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Age, growth and mortality of southern rays bream *Brama australis* (Bramidae) off the southeastern Pacific coast

Edad, crecimiento y mortalidad natural de la reineta *Brama australis* (Bramidae)
en la costa este del Pacífico sur

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Resumen.- Se determinó la edad, función de crecimiento y mortalidad natural de la reineta *Brama australis* provenientes de capturas comerciales realizadas en la zona central de la costa de Chile. Los resultados indican que la especie crece rápidamente durante el primer año y alcanza la máxima longitud asintótica (59 cm) aproximadamente al octavo o noveno año de edad. La función de crecimiento de von Bertalanffy describió satisfactoriamente el crecimiento en longitud a través de la edad de *B. australis*, determinada mediante el análisis de los otolitos. Los parámetros estimados para ambos sexos combinados fueron: en longitud, $L_{\infty} = 58,95$ cm, $K = 0,277$ año⁻¹, $t_0 = -0,371$ años; y en peso, $W_{\infty} = 2508,8$ g, $K = 0,257$ año⁻¹, $t_0 = -0,712$ años. No se encontraron diferencias en la longitud a la edad entre sexos. La tasa de mortalidad total (Z) desde el análisis de la edad máxima y curva de captura fue relativamente alta (0,9 año⁻¹). La tasa de mortalidad natural (0,45 año⁻¹) es consistente con los parámetros de vida de un pez pelágico de tamaño medio, de explotación relativamente baja en el periodo en que fueron colectadas las muestras.

Palabras clave: Bramidae, edad y crecimiento, mortalidad, Pacifico sureste, reineta

Abstract.- The age and growth function and mortality were determined for southern rays bream *Brama australis* caught in commercial trawls off the coast of central Chile. The results show that this species grows quickly in the first year and reaches the maximum asymptotic length (59 cm) at approximately 8 or 9 years old. The von Bertalanffy growth function described *B. australis* growth satisfactorily with length-at-age determined using otolith analysis. Parameters for the entire population (males and females) were: for length, $L_{\infty} = 58.95$ cm, $K = 0.277$ yr⁻¹, $t_0 = -0.371$ yr; and for weight, $W_{\infty} = 2508.8$ g, $K = 0.257$ yr⁻¹, $t_0 = -0.712$ yr. No differences were found in length-at-age between sexes. Estimates of total mortality rates (Z) from maximum age and catch-curve analyses were relatively high (0.9 year⁻¹). The natural mortality rate ($M = 0.45$ yr⁻¹) is consistent with the life parameters of middle-sized pelagic fish with relatively low exploitation at the time of sampling.

Key words: Bramidae, age and growth, mortality, eastern South Pacific, southern rays bream

INTRODUCTION

The Southern rays bream, *Brama australis* Valenciennes, 1838, is a member of the family Bramidae that is exploited by the artisanal fleet along the Chilean coastline. According to Mead (1972) and Last & Baron (1994), this family inhabits epipelagic ecosystems at depths over 200 m, although it has been reported at depths exceeding 400 to 500 m. *B. australis* is widely distributed in the South Pacific Ocean; it has an apparent circumpolar distribution in the hemisphere and is restricted to the circulation boundaries of the subtropical water masses (35°-48°S) (Pavlov 1991a).

Until a few years ago, *B. australis* was not considered to be a commercially important species. Rather, it was caught as bycatch during trawling for Patagonian grenadier (*Macruronus magellanicus* Lönnberg, 1907) and Chilean jack mackerel (*Trachurus murphyi* Nichols, 1920) (Muñoz *et al.* 1995). However, *B. australis* is currently highly valued for human consumption in central Chile. Official records were begun for *B. australis* catches off the Chilean coast in 1994 (SERNAPESCA 2011). The mean landings have increased from 5000 tons (t) between 1994 and 2000 to over 15000 t since 2010 (Fig. 1). The

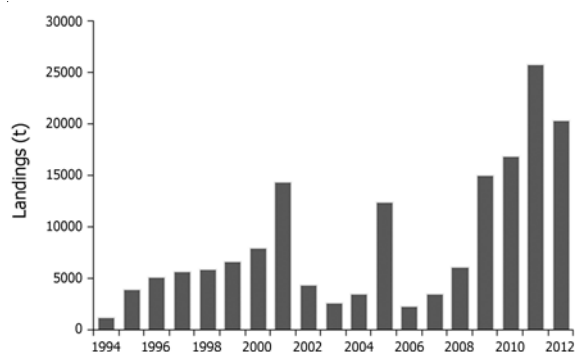


Figure 1. Total landings of southern rays breams registered in Chile from 1994 / Desembarques totales de reineta registrados en Chile desde 1994

fishery shows seasonality with higher catches during spring-summer from October to April.

Information on the biology and ecology of *B. australis* is limited despite its newfound ecological and commercial importance for the artisanal fleet. Pavlov (1991a, b, 1994) performed morphometric, taxonomic, ecological and reproductive studies on members of the *Brama* genus from southeastern Pacific Ocean. Muñoz *et al.* (1995) and Garcia & Chong (2002) studied the feeding habits of *B. australis* off the coast of central Chile, characterizing this species as a secondary consumer that preys mostly on crabs, squids, and small fishes, as it has been reported in other species of *Brama* (Seki & Mundi 1991, Percy *et al.* 1993). Leal & Oyarzún (2003) described *B. australis* reproduction along the Chilean coast, reporting higher reproductive activity in winter and an active female maturation process over 35 cm fork length.

Given the lack of reliable information on biological parameters for this species, the objective of this work was to study growth and mortality in the eastern South Pacific population of *B. australis* based on otolith age analysis of annual increments in their otoliths.

Materials and Methods

Sampling took place between 35°20'S and 38°50'S off the eastern South Pacific coast (Fig. 2). Specimens were collected monthly from November 1994 to December 1996 from pelagic commercial fisheries. Fishes were sexed macroscopically, and measured for total length (L_T , cm) and total weight (W_T , g). Sagittal otoliths were taken from each specimen and stored in dry bags. Prior to analysis, each left otolith was hydrated in distilled water from 24 to 48 h. The external surface of each otolith was examined microscopically under reflected light.

Organisms were aged by counting the number of growth marks found in the otoliths. Prior to aging the individuals, a periodicity analysis was done to evaluate the formation of annual growth bands. The number of translucent zones on each otolith and the nature of the border were recorded.

To assess the precision of aging, all otoliths were read twice by 2 different readers and the agreement between and within readers was evaluated by percent agreement methods (Beamish & Fournier 1981). Lack of consensus resulted in the otolith being rejected as «non-interpretable» and excluded from analysis.

After age determination, parameters of the von Bertalanffy growth function (BGF, Ricker 1975) in length, $L_t = L_\infty (1 - \exp(-k(t - t_0)))$ and weight, $W_t = W_\infty (1 - \exp(-k(t - t_0)))^b$ were obtained. Where L_t and W_t are the length (cm) and weight (g) of fish aged t (years) respectively, L_∞ and W_∞ are the theoretically maximum length (cm) and weight (g) respectively, K is coefficient of growth, t_0 is theoretical age at which the length of fish is 0 and b is slope parameter in the length-weight relationship.

The parameters of BFG were fitted using non-linear regression (the NONLIN module of SYSTAT v.7, Wilkinson 1988) with a Gauss-Newton algorithm, where growth parameters and the residual sum of squares (RSS) were obtained from each iteration (1000) through quadratic minimization. Growth curve parameters were compared between sexes with RSS analysis modified for non-linear minimum squares (Chen *et al.* 1992).

A length-weight relationships ($W = a \cdot T_L^b$) was fitted to the data and utilized to calculate the parameters used in BGF for weight. T_L is a total length, a and b are regression coefficients. The estimated value a that came from the logarithmic scale (Smith 1990) was transformed to an arithmetic function. The growth performance index $f = \log_{10}(K) + 2/3 \log_{10}(W_\infty)$ was computed from the growth parameters for comparing with another species (Sparre & Venema 1997).

A catch curve-at-age was constructed by expanding the length-frequency distribution at abundance caught at age. The total mortality rate (Z) for both sexes was determined from the descending limb of the curve according to Sparre & Venema (1997).

The lack of data concerning fishing effort and the unavailability of data on unfished areas made it not possible to make a direct estimation of natural mortality rate (M). Instead, empirical models based on the

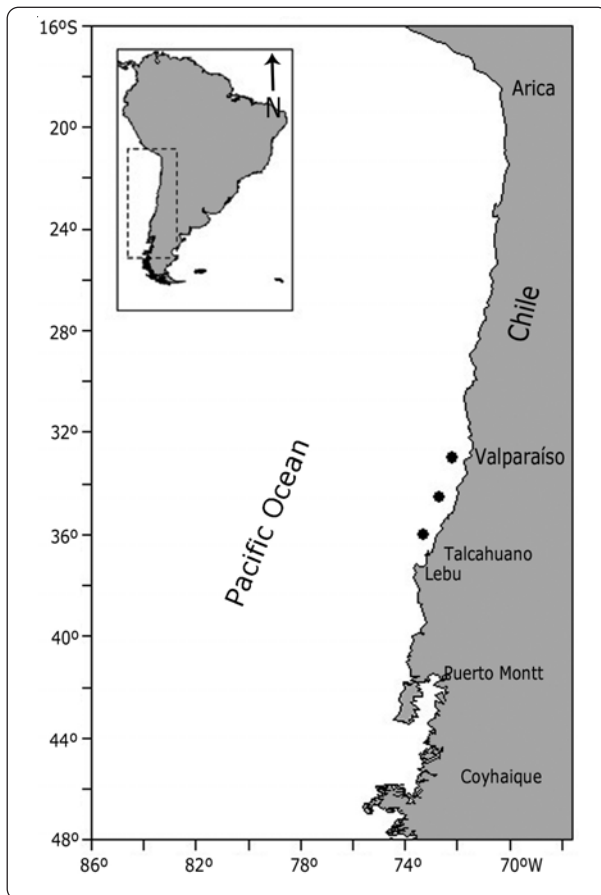


Figure 2. Geographic location of the study on the central coast of Chile. The black points indicate the approximate sampling sites / Localización geográfica del estudio en la costa central de Chile. Los puntos negros indican los sitios aproximados de muestreo

relationships between M , growth parameters and mean habitat temperature ($T^{\circ}\text{C}$) were used to obtain approximate estimates (Pauly 1980). Additionally, Alagaraja (1984), proposed an alternative method of estimating M by relating to the natural life span of fish which was defined as an age at which 1% of a cohort is still alive (T_1 , years). This approach was also used in order to provide an estimate of the natural mortality rate in *B. australis*.

Results

A total of 534 adult brems were analyzed. Individuals ranged from 21 to 58 cm T_L . Of the total specimens measured, 109 were discarded due to otolith breakage or loss or because they were classified as non-interpretable, as defined in the methods section.

The edge analysis showed that the percentage of translucent (hyaline) edges increased markedly in those

periods in which opaque edges decreased, showing one peak per 12-month period and thereby demonstrating that the translucent zones (hyaline bands) are formed annually.

Individuals of both sexes showed age range between 2 to 8 years *i.e.*, from 2 to 8 marks (hyaline bands). In terms of numbers, most males were younger (2-4 years) and most females older (5-7 years). For both sexes, 4 years-old specimens showed the highest frequency. The VBFG equations for male, female and for pooled are showed in the Fig. 3.

Observed lengths did not vary greatly with age. Growth was fast in the first years of life and slow from year 7 onward. Southern rays breem achieve 50% of their L_{∞} at age 2, apparently one year before the recruitment to the fishery.

No differences were found in growth curve parameters for length between the sexes ($P > 0.05$). We did not observe large numbers of either the youngest or oldest fish.

The weight of the southern rays breem varied greatly with age. As it was found for age-length data, growth was rapid in the first 4 years. Although it slowed thereafter, the fish still grew appreciably in weight until 10-11 years, at which point growth substantially slowed. Hence, the fish grew apparently more slowly in weight than in length. The BGF equation for pooled data was: $W_t = 2508.8 (1 - \exp(-0.257(t+0.712)))^{2.84}$. Table 1 shows the estimated parameters, asymptotic standard errors (ASE), and 95% confidence intervals. The growth performance of *B. australis* was $\phi = 1.67$. A pooled length-weight regression (Fig. 4) with a fitted value for a was developed ($R^2 = 0.97$; $n = 425$; $P < 0.01$). The slope of the regression line ($b = 2.84$; $SE = 0.067$) was significantly different from 3.0 ($P < 0.05$), indicating allometric growth.

Table 1. Summary of estimated parameters for the von Bertalanffy growth equation of total length (cm) and total weight (g) of *Brama australis* for the pooled data / Resumen de los parámetros estimados por la ecuación de crecimiento de von Bertalanffy para la longitud total (cm) y peso total (g) de *Brama australis* para el total de los datos

Measurement	Parameter	Estimate	ASE	Lower lim. (95%)	Upper lim. (95%)
Length (cm)	L_{∞}	58.952	2.176	54.675	63.23
	K	0.277	0.034	0.21	0.345
	t_0	-0.371	0.217	-0.799	0.056
Weight (g)	W_{∞}	2508.8	65.073	2367	2650.6
	K	0.257	0.005	0.215	0.299
	t_0	-0.712	0.05	-0.821	-0.604

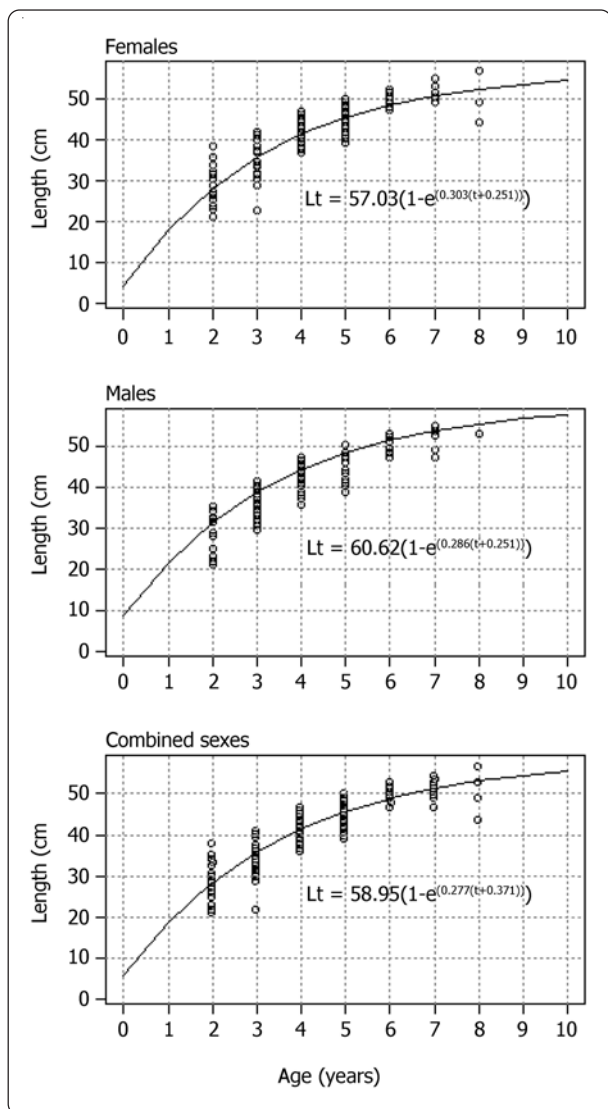


Figure 3. Length growth curve for females, male and for combined sexes of southern rays breams / Curva de crecimiento en longitud para hembras, machos y sexos combinados de reineta

The total mortality rates (Z) were determined from the descending limb of the resulting curve for catch-at-age, considering a maximum observed age of 11 years for the combined sexes. A regression estimate obtained from the slope of a catch-curve truncated at older ages (Fig. 5) was $Z = 0.9 \text{ yr}^{-1}$. On the other hand, using growth parameters for pooled data, M was estimated in 0.46 yr^{-1} following Pauly (1980). The mean habitat temperature of 14°C was assumed for calculating M with this method. The M value obtained with Alagaraja (1984) method was 0.44 yr^{-1} , using 11 years to T_L . A compromise value of 0.45 yr^{-1} was assumed to M in *B. australis*.

Discussion

This paper presents new information about important biological aspects of *Brama australis* in the eastern South Pacific and the results may be used to prove potential temporal changes in growth parameters and natural mortality.

The reports of biological and ecological data for *B. australis* are restricted to taxonomical studies (Pavlov 1991a, b), feeding ecology (Muñoz *et al.* 1995), and reproduction dynamics (Pavlov 1994, Leal & Oyarzún 2003). Furthermore, several studies of population dynamics have targeted congeneric species of *Brama* inhabiting other latitudes for purposes of commercial exploitation and management. This interesting fishery has been explored off the coasts of Australia, New Zealand, Spain, and Portugal (Seki & Mundi 1991, Savinykh 1993, Last & Baron 1994).

The generalized VBGF satisfactorily described the growth of *B. australis*, and the similar growth curves for males and females provided a graphic representation of the lack of significant differences in mean length-at-age by sex. A slight difference was observed between sexes in terms of length, possibly due to different proportions of length in the sampled individuals: despite a 1:1 proportion of sexes, females tended to be slightly larger than males.

Interestingly, in this study most of the sampled specimens were adults. The lack of juveniles in the study could result in overestimated values of the growth parameters (Francis & Campana 2004). Nevertheless, this result agrees with the reports about other species of *Brama* (Pavlov 1991b, Savinykh 1994, 1995; Seki & Bigelow 1996), indicating the possibility of differential bathymetric distributions for juveniles (pelagic-coastal) and adults (oceanic-demersal), or the lack of selectivity of the gears for sampling this etary group. On the other hand, perhaps the strongest alternative explanation for the lack of young-of-the-year lies in the migratory patterns observed in many bramids. Specifically, breams undergo long-range migrations along the oceanic water mass according to circumtropical circulation (Seki & Mundi 1991). Pavlov (1994) suggests a feeding migration of *B. australis* from north to south in summer-autumn and from south to north in winter-spring to spawn.

Our results about age (2 to 8 years) in *B. australis* observed ranged from 21 to 58 cm T_L are consistent with Pavlov (1994) which suggested one to 6 age group to a few sample number of 13–48 cm *B. australis* from southeast

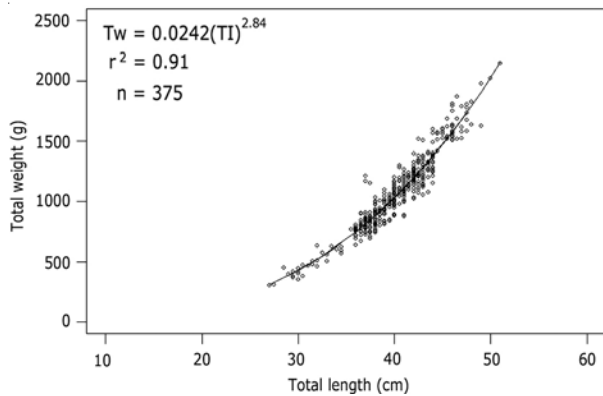


Figure 4. Length-weight relationship curve of southern rays brems fitted to an exponential model / Curva de la relación longitud-peso de reineta ajustada por un modelo exponencial

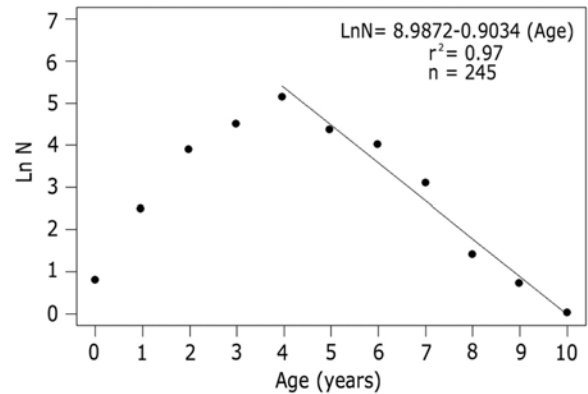


Figure 5. Catch-curve and estimate of total mortality for southern rays brems / Curva de captura y tasa de mortalidad total estimada para reineta

Pacific Ocean. For *Brama japonica*, Savinykh & Vlasova (1994) examined whole stained otoliths of 14-54 cm from the North Pacific and found a maximum age of 9 years, with 3 and 4 year fish predominating in the catch. For the same species, rapid growth is observed during the first 3 years, when they reach 80% L_{∞} (Pearcy *et al.* 1993). This species reaches its asymptotic length at approximately 9 to 11 years of age. Lobo & Erzini (2001) used readings of whole otoliths for 32-56 cm *B. brama* from Portugal to identify age groups 3 to 12 years.

Both the growth trends and the age and growth parameters obtained in this study agree with those reported for *B. japonica* and *B. brama* with a maximum asymptotic length observed near 60 cm (TL), although only 4 of the specimens used in this study were larger than 55 cm L_{∞} .

The previous background support maximum ages of 8 to 12 years for species of *Brama* and seem reasonable for a middle size of pelagic fish. This also supports the annual formation of translucent zones (hialine bands) observed in this study.

This work is the first study on age, growth, and mortality for *Brama australis* in the Chilean coast based on otolith analysis, so no comparison is possible with other studies of this species. When compared with the total mortality rates (Z), estimates of M are consistent. The yield, exploitation rates, and F/M ratio are lower than those reported for other species exploited in this area (Böhm *et al.* 1995). However, the natural mortality rate seems to be consistent with the life parameters of middle-sized pelagic fishes with relatively low exploitation at the time of sampling.

Thus, considering the time in which samples were obtained, when the resource was still subject to low-moderate exploitation rates, the results of this report provide an important point of comparison with current or future studies. For example, to assess possible fishing effects on individual growth rates and M. The parameters may also be used in stock assessment analysis providing management advice for fishery along the Chilean coast.

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