

MAUROLICUS STEHMANNI PARIN & KOBLYANSKY, 1993 (STERNOPTYCHIDAE):
LENGTH OF FIRST MATURATION, AND SPAWNING SEASONS IN
THE SOUTH-SOUTHEAST BRAZILIAN REGION

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ABSTRACT

Maurolicus stehmanni (Sternoptychidae) is a mesopelagic species of fish inhabiting the outer continental shelf and slope of the south-southeastern Brazilian (ZEE), where it presents a considerable biomass and is an important component of the trophic chain, as a forage species. On the basis of catches made with a mid-water-trawl net in 1996 and 1997, as part of the REVIZEE program, samples from 38 hauls were analyzed as regards the length structure of the population, the average length of the first maturation and the spawning seasons of the species. The analysis of histological cross-sections of the ovaries made it possible to describe the oocytic development and assess the macroscopic criteria used to classify the ovary maturation. Results showed that the average length of the first maturation occurs at 32 mm (standard length), females spawn all year round throughout the area studied and the oocytic development is asynchronous.

RESUMO

Maurolicus stehmanni (Sternoptychidae) é um pequeno peixe mesopelágico que habita a plataforma continental e o talude da região entre Cabo de São Tomé (22 S) e Chui (34 S). No Atlântico Oeste, apresenta biomassa de cerca de 1 ton e é um importante componente da dieta de peixes pelágicos e demersais com valor comercial. A partir de capturas realizadas com rede de meia água, em 1996 e 1997, dentro do programa (REVIZEE), exemplares provenientes de 38 lances de pesca foram analisados em relação à estrutura da população em comprimento e aos estágios de maturação macroscópica das gônadas, dados que, associados a dados biométricos, permitiram estimar o tamanho médio da 1ª maturação e épocas de desova da espécie. Foram realizados, ainda, cortes histológicos de ovários e testículos com vistas a aferir a avaliação macroscópica e analisar o desenvolvimento ovocitário da espécie. Os resultados indicam que o tamanho médio da 1ª maturação é de 32 mm de comprimento padrão, as fêmeas desovam o ano todo e que a desova ocorre ao longo de toda a borda da plataforma continental sudeste-sul do Brasil. O desenvolvimento ovocitário é assíncrono, mostrando que *M. stehmanni* apresenta desova parcelada.

Descriptors: *Maurolicus stehmanni*, Mesopelagic fish, Spawning sites, Reproduction, Length of first maturation, Ovary development.

Descritores: *Maurolicus stehmanni*, Peixes mesopelágicos, Reprodução, Comprimento da primeira maturação, Desenvolvimento ovariano.

INTRODUCTION

Maurolicus stehmanni Parin & Kobylansky, 1993 (Sternoptychidae) is found in the Western Atlantic between 23°S and 40°S. It is of great importance to the pelagic and demersal ecosystems of the outer shelf and slope of the south-southeastern Brazilian region since it constitutes an important item in the diet of large pelagic and demersal fishes (ZAVALA-CAMIN, 1981; ANKEBRANDT, 1985; HAIMOVICI et al., 1994; MUTO et al., 2005). During

hydroacoustic prospecting cruises undertaken between August 1996 and December 1997 in the south-southeastern Brazilian region, the average biomass of this species was estimated at 1 million tons (GREIG, 2000; MADUREIRA et al., 2005).

Species of the *Maurolicus* genus have a short life span, rapid growth and great fecundity and, thus, alterations in the environment, whether in physical or biological terms, may lead to rapid changes in these biological parameters (SALVANES; STOCKLEY, 1996).

Since *M. stehmanni* presents a considerable biomass and is an important element of the food web

in the region, its stock management should be preceded (and maintained) by biological studies which will allow its monitoring. To date, only age and growth parameters are available (BELLUCCO et al., 2004). The aim of the present study is to contribute with new biological information about the species, regarding its population composition, in terms of proportions of males and females, and young and adults, average size of first maturation, spawning seasons, oocytic development and species spawning phases.

MATERIAL AND METHODS

The samples used in this study were caught with a mid-water-trawl net during three cruises using acoustic prospections for pelagic resources of the REVIZEE program, undertaken with the R/V *Atlântico Sul*. Details on the collection and characteristics of the study area are to be found in Almeida (2001), Figueiredo et al. (2002) and Madureira and Rossi-Wongtschowski (2005). Three cruises (I, II, III) were undertaken during the winter of 1996 (July, August, September), the autumn of 1997 (April, May) and the spring of 1997 (November, December), respectively, covering the whole area between the Cape of São Tomé (22°S) and the Arroio Chuí (34°S), between depths of 100 to 1500 m (Fig. 1). *M. stehmanni* was collected in 42 catches (Fig. 2).

Once on board 150 specimens were separated randomly from each catch and then frozen and sent ashore for analysis.

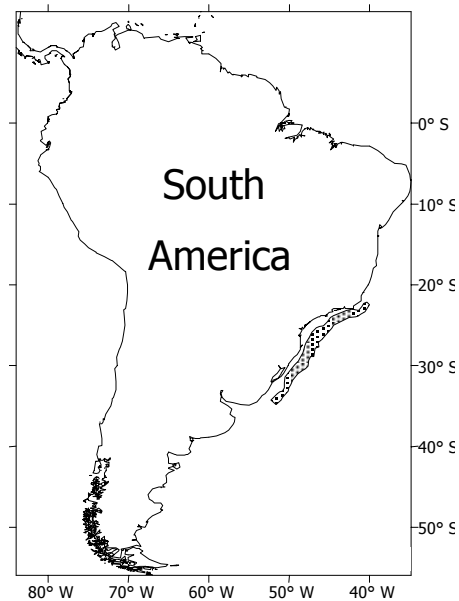


Fig. 1. Study area (shaded).

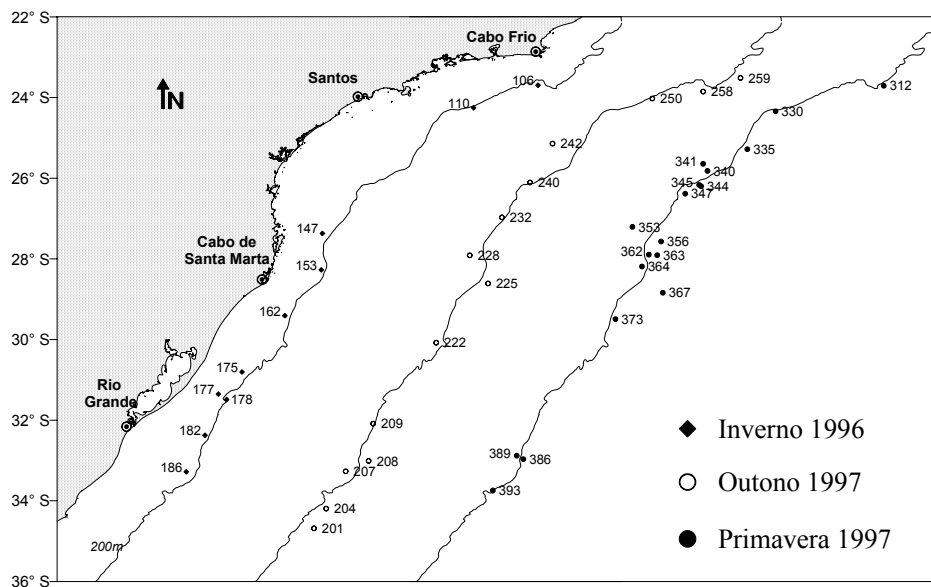


Fig. 2. *Maurolicus stehmanni*: distribution of fishing catches by species and season of the year.

At the laboratory, the measurements of standard length (Ls), in mm, and of total weight (Wt) in g, were obtained, sixty of the specimens were identified by sex and the maturity of their gonads classified under the stereomicroscope in accordance with the maturity scale proposed by Vazzoler (1996), which used five stages, namely, immature (A), undergoing maturation (B), mature (C), spawned (D) and at rest (E). The gonads were removed, weighted (W_0) and maintained in 4% formaline for 24 hours, then transferred to 70% alcohol.

Samplings from two other cruises (IV, V), undertaken using the same methodology as the previous ones, though covering a more restricted area, near Itajaí (MADUREIRA et al., 2005), were used for histological analysis of the ovaries. Fish from each of the catches had their length measurements taken and their ovaries were fixed in 4% formaline, as soon as they were taken out of the net, in order to preserve their cells and ovarian structures. Before being fixed, these gonads were classified macroscopically and later received the same treatment for the mounting of permanent preparations as that described before.

Analyses Undertaken

Population Structure

The proportion of males and females per catch was calculated, as well as their relationship to the length of specimens, in accordance with the method described in Vazzoler (1996). The hypothesis of the proportion of males to females being 1:1 ($p=0.05$) was tested by the X-squared test (ZAR, 1996).

Juveniles and adults proportion was analyzed by season, juveniles being understood as fish whose gonads were immature (A) and as adults, all those classified in the other stages (B, C, D and E).

Average Length of the First Maturation

According to Vazzoler (1996), this is the length at which 50% of the fish of a particular species attain gonadal maturity (L_{50}) for the first time. This length was estimated on the basis of the adult individuals proportion, by class of standard length, the logistic curve being adjusted to the points obtained using the method proposed by King (1995). The calculation of the L_{50} was performed for males and females together, due to the difficulty in identifying sex of the immature fish macroscopically.

For the purpose of comparing data obtained in this study with information available in the literature, both the minimum standard length of maturation (L_{min}) and the maximum standard length of maturation (L_{max}) were calculated separately for males

and females, representing the minimum and maximum sizes of the fish with ripe gonads, namely, those in stage C (DALPADADO; GJØSÆTER, 1987; YOUNG et al., 1987; PROSCH, 1991; RASMUSSEN; GISKE, 1994).

In order to evaluate the influence of environmental factors on the average size of the first maturation and in the theoretic maximum length, the relationship L_{50}/L_{∞} , proposed by Longhurst and Pauly (1987) was calculated for the whole set of data and for each season. This calculation was also performed using the L_{min} , thus permitting comparisons with data from the related literature.

Spawning Seasons

The following items were analyzed for the purpose of verifying the existence of the spawning seasons of *M. stehmanni* in the study area:

- Frequency of the gonadal maturity stages by cruise, for all fishes (males and females in their respective groups), which, according to West (1990), indicates spawning through the presence of mature fish.

- Gonadosomatic relationship (GSR), which expresses the ratio, as a percentage, of the gonad weight to the fish weight (total or body weight). Its variation, over time, indicates the period of greatest reproductive activity, so as this ratio tends to increase during ovarian development (WOOTTON, 1990; KING, 1995).

The average value of the GSR was calculated on the basis of the expressions below, presented by Vazzoler (1996), for adult females, taking into account the seasons of the respective catches and the stages of ovarian maturity:

$$GSR_1 = 100 * W_0 / W_t \quad \text{and} \quad GSR_2 = 100 * W_0 / W_c$$

where,

$$W_c = W_t - W_0 = \text{body weight.}$$

- Delta K (ΔK). This index reveals, in relative terms, how much of the energy obtained by the fish is being carried to gonadal development, being an indicator of the reproductive period (VAZZOLER, 1996). One is here dealing with the subtraction of the condition factor (K) from the factor of the body condition (K') calculated as the body weight minus the weight of the gonad, and was calculated only for adult females, by stage of maturity, and by season, using the formulae:

$$\Delta K = K - K' \quad \text{where} \quad K = W_t / L_s^b \quad \text{and} \quad K' = W_c / L_s^b * 10^4$$

b, being the linear regression of the logarithmic data obtained from the length-weight relation. Differences

between males and females slopes were examined using Student's *t*-test (ZAR, 1996).

Histology of the Gonads

Permanent preparations of ovaries and testicles cross-sections were mounted, in accordance with Vazzoler (1996) methodology, to evaluate the accuracy of the macroscopic classification of the used gonadal maturity stages. In this case, the number of gonads examined varied, seeking to obtain the preparation of at least three gonads of each maturity stage found in fish captured in each catch. The analysis of the gonad histological cross sections were also used in order to describe the oocytic development of the species.

RESULTS AND DISCUSSION

The total sampling consisted of 6132 specimens of *M. stehmanni*, with standard lengths between 12 and 50 mm.

Composition of the Population

Sexual proportions of specimens captured in catches of cruises I to III and the result of the X-squared test are displayed in Table 1. Only 8 catches out of 42, presented a ratio significantly different from 1:1 ($p = 0.05$), and no space-time pattern was found in the distribution of males and females.

Table 1. *Maurolicus stehmanni*: numerical values, percentage of males and females and values of X-squared test, by fishing catch and season of the year. The asterisks (*) indicate those captures with sexual proportions significantly different from 1:1 ($p = 0.05$).

	Catch	Numbers		Percentage (%)		χ^2 Value	F/M Ratio	Ls (mm)	
		Males	Females	Males	Females			Min	Max
W i n t e r	106	78	63	55,3	44,7	1,60		33	42
	110	76	77	49,7	50,3	0,01		33	44
	147	22	9	71,0	29,0	5,45 *	0,41	24	40
	153	73	71	50,7	49,3	0,03		33	48
	162	0	2	0,0	100,0			23	35
	178	39	44	47,0	53,0	0,30		24	44
	186	4	2	66,7	33,3	0,67		28	42
A u t u m n	259	17	33	34,0	66,0	5,12 *	1,94	38	49
	258	23	21	52,3	47,7	0,09		30	49
	250	33	15	68,8	31,3	6,75*	0,45	31	45
	242	2	7	22,2	77,8	2,78		29	38
	240	24	14	63,2	36,8	2,63		34	51
	232	10	19	34,5	65,5	2,79		34	47
	228	18	7	72,0	28,0	4,84 *	0,39	24	30
	225	28	22	56,0	44,0	0,72		30	45
	222	13	13	50,0	50,0	0,00		29	39
	209	29	21	58,0	42,0	1,28		30	40
	207	8	4	66,7	33,3	1,33		30	39
	203	23	14	62,2	37,8	2,19		30	39
201	7	6	53,8	46,2	0,08		31	39	
S p r i n g	312	11	18	37,9	62,1	1,69		30	40
	330	13	10	56,5	43,5	0,39		31	41
	335	29	28	50,9	49,1	0,02		37	46
	340	7	49	12,5	87,5	31,50 *	7,00	27	46
	341	14	7	66,7	33,3	2,33		33	44
	344	24	16	60,0	40,0	1,60		30	46
	345	30	29	50,8	49,2	0,02		37	47
	347	26	33	44,1	55,9	0,83		35	45
	353	26	28	48,1	51,9	0,07		29	37
	356	11	11	50,0	50,0	0,00		28	47
	362	5	9	35,7	64,3	1,14		25	40
	363	4	3	57,1	42,9	0,14		27	43
	364	6	4	60,0	40,0	0,40		28	35
	367	3	0	100,0	0,0			28	48
	373	9	25	26,5	73,5	7,53 *	2,78	24	40
386	18	33	35,3	64,7	4,41 *	1,83	40	46	
389	1	17	5,6	94,4	14,22 *	17,00	31	38	
393	3	4	42,9	57,1	0,14		34	41	

Differently from the result of this study, Rasmussen and Giske (1994) in Norway; Prosch (1991) in South Africa; Dalpadado and Gjørseter (1987) in the Red Sea; Young et al. (1987) in Tasmania and Clarke (1982) in Australia, studying species of the genus *Maurolicus*, reported a significantly larger number of females than males. Prosch (op. cit.) found a 1.2:1 female to male ratio and suggested that this difference might be due to sexual stratification, in view of the fact that females undertook vertical nocturnal migration closer to the surface in the summer. Young et al. (op. cit.) reported several fishing catches containing only males or females, suggesting the existence of a spatial segregation as between shoals of males and females. No such facts were observed for *Maurolicus stehmanni* in the south-southeastern region of Brazil.

As for the sexual proportion by standard length class (Ls), due to the difficulty in sex identification of the immature fish, the number of small-sized specimens was small; however, for the adult fish, an oscillation around 50% was observed,

with no clear and defined pattern below 48 cm, above which point only females appeared (Fig. 3).

The observation that among the greater lengths only females appeared is corroborated by studies of Rasmussen and Giske (1994); Prosch (1991); Young et al. (1987); and Dalpadado and Gjørseter (1987), for different species of *Maurolicus*. Rasmussen and Giske (op. cit.) attribute this fact to a higher mortality rate among males, which present different growth patterns from those of the females. Different growth patterns have been described by Bellucco et al. (2004), for males and females of *M. stehmanni*, in the same area where the present study was undertaken, revealing that females attain greater lengths and ages than the males.

The proportion of juveniles and adults, by seasons, is given in Figure 4, in which it may be seen that juveniles and adults occurred in all of the three periods, with minor variations. Results show that recruiting occurred in the three seasons, though with a greater incidence of juveniles in the spring and a minor one in the autumn.

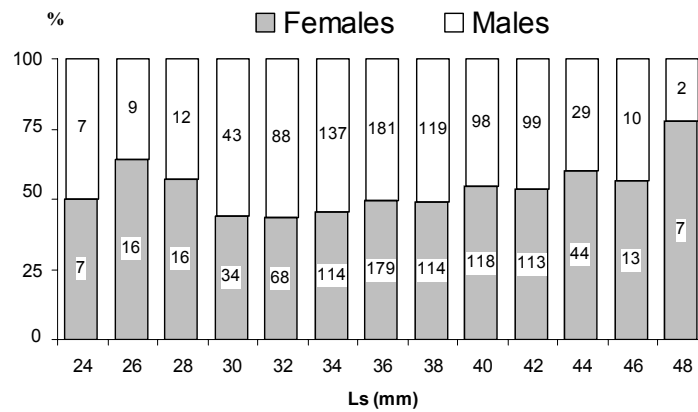


Fig. 3. *Maurolicus stehmanni*: proportion of males and females by standard length class (Ls). Numbers inside columns correspond to individuals analysed.

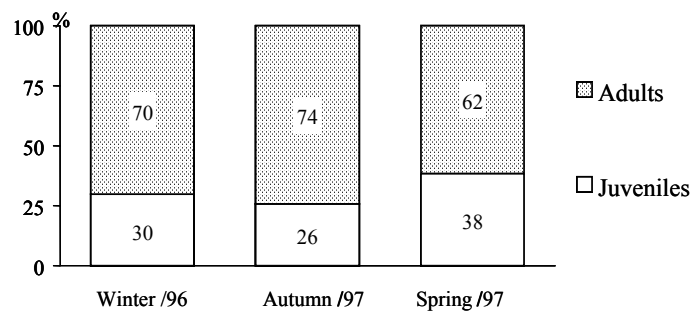


Fig. 4. *Maurolicus stehmanni*: proportion of juvenile and adult fish by season. Numbers inside columns correspond to individuals analysed.

Average Length of the First Gonadal Maturation

The proportion of adult fish by standard length class and the estimate of L_{50} are given in Figure 5. The average size of the first gonadal maturation, namely, the size at which 50 % of fish population presents gonadal maturity, was estimated at 32 cm.

Due to the difficulty in identifying the sex of individual immature fish macroscopically, this parameter was calculated with data of males and females altogether, what did not permit comparisons with other studies that have mentioned differences between the maturation of males and females of various species of the genus (YOUNG et al., 1987; DALPADADO; GJØSÆTER, 1987; PROSCH, 1991 and RASMUSSEN; GISKE, 1994). Nevertheless, different growth rates between males and females of *Maurolicus stehmanni* were found by Bellucco et al. (2004), that showed females attaining greater lengths than males.

The minimum (L_{\min}) and maximum (L_{\max}) maturation sizes obtained for males and females of *M. stehmanni*, as well as the results of other studies undertaken with related species, may be seen in Table 2.

According to the results obtained it was found that males of *M. stehmanni* present such sizes at shorter lengths than those of females, corroborating other studies undertaken on the genus (YOUNG et al., 1987; DALPADADO; GJØSÆTER, 1987; PROSCH, 1991; RASMUSSEN; GISKE, 1994).

Stearns and Crandall (1984) and Wootton (1990) emphasize that, within one and the same species, the age and/or length of maturation may vary and that this plasticity is genetically determined and molded by environmental variables. Such facts result

in different growth and mortality rates, leading to distinct ages (and lengths) of maturation.

Vazzoler (1996) discusses the concept of "critical minimum size", which corresponds to the size at which the critical reproductive processes begin and suggests that species with a short life cycle and small L_{∞} (r-strategists), as is the case with *M. stehmanni*, attain mature gonadal stages earlier than those species with longer life-cycles and greater L_{∞} (k-strategists).

Longhurst and Pauly (1987) present the hypothesis that the theoretical maximum size (L_{∞}) and the first maturation (L_{50}) average length is determined mainly by the interaction between the supply of and demand for O_2 (that is to say, the intake and expenditure of energy), and that this relationship is limited by the area of the gills, which guarantee the supply of O_2 and do not grow in the same proportion as the volume of the body, responsible for the O_2 demand. According to those authors (op. cit.), the gonads maturation must occur while there is an "excess" in the supply of energy and that the total metabolism (active metabolism + metabolism of maintenance) should be 1.4 times greater than the metabolism of maintenance. Thus, within one and the same taxonomic group, the relation L_{50}/L_{∞} will remain constant and although environmental alterations may lead to variations in both the L_{50} and the L_{∞} , they will not affect the relationship between these parameters. Finally, those authors showed that this relationship varies between 0.4 and 0.9 and that there is a tendency for these values to be smaller in larger fish and greater in smaller fish. In the light of Bellucco et al. (2004) estimate for *M. stehmanni*'s L_{∞} of 53 mm, the result of the relationship L_{50}/L_{∞} would be 0.6.

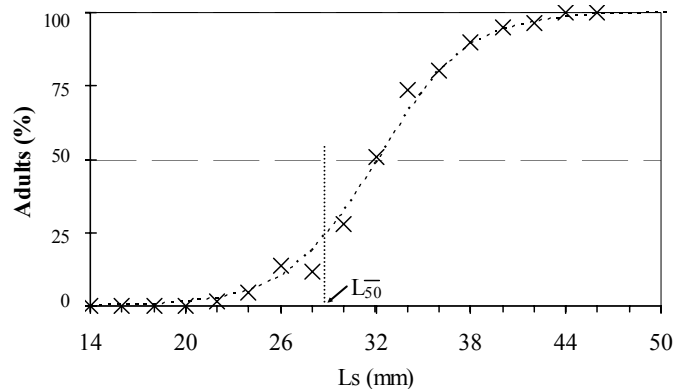


Fig. 5. *Maurolicus stehmanni*: percentage of adult individuals by standard length class (Ls). X: values obtained. (L_{50}): average length of the first gonadal maturation. The graph has been adjusted in accordance with King's (1995).

Table 2. Minimum (L_{\min}) and maximum lengths (L_{\max}) of gonadal maturation; maximum sizes observed (LS_{\max}) and relation between the minimum size of gonadal maturation and the maximum size obtained (L_{\min}/LS_{\max}) in this study for *Maurolicus stehmanni* and, by various authors, for other species of the genus *Maurolicus*.

Reference	Area	L_{\min} (mm)		L_{\max} (mm)		LS_{\max} (mm)	L_{\min}/LS_{\max}
		Females	Males	Females	Males		
This study <i>M. stehmanni</i>	(22 to 35°S)	24	23	51	48	52	0.46
Yuuki (1982)	Japan (35 to 39°S)	40	-	56	-	56	0.71
Young <i>et al</i> (1987)	Tasmania (42°S)	38	34	53	46	54	0.70
Dalpadado and Gjosæter (1987)	Southeast Australia (33 to 43°S)	20	19	40	34	40	0.50
Prosch (1991)	South Africa (31 to 35°S)	26	24	53	-	53	0.49
Rasmussen and Giske (1994)	Norway (60°N)	25	-	59	48	59	0.42

For the purpose of testing Longhurst and Pauly (1987) hypothesis described before, and without literature information for L_{50} or L_{∞} for the *Maurolicus* genus, but making use of the data on L_{\min} , and assuming that L_{\max} approximates to L_{∞} , the ratio between the L_{\min} of females and the maximum size *Maurolicus* genus species were calculated and are given in Table 2. The values obtained were about 0.5, with exception of YOUNG *et al.* (1987) and YUUKI (1982) studies, the values obtained were 0.70 and 0.71, respectively.

As compared with related species of South Africa and Norway, *M. stehmanni* matures at a closely similar minimum size, though smaller than that occurring off Japan and Tasmania waters. These differences cannot be related to latitude, but rather to ecological characteristics of each ecosystem, whether physical (hydrological structure) or biological (growth, competition and predation), which may lead to alterations in the population parameters such as size of maturation, growth rate and mortality rate.

Spawning Seasons

The analysis of the maturity frequency stages revealed high values for immature individuals (A), those in the process of maturation (B) and mature (C), in all of the three seasons covered by the cruises

(Fig. 6). No fish which had already spawned (D) or in resting phase were observed by eye in the samples. In winter, the proportion of specimens in the process of maturation was 46% and of mature fish 24%. In spring, 36% of the fish were in maturation and 25% were mature. In autumn, the relative value for fish in maturing stage was 28% and the percentage of mature specimens was the highest found, 47%. West (1990) affirms that the estimation of the stages of gonadal development frequencies permits the analysis of the length of maturation, the spawning season and the duration of the reproductive period. On the other hand, Vazzoler (1996) says that the ovarian development is a continuous and cyclical process and that its subdivision into stages is artificial but that the proportion between these stages is important for the studies on first maturation length, the reproductive period and the area of reproduction.

Although there are no data available related to summer, the high percentage of individuals both mature and in the maturation process, and yet the presence of immature fish in all the seasons indicate that *Maurolicus stehmanni* spawns throughout the area and all year round.

The parameters of the regression between W_s "versus" L_s are presented in Figure 7.

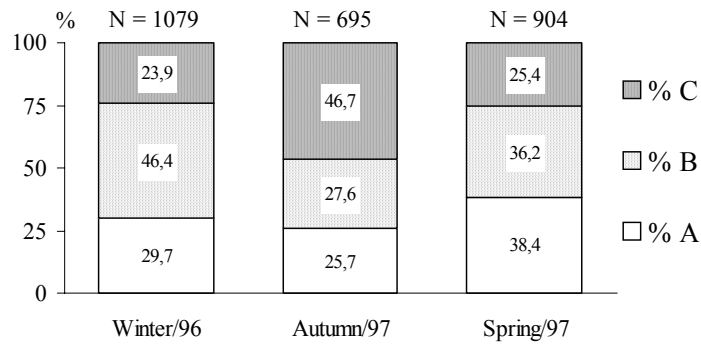


Fig. 6. *Maurolicus stehmanni*: percentage of the stages of gonadal maturity by season of the year. A – immature fish (juveniles); B - fish in the process of maturation (adults) and C – mature fish (adults). Numbers inside columns correspond to individuals analysed.

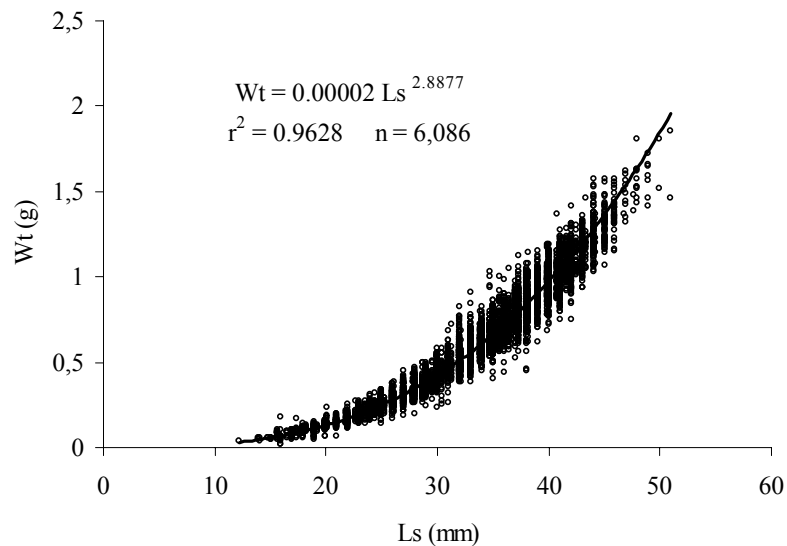


Fig. 7. *Maurolicus stehmanni*: length weight relationship.

The averages and the standard deviations of the Gonadosomatic Relationships (GSR_1 and GSR_2) for the females are given in Table 3. The average values of these indices for the mature females (C), in winter, were about 3.3% higher.

In spring and autumn the values approximated to 2.4. For the females in the maturation process (B), the lowest values, around 0.8, were obtained in spring.

In the light of the above descriptions, the values of GSR_1 and GSR_2 were always higher for the “C” females, which means that the weight of the

gonads and their value in relation to the body weight may be used as appropriate tools for the assessment of the gonadal maturation of the species.

Studies on the gonadosomatic relationship of the females of *Maurolicus muelleri* undertaken by Clarke (1982) and Young et al. (1987) in Australia, and by Rasmussen and Giske (1994) and Salvanes and Stockley (1996) in Norway, show that the highest values of GSR_1 corresponded to more advanced stages of ovarian development, corroborating the estimates of the spawning seasons of the species.

Table 3. Mean values and standard deviations of GSR_1 and GSR_2 of females in process of maturation (B) e mature (C) of *Maurolicus stehmanni*, for the three periods sampled.

		GSR_1		GSR_2	
		B	C	B	C
Winter	Mean	1.923	3.229	1.976	3.364
	s.d.	1.171	1.567	1.227	1.697
Autumn	Mean	1.239	2.391	1.261	2.463
	s.d.	0.810	1.123	0.835	1.191
Spring	Mean	0.769	2.397	0.779	2.478
	s.d.	0.590	1.410	0.603	1.498

Values of GSR_1 reported in the literature, as related to *Maurolicus muelleri*, were similar to those found in this study for *M. stehmanni*. For the former, Rasmussen and Giske (1994) in Norway, found a maximum value of 7%, as well as discovered that specimens of less than 30 mm never attain values above 2%. Further, Clark (1982) in Australia, presented a range for GSR_1 values between 1.6 and 9.6%, a maximum value similar to that obtained for *M. stehmanni* in the present study. Salvanes and Stockley (1996), analyzing specimens from areas of the open ocean and of Norwegian fjords in different localities, found average values of GSR_1 between 1.21 and 5.26 % for *M. muelleri*, the highest averages being intimately related to the diameter of the oocyte, that is

to say, the highest values of GSR_1 occurred in females which presented more advanced stages of ovarian maturity. Young et al. (1987), in Tasmania, Australia, also for *M. muelleri*, found a direct relationship between GSR_1 and ovarian development and, further, average values of this index, varying from 4 to 4.5%, in the peak spawning seasons.

In the present study, the average values for GSR_1 and GSR_2 , as much for the mature females (C) as for those in the process of maturation (B), were higher in winter, diminishing in the other periods. The occurrence of fish with high values of GSR_1 (about 6%) in the three seasons shows that *M. stehmanni* presented reproductive activity in all the seasons. Higher values of GSR_1 , GSR_2 and delta K (ΔK), for females in the process of maturation (B) and mature (C) in the winter and lower in spring (Fig. 7), suggest that there was a greater reproductive investment in winter, that is to say, a possible maturation peak.

It should be observed that the values of ΔK (Fig. 8) were always greater for the C females than for the B ones, showing that the gonad weight given by this index is appropriate for the assessment of the *M. stehmanni* maturity.

Figure 8 presents the length/weight relationship for *Maurolicus stehmanni*. Since there was no significant difference between males and females slopes ($P > 0.05$) data were grouped and the parameters a and b of the equation were estimated for fish of both sexes altogether.

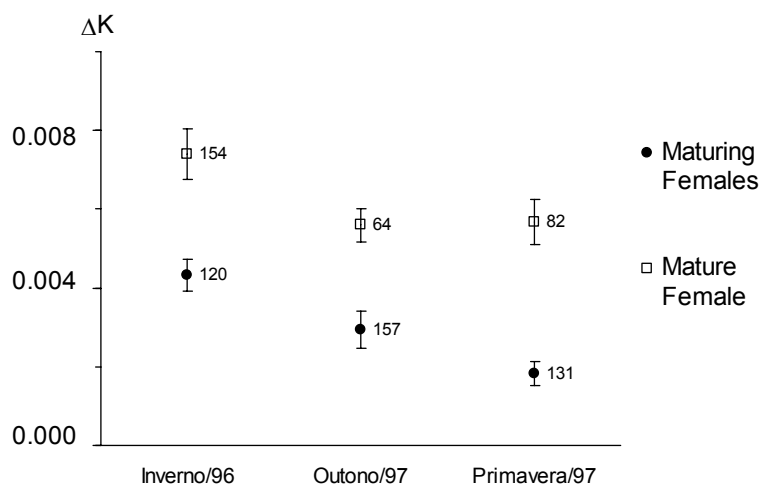


Fig. 8. *Maurolicus stehmanni*: average values of Delta K for females in maturation (B) and mature (C), by season of the year. The vertical bars represent the confidence intervals ($p = 0.05$). Numbers next to dots correspond to individuals analysed.

Studies on the ichthyoplankton undertaken in the southern region (WEISS et al., 1988; BONECKER; HUBOLD, 1990) and in the southeastern region (RIBEIRO, 1996) of Brazil, in the same region as that of the present study, demonstrated the occurrence of eggs and larvae of *M. stehmanni* in all the seasons analyzed. Ribeiro (op. cit.) concluded that the species spawns all year round, with a spring/summer peak. In this study the highest values of GSR₁ and ΔK, obtained for winter indicate that in this period the species presents maximum maturation, and that in it a spawning peak may have occurred.

Despite the fact that no hydrated ovaries were found, which would indicate imminent spawning, the results show that *M. stehmanni* presented reproductive activity in all the three seasons analyzed, thus corroborating the studies of Weiss et al. (op. cit.), Bonecker and Hubold (op. cit.) and Ribeiro (op. cit.), inspite the fact that it has not been possible to undertake summer catches, would not allow to affirm anything regarding reproductive activity in that season.

Prosch (1991) concluded that in South Africa *Maurolicus muelleri* spawns all year round with a peak in spring/summer. It has been demonstrated in

Japan (YUUKI, 1982) and in Norway (GJØSÆTER, 1981; DALPADADO; GJØSÆTER, 1987) that species of this genus present prolonged spawning in spring. In Tasmania, Young et al. (1987) reported that the spawning of *M. muelleri* begins in spring, extending into the summer, and Clarke (1982), in southeastern Australia, confirmed that this process begins in the winter and continues into spring. These results show that the different species of *Maurolicus* present great plasticity as regards the spawning season, which means different reproductive tactics in distinct physical and biological environmental conditions.

Histology of the Ovaries

Table 4 presents the characteristics of the oocytic developmental phases found for *M. stehmanni*. The analysis of the preparations of the ovaries resulting from cruises IV and V shows:

- Oocytes in phases II, III, IV and V, besides the post-ovulatory follicles (POs) and follicular atresia (Fig. 9) in the female gonads, macroscopically defined as mature females (stage C).
- No oocytes with pré-ovulatory hydration were found.

Table 4. Characteristics of the phases of oocytic development of *M. stehmanni* observed in this study.

		Description	Occurrence
Phase	II	Oocyte of the reserve stock (perinucleolar) Well defined, basophilic cytoplasm. Sometimes spherical. basophilic nucleoli are visible in the nucleus. They generally present triangular oval or rectangular shape.	In all stages
	III	Oocyte with lipid vitellogenesis Substantial increase in size due to growth of cytoplasm. Vacuolization occurs due to lipid deposition. The nucleus has a small increase in size and it is still possible to observe the nucleoli. Appearance of vitelline membrane (a-cellular) surrounded by follicular cells.	Stages B and C
	IV	Oocyte with lipidic and protein vitellogenesis Beginning of protein deposition in the form of acidophile platelets. The vacuoles are found in the central region. Nucleus still evident. Thickening of the vitelline membrane.	Stages B and C
	V	Oocyte with complete vitellogenesis (mature) NoTABLE increase in size due to greater protein deposition. The lipid granules coalesce in one large vacuole. The basophilia disappears. The vitelline membrane thickens and may present radial lines. The follicular cells become flat.	Stage C
		Post-ovulatory follicle Consists of follicular cells which remain after spawning and the liberation of the oocyte. the cells fill the empty space and present basophile cytoplasm.	Stage C
	Atresic follicle undergoing absorption Degenerative process in which the oocyte breaks down and loses the vitelline membrane its vitello being absorbed and its contents vacuolized.	Stage C	

Figure 9 shows the presence of oocytes of types IV and V, revealing a mature ovary, but the occurrence of ovulatory follicles (POs) indicating that spawning had already occurred has not been observed during the macroscopic analysis.

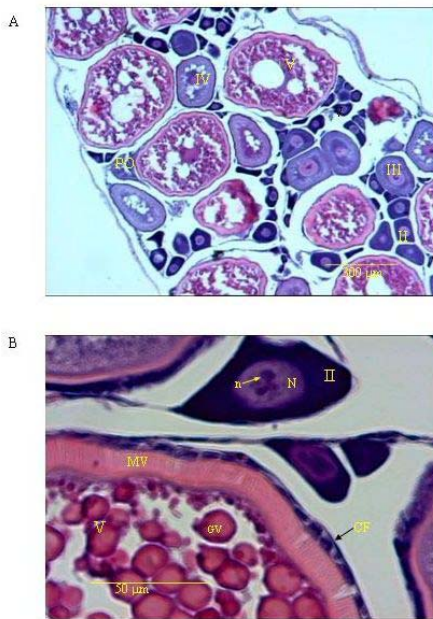


Fig. 9. Cross-sections of ovaries of specimens of *Maurolicus stehmanni*: A) Ovary in the mature stage (C) with oocytes in different phases of development (II, III, IV and V) and post-ovulatory follicle (PO). B) Oocyte in phase V, with complete vitellogenesis (V); VM – vitellin membrane; PG – protein granule and FC – follicular cells and oocytes in phase II, of the reserve stock (II); N – nucleus and n – nucleole.

The absence of ovaries undergoing hydration showed that the females were not about to spawn, since hydration is a phenomenon characteristic of that moment, causing a substantial increase in the volume of the oocytes, which occurs a few hours only before the ejection into the external environment (CHAVES, 1989; VAZZOLER, 1996; DIAS et al., 1998).

As to the identification of the phases of maturation, the permanent preparations with sections of the gonads indicated that the macroscopic scale adopted was appropriate for the adult fish, but not for the immature ones with standard length smaller than 30 cm, due to the very small size of the gonads which often presented weights of less than one mg.

It was detected that females with a standard length around 30 cm, captured during the November 1997 cruise, and classified as being in the process of maturation (stage B), already presented oocytes in phases II, III and IV (Fig. 9e); however, females in the same condition, resulting from cruises I and II,

were identified as immature (A), due to the very small size of the gonads, the filliform appearance of the ovaries and the presence of oocytes of small diameter. These data lead to the conclusion that a superestimation of the average size of the first maturation, which was of 32 cm, may have occurred.

Dias et al. (1998) also reported differences between the macro and microscopic classifications of the ovaries in various teleosts species and called attention to the special care which should be taken regarding the macroscopic analysis of species with partial spawning, the liberation of the oocytes which may be macroscopically imperceptible, because their occurrence can only be accurately shown by the presence of post-ovulatory follicles (POs) (recent spawning) or of hydrated oocytes (imminent spawning), structures which are only visible in the histological preparations of ovaries.

Generally speaking, the classification of maturity stages undertaken by stereomicroscopy, underestimate the ovarian development. It was found that the relative size of *M. stehmanni* gonad, as also its irrigation and turgidity and the size and opacity of their oocytes, are not appropriate characteristics for the evaluation of the stages of gonadal maturity, thus demonstrating the absolute need for the analysis of cross-sections of the gonads prepared for their correct definition.

The presence, in one and the same ovary, of cells in the various phases of development and of post-ovulatory follicles (Fig. 9A) showed that the oocytic development of *M. stehmanni* is asynchronous. Melo and Armstrong (1991), studying the reproductive behavior of *Maurolicus mulleri* in South Africa, concluded that there must be multiple spawning. They arrived at this conclusion after a microscopic study of the gonads, in which they discovered the presence of post-ovulatory follicles, the existence of various kinds of modal values of frequencies of the oocytes diameters and that the number of juvenile oocytes was always greater than that of older oocytes. This is a characteristic of fishes which spawn frequently, after short intervals (PRABHU, 1956 apud MELO; ARMSTRONG, op. cit.), occurring commonly in species with prolonged spawning (HICKILING; RUTEMBERG, 1936, apud MELO; ARMSTRONG, op. cit.).

Hunter et al. (1985) show that fish which multiple spawning have gonads with oocytes distributed in many phases of development, their diameters varying continuously between oocytes without yolk and mature oocytes. West (1990) adds that the presence of various modes of oocytic development may indicate that more than one batch of oocytes will enter the process of maturation, although additional information is necessary to confirm multiple spawning.

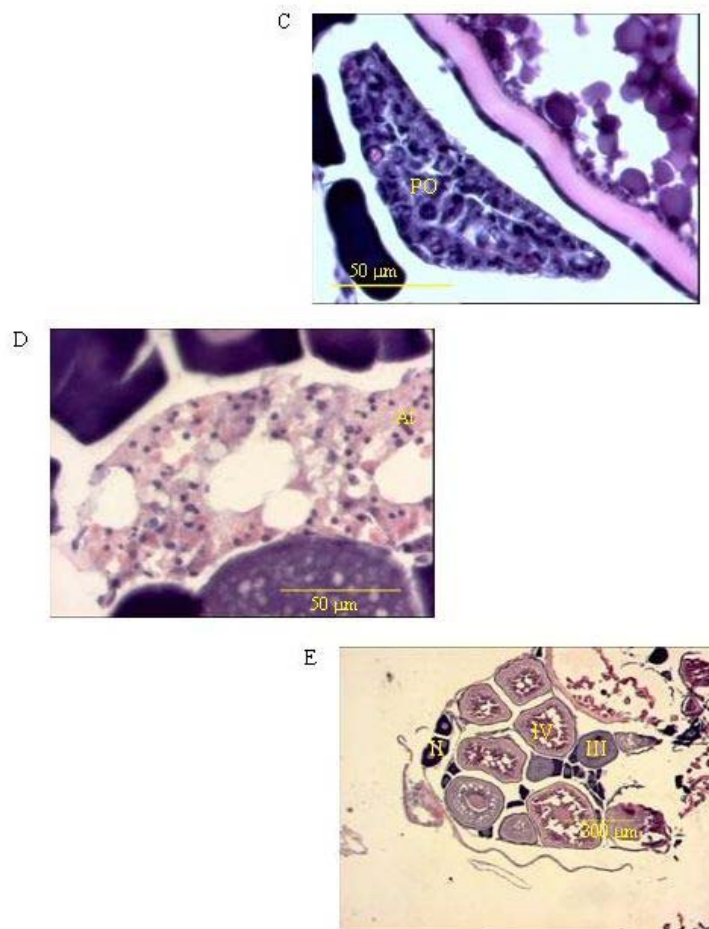


Fig. 9 (cont.). Cross-sections of ovaries from females of *Maurolicus stehmanni*: C) Post-ovulatory follicle (PO). D) Atresic follicle (At). E) Mature ovary (stage C) of a fish with standard length of 30 mm, presenting oocytes in different phases of development (II, III e IV).

A fish with asynchronous oocytic development may present total spawning, and the non-mature oocytes would be absorbed (atresia) or the spawning would take place only after the complete development of all the oocytes in the more advanced phases of development. In this case, probably, the spawning would only be perceptible by the macroscopic evaluation of the ovaries, which would be empty, with a flacid appearance and a smaller weight, a fact not observed during this study.

Thus, the aspects mentioned above and the results obtained show that *M. stehmanni* presents asynchronous oocytic development, spawns by phases, presents reproductive activity all the year round, over

all the outer shelf and slope of the south-southeastern Brazilian region, and that the average length of the first gonadal maturation of the species being 32 mm.

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