

## Biology of Sanzo's goby, *Lesueurigobius sanzoi* (de Buen, 1918), off Cabo Raso, Portugal\*

CRISTINA PAULO-MARTINS<sup>1</sup>, PEDRO LOPES DA CUNHA<sup>2</sup> and  
PEDRO RAPOSO DE ALMEIDA<sup>1,3</sup>

<sup>1</sup> Instituto de Oceanografia, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal.

<sup>2</sup> Instituto de Engenharia e Tecnologia Industrial, Azinhaga dos Lameiros Ed. E piso 0, 1649-038 Lisboa, Portugal.

<sup>3</sup> Unidade de Biologia da Conservação, Departamento de Biologia, Universidade de Évora, 7002-554 Évora, Portugal.  
E-mail: pmraposo@mail.telepac.pt

**SUMMARY:** The presence of Sanzo's goby, *Lesueurigobius sanzoi* (de Buen, 1918), off Cabo Raso, Portugal, is recorded for the first time. The biology of this population was studied using 11 samples collected between April 2000 and September 2001 at depths of 70-100 m on muddy and sandy bottoms. The females reach a standard length of 110 mm and the males 103 mm. It attains an age of 24 months, which equals two breeding seasons. The otoliths form two translucent rings each year, which corresponds to the winter growth and the reproduction period. Sanzo's gobies can be classified as "premature" and "standard" individuals, according to whether the first breeding occurs before or after the first winter respectively. "Standard" individuals, which have an extended first growth, reach a longer length than "premature" individuals, whose first growth is much shorter. Although discrete, sexual dimorphism was noticeable even outside the spawning season. The breeding season occurs between May and September/October with more than one spawning. The minimum length for which the maturity stage occurs is 64 mm, at an age of 0+. The feeding activity is quite constant throughout the year, and the diet consists predominantly of small crustacea and molluscs, although polychaets also feature commonly in its diet.

**Key words:** Sanzo's goby, age, reproduction, diet, Gobiidae.

**RESUMEN:** BIOLOGÍA DEL GOBIO DE SANZO, *LESUEURIGOBIOUS SANZOI* (DE BUEN, 1918), EN EL CABO RASO, PORTUGAL. – Por primera vez, se registra la presencia del gobio de Sanzo, *Lesueurigobius sanzoi* (de Buen, 1918), a lo largo del Cabo Raso, Portugal. La biología de esta población se estudió con base en 11 muestras recogidas entre abril del 2000 y septiembre del 2001, a profundidades de entre 70 y 100 m, en fondos fangosos y cubiertos de arena. Las hembras alcanzan una longitud uniforme de 110 mm y los machos de 103 mm. Alcanzan una edad de 24 meses lo que iguala a dos épocas de reproducción. Cada año, los otolitos forman dos anillos translúcidos, que corresponden al crecimiento de invierno y al período de reproducción. Dependiendo si la primera reproducción ocurre antes o después del primer invierno, el gobio de sanzo se puede clasificar en "premature" o "estándar", respectivamente. Al tener un crecimiento inicial más prolongado, los individuos "estándar" alcanzan una mayor longitud que los individuos "prematuros", cuyo primer crecimiento es mucho más corto. Si bien discreto, el dimorfismo sexual fue evidente, aunque ocurriese fuera de la época del desove. La temporada de reproducción tiene lugar entre Mayo y Septiembre / Octubre, ocurriendo más de un desove. La longitud mínima para la cual la etapa de madurez sucede es de 64 mm, en una edad de 0+. El ritmo de la actividad alimentaria es bastante constante a lo largo de todo el año y consiste, predominantemente, en crustáceos y moluscos pequeños; sin embargo se encuentran comúnmente poliquetos en su dieta.

**Palabras clave:** gobio de Sanzo, edad, reproducción, dieta, Gobiidae.

\*Received November 19, 2002. Accepted October 20, 2003.

## INTRODUCTION

Gobies are among the most successful teleost groups in temperate and tropical waters, and form the dominant taxa in the small fish fauna of benthic habitats (Fouda *et al.*, 1993). According to several authors (Fonds, 1973; Gros, 1980; Nash, 1982; Miller, 1984; Magnhagen and Kvarnemo, 1989; Nellbring, 1993; Ota *et al.*, 1996), the reproductive behaviour of gobioid fishes is very complex. Females deposit demersal eggs on the ceiling of the nest constructed by the territorial male in the muddy substrate or under empty shells. Brood care is usually done by the male parent until hatching. The majority possess a long breeding season with several spawnings per individual, after which they usually die (Miller, 1984).

The distribution range of Sanzo's goby extends from the south coast of Portugal to Mauritania in the eastern Atlantic and into the Alboran sea in the western Mediterranean (Miller, 1986). Sanzo's goby, *Lesueurigobius sanzoi* (de Buen, 1918) was studied in the 1980's off northern Namibia, on the west coast of Africa (Lloris *et al.*, 1984; Olivar, 1989).

In Portugal, there is a considerable lack of knowledge about the biology, ecology and ethology of this species, essentially due to the null commercial value of this species, which is usually discarded by fishermen.

This study, besides being the first record of *L. sanzoi* off Cabo Raso, presents some aspects of the species biology, such as its reproduction, age and growth, and feeding behaviour. This new knowledge will allow other studies on the ecology and ethology of Sanzo's goby, and even a deeper study on its biology.

## MATERIAL AND METHODS

Samples were obtained off Cabo Raso (Fig. 1) from the by-catch of a commercial otter trawler at 70 to 100 m depths. The study area presents bottom sediment composed of mud, sand and sandy mud, with a few rocky spots. This is an oligotrophic area, with a mean air temperature ranging from 9 to 23°C, and a mean water temperature ranging from 14 to 19°C. Salinity varies between 35.000 and 36.000, and the pH between 8.0 and 8.2 (Anonymous, 2000). All fish were caught with a 40 m long otter trawl with a 65 mm knot to knot mesh size between

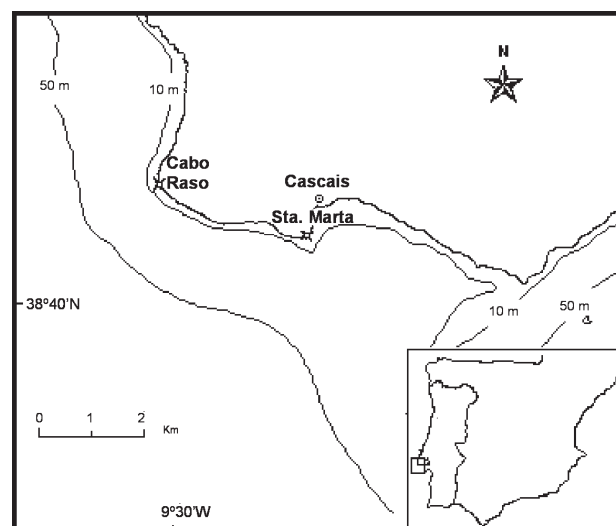


FIG. 1. – Location of the sampling area.

April 2000 and September 2001. Due to bad weather conditions and some logistic problems, it was not possible to obtain samples on a monthly basis.

A total of 915 specimens were caught during the 11 sampling sessions. The fishes were put on ice aboard and frozen on arrival at the laboratory. The laboratorial analysis procedure consisted in the observation of the external morphology, measured to the nearest 1 mm (standard length, *SL*), after which they were eviscerated and weighed to the nearest 0.0001 g (eviscerated weight, *EW*). After dissection, gonads and gastrointestinal contents were removed and weighed separately to the nearest 0.0001 g. Sagittal otoliths were removed from all fish, cleaned from the adjacent tissues and stored in 96° alcohol for at least two weeks. After polishing, total otolith radius (*OR*) and each growing ring radius were measured using a dissecting microscope with incident light.

A total of 472 otoliths were successfully read to study the population age structure and the species growth. Based on the method described by Bagenal and Tesh (1978), the condition factor (*K*) and the theoretical length of each fish was back-calculated using the relationship between *SL* and *OR*. Back-calculated mean standard lengths were compared with a t-test (Sokal and Rohlf, 1995).

The fish were sexed and the gonads were classified into six stages of maturation (N=509) based on Miller's criteria (Miller, 1961), and the oocytes were measured using micrometer, which was adapted to the eyepiece lens of the magnifier. The gonadosomatic index (*GSI*) was determined as the ratio of gonad weight to *EW*. The sex ratio was established

as the ratio of the number of females to the number of males for all mature individuals (i.e.  $SL \geq$  size of first maturity). This comparison was based on a G-test of independence.

The total gastrointestinal contents were removed from 508 Sanzo's gobies. The proportion of sexes in the monthly samples was compared using a G-test of independence (Sokal and Rohlf, 1995) and food items were counted and identified to the lowest taxonomic level possible. The frequency of occurrence ( $FO$ ), the numerical frequency ( $Fi$ ), the vacuity index ( $VI$ ) and the fullness index ( $FI$ ) were estimated according to Hyslop (1980) and Assis (1992). The comparison of the monthly fullness index and the proportion of empty stomachs in each of the monthly samples were performed using a Kruskal-Wallis test and a G-test of independence respectively (Sokal and Rohlf, 1995). Due to the small size of most preys and to the fact that some of the food items were already partially digested, it was decided to use only a numerical approach to characterise the species diet. The degree of overlap between diets during reproduction and non-reproduction periods for males and females was calculated using the Shorigin index (Wallace, 1981). The diet diversity was also estimated using the Shannon index (Ludwig and Reynolds, 1988).

## RESULTS

### Age and growth

The otoliths of *L. sanzoi* are large, rhomboidal in outline and plano-convex in section, and exhibit translucent and opaque rings. In practice, after polishing the otoliths in this species are normally read with ease. However, some otoliths were illegible, and a few exhibited structural variations, such as excrescences on the otolith edge or an uncommon shape. Nevertheless, excluding two cases, these differences only occurred in one otolith of the pair.

By recording the type of edge observed on the otolith, it was noticed that throughout the sampling period there were always individuals presenting a translucent edge, even in summer (Fig. 2). According to the otolith edge type and the month of capture (Fig. 3), the individuals were classified as premature, i.e. fish that spawn before the first winter, or standard, i.e. fish that spawn after the first winter. Using this classification it was possible to form six groups of individuals based on the type of edge and

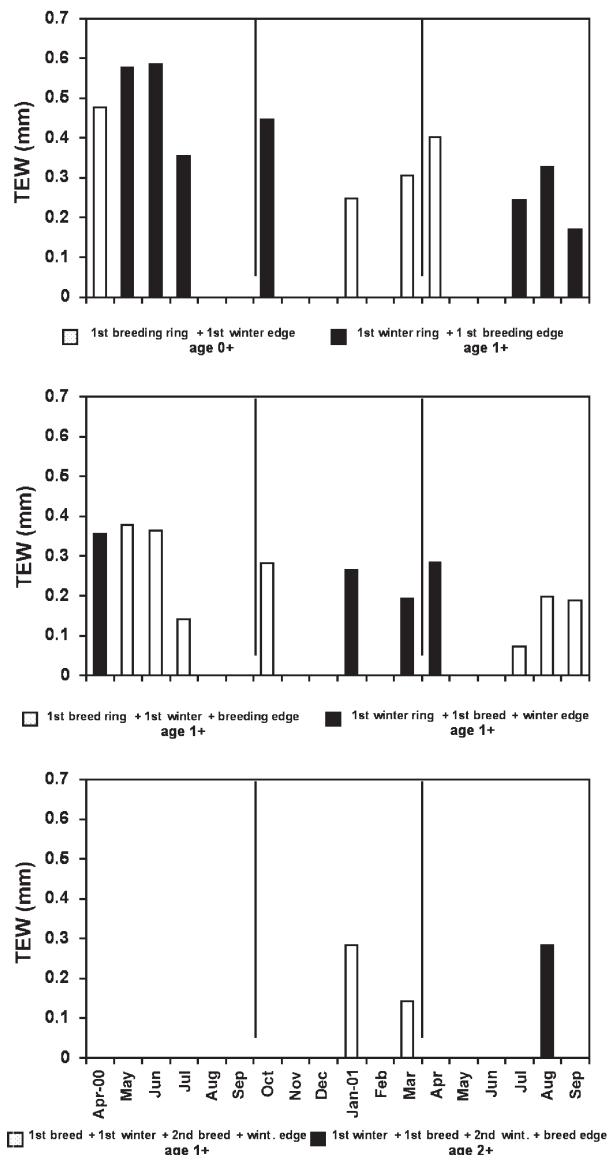


Fig. 2. – Variation of translucent edge mean width (TEW) during the sampling period. □ “premature” individuals and ■ “standard” individuals.

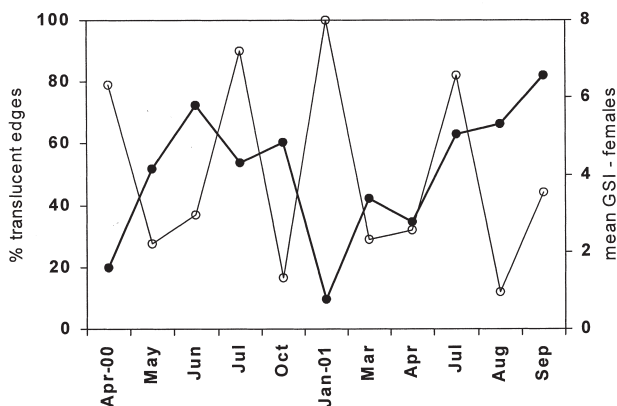


Fig. 3. – Percentage of translucent edges (open circles) vs. female mean gonadosomatic index (GSI) (full circles).

TABLE 1. – Back-calculated mean standard length ( $\overline{SL}$ ) (mm), and t-test results; sd, standard deviation; t, t-test of student; df, degrees of freedom; P, significance level; \*,  $P < 0.05$ .

	$\overline{SL}$	sd	t	df	P
Premature Females	64.8	8.2	1.164	111	0.247
Premature Males	64.9	8.9			
Standard Females	37.0	9.6	0.147	305	0.883
Standard Males	36.8	10.1			
Total Premature	65.9	8.5	6.546	418	*
Total Standard	36.9	9.8			

the number of translucent rings present in the otoliths:

0+: premature individuals aged 0+ with a complete translucent ring (spawning mark) and translucent edge (winter growth), which corresponds to the individuals captured between January and April;

I: standard individuals aged 1+ with a complete translucent ring (winter growth) and a translucent edge (spawning mark), captured between May and October;

II: premature individuals aged 1+ with 2 complete translucent rings (1<sup>st</sup> spawning mark + winter growth) and a translucent edge (2<sup>nd</sup> spawning mark), captured between May and October;

III: standard individuals aged 1+ with 2 complete translucent rings (winter growth + 1<sup>st</sup> spawning mark) and a translucent edge (2<sup>nd</sup> winter growth), captured between January and April;

IV: premature individuals aged 1+ with 3 complete translucent rings (1<sup>st</sup> spawning mark + 1<sup>st</sup> winter growth + 2<sup>nd</sup> spawning mark) and a translucent edge (2<sup>nd</sup> winter growth), captured between January and April;

V: standard individuals aged 2+ with 3 complete translucent rings (1<sup>st</sup> winter growth + 1<sup>st</sup> spawning mark + 2<sup>nd</sup> winter growth) and a translucent edge (2<sup>nd</sup> spawning mark), captured between May and October.

The back-calculated mean standard length ( $\overline{SL}$ ) attained by males and females at the first winter check, for both premature and standard individuals, showed no significant differences between sexes (Table 1). However, between premature and standard individuals there was a significant difference in the  $\overline{SL}$ .

Due to the small number of individuals that reached the second year of life ( $N = 8$ ), it was not possible to make a thorough analysis of the data. Apparently, only standard individuals showed three summer growing rings in their otoliths.

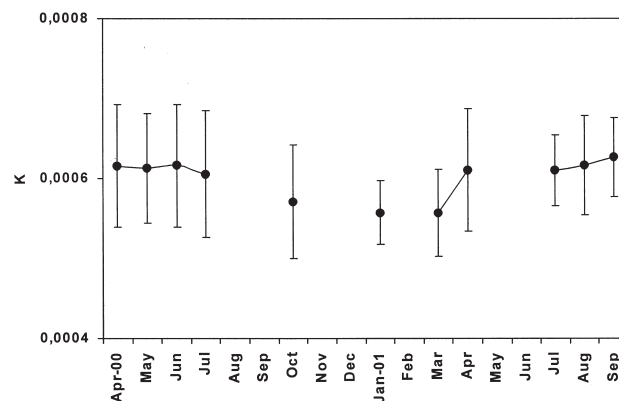


FIG. 4. – Variation of the condition factor ( $K$ ) during the sampling period. Vertical bars report the standard deviation.

The fish length and weight relationship was:

$$\log EW = -5.26 + (\log SL \times 3.29),$$

$$(F = 10135; df = 1; P < 0.05)$$

Since  $b = 3.29$  it can be considered that this species growth is allometric, i.e. during growth there is a change in body proportions and specific gravity (Ricker, 1975; Bagenal and Tesh, 1978).

Condition factor ( $K$ ) showed a slight decrease in October and attained a minimum in January. The increase in  $K$  observed in April reflected a gain in the fish condition prior to the breeding season although in July, when the fishes spent a considerably amount of energy on gonad maturation and reproductive behaviour,  $K$  also showed a low decrease (Fig. 4).

## Reproduction

According to our observations, all males possess more coloured anal and caudal fins and all females possess soft grey pigments near the genital opening. This shows a smooth sexual dimorphism independent of the reproductive period.

Six stages of maturation were reported (Table 2). According to the monthly variation in maturity stages, males and females start ripening in April and spawn from May until September/October (Fig. 5). Stage IV appeared in April for both sexes, and males and females in stage IV/VI first appeared in May and increased their number in June. From April to September, a great number of individuals were at a ripening stage. All males collected in October were at spent stages, and in January all individuals were at recovering stages. The greatest number of immature individuals appeared in March and April.

TABLE 2. – Macroscopic maturation scale for *L. sanzoi*.

Stage	Females	Males
<b>I</b> (immature)	Ovaries threadlike and colourless; oocytes diameter 0.071-0.213 mm	Testes threadlike and colourless
<b>II</b> (1 <sup>st</sup> ripening phase)	Ovaries cylindrical, narrow, whitish to pale yellow, small compared with peritoneal cavity; oocytes diameter 0.284-0.355 mm	Testes threadlike of triangular section, narrow bands, with a homogeneous yellowish colour in individuals already spent; with seminal vesicles
<b>III</b> (2 <sup>nd</sup> ripening phase)	Ovaries swollen, in contact most of its length, orange yellow; oocyte diameter 0.426-0.497 mm	Testes broader bands and longer; deferent canal reddish and linear, seminiferous tubes becoming full
<b>IV</b> (ripe)	Ovaries swollen, pressed together in length, occupying nearly all abdominal cavity; orange coloured; oocytes diameter 0.568-0.71 mm	Testes with full seminiferous tubes and well limited, firm appearance, milky coloured
<b>IV/VI</b> (spending)	Ovaries apparently in stage IV, with some oocytes 0.639-0.71 mm diameter, and others 0.071-0.142 mm diameter; already spent and recovering for the next egg deposition	Testes with more or less homogeneous colour; seminiferous tubes are “half full”, as if they have only spent part of the fluid; recovering for another spawn
<b>VI</b> (spent)	Ovaries flattened; light orange colour, without oocytes	Testes coloured homogeneously, without seminal fluid

*L. sanzoi* showed a breeding season that extended from May to September/October, with a maximal gonad activity during June. The mean *GSI* (Fig. 6) attained a minimum in January, which was a rest period. During spring and summer, the fish invested in gonad development, which resulted in an increase in the mean *GSI* values.

The samples collected in September included two premature females (*SL* = 64 mm) and one premature male (*SL* = 65 mm) aged 0+ exhibiting

mature stage IV/VI. These fish possessed the minimal length for which the maturity stage was  $\geq$  IV, so 64 mm was considered to be indicative of the dimension of the first spawning for premature individuals. In fact, 82% of the females sampled during the sampling season with a *SL* between 60 and 65 mm were mature specimens, or showed ovaries in an advanced stage of maturation.

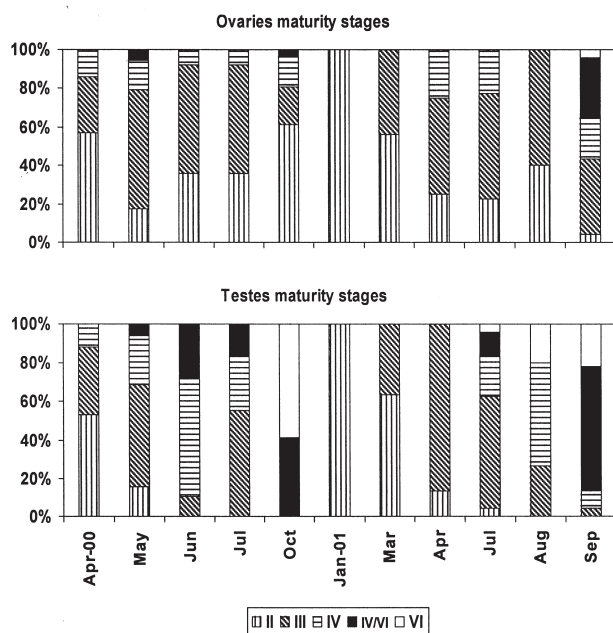
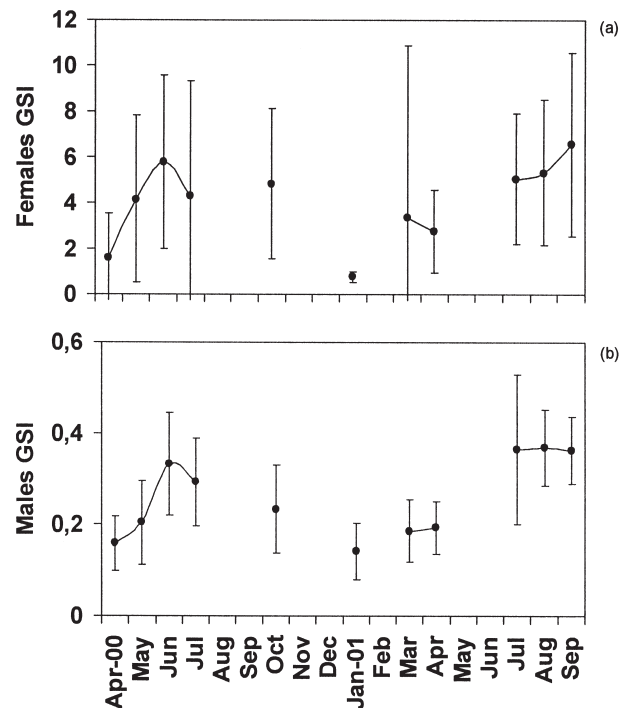
FIG. 5. – Monthly variation in maturity stages of *L. sanzoi*.FIG. 6. – Monthly mean gonadosomatic index (*GSI*) of *L. sanzoi* females (a) and males (b). Vertical bars report the standard deviation.



TABLE 3. – Proportion of males and females in each monthly sample and corresponding mean SL; M SL min, male minimum standard length; M SL max, male maximum standard length; M  $\overline{SL}$ , male mean standard length; F SL min, female minimum standard length; F SL max, female maximum standard length; F  $\overline{SL}$ , female mean standard length;  $G_w$ , G statistics with Williams correction; df, degrees of freedom;  $G_H$ , heterogeneity G;  $G_T$ , total G; P, significance level.

Month	Males	M SL min	M SL max	M $\overline{SL}$	Females	F SL min	F SL max	F $\overline{SL}$	Sex ratio	$G_w$	df	P
Apr 00	14	45	96	66	8	45	95	63.3	0.5714	1.620	1	0.2030
May 00	34	58	103	81.8	30	56	93	84.3	0.8824	0.248	1	0.6183
Jun 00	29	75	98	90.2	26	77	110	91.7	0.8965	0.162	1	0.6871
Jul 00	19	62	84	60.3	20	61	92	71.6	1.0526	0.025	1	0.8736
Oct 00	65	69	100	87.2	61	70	101	85.5	0.9385	0.127	1	0.7221
Jan 01	6	77	99	90.8	3	79	82	81.0	0.5000	0.966	1	0.3257
Mar 01	23	72	100	87.7	19	58	99	85.5	0.8261	0.377	1	0.5392
Apr 01	15	71	100	84.9	9	76	97	85.2	0.6000	1.485	1	0.2230
Jul 01	135	57	84	67.1	117	58	89	66.1	0.8667	1.284	1	0.2571
Aug 01	15	73	87	83.7	13	70	97	84.7	0.8667	0.140	1	0.7078
Sep 01	133	65	93	75.1	121	64	92	73.5	0.9098	0.566	1	0.4518
Test - G	df	P										
$G_H$	10	0.9798										
$G_T$	11	0.7878										

Statistical analysis by G-test of independence showed that the proportion of males and females did not vary between the samples and was close to 1:1 ratio in most of the months (Table 3).

### Feeding ecology

Monthly variation of the vacuity index (VI) and fullness index (FI) showed that there were some fluctuations during the sampling period (Fig. 7). According to the G-test of independence, during the first and the last month of the breeding season, May ( $G_w = 2.582$ ; df = 1; P = 0.6170) and October 2000 ( $G_w = 1.131$ ; df = 1; P = 0.7216) respectively, total VI reached the higher values. Only in July 2000 did a significant difference occur between males and females VI ( $G_w = 7.181$ ; df = 1; P < 0.05). In January 2001, only males had empty stomachs, but due to the small sample size the differences were not

considered significant ( $G_w = 0.548$  df = 1; P = 0.6858). Throughout the year all individuals had food in their guts. According to the Kruskal-Wallis test (KW) used to compare the monthly FI (KW = 10; df = 10; P = 0.44), there were no significant differences considering only the part of the population that was feeding.

A total of 44 different food items were identified in the gastrointestinal contents of the analysed Sanzo's gobies (Table 4). Most items were identified as belonging to the Crustacea class (Fig. 8). This group is doubtless the most important, representing 66.7% of all food items (Fi) and occurring in 83.3% of the analysed gut contents (FO) (Table 4). Polychaeta and Mollusca exhibited relevant values concerning Fi and FO. Shannon diversity index (Fig. 9) showed the lowest diversity among ingested preys in April and May 2000, and between January and April 2001.

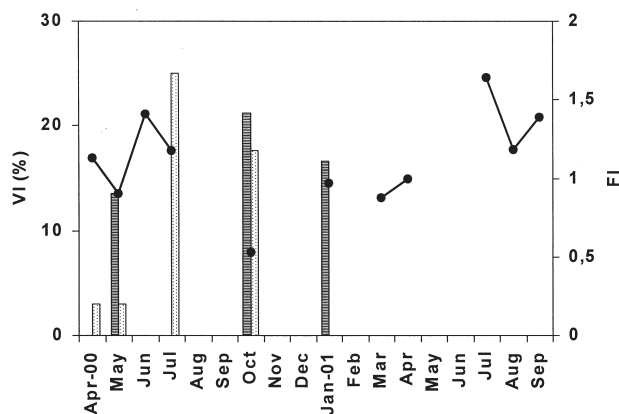


FIG. 7. – Monthly variation of vacuity index (VI) males (dark bars), females (light bars), and fullness index (FI) (full circles).

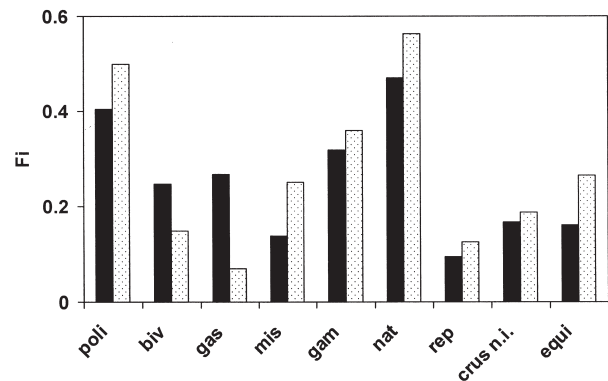


FIG. 8. – Numerical frequency (Fi) of taxa during breeding season for males (black bars) and females (grey bars). Poli: Polychaeta; biv: Bivalvia; gas: Gastropoda; mis: Mysidacea; gam: Gammaridea; nat: Natantia; rep: Reptantia; n.i. crus: non identified Crustacea; equi: Echinodermata.

TABLE 4. – Diet of *L. sanzoi* based on 1708 preys identified on a sample of 477 full gastrointestinal guts

Taxa	FO	Fi
ALGAE	0.1	0.003
NEMATODA	0.002	0.0006
ANNELIDA		
Polychaeta	0.391	0.113
<i>Leptonereis glauca</i>	0.012	0.003
Nereidae n.i.	0.025	0.008
<i>Lycastria</i> sp.	0.002	0.0004
Polychaeta n.i.	0.36	0.101
MOLLUSCA		
Bivalvia	0.128	0.057
Bivalvia n.i.	0.128	0.057
Gastropoda	0.167	0.105
Nassaridae spp.	0.105	0.068
Gastropoda n.i.	0.084	0.036
ARTHROPODA		
Crustacea		
Order Ostracoda		
Ostracoda n.i.	0.023	0.012
Order Copepoda		
Laophotidae	0.004	0.001
Order Cumacea		
Cumacea n.i.	0.006	0.002
Order Mysidacea	0.165	0.076
<i>Siriella clausii</i> G. Sars	0.006	0.002
<i>Leptomysis brguii</i> Bacescu	0.019	0.006
Mysidacea n.i.	0.14	0.068
Order Amphipoda		
Gammaridea		
<i>Ampelisca</i> sp.	0.002	0.0004
Gammaridea n.i.	0.331	0.161
Caprellidea		
<i>Phthisica marina</i> (Slaber)	0.004	0.002
Caprellidea n.i.	0.025	0.012
Hyperidea		
Hyperidea n.i.	0.004	0.001
Order Isopoda		
Isopoda n.i.	0.013	0.005
Order Euphausiacea		0.022
Euphausiacea n.i.	0.05	
Order Decapoda		
Infra Order Caridea	0.418	0.26
Alpheidae		
<i>Alpheus glaber</i> (Olivi, 1972)	0.071	0.022
Processidae		
<i>Processa canaliculata</i> (Leach, 1915)	0.04	0.012
<i>Processa</i> sp.	0.015	0.022
Hippolytidae		
<i>Eualus pusiulus</i> (Kroyer, 1841)	0.082	0.045
Crangonidae		
<i>Pontophilus norvegicus</i> (M. Sars, 1861)	0.004	0.003
<i>Philocheras bispinosus</i> (Hailstone, 1835)	0.111	0.063
<i>Philocheras monacanthus</i> (Holthuis, 1961)	0.042	0.015
<i>Philocheras</i> sp.	0.033	0.098
Caridea n.i.	0.13	0.045
Infra Order Thalassinidea	0.004	0.0006
<i>Axius stirhynchus</i> (Leach, 1851)	0.004	0.0006
Infra Order Anomura	0.065	0.032
<i>Galathea intermedia</i> (Liljeborg, 1851)	0.063	0.032
<i>Anomura</i> n.i.	0.002	0.0004
Infra Order Brachyura	0.05	0.015
<i>Homola barbata</i> (Fabricius, 1793)	0.006	0.002
<i>Ebalia</i> sp.	0.004	0.0004
<i>Liocarcinus pusillus</i> (Leach, 1815)	0.031	0.009
<i>Goneplax rhomboides</i> (Linnaeus, 1758)	0.013	0.004
Reptantia n.i.	0.006	0.002
Decapoda Larvae	0.006	0.002
Decapoda n.i.	0.013	0.002
Crustacea Larvae	0.01	0.004
Crustacea n.i.	0.228	0.083
EQUINODERMATA		
Order Ophiurae	0.146	0.041
Ophiurae n.i.	0.146	0.041
NON-IDENTIFIED	0.008	0.004

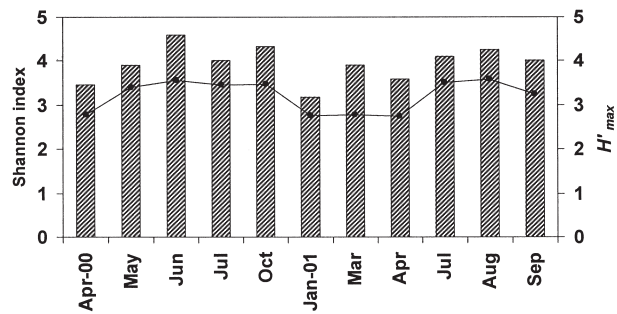


Fig. 9. – Monthly variation of diversity (Shannon index) (full circle) and maximum diversity ( $H'_{max}$ ) (bars).

During the breeding season, males and females showed differences in their diet behaviour (Table 5). Using a G-test of independence (Table 5), it was observed that the three taxa that did not show significant differences between sexes were Bivalvia, Gammaridea and Crustacea n.i. The degree of diet overlap was calculated for males vs. females during reproduction and non-reproduction periods (Table 6). It can be observed that the minimum overlap occurred for males in the reproduction period vs. non-reproduction period. The maximum overlap occurred for the non-reproduction period between males and females.

## DISCUSSION

The occurrence of Sanzo's goby off Cabo Raso, on the west coast of Portugal at depths of 70 to 100 m in mud and sand bottoms could mean that the distribution of this species has been spreading northward in the last years, following the trend of other southern fish species, probably as a result of a global change in the climate (Cabral *et al.*, 2001).

Contrary to what would be expected for temperate climates (Bagenal and Tesh, 1978), Sanzo's goby forms two translucent rings each year in its otoliths. Comparing the relationship between the breeding season and the deposition of the translucent ring, it was observed that there were two major peaks of individuals with translucent rings, which corresponded to two low values of the gonadosomatic index (*GSI*). It was also clear that the *GSI* peak in June 2000 resulted in a high percentage of individuals with translucent edges in July. On the other hand, in January the high percentage of individuals with translucent edges was mostly due to the slow winter growth. The winter ring was formed due to the slow growth rate conditioned by adverse abiotic factors, and the spawning ring was probably due to physio-

TABLE 5. – Preys' numerical frequency during breeding season; FN, number of *i* preys in females' gastrointestinal contents; FNr, total number of preys (except prey *i*) in female gastrointestinal contents; MN, number of *i* preys in male gastrointestinal contents; MNr, total number of preys (except prey *i*) in male gastrointestinal contents;  $G_Y$ , G statistical with Yates correction; df, degrees of freedom; P, significance level; \*,  $P < 0.05$ .

Prey	FN	FNr	MN	MNr	$G_Y$	df	P
Polychaeta	63	461	40	559	11.102	1	*
Bivalvia	36	488	52	547	1.037	1	0.31
Gastropoda	23	501	92	507	37.994	1	*
Mysidacea	57	467	36	563	8.097	1	*
Gammaridea	65	459	65	534	0.515	1	0.47
Caridea	192	332	132	467	28.371	1	*
Reptantia	35	489	14	585	11.808	1	*
Crustacea n.i.	34	490	27	572	1.762	1	0.18
Ophiuræ	36	488	22	577	5.206	1	*

TABLE 6. – Diet overlap between males and females within the reproductive and the non-reproductive periods; R, reproductive period; NR, non-reproductive period.

Shorogin index	
R / vs. NR /	0.6447
R ? vs. NR /	0.6752
NR / vs. NR ?	0.7767
R ? vs. NR ?	0.5551

logic changes during this period, which conditions otolin mineralisation (Härkönen, 1986). It is possible that although some individuals formed a translucent ring during spawning, they did not actually get to spawn. Sanzo's goby attains a maximum life span of 24 months, corresponding to two breeding periods. Nevertheless, the number of individuals that can reach the second breed was low, since most of them die after the first breeding season. These results are far different from the ones for Fries's goby, which reaches a maximum age of 9 years in the Firth of Clyde (Nash, 1982), and 11 years in the Lynn of Lorne (Gibson and Ezzi, 1978), both in Scotland.

The Sanzo's goby population studied was divided into two types of individual, standard and premature. Standard individuals first spawned after the first winter aged 1+, whereas premature individuals first spawned in the last months of the breeding season (September/October), a few months after hatching, aged 0+ and with a minimum length of 64 mm. Theoretical mean growth between premature and standard individuals was different, in spite of an identical growth for both sexes within each group. Premature individuals reached longer lengths than standard ones. As premature individuals hatched at the beginning of the breeding season, they had a first fast growth period longer than that of standard individuals, which hatched late during the breeding sea-

son and reached the next spring with shorter lengths than premature ones. In hypothesis, premature individuals' descendents, which will hatch in the last months of the breeding season, will be standard individuals that will spawn during the next breed.

There was a numerical difference between the total number of premature ( $N = 113$ ) and standard ( $N = 307$ ) individuals captured. Apparently, a cohort that hatched at the beginning of the breeding season should have greater success because this period has more favourable abiotic conditions, and there is far more food available. Therefore, it is possible that premature individuals have a higher mortality rate or that their progenitresses (standard individuals) have a lower fecundity. The largest fish caught was a one-year-old premature female with 110 mm standard length (*SL*), which is larger than the maximum standard length of 70 mm for Namibia and 100 mm for Faro, south Portugal, recorded by Lloris *et al.* (1984) and the 95 mm recorded by Miller (1986).

Sanzo's goby is an oviparous and gonocoric species with secondary sexual dimorphism and a short life cycle. Ovaries are elongated and rounded, and testes have an elongated and triangle section. Due to the long breeding season, between May and September/October, and the great number of males and females apparently spent but actually "semi-spent" or with developing oocytes, it can be considered that *L. sanzoi* has more than one spawning per breeding season, like other Gobiidae species (Miller, 1961; Fonds, 1973; McEvoy and McEvoy, 1992). According to Cole (1954), Sanzo's goby is an abbreviate iteroparous species. The ripe eggs with a diameter of 0.56-0.71 mm are similar to Fries's goby eggs with a diameter of 0.5-0.6 mm (Gibson and Ezzi, 1978).

The number of reproduction cycles can be determinant in the life spawn of this species, as both pre-



mature and standard individuals showed two spawning marks on their otoliths and no fish showed signs of a third spawning. It can therefore be concluded that this Sanzo's goby population only reaches the second year of life and has two breeding seasons during its lifetime, after which they die.

This *L. sanzoi* population had a sex ratio quite close to 1:1, which reveals there was no dominance of either sex and that males and females had an equal vulnerability to capture. A similar result occurs with *L. friesii* in the Firth of Clyde (Nash, 1982), although Gibson and Ezzi (1978) refer this same species as having a sex ratio in favour of females (female to male sex-ratio 1.2:1). A greater number of females would be expected, mainly during spawning, when males are guarding the nest. It is possible that the samples were collected in an area far from the nest sites, or that the trawl was destroying the nest as it passed.

Feeding activity went through some fluctuation during the year. In May 2000 some individuals were not feeding. This behaviour was possibly due to the males' reproductive behaviour, since a significant number of males showed a high VI in comparison with females. Also, in October 2000 both sexes showed high values of VI, suggesting that the end of the breeding season induces a decrease in the feeding activity of this species, or that the number of available preys was lower at this time of the year. Nevertheless, all the individuals kept feeding during the sampling period, showing a feeding activity that was quite constant throughout the year.

The gastrointestinal content analysis showed that Sanzo's goby fed mainly on Polychaetes, Crustacea Gammaridea and Crustacea Caridea, although it was considered as a generalist species because none of the preys was consumed in quantities exceeding 50%. There was no major fluctuation in prey ingestion during the year, although during the reproductive period diversity increased, suggesting that there was a higher diversity of preys available during this period. In June 2000 and March 2001 maximum diversity showed that Sanzo's goby turned out to be more specialist, ingesting a greater number of *Phyllocheras* sp., *Gastropoda* and *Gammaridea* respectively (unpublished data). Once this species has a peculiar reproductive behaviour, it induced some consequences in the diet of both sexes. Considering the need to spend high levels of energy on the primary reproductive effort (Miller, 1984), females would be expected to consume more food than males. During breeding, males preferred molluscs to

crustaceans. It is likely that the great stress males suffer due to the territory and nest guard during breeding affects their ability to seek preys. Thus, males eat more molluscs because they are easier to hunt, due to their epibenthonic way of life and weak capacity to make sudden moves in order to escape from a potential predator. Males would be expected to ingest a similar number of *Bivalvia* and *Gastropoda*. Therefore, the differences found could result from the fact that *Gastropoda* show a higher mobility than *Bivalvia*, and therefore it is possible that their densities in the males' territories are kept more or less constant.

## REFERENCES

- Anonymous. – 2000. *Relatório de síntese do programa de monitorização elaborado para a Sanest, S.A.; I.H.; INET; IST and U. Aveiro*. pp. 105.
- Assis, C.A. – 1992. *A ecologia alimentar dos peixes: metodologia empregue no seu estudo*. Provas de aptidão pedagógica e capacidade científica. Faculdade de Ciências da Univ. Lisboa, Lisboa.
- Bagenal T.B. and F.W. Tesh. – 1978. Age and growth. In: T. Bagenal (ed.), *Methods of assessment of fish production in fresh waters*, pp. 101-130. Blackwell Scientific Publications, IPB Handbook 3, 3<sup>rd</sup> edition, Oxford.
- Fonds, M. – 1973. Sand gobies in the Dutch Wadden Sea *Pomatoschistus*, (Gobiidae, Pisces). *Neth. J. Sea Res.*, 6(4): 417-478.
- Fouda, M.M., M.Y. Hanna and F.M. Fouda. – 1993. Reproductive biology of a Red Sea goby, *Silhouettea aegyptia*, and a Mediterranean goby, *Pomatoschistus marmoratus*, in Lake Timsah, Suez Canal. *J. Fish Biol.*, 43: 139-151.
- Gibson, R.N. and I.A. Ezzi. – 1978. The biology of a Scottish population of Fries' goby, *Lesueurigobius friesii*. *J. Fish Biol.*, 12: 371-389.
- Gros, P.H. – 1980. Description mathématique de la croissance de *Lesueurigobius friesii* (Teleostei, Gobiidae). *Essai de synthèse*. *Oceanol. Acta*, 3(2): 161-168.
- Härkönen, T. – 1986. *Guide to the otoliths of the bony fish of the Northeast Atlantic*. Danubiu APS.
- Hyslop, E.J. – 1980. Stomach contents analysis - a review of methods and their application. *J. Fish Biol.* 17: 411-429.
- Lloris, D., J.A. Rucabado and J.A. Gomes. – 1984. *Lesueurigobius sanzoi* (De Buen, 1918), (Osteichthyes, Gobiidae), in the south-east Atlantic (Namibia). *Thalassas*, 2: 93-97.
- Ludwig, J.A. and J.F. Reynolds. – 1988. *Statistical Ecology. A Primer on Methods and Computing*. John Wiley and Sons, New York.
- McEvoy, L.A. and J. McEvoy. – 1992. Multiple spawning in several commercial fish species and its consequences for fisheries management, cultivation and experimentation. *J. Fish Biol.*, 41 (Suppl. B): 125-136.
- Magnhagen, C. and L. Kvarnemo. – 1989. Big is better: the importance of reproductive success in male *Pomatoschistus minutus* (Pallas) (Pisces, Gobiidae). *J. Fish Biol.*, 35: 755-763.
- Miller, P.J. – 1961. Age, growth and reproduction of the rock goby, *Gobius paganellus* L., in the Isle of Man. *J. mar. biol. Ass. U.K.*, 41: 737-769.
- Miller, P.J. – 1984. The tokology of gobioid fishes. In: G.W. Potts and R.J. Wootton (ed.), *Fish Reproduction: Strategies and Tactics*, pp. 119-131. R.J. Academic Press, London.
- Miller, P.J. – 1986. Gobiidae. In: P.J.P. Whitehead; M.C. Bauchot; J.-C. Hureau; J. Nielson, and E. Tortonese (eds.), *Fishes of the north-eastern Atlantic and Mediterranean*, pp. 1019-1085. Volume 3, Unesco.
- Nash, R.D.M. – 1982. The biology of Fries's goby, *Lesueurigobius friesii* (Malm), in the Firth of Clyde, Scotland, and comparison

- with other stocks. *J. Fish Biol.*, 21: 69-85.
- Nellbring, S. – 1993. Spawning of two *Pomatoschistus* species (Gobiidae) in relation to nest availability and depth: a field experiment. *Neth. J. Sea Res.*, 31(2): 173-179.
- Olivar, M.P. – 1989. Spawning and development of *Lesueurigobius sanzoi* off northern Namibia. *S.-Afr. Tydskr. Dierk.*, 24(2): 132-138.
- Ota, D., M. Marchhesan and A. Ferrero. – 1996. Sperm release behaviour and fertilization in the grass goby. *J. Fish Biol.*, 49: 246-256.
- Ricker, W.E. – 1975. Computation and interpretation of Biological statistics of fish populations. *Bull. Fish. Res. Bd Can.*, 191: 203-217.
- Seiwald, M. and R.A. Patzner. – 1989. Histological, fine-structural and histochemical differences in the testicular glands of gobiid and blennioid fishes. *J. Fish Biol.*, 35: 631-640.
- Wallace, R.K. – 1981. An assessment of diet overlap indexes. *Trans. Am. Fish. Soc.*, 110: 72-76.

Scient. ed.: A. Sabatés