AGE, GROWTH AND MATURITY IN CHUB MACKEREL (*Scomber japonicus* HOUTTUYN, 1782) FROM THE AZORES

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Sagittae from 349 specimens of chub mackerel collected between 1996 and 2002 were used in this study. Fork length ranged from 90 mm to 530 mm, corresponding to 9.6 mm and 56.57 mm TL ages ranged between 0 to 13 years. The von Bertalanffy growth equation was fitted to the length-at-age data and the estimated parameters were as follows: $L_\infty = 57.52$ TL; $k = 0.201$ years^{-1}; $t_0 = -1.093$ years.
Life span was estimated as being between 13 and 15.6 years and the instantaneous rate of natural mortality as 0.192. The spawning season in the Azores extends from March to August and length at 50% maturity was estimated as 27.78 cm TL ($A_{50}\% = 2.23$ years). Length-weight and length-length relationships were also determined: $W = 0.0049FL^{3.2612}$; $TL = 1.039\ FL^{1.015}$; $SL = 0.927FL^{\ 0.999}$.

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INTRODUCTION

The chub mackerel (*Scomber japonicus* Houttuyn, 1782) is a cosmopolitan species inhabiting temperate waters of the Atlantic, Indian and Pacific Oceans and neighbouring seas. In these waters, adult chub mackerel carry out reproductive migrations from deeper shelf–break waters to coastal areas (COLLETTE & NAUEN 1983; CASTRO & SANTANA 2000).

The Atlantic chub mackerel has been the focus of several studies in the recent past. In the southwestern Atlantic, studies have highlighted different aspects of the fishery and biology of this species (e.g. SECKENDORFF & ZAVALA-CAMIN 1985; PERROTTA 1992; PÀJARO 1993; PERROTTA & CHRISTIANSEN 1993; PERROTTA & PERTIERRA 1993; PERROTTA et al. 1998; PERROTTA et al. 2000). LORENZO & PAJUELO (1993, 1996) studied the chub mackerel off the Canary Islands and emphasized the usefulness of regional studies in improving the understanding of the behaviour of the species in less known geographical areas. WESTHAUS-EKAU & EKAU (1982), in their preliminary study on the chub mackerel analysed aspects of the fishery and biology of this species in the Azores. To our knowledge, their results, although preliminary, constitute the only information on the biology of chub mackerel in the Azores to date.

In the Azores, most of the fishing activity falls into three main types: (i) an artisanal or small open deck fleet, operating in coastal and nearshore waters, using purse seine nets, dipnets and liftnets and whose main target species include juvenile or young blue jack mackerel *Trachurus picturatus*, chub mackerel *Scomber japonicus*, European pilchard *Sardina pilchardus* and blackspot seabream *Pagellus bogaraveo*; (ii) a seasonal pole and line tuna fishery which begins in March/April and lasts until September/October and (iii) a bottom longline and handline multispecific fishery. These fisheries are all interrelated, not only because there is a considerable mobility of fishermen between them, but also because the tuna, longline and handline fisheries use blue horse mackerel and chub mackerel as bait (SANTOS et al. 1995). Chub mackerel is also caught as bycatch in the longline demersal fishery operating essentially in offshore

areas (banks and seamounts). Annual landings of chub mackerel in the Azores have decreased during the last few years, from approximately 530 tons in 1998 to 180 tons in 2000.

Given the lack of information on the chub mackerel in the Azores and its relative importance to the main Azorean fisheries, we conducted a study aimed at gathering biological data on this species. The present paper focuses on the age and growth and aspects of reproduction of the chub mackerel in the Azores.

MATERIALS AND METHODS

Samples were collected in the Azores Archipelago, from cruise surveys aboard the R/V ARQUIPÉLAGO and from commercial landings at Faial and São Miguel islands, between 1996 and 2002 (Fig. 1).

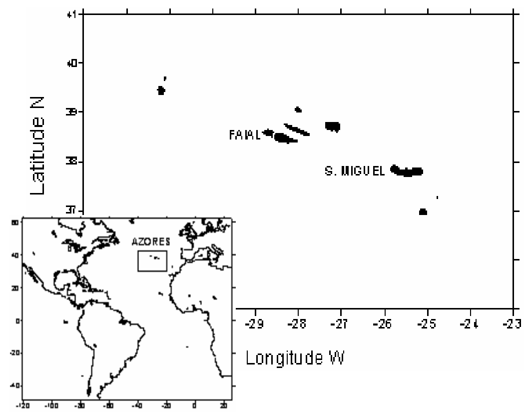

Fig. 1. Location of the Azores Archipelago in the Northeast Atlantic.

Fork length (FL), standard length (SL) and total length (TL) were measured to the lowest nearest mm. Individual total weight (W) was recorded to the nearest mg. As previous studies on the chub mackerel have shown that no significant differences in growth and other morphological characteristics exist between sexes (WESTHAUS-EKAU & EKAU 1982; PERROTTA 1992, 1993; ROLDÁN et al. 2000), the data were analysed with both sexes pooled.

The parameters of the length-length and length-weight relationships were estimated by fitting a linear regression (least squares method) to the log transformed data. The significance of the regressions were assessed by analysis of variance (ANOVA), testing the hypothesis H_0: $\beta=0$ against H_A: $\beta\neq0$ (ZAR 1996).

Maturity stages of 849 specimens were determined macroscopically and classified according to an adapted version of a six-grade scale commonly used for the European chub mackerel (CARDADOR & BORGES 1999) (Table 1). Length at 50% maturity (L_{50}), corresponding to the point at which the maturity ogive reaches a value of 0.5, was estimated by fitting a logistic model (non-linear method) to the mature proportion at length class. Its correlation coefficient was calculated according to the mathematical expression obtained from OSTLE (1979).

Table 1
Macroscopic maturation stages for the chub mackerel, *Scomber japonicus* adapted from CARDADOR & BORGES (1999).

Maturation stage	Males	Females
I *Virgin/ Resting*	Gonads small, pale, compressed and transparent.	Gonads small, dark red and torpedo shaped
II *Developing*	Gonads occupying 1/4 to 3/4 abdominal cavity, whitish in colour, absence of sperm.	Gonads occupying 1/4 to 3/4 abdominal cavity, visible opaque eggs, light pink or yellow in colour.
III *Pre-spawning*	Gonads occupying 3/4 to entire abdominal cavity, creamy white in colour.	Gonads occupying 3/4 to entire abdominal cavity, yellow to orange in colour, eggs larger and may contain oil droplet.
IV *Spawning*	Gonads occupying entire abdominal cavity, sperm expelled easily when compressed.	Gonads vary in dimension (1/4 to 1), characterized by the presence of translucent eggs, independent of abundance or degree of hydration.
V *Partial spawning / recovering*	Gonads occupying 3/4 to less than 1/4 abdominal cavity, flaccid at the anal end, sperm still present.	Gonads occupying 3/4 to less than 1/4 abdominal cavity, more flaccid than stage 3 and frequently hemorrhagic.
VI *Spent*	Gonads occupying 1/4 or less of the abdominal cavity, opaque, brownish in colour and without sperm.	Gonads occupying 1/4 or less of the abdominal cavity, reddish in colour, occasionally with dispersed opaque eggs.

Proportional measurements of opaque and translucent bands along the edge of the otoliths were examined monthly to observe the annual periodicity of band formation. However, no samples were collected in October, December or January. By convention, a birthdate of 1 January was used. As of this date, the translucent band formation on the edge of the otolith was included as an annulus until seasonal growth (opaque band) resumed.

Sagittal otoliths from 349 specimens were used for age determination. Age estimates were obtained by counting the translucent bands from the nucleus according to criteria described in PERROTTA (1992, 1993) and LORENZO et al. (1995). Two independent readings were carried out for each otolith. When both readings did not match, a third one was attempted and accepted only when it coincided with one of the previous readings.

The growth parameters were estimated taking into account age groups 1 – 13 years. Length-at-age data was fitted to the von Bertalanffy growth curve using the maximum likelihood method, considering a normal distribution and unequal variances of the residuals per age class (AUBONE & WÖHLER 2000).

Natural mortality (M) and life span ($A_{0.95}$) were estimated by TAYLOR'S method (1959), defining life span as the time required to attain 95% of asymptotic length (L_∞).

RESULTS AND DISCUSSION

Length and weight relationships

Sizes of fish sampled ranged from 9.1 and 53 cm FL, corresponding to approximately 5.4 g and 2000 g in weight, respectively.

All length-length and length-weight regressions were highly significant, with all coefficient of determination values (r^2) greater than 0.97 (Fig. 2, Fig. 3).

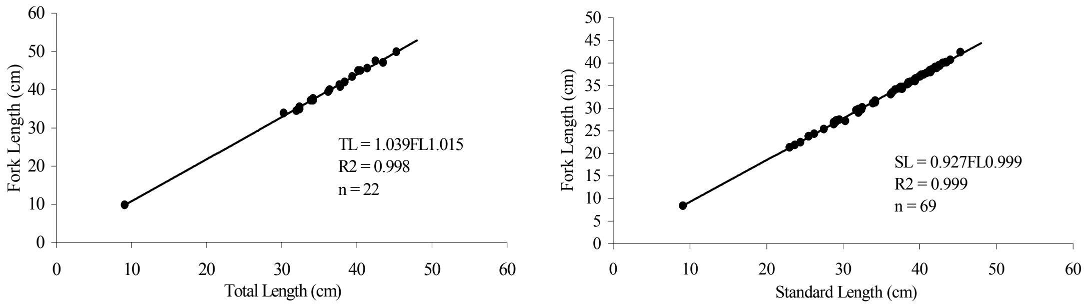

Fig. 2. Regressions and estimated parameters of the length-length relationships for the chub mackerel, *Scomber japonicus* in the Azores: (a) fork length-total length (b) fork length-standard length relationship.

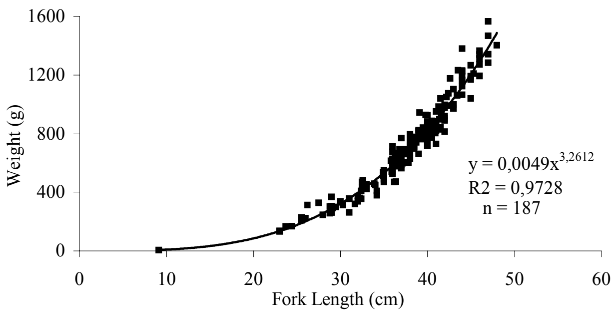

Fig. 3. Regression and estimated parameters of the length-weight relationship of the chub mackerel, *Scomber japonicus* in the Azores.

Maturity ogive and spawning

Length at 50% maturity (L_{50}) was estimated as 25.46 cm FL (or 27.78 cm TL) (Fig. 4), corresponding to 2.23 years. This value is within the estimated range of 24-27 cm TL (age groups 1-2) for chub mackerel from Argentina (COUSSEAU & PERROTTA 2000) but below the estimated value of 31 cm TL (age group 3) for chub mackerel off the Portuguese mainland coast (MARTINS et al. 1983) and above the estimated value of 19.9 cm TL for the Canary Islands (age group 1) (LORENZO & PAJUELO 1993; PERROTTA 1993). Fish in spawning condition were observed between March and August (spring and summer). However, according to WESTHAUS-EKAU & EKAU (1982), determined that chub mackerel in the Azores spawn between March and July, with a peak in April/May. Thus, our results suggest that the spawning season may extend over a slightly longer period. These differences may be due to inter-annual variations in environmental factors.

The spawning season of the chub mackerel varies between regions, usually extending over a period of 3 to 5 months. In general, the spawning season appears to be limited to the first half of the year in the northern hemisphere; during the second half of the year in the southern hemisphere; and all year round in areas near the equator (CASTRO & SANTANA 2000).

In Argentina, spawning in chub mackerel appears to be associated with surface water temperatures, with optimum values ranging between 16-18ºC (PERROTTA & CHRISTIANSEN 1993, PERROTTA et al. 2001). Adults migrate from cooler overwintering shelf waters to warmer coastal areas to spawn from early October to late January (late spring and early summer) (PERROTTA et al. 2001). This type of spatial-temporal distribution has been recorded in the same species in other regions, namely the Canary Islands (LORENZO & PAJUELO 1993), and along the northeast African coast (HABASHI & WOJEIECHOWSKI 1973). In the Azores, chub mackerel also appear to undergo spawning migrations from deeper offshore waters to coastal areas. This hypothesis is supported by the fact that adult chub mackerel are essentially captured as bycatch in the Azorean longline demersal fishery in offshore areas (banks and seamounts), while juveniles are captured with net gears in coastal waters by the local fishing fleet and tuna fleet for live bait. However, juvenile chub mackerel appear to be relatively rare in Azorean waters and are usually captured in mixed schools along with the blue jack mackerel *Trachurus picturatus* (pers. obs).

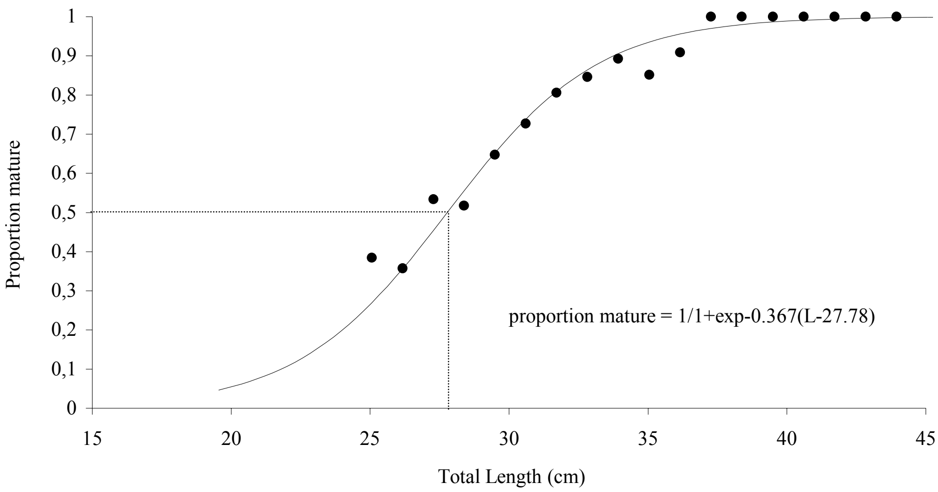

Fig. 4. Logistic curve fitted to the proportion of mature chub mackerel, *Scomber japonicus* as a function of length.

Age determination

A pattern of two bands, one opaque and one translucent were laid down each year on the otoliths, indicating the annual formation of growth marks. The first strong translucent zone after the nucleus was interpreted as the first annulus. Subsequent translucent zones were counted as annuli.

Several authors have observed that the growth rate for chub mackerel inhabiting different parts of the world is slower during colder months and higher during warmer months, and proved that the formation of growth bands is related to feeding intensity and temperature (e.g. BAIRD 1977, OUCHI 1978, SECKENDORFF & ZAVALA-CAMIN 1986, DAWSON 1986, FORCINITI & PERROTTA 1988, LORENZO 1992 *in* CASTRO & SANTANA 2000).

However, in the present study, although no samples were obtained for the months January, October and December, the annual periodicity of band formation was apparent. Analysis of the border of the otolith showed that translucent bands begin to form at the end of autumn (November or October), ending during late spring (May), while opaque bands predominate during the remaining months of the year (May – September or perhaps October) (Fig. 5). The onset of rapid growth thus appears to occur in late spring-early summer, following the peak in spawning activity, which according to WESTHAUS & EKAU (1982) occurs during April/May. The same phenomenon has also been observed in the chub mackerel from Argentina (PERROTTA 1992; PERROTTA & CHRISTIANSEN 1993), where translucent band formation coinciding with the peak in spawning activity is evident.

A wide range of ages (0 – 13 years) was determined. Irregular spacing of annuli or when these, especially in older fish, become extremely thin and closely spaced near the edge of the otolith often made age interpretation difficult. Such growth pattern anomalies also appear to be common in other mackerel species, e.g. the Atlantic mackerel *Scomber scombrus* (PENTTILA & DERY 1988).

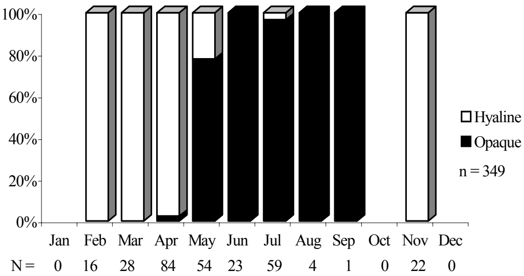

Fig 5. Monthly percentage of translucent and opaque band formation on otolith edges of the chub mackerel, *Scomber japonicus* in the Azores.

Length-age relationship

The length-age key and growth parameters indicated initial rapid growth that began to slow at age (Tables 2 and 3). Since age groups 0 and 1 comprised only one individual each, they were not considered representative of the population and, thus omitted from further analyses. However, in order to obtain a clearer understanding of the chub mackerel's growth in the Azores age 1 data estimated from WESTHAUS & EKAU (1992), was used for analysis in the present study (Fig. 6).

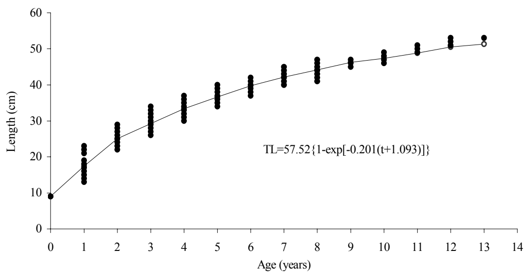

Fig. 6. Growth curve of the chub mackerel, *Scomber japonicus* in the Azores.

WESTHAUS & EKAU (1992) observed eight age classes for the chub mackerel inhabiting Azorean waters. However, those authors, in relation to values estimated in the present study (Table 3), determined a lower asymptotic length (44.73 cm TL) and a higher growth coefficient (K = 0.245). It is interesting to point out that, along

Table 2.
Length-age key for the chub mackerel, *Scomber japonicus* in the Azores.

Age	N	TL med (cm)	SD	Range
0	*1*	*9.8*	-	-
1*	*62*	*18.93*	*6.73*	*14-25*
2	*65*	*27.33*	*3.08*	*23-31*
3	*45*	*32.06*	*2.49*	*28-37*
4	*34*	*36.61*	*2.19*	*32-40*
5	*33*	*40.21*	*2.05*	*37-43*
6	*29*	*43.69*	*1.69*	*40-46*
7	*37*	*46.36*	*1.97*	*43-49*
8	*10*	*48.64*	*5.51*	*45-51*
9	*12*	*50.93*	*0.39*	*49-51*
10	*8*	*52.20*	*0.55*	*50-52*
11	*6*	*53.82*	*0.57*	*52-55*
12	*4*	*55.68*	*0.33*	*55-56*
13	*3*	*56.57*	*0.33*	*56-57*

* Age 1 data estimated from Westhaus & Ekau (1982).

its distribution range, this species may reach between 35.4 and 62.6% of the asymptotic length during their first year of life (CASTRO & SANTANA 2000). In the Azores, the growth rate revealed to be slower, increasing at a rate of 32.9% of the asymptotic length during the first year, making it one of the slowest growing populations of chub mackerel. However, the growth rate increases significantly during the second year of life, reaching up to 47.5% of the maximum length during the second year. When comparing K values obtained for chub mackerel populations distributed in the NE Atlantic, the growth coefficient estimated for the Azores was found to be similar to that of the Canary Islands (0.210), but higher than along NW Africa (0.118) and the Portuguese continental coast (0.189) (see CASTRO & SANTANA 2000). Life span for chub mackerel in the Azores was estimated to be between 13 (maximum age observed through otoliths) and 15.6 years (estimated value), with a natural mortality of 0.192.

Table 3
Estimated growth parameters and confidence intervals (C.I.) (α=0.05) for the chub mackerel, *Scomber japonicus* in the Azores.

Parameter	C.I. (95%)
L_∞ (cm TL) = 57.52	(50.25; 64.80)
k (years $^{-1}$) = 0.201	(0.131; 0.270)
t_0 (years) = -1.093	(-1.661; -0.524)

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REFERENCES

AUBONE, A. & O.C. WÖHLER 2000. Aplicación del método de máxima verosimilitud a la estimación de parámetros y comparación de curvas de crecimiento de von Bertalanffy. *INIDEP Informe Tecnico,* 37: 21 pp.

CARDADOR, F. & L. BORGES 1999. Manual dos Cruzeiros Demersais do IPIMAR. *Departamento de Recursos Marinhos. IPIMAR*. 16 pp.

CASTRO, J.J. & A.T. SANTANA 2000. Synopsis of biological data on the chub mackerel (*Scomber japonicus* Houttuyn, 1782). *FAO Fisheries Synopsis* Nº 157:77pp.

COLLETTE, B.B. & C.E. NAUEN 1983. Scombrids of the world: an annotated and illustrated catelogue of tunas, mackerels, bonitos and related species known to date. FAO species catalogue vol. 2, *FAO Fisheries Synopsis* 125:1-137.

HABASHI, B. & J. WOJEIECHOWSKI 1973. Observations on the biology of *Scomber japonicus* off northewest Africa. *Journal du Conseil International pour l'exploration de la mer (CIEM/ICES)* 20: 9pp.

LORENZO, J.M.N. & J.M.G. PAJUELO 1993. Determinación de la talla de primera madurez sexual y período reproductivo de la caballa (*Scomber japonicus* Houttuyn, 1782) de las islas Canarias. *Boletin del Instituto Español de Oceanografía* 9 (1): 15-21.

LORENZO, J.M.N.; J.M.G. PAJUELO & A.G. RAMOS 1995. Growth of the chub mackerel *Scomber japonicus* (Pisces: Scombridae) off the Canary Island. *Scientia Marina,* 59 (3-4): 287-291.

LORENZO, J.M.N. & J.M.G. PAJUELO 1996. Determinación del crecimiento de la caballa (*Scomber japonicus* Houttuyn, 1782) de las islas Canarias a través del análisis de las frecuencias de tallas. *Boletin del Instituto Español de Oceanografía* 12 (2): 83-90.

MARTINS, M.M.B., I. M. JORGE & L. S. GORDO 1993. On the maturity, morphological characteristics and growth of *Scomber japonicus* Houttuyn, 1780 of West continental coast of Portugal. *Council Meeting of the International Council for the Exploration of the Sea*, Gothenburg, Sweden, 22 pp.

OSTLE, B. 1979. *Estadística aplicada*. Editorial Limusa. México. 629 pp.

PÁJARO, M. 1993. Consideraciones sobre la alimentacíon de la caballa con especial énfasis en la depredacíon de huevos y larvas de peces. *INIDEP Documento Cientifico,* 2:19-29.

PERROTTA, R.G. 1992. Growth of mackerel (*Scomber japonicus* Houttuyn, 1782) from the Buenos Aires Patagonian Region (Argentine Sea). *Scientia Marina,* 56(1): 7-16.

PERROTTA, R.G. 1993. Comparación mediante el empleo de los carácteres merísticos y el crecimiento de caballas originarias de varias regiones geográficas (Cataluña, Islas Canarias y Sudamérica). *INIDEP Documento Cientifico*, 2: 7-18.

PERROTTA, R.G. & H.E. CHRISTIANSEN 1993. Estimación de la frecuencia reproductive y algunas consideraciones acerca de la pesca de la caballa (*Scomber japonicus*) en relación con el comportamiento de los cardúmenes. *Physis*, A, 48 (114-115):1-14.

PERROTTA, R.G. & J.P. PERTIERRA 1993. Sobre la dinámica poblacional de la caballa en la pesquería de Mar del Plata. Período 1980-1990. *INIDEP Documento Cientifico*, 2:31-44.

PERROTTA, R.G. & L. FORCINITI 1994. Un estudio preliminar del crecimento de la caballa (*Scomber japonicus*) en dos áreas de su distribución. Contrabución del INIDEP Nº 667. *Revista Frente Marítimo,* vol. 15, Sec. A:101-109.

PERROTTA, R.G., J.P. PERTIERRA, M.D. VIÑAS, & L.S. TRIGALI 1998. Pautas de Manejo Pesquero para la optimización de la explotación de la caballa (*Scomber japonicus*) en la pesquería de Mar del Plata. *INIDEP Informe Tecnico* 23:1-24.

PERROTTA, R.G., L. TRIGALI, A. IZZO, J. BOCCANFUSO, F. LÓPEZ & G. MACCHI 2000. Aspectos económicos de la pesquería de caballa (*Scomber japonicus*) y muestreo de desembarque en el puerto de Mar del Plata. *INIDEP Informe Tecnico*, 38: 1-14.

PERROTTA, R.G., M.D. VIÑAS, D.R. HERNANDEZ & L. TRIGALI 2001. Temperature conditions in the Argentine chub mackerel *Scomber japonicus*) fishing ground: implications for fishery management. *Fisheries Oceanography,* 10:3, 275-283.

PENTTILA, J. & L.M. DERY 1988. Age determination methods for Northwest Atlantic species. National Marine Fisheries Serv., Woods Hole, MA (USA). Northeast Fisheries Cent., 142 pp.

ROLDÁN, M.I., R.G. PERROTTA, M. CORTEY & C. PLÁ 2000. Molecular and morphologic approaches to discrimination of variability patterns in chub mackerel, *Scomber japonicus. Journal of Experimental Marine Biology and Ecology,* vol. 253(1): 63-74.

SANTOS, R.S., S. HAWKINS, L.R. MONTEIRO, M. ALVES & E.J. ISIDRO 1995. Marine research, resources and conservation in the Azores. *Aquatic Conservation: Marine and Freshwater Ecosystems,* vol. 5 (4):311-354.

SECKENDORFF, R.W. & L.A. ZAVALA-CAMIN 1985. Reproducao, crescimento e distribucao de *Scomber japonicus*. *Bol. Inst. Pesca*, 12 (2):1-13.

TAYLOR, C.C. 1959. Temperature, growth and mortality - the Pacific cockle. *Journal du Conseil International pour l'exploration de la mer (CIEM/ICES)*, 26:117-24.

WESTHAUS-EKAU, P. & W. EKAU 1982. Preliminary report of the investigations on Cavala (*Scomber japonicus*) and Chicharro (*Trachurus picturatus*) at the Department of Oceanography and Fisheries, Horta. *Relatório Interno*, *Departmento de Oceanografia e Pescas*, Horta. 24pp.

ZAR, J.H. 1996. *Biostatistical analysis*, 3rd. Edition. Prentice-Hall, Englewood Cliffs, NJ. 662 pp.

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