

First data on the demography and growth of *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891) (Teleostei; Gobiidae), in Corsica (France)

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This rare species found in the Lavezzi Islands (South of Corsica) has never been studied before to the ecological and biological point of view. On the basis of 197 specimens caught at different periods (July 1988 and 1992, September 1989 and October 1990), the ecology of the species is addressed from the aspect of its population structure. The size of the young ranged from 12 to 27 mm, while that of adult males and females varied from 16 to 40 mm and 15 to 36 mm respectively. The demographic structure of this goby, composed of three cohorts, did not change. The sex ratio varied a little according to the sample-taking period (0.44 in July and 0.71 in October). The mathematical models used helped us to establish that the life span of this species is at least 24 months.

Key words: Mediterranean Sea, Corsica, fish, size, sex ratio, age

INTRODUCTION

The *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891) is a rare species (Fig. 1) belonging to the Gobiidae family known for its wide ecological diversity (MILLER, 1984), since

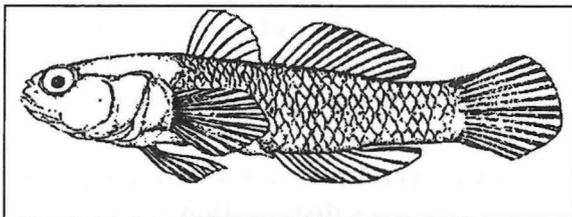


Fig. 1. *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891), according to BOUCHEREAU and TOMASINI (1989)

this family has adapted to coastal, estuarine, lagoon and even off-shore ecosystems.

This endemic species of the Mediterranean Sea, whose size can reach 43.5 mm, has been found on the Dalmatian coast of the Adriatic, Milna, Brač Island (KOLOMBATOVIĆ, 1891; CARUS 1893), the Levantine Sea (MILLER, 1986), and has recently been discovered in the Aegean Sea (ECONOMIDIS in MILLER, 1986), in the Mar Menor (RAMOS-ESPLA and PÉREZ RUZAFÁ, 1985, 1987) and in the Bonifacio Straits along the coast of the Lavezzi Islands, south of Corsica (BOUCHEREAU and TOMASINI, 1989) in the western Mediterranean. It lives in a shallow coastal environment (<4 m) on rocky substrata (MILLER, 1986), algae or sea-grass beds (RAMOS-ESPLA and

PÉREZ RUZAFÁ, 1987) and in association with sea urchin (PATZNER and MOOSLEITNER, 1999). This species has been studied on a systematic basis (MILLER, 1971; GANDOLFI *et al.*, 1978; BOUCHEREAU and TOMASINI, 1989), but few studies have considered its biology. Its feeding habits (RAMOS-ESPLA and PÉREZ-RUZAFÁ, 1987; BOUCHEREAU and GUELORGET, 1999), reproduction (BOUCHEREAU and TOMASINI, 1989) and ethology (GANDOLFI *et al.*, 1978) have nevertheless been investigated.

Because of the few data existing on the biology of this species and the weak number of specimens collected in the studied region up to now, *M. macrocephalus* can be considered as rare on the Corsican coasts. The aim of this study is to investigate the demographic structure of the populations of *M. macrocephalus* in the Lavezzi Islands and to give further information on its biology to improve knowledge of the species. The few specimens available and used for this study were gathered from the Lavezzi Islands (Corsican Marine Natural Reserve). They were pooled per summer and autumn season supposing the population structures do not differ between years 1988 and 1992, 1989 and 1990, and between sexes.

MATERIALS AND METHODS

Sampling sites

The Lavezzi Islands are situated in the Mouth of Bonifacio City, south of Corsica (Fig. 2).

Two different sites on the west coast of those small islands were explored to collect samples. One of these sites is the small channel "U passetu", passage measuring 192 m², and the other is a creek of 573 m² right on the edge of the Sémillante cemetery (Fig. 2). An average depth of each site is one metre (BOUCHEREAU and TOMASINI, 1989). They both consist of a rocky substratum partly covered with algae, mainly *Cystozeira*, with a high degree of architectural complexity and topography, which is typical of the facies. The creek, relatively enclosed, comes into direct contact with the sea only through narrow outlets. Both of the channel outlets give onto wide basins with rather irregular stones. The east basin is very sheltered

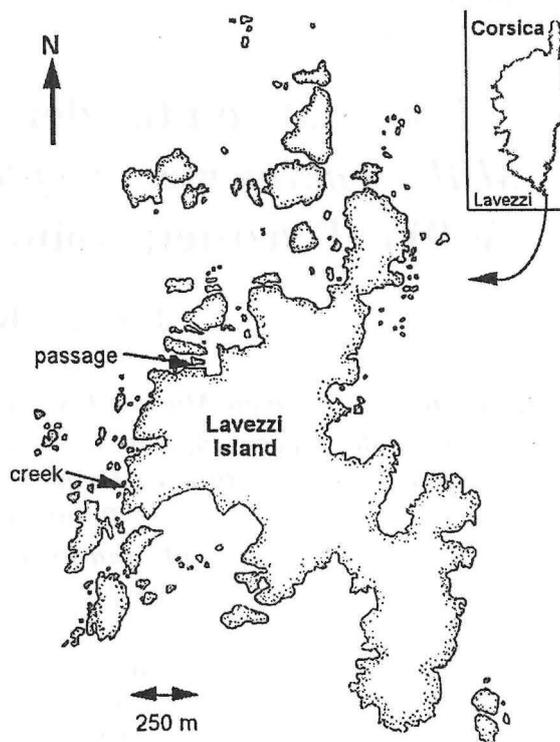


Fig. 2. Sampling sites in the Lavezzi Islands (Corsica, France)

with calm waters, while the waters of the west one, though it is also sheltered, are often rough because it gives onto the open sea. The fish have been collected between 10 a.m. and mid-day (UT), using rotenone (3 kilograms for each sample batch). This product was mixed into wet sand to facilitate its immersion. It acted only on branchial organisms, limiting gaseous exchanges. The main difficulty lied in obtaining an adequate distribution of the product throughout the water column so that it was sufficiently concentrated to act on the fish. The mixture was released into the environment once nets were installed to confine the temporarily affected fish of the sampling area. The specimens were caught with hand nets from the entire depth of the water column, on the rocks and bed, and were then fixed in formol (8%). The sampling area was examined several times during sampling.

Sex determination and size frequencies distribution

Sex was determined under a stereomicroscope looking at the shape of the urogenital

papilla which is conical in males and cylindrical in females (BOUCHEREAU and MARQUES, 1998). Specimens, which could not be sexed by this method, were dissected to examine the gonads under a stereomicroscope and were assumed to be immature if gonads were not developed. The total length (TL) of all specimens was measured to the nearest millimetre (mm). Length data were first ranged in class size of 2 mm. They were grouped by four size classes to obtain a sufficient number allowing the use of chi-squared χ^2 and test the sex ratio. Some of the specimens of this species (reference: 1996-0682) have been sent to the French National Museum of Natural History.

Data analysis

For each sex, sampling dates and areas, the total length of individuals was grouped according to size classes of 2 mm. Then, the size frequency distribution obtained was exploited by using the methods of BATTACHARYA (1967) and GHI'NO and LE GUEN (1968) to study po-

pulation structure and growth. The sex ratio (SR = number of males σ : number of females ρ) was calculated for each relevant size class. The growth model equation used is that of GULLAND and HOLT (1959):

$$dTl/dt = -KTLm + KTL_{\infty}$$

TLm being the mean total length of a cohort

All the parameters were studied according to the median points of the 2 mm size class (MPC).

RESULTS

Four different samples were collected representing 197 fish caught (Table 1). The number of male, female and immature specimens, the sex ratio and extreme values of eviscerated mass and length are shown in Table 1.

The weak number of individuals in the four following samples - 17th July 1988 ($n=30$), 9th July 1992 ($n=47$), 29th September 1989 ($n=80$) and 3rd October 1990 ($n=40$) - and the similar size range in the different seasons are given.

Table 1. Number of specimens (N), sex-ratio (SR), global sex-ratio (GSR) according to the sex and date of sampling; and, extremes of size TL (in mm) and eviscerated mass M (in g) of *Millerigobius macrocephalus* caught at the Lavezzi Islands (Corsica, France)

dates	Sept. 89	Oct. 90	July 88	July 92	min-max TL	min-max M
	N	N	N	N		
Males	21	5	8	24	16-40	0.032-0.735
Females	39	20	22	23	15-36	0.025-0.449
Immatures	20	15	0	0	12-27	0.016-0.045
SR	0.538	0.250	0.364	1.043	-	-
GSR	0.441		0.711		-	-

Table 2. Number of males σ and females ρ , sex-ratio σ/ρ , and percentage of males $\% \sigma$, according to the size classes of 2 mm and the season

TL (mm)	15	17	19	21	23	25	27	29	31	33	35	37	39	41
autumn														
σ	0	4	3	5	2	1	1	4	2	2	0	0		
ρ	2	5	12	5	4	4	8	12	4	0	1	1		
σ/ρ	0	0.80	0.25	1.00	0.50	0.25	0.12	0.33	0.50	0	0	0		
$\% \sigma$	0	44	20	50	33	20	11	25	33	100	0	0		
summer														
σ						1	1	0	3	11	2	8	0	2
ρ						2	11	17	10	4	4	0	0	0
σ/ρ						0.50	0.09	0.00	0.30	2.75	0.50	0	0	0
$\% \sigma$						33	8	0	23	73	33	100	0	100

The samples were divided into two groups - a summer (global $SR=0.71$) and an autumn one (global $SR=0.44$), in order to obtain an efficient growth model with the GULLAND and HOLT's method (1959).

The maximum lengths of both sexes (Table 1) are well separated: 40 mm for the males and 36 mm for the females. They differ particularly in summer by 2 size classes: 4 mm in favour of males (Table 2).

The sex ratio according to the size class in the summer distribution pattern ranges from 0.1/1 to 2.75:1 and reached a maximum peak for the 33 mm class (Fig. 3).

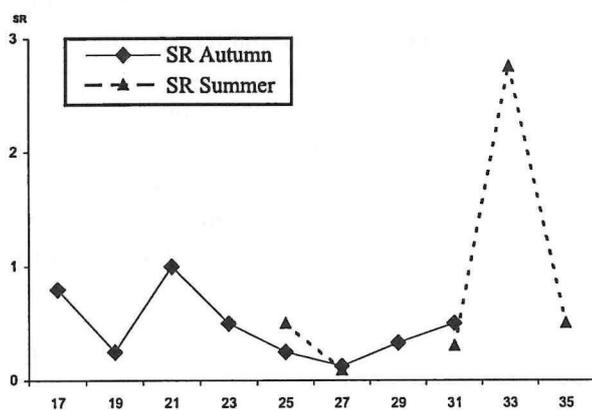


Fig. 3. Distribution of sex ratio according to the median points of 2 mm size classes (MPC) of *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891), caught in summer and autumn off the Lavezzi Islands (Corsica, France)

The autumn sex ratio, varying between 0.12:1 and 1:1, is biased towards females, whatever the size, and reaches its maximum between 17 and 23 mm. It is significantly different between the total number of each sex, all size classes added (χ^2 , $p=0.007$) or groups of four size classes added: 17 to 23 mm (χ^2 , $p=0.02$) and 25 to 31 mm (χ^2 , $p=0.01$). Application of the successive maximum method (GHÉNO and LE GUEN, 1968) to all distribution patterns combined (Figs. 4 and 5) showed the presence of three cohorts in autumn:

- mean length of the first cohort $TLm1=18.64$ mm;

numbers of fish in the first cohort $n1=79$;
standard error in the first cohort $S1=3.08$;

- $TLm2=28.75$ mm, $n2=32$, $S2=1.39$;

- $TLm3=34.50$ mm, $n3=4$, $S3=1.66$;

and three cohorts in summer:

- $TLm1=29.00$ mm, $n1=47$, $S1=2.02$;

- $TLm2=33.00$ mm, $n2=14$, $S2=0.76$;

- $TLm3=36.20$ mm, $n3=13$, $S3=0.97$.

The BATTACHARYA method showed the presence of two cohorts in the autumn sample:

- $TLm1 = 18.14$ mm, $n1=80$, $n1'=81$, $S1=3.12$
($n'I$ = adjusted numbers of cohort i);

- $TLm2=26.74$ mm, $n2=34$, $n2'=34$, $S2=3.38$;

and a single cohort for the summer sample:

- $TLm1 = 29.16$ mm, $n1=51$, $S1=2.20$

In the latter cohort 23 specimens were not attributed to this cohort and probably belong to a second age group. One method shows the same number of cohorts in the both seasons studied. So, the growth model (GULLAND and HOLT, 1959) has been applied to the distribution patterns obtained by the maximum successive method, assuming that the first autumn cohort (TL) corresponds to the first summer cohort ($TL+1$), the second autumn cohort to the second summer one, and so on. We then obtained: $K=0.084$, $TL_{\infty}=37.26$ mm with $r^2=0.988$. When trying to determine the egg-laying period, the best adjustment of the model was obtained for a mathematical hatching size of 0 mm (the intersection point of the curve defined by the model equation and the abscissa axis) and a time lapse of 8 months between hatching (value added to model: 0 mm) and the first cohort ($TLm1=18.64$). We then obtained: $K=0.084$, $TL_{\infty}=37.25$ mm with $r^2=0.998$, and $t_0=0.457$ months with $r^2=0.978$. Two mathematical new data ($TL=0$ mm and $t=8$ months) have thus been included in the model already made with the collected data (TLm and t) calculated by the successive maximum method.

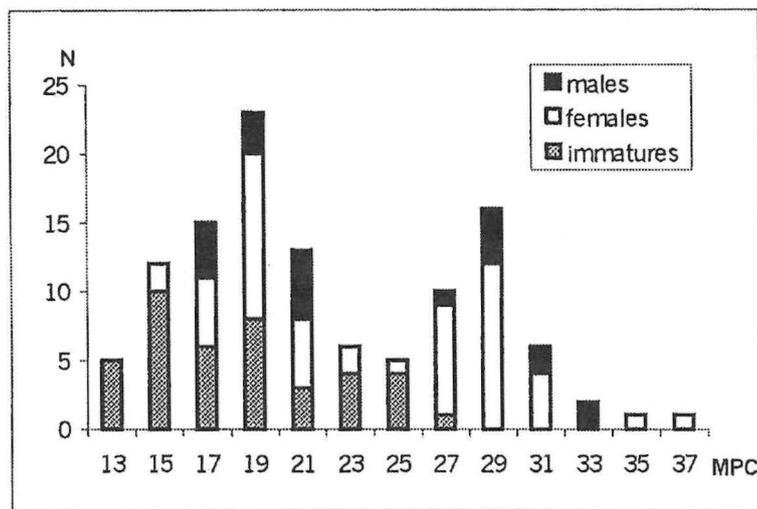


Fig. 4. Distribution pattern of size frequencies distribution (MPC = median points of 2 mm size classes) of (N) specimens of *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891), caught in autumn off the Lavezzi Islands (Corsica, France)

DISCUSSION

Whatever the site and the season, the size frequency distribution of *M. macrocephalus* is relatively stable. However, the maximum size observed (40 mm) was smaller than that (43.5 mm) obtained by MILLER (1986). One hypothesis to explain this could be a lower growth rate in Corsica and not due to our sampling method as all the fish have normally been collected (except perhaps some nesting males stuck in rocky cavity) and the sampling areas have been checked several times.

Autumn distribution pattern

The autumn distribution pattern (Fig. 4) was characterised by the presence of many immature (young of the year: YOY) and few males.

The presence of the newly born, which corresponds to the new recruitment, indicates the proximity of the breeding season, which should occur in summer time according to different authors (GANDOLFI *et al.*, 1978; BOUCHEREAU and TOMASINI 1989). Could the presence of large individuals of both sexes be explained by an absence of differential growth between males and females or by the higher secondary reproductive effort made by the males during the breeding season? MILLER (1984) described

two types of reproductive effort in small fishes. A primary effort devoted to the development of the gonads, and a secondary partly devoted to the catabolism required for migration, courtship display and nest building, and partly to the anabolism required for allometric growth of both sexes and for colouring in males. In the case of *M. macrocephalus*, and according to the autumn distribution pattern, the secondary effort of males devoted to courtship, nest building and coloration of fins, was probably high and made them spend as much energy as the females do in the development of their gonads several times during a breeding season. However, the lack of difference in size distribution could also be due to the fact that the females have managed to make up their growth deficit caused by a high investment of energy during the breeding season.

The excess of females (Fig. 3) in all size classes (global $SR=0.44$) could be interpreted as the result of a reproductive strategy of this species in which males should hold nest in rocky bottom, the only nesting support available in this area. Then, males defend the eggs laid in their nest like in other goby species (VESTERGAARD, 1976; BOUCHEREAU *et al.*, 1991, 1992; PAMPOULIE *et al.*, 2001) and are more difficult to catch than females which constantly

look for nest where to lay their eggs. Moreover, males holding a nest in rocky habitat could be stuck in their nest cavity due to our sampling methods (rotenone), causing a biased in the observed sex ratio.

Depending on the mathematical model applied, two (BATTACHARYA) or three (GHÉNO and LE GUEN) cohorts have been distinguished. The difference in these results emphasises the difficulty of the following:

- separation into different cohorts,
- using mathematical models on low sample size,
- inclusion or not of older specimens in the last cohort.

Summer distribution pattern

The summer distribution pattern (Fig. 5) does not include any YOY. It was characterised by the presence of large specimens ($TL > 24$ mm). The absence of young indicates that recruitment does not occur in summer or that the YOY did not occupy the same area as their parents did. The absence of large females (more than 36 mm) could be explained by their strong reproductive effort during the breeding season that could be done at the expense of the growth as trade off between growth and reproductive investment in fish is well known. This

sexual dimorphism and the darker coloration of males in the breeding season has already been noted in *M. macrocephalus* by GANDOLFI *et al.*, (1978) and BOUCHEREAU and TOMASINI (1989).

The global sex ratio ($SR=0.71$) observed during the summer period (Fig. 3), slightly higher than the one observed in autumn, confirmed the hypothesis of the reproductive strategy exposed for the autumn distribution pattern. The males which belong to the large size groups ($32 < TL < 42$) are probably nesting and guarding males as it has already been shown in other species such as *Pomatoschistus minutus* (LINDSTRÖM, 1988; BOUCHEREAU *et al.*, 1991) and *P. microps* (BOUCHEREAU *et al.*, 1991; PAMPOULIE *et al.*, 2001). Although no significant difference in length frequencies between sexes was not proved due to small number of specimens, some evidence of sexual dimorphism in size differences observed with the extreme sizes was measured during the breeding season (Table 2). It is probably caused by males making a lower reproductive investment than females, or by the fact that large males were nesting males that we were not able to catch during our sampling. However, in both sexes, the primary effort, highly developed in these small species, requires more energy than the secondary effort and should be much impor-

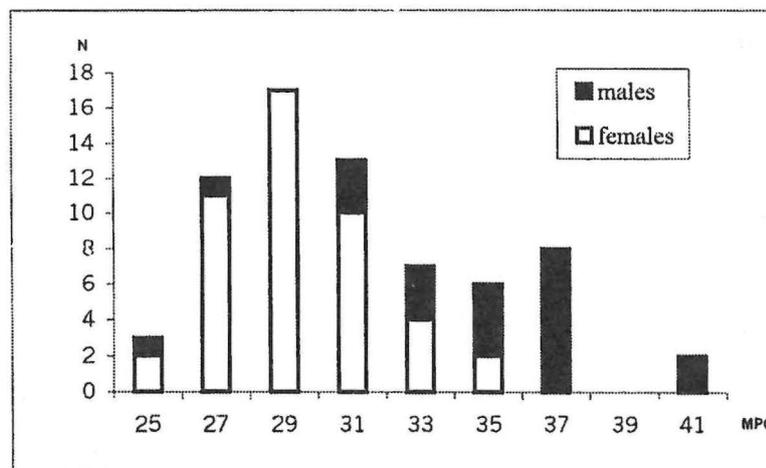


Fig. 5. Distribution pattern of size frequencies distribution (MPC = median points of 2 mm size classes) of (N) specimens of *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891), caught in summer off the Lavezzi Islands (Corsica, France)

tant in females than in the oligospermatic males. Constant investment of energy by the females in gametogenesis (contracted iteroparity) during the breeding season probably implied that their allometric growth cannot be the same as for males. This explains the presence in the summer samples of a size dimorphism to the disadvantage of females whose energy expenditure, due to successive laying of large amount of eggs, is greater than that furnished by males (spermatogenesis, colouring, nest building and guarding).

Growth models

Application of the mathematical models used made it possible to distinguish two cohorts (BATTACHARYA, 1967) or three cohorts (GHÉNO and LE GUEN, 1968). These results could be due to the low number of fish caught during our sampling. The growth model is applied to summer and autumn distribution patterns, assuming that the first autumn cohort (TL) corresponds to the first summer cohort ($TL+1$), the second autumn cohort to the second summer one, and so on. The model is designed on the basis of the general movement of modes to large sizes resulting from slower growth in winter and renewed growth in summer, which determine the growth parameters. An optimal adjustment of the model puts the age of the first autumn cohort at 8 months. This model implies that the larval hatching date is in February, while GANDOLFI *et al.* (1978) put it in August and BOUCHEREAU and TOMASINI (1989) have found females ($n=3$) ready to spawn in July, in the Lavezzi Islands. According to these data, one may say that the first cohort of autumn, which is the youngest, is made up of 0^+ specimens of 3 months (4 at most). Thus, on the basis of the samples gathered, the *M. macrocephalus* life span could be estimated at 36 months. However, the difficulty in distinguishing between the last two cohorts implies that the goby's life span is probably at least 24 months, and rarely 36. The determination of cohorts by means of size frequency combined with the analysis of the goby's otoliths or scales would help to confirm these results (it was not possible

to analyse the scales on the study samples because the material had been conserved for too long in formol). Moreover, as *M. macrocephalus* is rare, capture-recapture projects could be considered as a solution to acquire better knowledge on the demographic structure of this species.

Nonetheless, our results concur with those of GANDOLFI *et al.* (1978) and BOUCHEREAU and TOMASINI (1989), and therefore confirm the estimated life span of *M. macrocephalus*.

The large size of males and the iteroparity observed emphasise the effort furnished by *M. macrocephalus* to ensure the success of the breeding season and the survival of the species. Whenever possible, the females optimise the success of the breeding season at the expense of their own survival.

CONCLUSIONS

M. macrocephalus is probably a sedentary species of the Lavezzi Islands with a population which is identical whatever the creek it has been found in. The population was mainly composed of three age groups - 0^+ , 1^+ and 2^+ - which ensure the survival of the species and whose size ranges from 12 to 40 mm. The population structure does not vary, even though a slight difference can be observed between summer and autumn. These results are similar to those of GANDOLFI *et al.* (1978), even if the maximum size is smaller than the one they mention. On the basis of the models used, the life span of the goby is estimated at, at least, 24 months, thus confirming the hypothesis of BOUCHEREAU and TOMASINI (1989). The sex-ratio varies in these two seasons summer and autumn and reveals a reproductive strategy which enables the goby to ensure and optimise its breeding season.

Annual monitoring of the species using monthly samples (which has not been done yet) giving rise to the development of mathematical models would help to confirm these first results on the demography of *M. macrocephalus*. Scale analysis and otolithometry could support the estimation of the life span calculated. It would

also be interesting to experiment capture and recapture in different sites near and around the Lavezzi Islands where the species is likely to be present (Madaleina reserve in Sardinia). That way we could ascertain any exchange of individuals and evaluate the degree of autonomy of the *M. macrocephalus* populations with regard to their genetic variability.

ACKNOWLEDGEMENTS

This study was supported by the PARC NATUREL DE CORSE, MARINE RESERVE OF LAVEZZI and CERBICALES ISLANDS to inventory over several years the ichthyofauna to depth between 0 and 35 m. This study is dedicated to Dr C. PAMPOULIE.

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Received: 10 January 2002

Accepted: 2 April 2002

Prvi demografski podaci i rast ribe *Millerigobius macrocephalus* (KOLOMBATOVIĆ, 1891) (Teleostei; Gobiidae) na Korzici, Francuska

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SAŽETAK

Ova rijetka vrsta pronađena oko otočja Lavezzi (južno od Korzike) do sada nije bila proučavana u ekološkom i biološkom smislu. Na temelju 197 uzoraka uhvaćenih u različitim razdobljima (srpanj 1988. i 1992., rujan 1989. i listopad 1990.), ekologija vrste je promatrana s obzirom na strukturu populacije. Veličina mladi kretala se od 12 do 27 mm, dok je veličina zrelih mužjaka varirala od 16 do 40 mm, a ženki od 15 do 36 mm. Demografska struktura tog gobiida, koja se sastoji od tri kohorte, nije se mijenjala. Odnos spolova je osjetno varirao ovisno o periodu u kojem su uzimani uzorci (0,44 u srpnju i 0,71 u listopadu). Služili smo se matematičkim modelima pomoću kojih smo utvrdili da životni ciklus ove vrste traje barem 24 mjeseca.

Ključne riječi: Sredozemno more, Korzika, ribe, veličina, odnos spolova, starost

