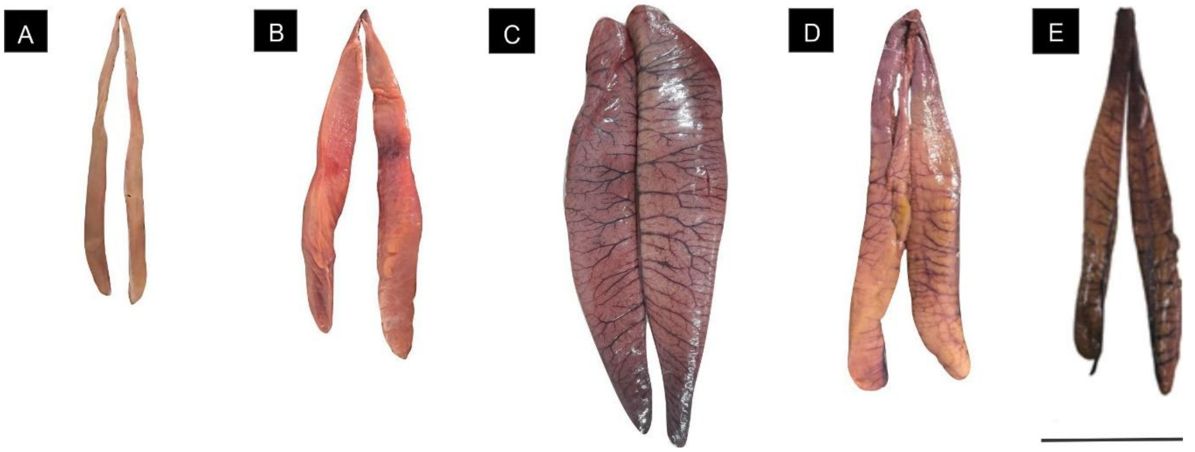

Figure 4. Macroscopic representation of the ovaries of *Thunnus alalunga* caught by the industrial pelagic longline fleet in the South Atlantic. Scale bar: 1 cm. A - Immature (Im), B - Developing (Dv), C - Capable of reproducing (CR), D - Active (At) and E - Regression (Re).

Figure 5. Macroscopic representation of the testes of *Thunnus alalunga* caught by the industrial pelagic longline fleet in the South Atlantic. Scale bar: 1 cm. A - Immature (Im), B - Developing (Dv), C - Capable of reproducing (CR), D - Active (At) and E - Regression (Re).

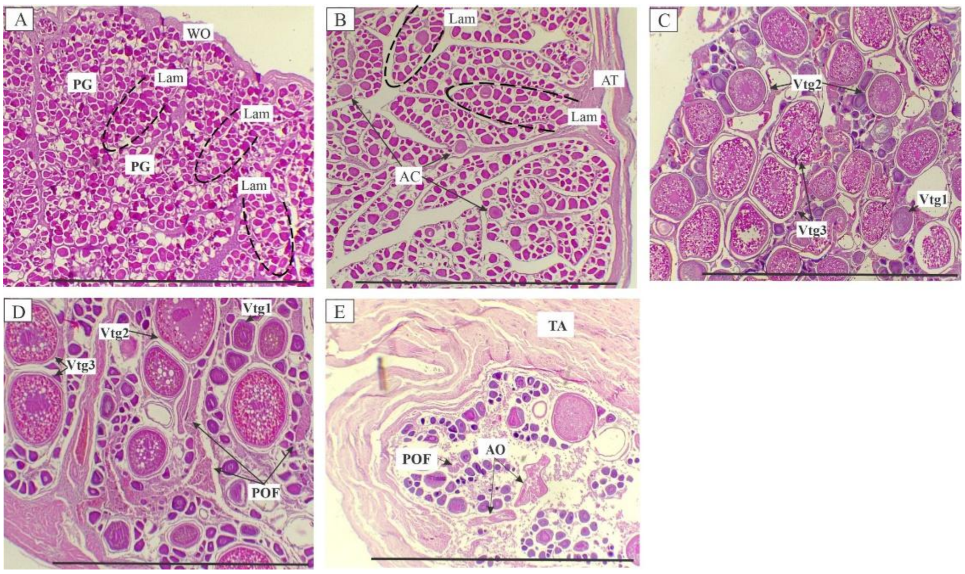

Figure 6. Maturation stages of the ovaries of *Thunnus alalunga.* (A) Immature; (B) Developing (Dv); (C) Capable of Reproducing (CR); (D) Active (A); (E) Regression (R). Legend: LAM = Lamella, TA = Tunica albuginea, PG = Primary Growth, AC = Cortical Alveolus, Vtg 1, 2, 3 = Vitellogenesis 1, 2, and 3, POF = Post-Ovulatory Follicle, AO = Atretic Oocyte. Staining: Hematoxylin-eosin. Scale bar: 500 µm.

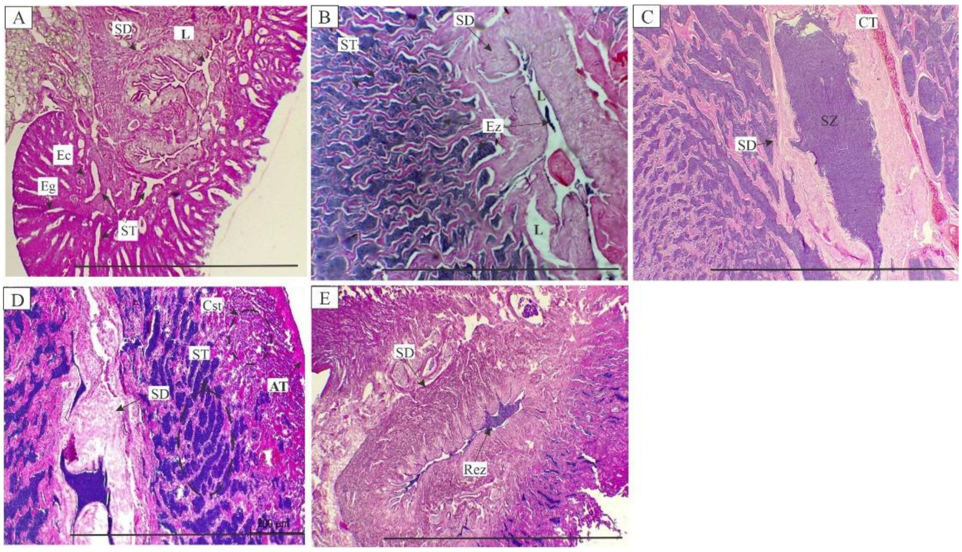

Figure 7. Maturation stages of the testes of *Thunnus alalunga.* (a) Immature (Im); (b) Developing (Dv); (c) Capable of Reproducing (CR); (d) Active (A); (e) Regression (R). Legend: SD = Spermatic Duct, ST = Seminiferous Tubules, Eg = Spermatogonia, Ec = Spermatocyte, Et = Spermatid, Ez = Spermatozoa, Ezr = Residual Spermatozoa, CT = Connective Tissue, AT = Tunica Albuginea, Cst = Cyst, RS = Residual Spermatozoa, L = Lumen. Staining: Hematoxylin-eosin. Scale bar: 500 µm.

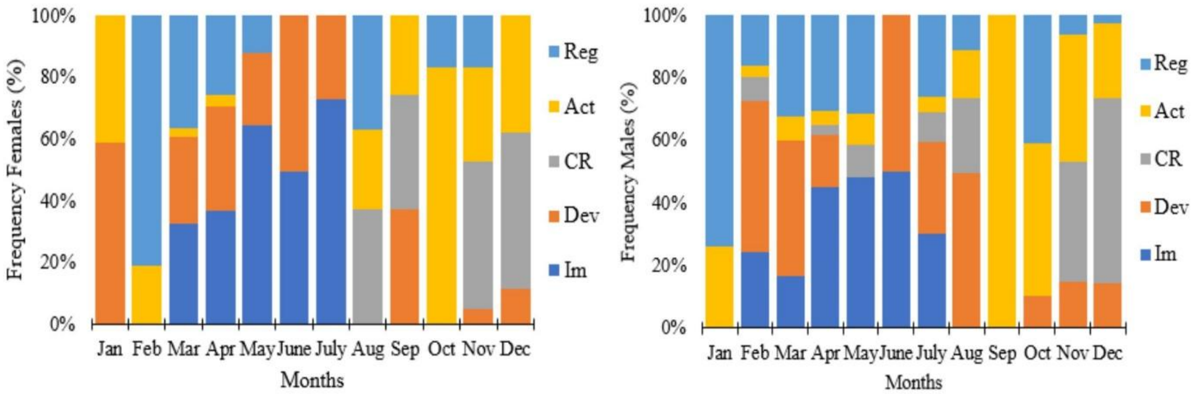

Figure 8. Microscopic representation of the frequency females and males of *Thunnus alalunga* caught by the industrial pelagic longline fleet in the South Atlantic.

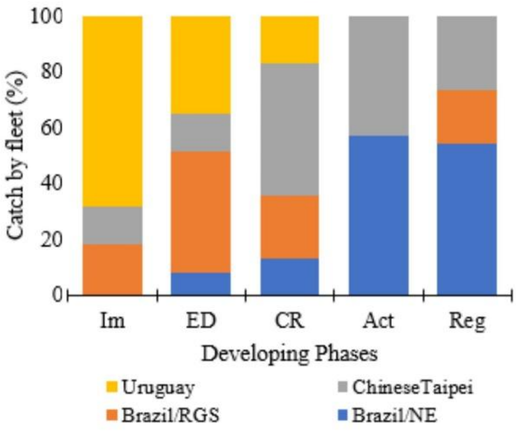

Figure 9. Percentage of occurrence of the maturation stages of *Thunnus alalunga* caught in the South Atlantic by fleet in the present study. A - Immature (Im), B - Developing (Dv), C - Capable of reproducing (CR), D - Active (At) and E - Regression (Re).

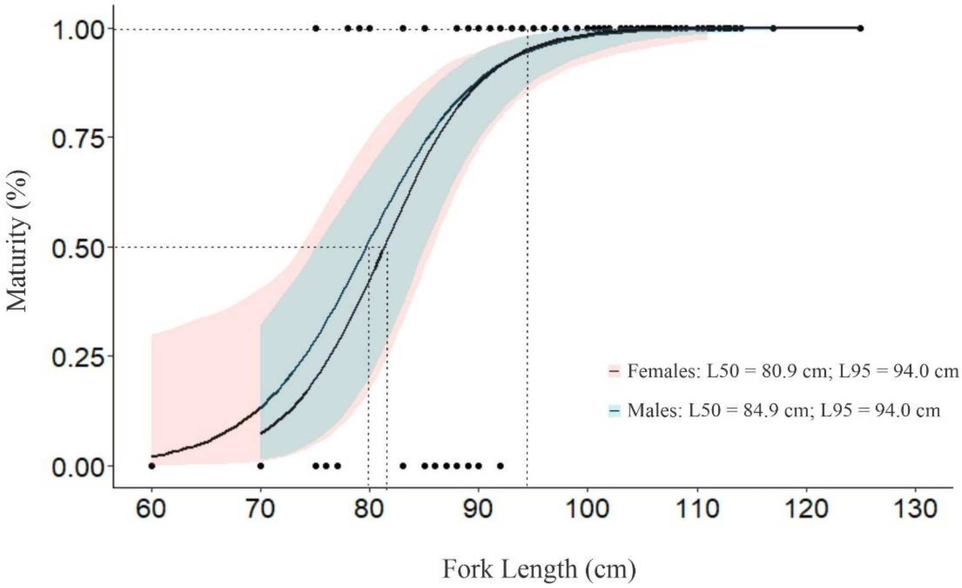

Figure 10. Size at first maturity (L50) for females and males of *Thunnus alalunga* caught in the South Atlantic, in this study.

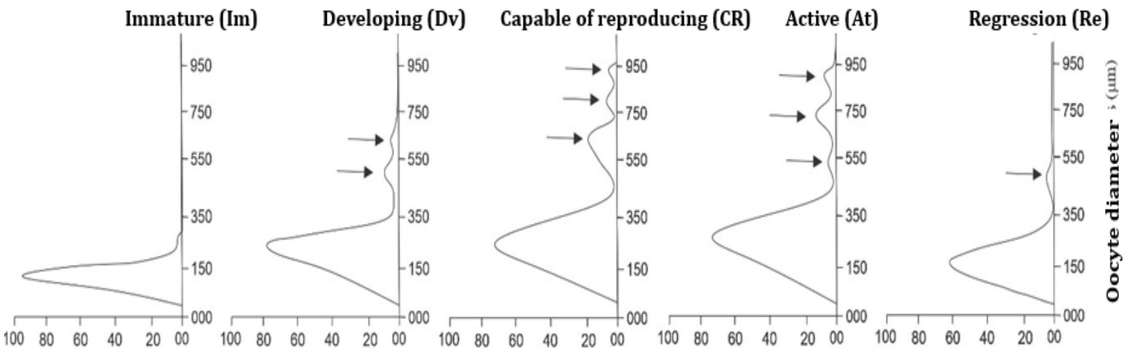

Figure 11. Frequency distribution of oocyte diameter in the five stages of ovarian development of *Thunnus alalunga* caught in the South Atlantic in this study (the arrows indicate the formation of batches of oocytes).

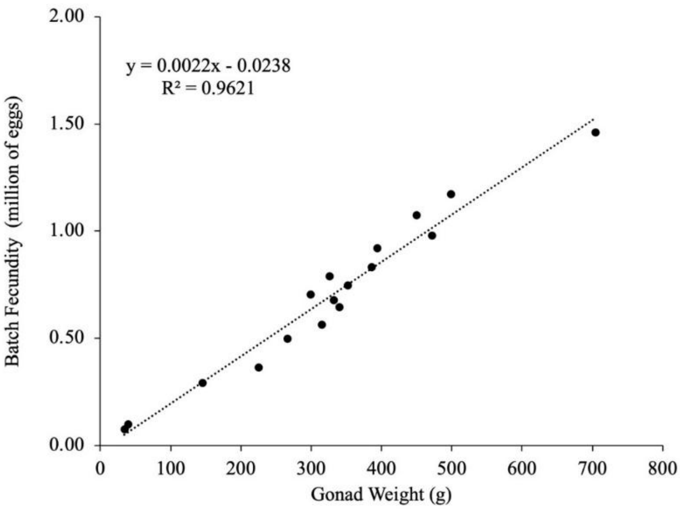

Figure 12. Relationship between batch fecundity and gonad weight for *Thunnus alalunga* from the Southwest Atlantic.

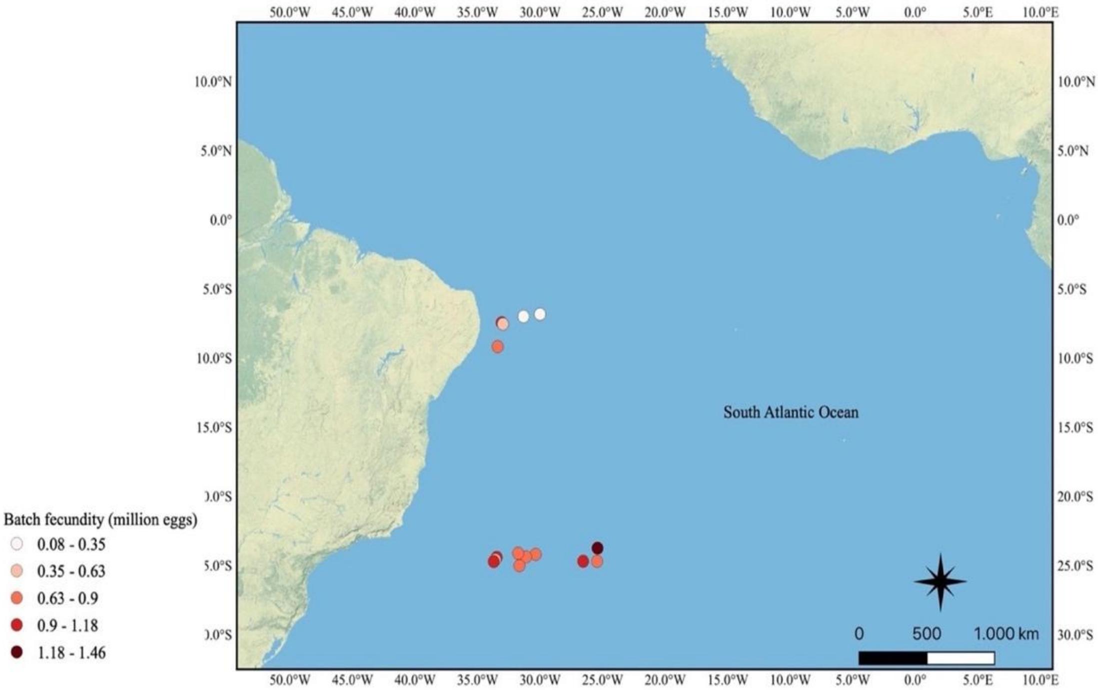

Figure 13. Spatial variation in the fecundity of *Thunnus alalunga* in the South Atlantic.

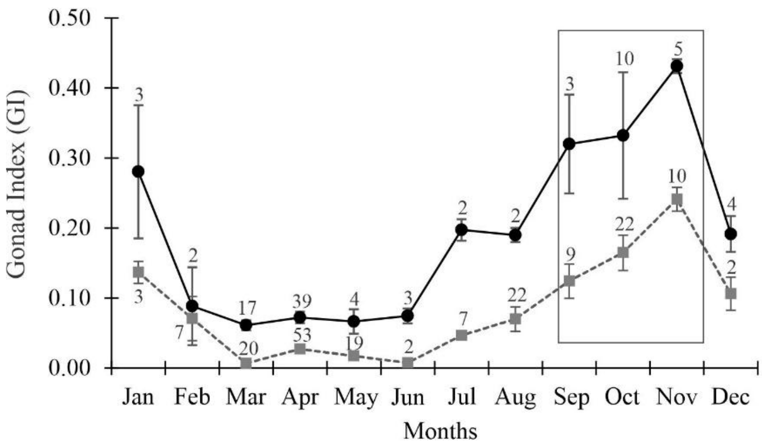

Figure 14. Average monthly GI for females and males of *Thunnus alalunga* caught in the South Atlantic and analyzed in this study.

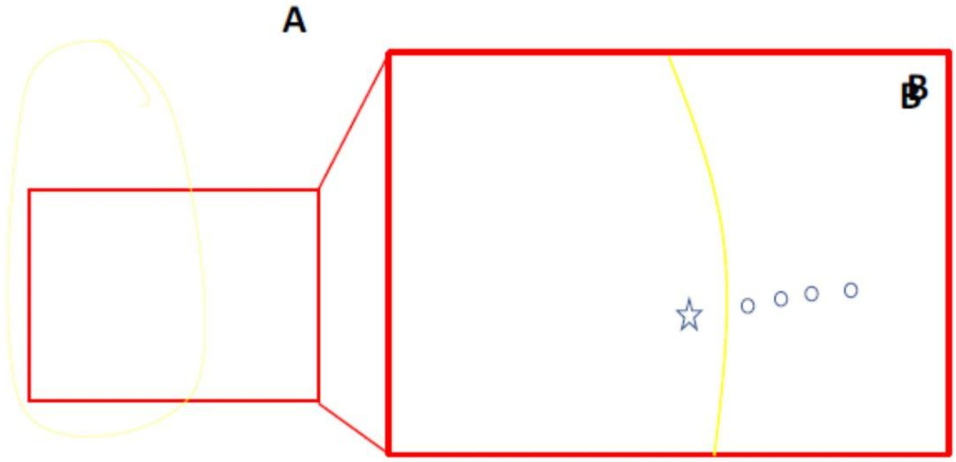

Figure 15. Cross section of the first dorsal fin spine of *Thunnus alalunga*, with the area of vascularization (A). Detail of the thorn section with the growth rings visible (numbers 1 to 4 or 5) and spine radius (SR) (B).