

## AGE AND GROWTH OF THE SEAROBIN (*PRIONOTUS PUNCTATUS*) IN BRAZILIAN WATERS

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### ABSTRACT

Age and growth of the searobin, *Prionotus punctatus* (Bloch, 1797), caught in Brazilian waters was studied by analyzing growth increments in the sagittal otolith. Analysis of marginal band (opaque or translucent) validated annual deposition of otolith growth increments. Two types of error formulations (additive and multiplicative) were used to fit growth models to age-length data. The generic model of Schnute was used as a tool to compare different specific growth models, and the von Bertalanffy model was the most parsimonious. The relationship between  $k$  and  $L_{\infty}$  for females and males differed; females grew somewhat more quickly and reached greater lengths than males.  $L_{\infty}$  estimates ranged from 42–51 cm for females and from 36–43 cm for males.  $k$  estimates ranged from 0.07–0.14 for females and from 0.06–0.12 for males.

The searobin, *Prionotus punctatus* (Bloch, 1797), is an important component of the demersal fishery (e.g., double rigs and pair trawlers) in the southeast coast of Brazil (GEP/UNIVALI, 2002). Although *P. punctatus* is not a target species due to its low market price, catches of this species are high year-round. Searobin landings are often larger than those of the target species (e.g., shrimps and flatfishes). For instance, in 2001 in the main fishery harbor of south Brazil (Itajaí-SC), 2060 t of searobin were landed by double rig vessels (13% of the total catch). Among more than 60 species usually caught by the double rig fleet, only landings of Brazilian codling, *Urophycis brasiliensis* (Kaup, 1858), exceeded catches of searobin in 2001 (GEP/UNIVALI, 2002). The searobin is considered a “buffer” resource that assures fishermen income even when the catch of valuable species is low.

Apart from political, sociological, and economic issues, fishery management decisions depend on the biomass of the exploited resources. Thus, age estimates and growth models are basic components of fishery assessment models (e.g., yield per recruit, virtual population analysis). Despite the importance of the searobin in the multi-species fisheries, the age and growth of this species has been poorly studied. The only estimate of growth parameters for Brazilian searobin is for young fish caught inshore (Peria, 1995).

Age estimates and growth parameters of many teleost fish can be obtained by analyzing the number of growth increments deposited on sagittal otoliths. Because the subjectivity of reading otolith growth increments can introduce bias, estimating precision indexes can provide useful information about sources of error in ageing studies (Campana and Jones, 1992).

Several models have been used to describe growth of fishes (e.g., Gompertz, Exponential, Pütter or von Bertalanffy). The von Bertalanffy (1938) model is the most popular, but generic models such as Schnute (1981) should be used to identify the most suitable model. The way that error is incorporated into the model is an important issue (Hilborn and Mangel, 1997; Quinn and Deriso, 1999). Two process error structures were assumed in order to estimate growth parameters of searobin.

## MATERIAL AND METHODS

**SAMPLING AND OTOLITH READINGS.**—Searobin are caught in relatively shallow waters (< 120 m) between 23°S and 34°S (Haimovici et al., 1994). Fish landed in the Itajaí harbor (Santa Catarina state, Brazil) were sampled between July 1997 and March 1999 (Table 1; Fig. 1) using a sampling design stratified by length class. In the laboratory, sagittal otoliths were removed, sex was determined, and fish weighed to the nearest 0.5 g and measured to the nearest 1 mm.

Otoliths were embedded in transparent resin blocks. The blocks were transversally cut to produce slices (0.7 mm width) containing the nucleus of the otoliths (Fig. 2). The approximate position of the nucleus in the otolith was determined by analyzing subsequent sections (anterior to posterior region) of several otoliths. Otolith sections were examined at 10× using incident light and a black background. Each of the three readers estimated the number of growth increments and the type of the edge (translucent or opaque) for each otolith. Precision indexes for the readings were estimated by calculating the coefficient of variation (CV) as proposed by Chang (1982).

Analysis of the monthly variation in edge type (opaque or translucent; Geffen, 1992) was used to validate the temporal pattern of increment deposition.

**ERRORS IN THE MODEL.**—Two process errors were assumed to fit the growth model, one additive, with normal probability distribution

$$\hat{Y}_i = Y_i + \varepsilon_i; \quad i = 1, \dots, n \quad (1)$$

and another exponential multiplicative, with a log-normal probability distribution

$$\hat{Y}_i = Y_i \cdot e^{\varepsilon_i}; \quad i = 1, \dots, n \quad (2)$$

where the random variable  $\varepsilon_i$  ( $i = 1, \dots, n$ ) is assumed to be independent and normal with mean zero and variance one. These two types of errors were used to fit the generic (Schnute, 1981) and specific growth models (e.g., Pütter or von Bertalanffy). Estimates of the parameters were obtained by minimizing the negative log-likelihood function.

Table 1. Number of searobin (*Prionotus punctatus*) sampled for aging studies. The data were gathered from landings of the trawler vessels that fished in the southeast coast of Brazil.

Year	Month	Male	Female
1997	July	6	14
	August	15	18
	September	9	18
1998	February	6	22
	April	14	8
	May	5	28
	June	15	43
	July	17	43
	September	10	15
	October	7	24
	November	7	14
	December	10	15
1999	January	18	31
	February	3	25
	March	18	12
Total		160	330

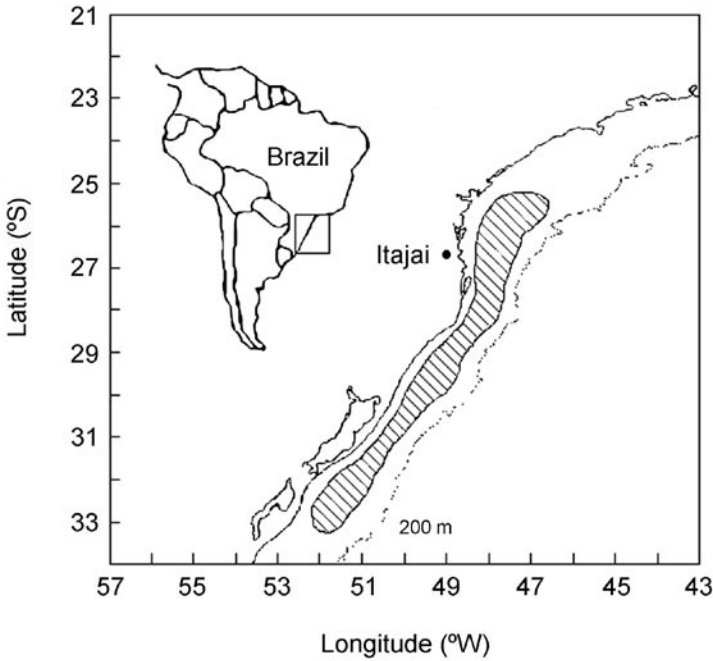


Figure 1. Map of the Itajaí harbor (Brazil) and the fishing ground covered by the sampled trawler fleet (hatched area).

Besides the traditional additive, the exponential multiplicative error model was also used because it can be more suitable when the length variance increases with age (or number of growth increments). To verify which error structure was more appropriate, the regression between the absolute residuals (observed – predicted) and the independent variable was tested. If the slope was significant, the residuals were not homoscedastic and the tested error (e.g., the additive error) structure was deemed not suitable.

**GROWTH MODELS.**—Specific growth models for fish are particular cases of the generic formulation of Schnute (1981). By fitting this generic model, one can obtain results that indicate which models are most suitable. Schnute's model is

$$Y(t) = \left[ y_1^b + (y_2^b - y_1^b) \frac{1 - e^{-a(t-\tau_1)}}{1 - e^{-a(\tau_2-\tau_1)}} \right]^{1/b} \quad (3)$$

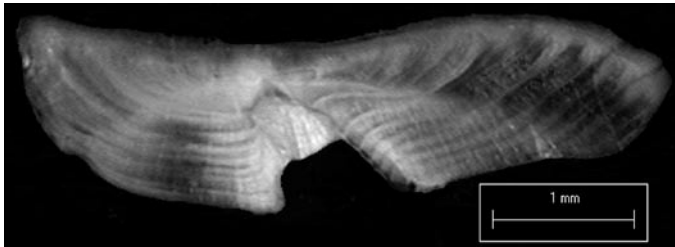


Figure 2. Section of a male *Prionotus punctatus* sagittal otolith. The fish was approximately 11 yrs old and 26.5 cm in length.

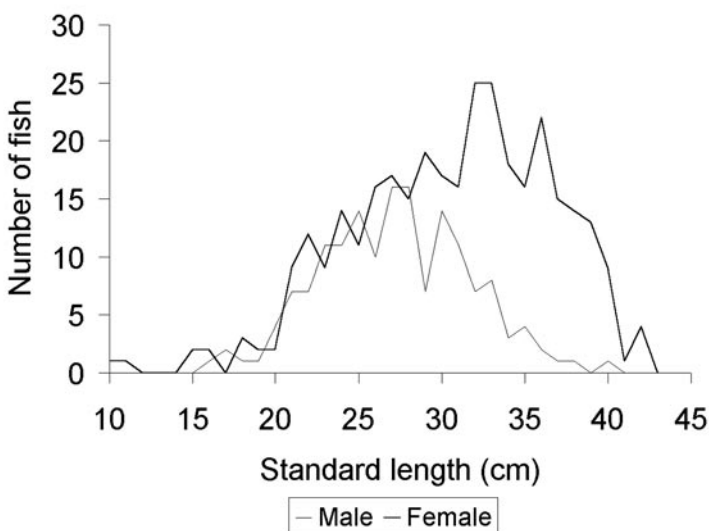


Figure 3. Length frequency distribution of *Prionotus punctatus* sampled.

where  $Y(t)$  is the estimated length for a fish with age  $t$ .  $\tau_1$  and  $\tau_2$  are two particular ages in the life of a fish, with the restriction that  $\tau_2 > \tau_1$ . The parameters to be estimated are  $a$ ,  $b$ ,  $y_1$  and  $y_2$ . The latter are lengths of fishes with ages  $\tau_1$  and  $\tau_2$  respectively. It is assumed that  $\tau_2 > \tau_1 > 0$ .

In the Schnute framework, specific growth models are identified according to the resulting estimates of  $a$  and  $b$  parameters. For example,  $a > 0$  and  $b \approx 1$  points to the classical von Bertalanffy growth model, whereas  $a > 0$  and  $b < 0$  points to a S-shaped model as being more suitable. Up to eight different specific models are nested in Schnute's formulation. Fisher statistics can be used to compare nested models to identify the most suitable models.

## RESULTS

**LENGTH AND WEIGHT DATA.**—Females dominated in the large length classes ( $> 30$  cm), but the largest sizes found for females and males were similar (Fig. 3). The length-weight relationships for female and male data sets were also very similar. The null hypothesis regarding differences between linearized length-weight equations for males and females cannot be rejected in a student t-test ( $P > 0.05$ ). Therefore, a single equation for all data ( $n = 477$ ) is presented for weight ( $W$ ) and length ( $L$ ) measured in kg and cm [ $W = 1 \times 10^{-5} \times L^{3.0094}$ ;  $r^2 = 0.9593$ ].

**VALIDATION AND BETWEEN-READER VARIABILITY.**—The monthly variation of percentage of otolith edge types determined by each reader was similar, thus the data were pooled. The percentage of fish with translucent otolith edges peak in the austral summer and decline quickly in the autumn (Fig. 4). Thus, increments were assumed to be deposited annually and could be used to determine age. Age was calculated as the total number of growth increments (opaque plus translucent band).

Increment counts by the different readers were similar in most cases. High values of CV tended to occur only when the mean number of growth increments was small (Fig. 5). Only one otolith with a mean number of growth increments  $> 12$  had a CV  $> 30\%$ . Two data sets were analyzed as defined by values of CV: (A) CV  $\leq 20\%$  (176 females and

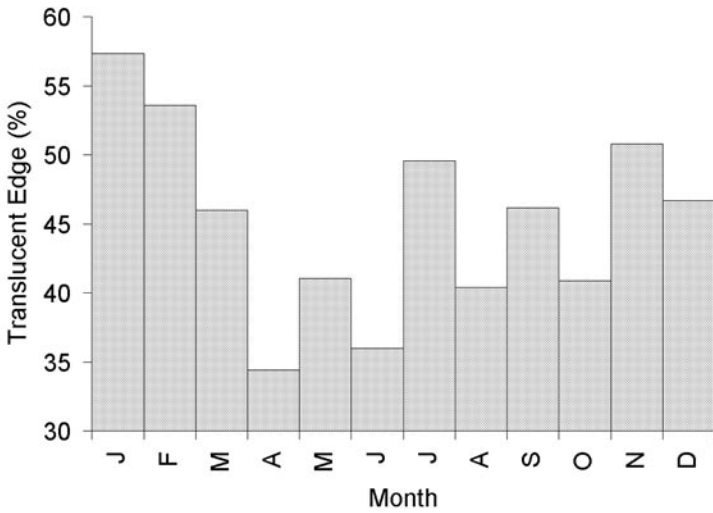


Figure 4. Monthly variation in otolith edge type of the examined *Prionotus punctatus* caught off Brazil.

79 males); and (B)  $CV \leq 30\%$  (262 females and 119 males). See Table 2 for examples of the age-length keys.

**GROWTH AND ERROR MODELS.**—The slope of the regression between the residuals of the length variable and the number of growth increments was not significant in a student t-test ( $P > 0.05$ ) for either error structures used (additive and multiplicative). Therefore, there is no evidence that length variance increases with age, and neither error model is clearly more suitable.

In order to identify the most appropriate growth model, the generic Schnute's model was fitted to all data sets and both error models (additive and multiplicative) were used. In all cases Schnute's model results were  $a > 0$  and  $b < 0$ . These estimated values suggest a S-shaped curve best describes searobin growth (for details see Schnute, 1981).

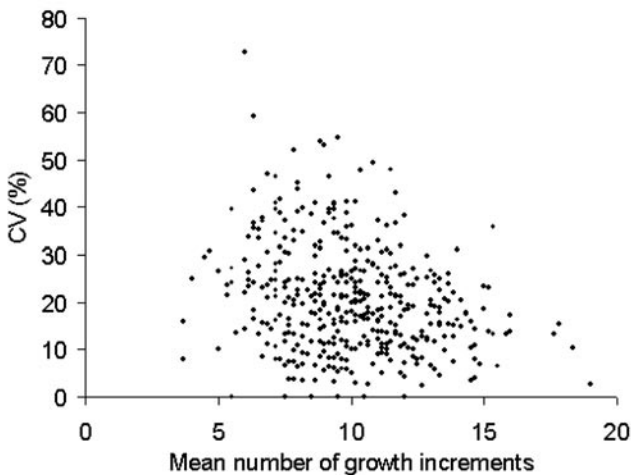


Figure 5. Coefficient of variation (CV) of readings of the number of otolith growth increments from searobin (*Prionotus punctatus*) caught off Brazil.

Table 2. One of the age-length keys used to estimate growth parameters for the searobin (*Prionotus punctatus*). The rounded mean number of otolith growth increments estimated by three independent readers is given for readings with coefficient of variation  $\leq 20\%$ .

Female		Age (years)																	
Length (cm)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total		
16		1	1														2		
18					1												1		
20							1		1								2		
22		1		1	3	1	1										7		
24				2		9	1	2									14		
26				1	1	3	4	6	1	1							17		
28				1	1	3	5	1	5								16		
30							2	4	3	2	1						12		
32				1	1	1	2	5	2	5	3	2	1				23		
34						3	4	4	5	4		3					23		
36							4	1	2	5	4	6	1				23		
38							2	5	1	5	3		1	3		1	21		
40										1	4	2				2	11		
42											2		1	1			4		
Total		2	1	6	6	21	25	29	20	27	15	12	5	3		3	176		
Male		Age (years)																	
Length(cm)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total		
20					1												1		
22					1	3	1										5		
24				2	1	3	2	2	1								11		
26		1				5	1	2	3	1							13		
28					2	2	3	4	3	2	1						17		
30						1	5	3	4	1	1	1	1				17		
32					1			1	2				1	1			6		
34									2	1	1						4		
36								1	1				1				3		
38											1						1		
40												1					1		
Total		1	2	3	14	14	14	16	5	4	2	3	1				79		

However, there was no significant difference ( $P > 0.05$ ) between the fittings of Schnute’s model with four parameters and that of von Bertalanffy’s model (with three parameters); therefore, von Bertalanffy was the alternative parsimonious model.

VON BERTALANFFY GROWTH PARAMETERS.—Acceptable values ( $35 < L_{\infty} < 50$  for males,  $40 < L_{\infty} < 55$  for females) for estimating the von Bertalanffy parameters were defined according to the length frequency distribution (Fig. 3). Despite the inherent error associated with three independent readers, the differences between the parameters estimated for male and female searobin, are clear (Fig. 6; Table 3).

DISCUSSION

Marginal increment analysis demonstrated that *P. punctatus* deposits annual increments. A similar result was found for a congeneric species (*Prionotus stephanophrys* Lockington, 1881; Schmitter-Soto and Castro-Aguirre, 1991). The seasonal pattern is evident in the type of otolith edge. The translucent band appears to be deposited in the

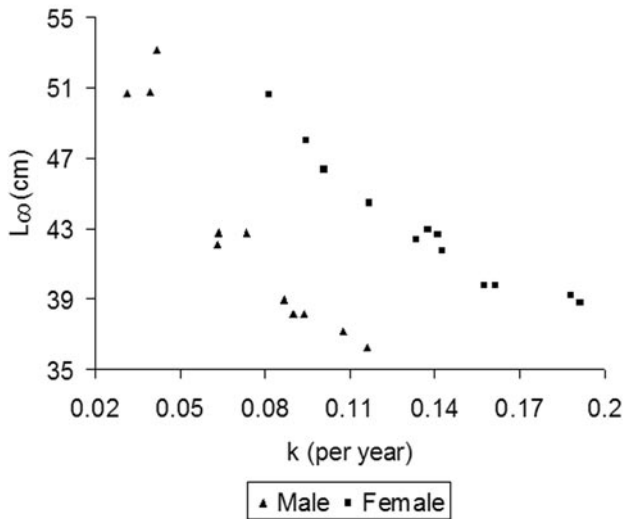


Figure 6. Relationship between  $L_{\infty}$  and  $k$  for male and female searobin (*Prionotus punctatus*) caught in Brazilian waters. All estimates obtained by the three readers are shown.

austral spring and summer. This is similar to patterns found for juvenile searobin caught in coastal Brazilian waters (Braga and Gointein, 1984). In addition to environmental factors (e.g., temperature), seasonal variation in the type of growth increments may be related to the reproductive cycle of the searobin. Searobin spawning peaks in the austral spring and summer (Teixeira and Haimovici, 1989) and somatic growth is likely reduced during this time. If this hypothesis holds for searobin, the translucent band could reflect low growth.

The relatively low values of CV for otolith readings indicated that searobin otoliths are useful for age and growth studies. Nevertheless, to ensure greater accuracy only select sets of aging data defined by high concordance between readers ( $CV \leq 20\%$  and  $CV \leq 30\%$ ) were used to estimate growth parameters. Selecting a CV threshold requires a balance between accuracy and sample sizes. If the CV threshold is too low (e.g.,  $CV \leq 5\%$ ) the data set will be precise, but the sample size too small. The effect of CV choice

Table 3. von Bertalanffy growth parameter estimates ( $L_{\infty}$  = asymptotic size;  $k$  = growth coefficient;  $t_0$  = intercept of the curve with the length variable axis) for female, male and all data sets. The model was fitted to the mean number of growth increments as calculated from the readings. Additive (A) and multiplicative (M) errors were used. Numbers in the third column (CV) are the maximum coefficient of variation of the readings in the data set analyzed.

Sex	CV	Error	$L_{\infty}$ (cm)	$k$ (per year)	$t_0$ (years)
all	20	A	52.705	0.067	-3.162
all	30	A	45.948	0.092	-1.892
all	30	M	46.637	0.088	-1.927
female	20	A	48.019	0.095	-1.399
female	20	M	50.623	0.082	-1.797
female	30	A	44.464	0.117	-0.601
female	30	M	46.366	0.101	-1.050
male	20	A	42.771	0.064	-7.715
male	30	A	42.771	0.074	-5.168

on the precision and accuracy of the parameter estimations in data-limited situations is unknown and should be studied in the future.

Regardless of the CV, the range of estimated growth parameters was wide. To present only one estimate (e.g., one vector of parameters) would convey a certainty that does not exist. Identifying all uncertainty in a fishery resource is important for allowing the precautionary approach and to avoid bad management actions (FAO, 1995).

Growth of male and female searobin are quite different, which is usual and widely explored in the literature (e.g., Beverton, 1992). The relationship between asymptotic size ( $L_{\infty}$ ) and the growth coefficient ( $k$ ) may occur as the result of a constraint on growth, and is one of the life history invariants suggested by Charnov (1993). Large organisms, which achieve larger lengths, require high energy for body maintenance, movement, metabolic functions, and less energy is available for growth (lower  $k$ ; Ursin, 1967; Charnov, 1993; Jensen, 1996, 1997). Females tend to exhibit lower  $k$  and higher  $L_{\infty}$  values than males (Beverton, 1992; Charnov, 1993). Nevertheless, results of this study suggest that females tend to grow faster, achieve larger lengths than males, and dominate larger size classes.

The von Bertalanffy growth equation was derived based on metabolic concepts (von Bertalanffy, 1938; Ursin, 1967), suggesting that one hypothesis to explain the differences between sexes is that female food uptake mechanisms are more efficient ("physiological hypothesis"). The lower final length males achieve together with slow growth has the consequence that a 35 cm male would be much older than a female of the same size. Therefore the probability of mortality (natural plus fishery-caused) before reaching a given larger size is greater for males. The occurrence of a sampling failure is also a possible explanation ("biased sampling hypothesis"). For instance, large males could be distributed in inaccessible areas and could be not vulnerable to the fishing fleet. Both hypotheses could result in the observed female dominance in larger size classes.

The growth parameters (especially  $k \approx 0.06\text{--}0.14 \text{ yr}^{-1}$ ) estimated in this work differ from that obtained by Peria (1995) for juveniles ( $< 5\text{-yrs}$  old) of the same species ( $k = 0.285 \text{ yr}^{-1}$ ). This disagreement is expected because the models presented in this paper are more suitable for commercially exploited parts of the searobin population (7–15 yrs old). These data further suggest that if length at first maturation is 26 cm (Teixeira and Haimovici, 1989) then the age of maturation is about 9-yrs old. Therefore, the searobin is mature in the second half of its life cycle.

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