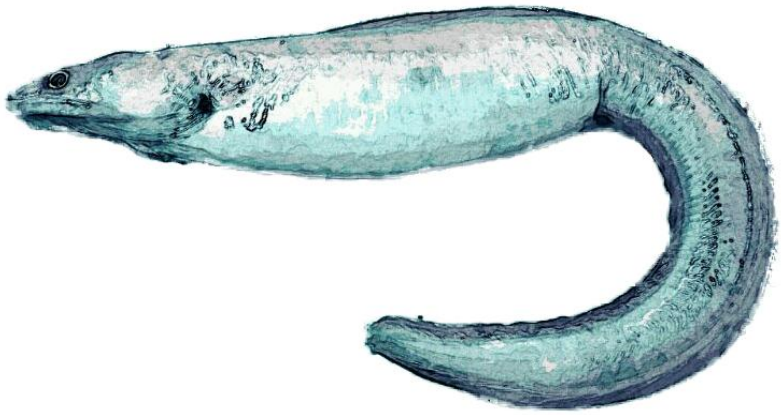
UNIVERSITY OF LAS PALMAS DE GRAN CANARIA

New Biometric Data and Contribution to the Reproductive Biology of *Myroconger Compressus* (Osteichthyes: Anguilliformes: Myrocongridae) in Cape Verde



TOMÁS GONZÁLEZ HERRERA

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UNIVERSITY OF LAS PALMAS DE GRAN CANARIA

MASTER IN SUSTAINABLE MANAGEMENT RESOURCES

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NEW BIOMETRIC DATA ANDA CONTRIBUTION TO THE REPRODUCTIVE BIOLOGY OF *MYROCONGER COMPRESSUS* (OSTEICHTHYES: ANGUILLIFORMES: MYROCONGRIDAE) IN CAPE VERDE

MASTER'S THESIS

Presented by: Mr. Tomás González Herrera

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Director	Director	Student

Las Palmas de Gran Canaria, November 2012

For the blue ocean,

this fascinating universe that absorbs me under its charms

and feeds my desire to discover

"What is a scientist after all? It is a curious man looking through a keyhole, the keyhole of nature, trying to know what is happening "

(Jacques Cousteau)

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New biometric data and contribution to the reproductive biology of *Myroconger compressus* (Osteichthyes: Anguilliformes: Myrocongridae) in Cape Verde

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Abstract

Myroconger compressus is a rare species of eel whose restricted tropical distribution gives the category of endemism. This study provides new specimens from Cape Verde and significanlty expands the information known about this species that barely had a redescription of the holotype and an incomplete specimen (Smith, 1984, 1989). A total of 78 specimens were captured by traps between June 2009 and July 2012. The size range varied between 308 and 611 mm LT. The length-weight relationship was defined by the parameters *b*=3.325 and *a*=0.0000002907 presenting positive allometric in the total sample and by sexes separated. The radial formulas were studied for the first time and completed the vertebral formula. No significant morphological differences between the sexes. The vertical distribution of the sample showed no segregation of sexes in depth. Histological analysis was used to verify the sexual tipology and sexual maturity states, previously established by visual allocation, and to verify the reproductive strategy of this species. The sexual species showed a pattern typical of gonochoric species, where the formation of sperm and eggs are produced in separate individuals. The sex ratio was (1: 0.48) in favor of males and showed significant differences. The reproductive period appears to cover the all year with a peak in the summer months. The sizes at maturity in the whole sample were 476 mm for histologically established states and 497 mm for macroscopically assigned states.

Keywords: Myocongridae, *Myroconger compressus*, Biometric data, Reproduction, Cape Verde.

Nuevos Datos Biométricos y Contribución a la Biología Reproductora de *Myroconger compressus* (Osteichthyes: Anguilliformes: Myrocongridae) de las Islas Cabo Verde

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Resumen

Myroconger compressus es una especie poco frecuente de congrio cuya restringida distribución tropical le confiere la categoría de endemismo. El presente estudio aporta nuevos ejemplares procedentes de Cabo Verde y amplía considerablemente la información conocida sobre la especie que apenas contaba con una redescripción del holotipo y un espécimen incompleto (Smith, 1984, 1989). Un total de 78 ejemplares fueron capturados mediante nasas entre junio del 2009 y julio del 2012. El rango de tallas varió entre 308 y 611 mm de LT. La relación talla-peso se definió por los parámetros a=0,0000002907 y b=3,325, presentando alometrías positivas en el total de la muestra y por sexos. Las fórmulas radiales fueron estudiadas por primera vez y se completó la fórmula vertebral. No se encontraron diferencias significativas morfológicas entre sexos. La distribución vertical de la muestra no mostró segregación de sexos en profundidad. El análisis histológico se utilizó para verificar la tipología sexual y estados de madurez sexual, establecidos previamente por asignación visual, y verificar la estrategia reproductora de la especie. La especie presentó un patrón sexual propio de especies gonocóricas, donde la formación de espermatozoides y óvulos se produce en individuos separados. La sex-ratio fue (1: 0,48) a favor de las machos y presentó diferencias significativas. El periodo reproductor parece abarcar todo el año con un pico en los meses de verano. Las tallas de primera madurez sexual en el conjunto de la muestra fueron de 476 mm para los estados establecidos histológicamente y 497 mm para asignados de manera macroscópica.

Palabras clave: Myocongridae, *Myroconger compressus*, Datos biométricos, Reproducción, Cabo Verde.

1. INTRODUCTION

Myroconger compressus (Günther, 1870), etymologically of greek "myros,-ou" (male of morey eels) and latin "conger" (eel) (Romero, 2002), is a rare species of eel belonging to the Myrocongridae monotypical family (Fig. 1). Myrocongridae family, by a number of features (separated frontal bones, reduction of branchial arches and pores of lateral line, position of posterior nostril by the upper edge of eye), is now considered as a primitive sisterly group of the families Clophosidae (=Xenocongridae) and Muraenidae (Nelson, 1984, Smith, 1984, 1989, 1990). Within this group, only four other species have been identified (*Myroconger gracilis* Castle, 1991; *Myroconger prolixus* Castle y Béarez, 1995; *Myroconger nigrodentatus* Castle y Béarez, 1995; *Myroconger seychellensis* Karmovskaya, 2006) (Froese y Pauly, 2012).

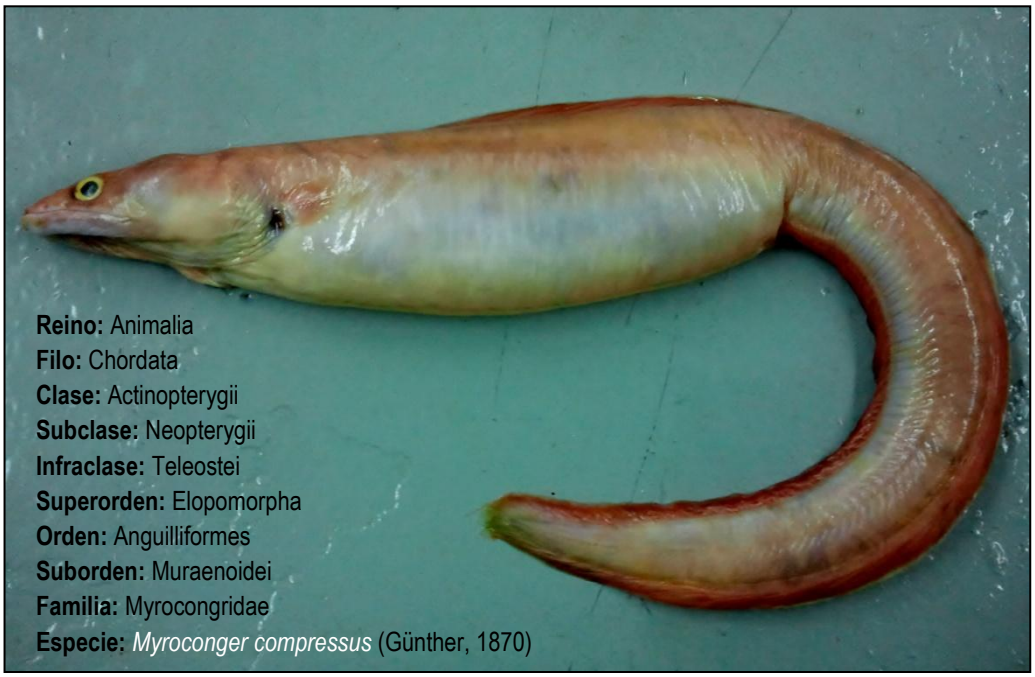

Fig. 1. Ejemplar de *M. compressus* capturado en aguas de Cabo Verde.

There are very few specimes of these little known conger whose distribution includes some regions of the Eastern Atantic, Eastern Pacific, Western Pacific and Indian Oceans. Recenlty, a sixth species was cited. This new species, captured in the western Atlantic (Brazil), has not been described yet (*Myroconger sp*., Paiva et al., 2011).

M. compressus is a tropical demersal species known from a few locations scattered throughout the Eastern Atlantic: St. Helena, Dakar in Senegal (Smith, 1990), Sao Tome and Principe (Smith, 1990; Afonso et al., 1999, unconfirmed record) Cape Verde Islands (Brito et al., 1999, González et al., 2004, Menezes et al., 2004, González y Tariche, 2009) and Vavilov Ridge (Parin et al., 2010) (Fig. 2). The studies of González et al. (2004) and González y Tariche (2009) extend the material collected in Cape Verde to nearly a hundred individuals.

Fig. 2. Geographical distribution of *M. compressus*.

In view of its peculiar biogeography, should be considered as an endemism of the Eastern Altantic region, with litlte descriptive literature and with a redescription of the holotype and an incomplete specimen (Smith, 1984, 1989, 1990, 1999).

M. compressus presents moderately elongated body, cylindrical and only strongly compressed along the tail. The anus or urogenital pore is located slighlty before the middle of the body. The caudal fin is blunt but soft. The head is strong, well muscled with well-developed eyes. The snout is slighlty depressed. The mouth is moderately large with nearly equal jaws, without flanges at the lips. The teeth are numerous, of moderate size, sharp, arranged in several rows on jaws. Teeth in vomer arranged in a long band of 1 to 3 rows. The anterior nostril is tubular, located just behind the tip of the snout. The posterior fossa is oval with a narrow raised border, situated in front of the top of the eye. Dorsal and anal fins are well developed and converge around the caudal fin. The dorsal fin arises in front of the pectoral fin base. The pectoral fins are well developed and widely rounded, its base covers the entire gill opening. Gill opening oblique, small but not grealty restricted or pore-like. No scales. The lateral line is incomplete with pores approximately 5 to 7 in the front of the channel, located slighlty before and after the pectoral fins. Pores in the upper and lower jaws and the front of the snout. Preserved specimens light brown, without markings. In life are yellow or reddish (Smith, 1999).

This benthic species has been captured by traps in various fisheries survey targeting crustaceans and fishes in deepwater between 100 and 1000 m depth.

This study provides new biometric data and contributes to the reproductive biology of *M. compressus*, in the framework of projects PROACTIVE 1-2 (2009-2012) and MARPROF-CV (2011-2013) that have provided new specimens from Cape Verde.

2. MATERIAL AND METHODS

Analized a total of 78 specimes of *M. compressus* from the Cape Verde Islands (Fig. 3). The specimens were captured between June 2009 and July 2012 through semi-floating and benthic shrimp traps between 108 and 265 m of depth. The semi-floating shrimp traps had dimensions of 56x57x57 cm with a rigid and rhomboid mesh of nelton with a mesh diameter of 15x20 mm; provided with a rigid individual flotation buoy of an 1 liter. This buoy is undeformable to 400 m depth and it keeps the trap suspended above the bottom betwen 2 and 2,4 m of depth. The trap was provided with a lateral inlet or slaughterhouse only 19 mm in diameter (Fig. 4 a). For benthic traps, each trap had dimensions of 1 × 1 m in base and 0.5 m in height. The trap was covered with a metalic mesh of 19 mm in mesh diameter and provided with a single entry truncated cone positioned down of dimensions 24 and 17 cm in exterior and interior diameter, respectively.

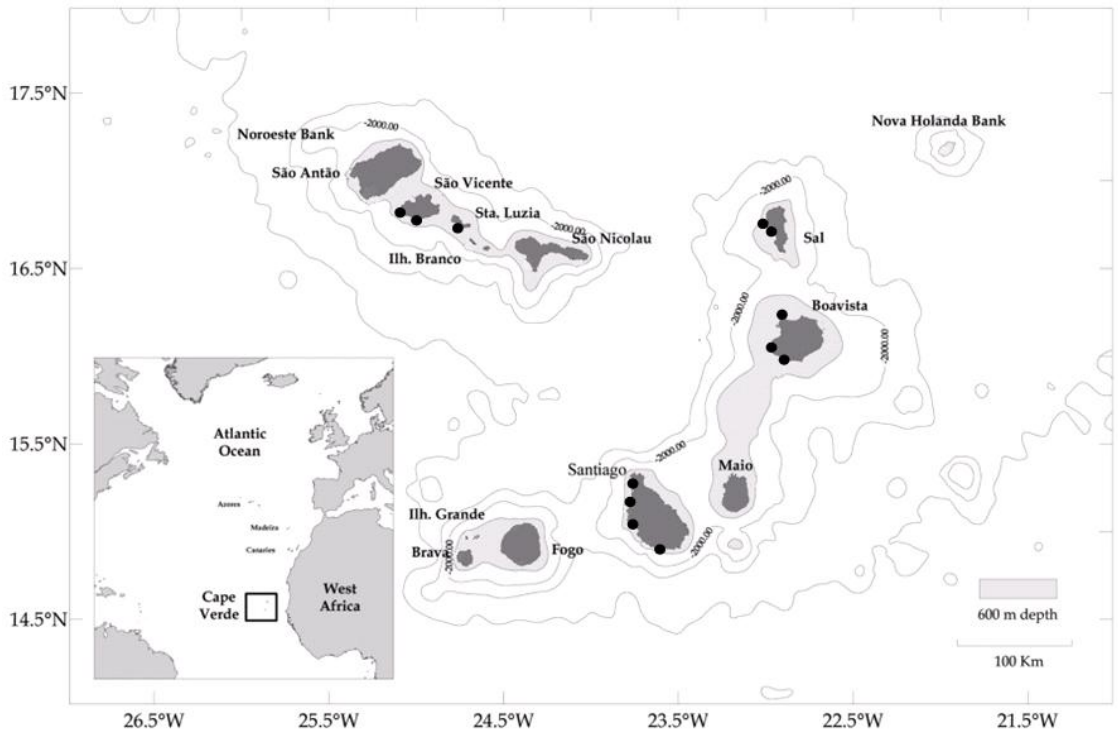

Fig. 3. Cape Verde archipelago. Capture localities location (black circles) of the sampled specimens of *M. compressus* (Adapted de Menezes et al., 2004).

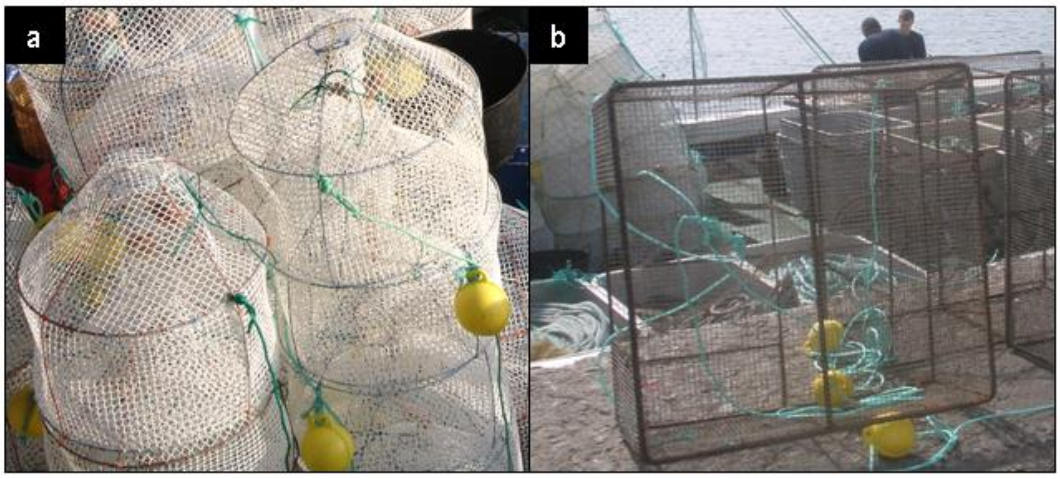

Fig. 4. Types of fishing gear used in the catches of *M. compressus*: (a) semi-floating shrimp traps and (b) benthic traps.

Catches were grouped into three bathymetric strata (stratum 1, <175 m; stratum 2, 175-250 m; stratum 3, > 250 m) to obtain information about the vertical distribution of the species. The data were grouped into three quarters (quarter 1, January-April; quarter 2, May-August; quarter 3, September-December) in order to obtain a better understanding of the distribution and reproductive aspects (sexual type, sex-ratio, spawning season, sexual maturity) of *M. compressus*.

The methodology used for the study was based on biometric criteria established by Böhlke (1982, 1989) for Anguilliformes (Fig. 5).

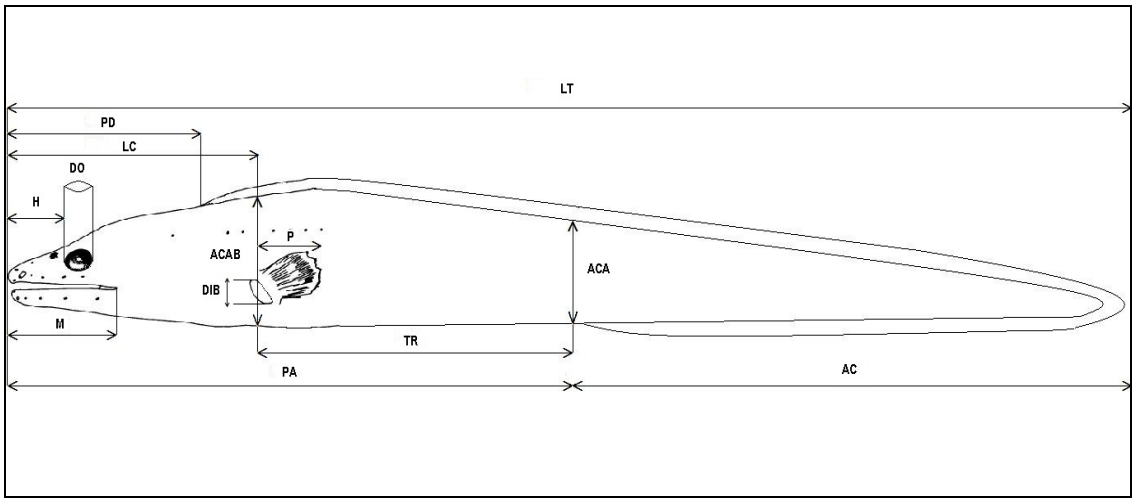

Fig. 5. Scheme of the measures taken in *M.compressus*. Abbreviations: AC, caudal fin length; ACA, body depth at anus level; ACAB, body depth at gill opening; DIB, interbranquial distance; DO, ocular diameter; H, snout length; LC, head length; LT, total length; M, length upper jaw; P, pectoral fin length; PA, preanal length; PD, predorsal length; TR, trunk length (Adapted from Böhlke, 1989).

In each specimen was measured total length (LT), caudal fin length (AC) and trunk length (TR) to mm nearest, predorsal length (PD), head length (LC), body depth at gill opening (ACAB), body depth at anus level (ACA), preanal length (PA), snout length (H), ocular diameter (OD), interorbital distance (DI), upper jaw length (M), interbrancuial distance (DIB) and pectoral fin length (P) with accuracy of 0.01 mm, the total weight (TW), gutted weight (PEvis), gonadal weight (PGon) and liver weight (pHEP) with accuracy of 0.01 g. The pectoral fin rays (RP) and the number of lateral line pores (PLL) on each side of the specimens sampled were determined using a binocular microscope (Fig. 6).

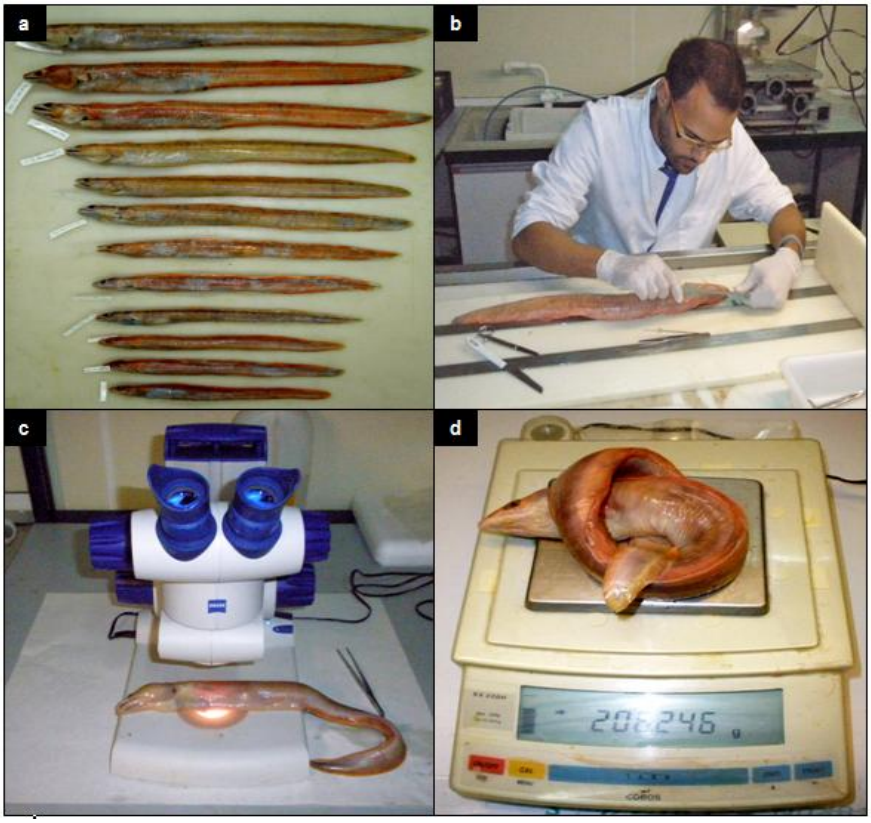

Fig. 6. (a) Detail of several specimens of *M. compressus* and (b, c and d) taking some measures during the sampling in the laboratory.

Also determined sex and sexual maturity at the macroscopic level. The maturity stage was assigned according to a scale of five values (immature I, resting II, mature III, mature and spawning IV, post-spawning V) (Holden y Raitt, 1975). The gonads were removed and fixed in formalin for further analysis.

The radiographic examination of a subsample of 12 specimens, performed with a digital mammography Medical Systems *Senographe Essential-GE model*, allowed to establish the vertebral formula and remaining radial formulas. The vertebral formula expressed as the range of counts of predorsal (PD), preanal (PA), precaudal (PC) and total vertebrae (VT) (Fig. 7). The radial formulas included total dorsal rays (RD), the dorsal rays before level of anus (RDA) and anal rays (RA).

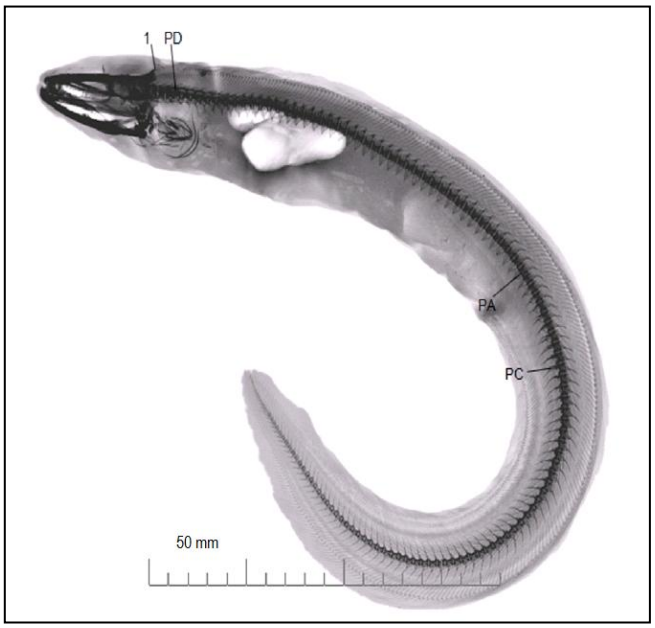

Fig. 7. Mammography of a specimen of *M. compressus* showing vertebral counts. Arrows indicate the first vertebra (1) vertebrae predorsal (PD), preanal vertebrae (PA) and caudal vertebrae (PC).

Differences in length and weight mean between sexes were analyzed using the Student *t* test, while for the range in size and weight between sexes was used non parametric Kolmogorov-Smirnov *Z* test.

The length-weight relationship was calculated by the potential equation $W = a\ Lb$, where *W* is the total weight (g), *L* is the total length (mm), *a* is a coefficient related to the shape of the body and *b* is the allometry coefficient and its growth indicates isometry when it is equal to 3 (Anderson y Neumann, 1996). The allometric were compared using the Student *t* test.

Differences between sexes for all the morphometric measurements were compared using the Student *t* test. For meristic measures were compared using the Wilcoxon for range with signs related samples for pectoral fin rays and Mann-Whitney U-test for independent samples in the other parameters.

Histological analysis of the gonads was used to confirm the sexual tipology, reproductive strategy, sexual maturity and spawning (Fig. 8).

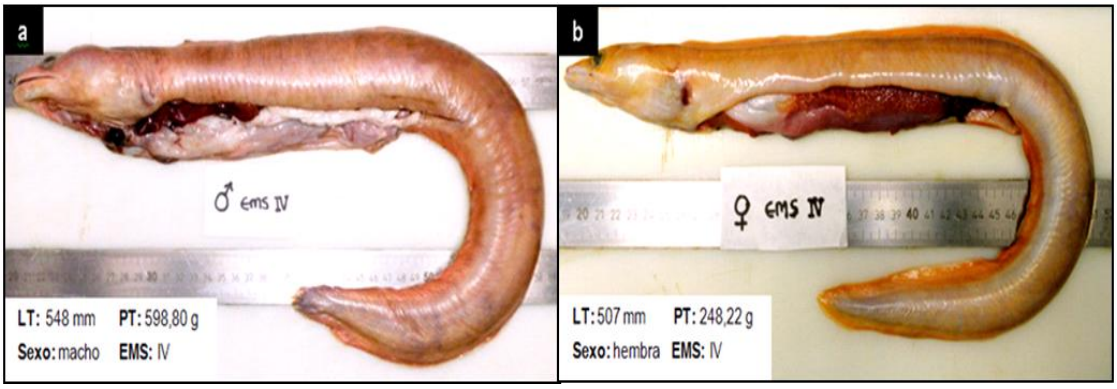

Fig. 8. Sexual maturity states assigned macroscopically in *M. compressus*: (a) male specimen in stage IV and (b) female specimen in stage IV.

For each specimen were taken two samples of gonadal tissue lobes. The dehydration process of samples was carried out automatically using the Thermo dehydrator *Shandon Citadel 2000* model (Fig. 9 a) and following the protocol described in Table Tissue samples were included in paraffin, sectioned at 5 microns using a manual microtome of Thermo *Shandon Finesse 325* model (Fig. 9 b), were collected on slides and placed in a stove at 100°C for 1 hour. Subsequenlty, stained manually (Fig. 9, c) following the protocol set out in Table 2. Finally, histological sections were observed through a Olympus microscope *CX41* model (Fig. 9, d).

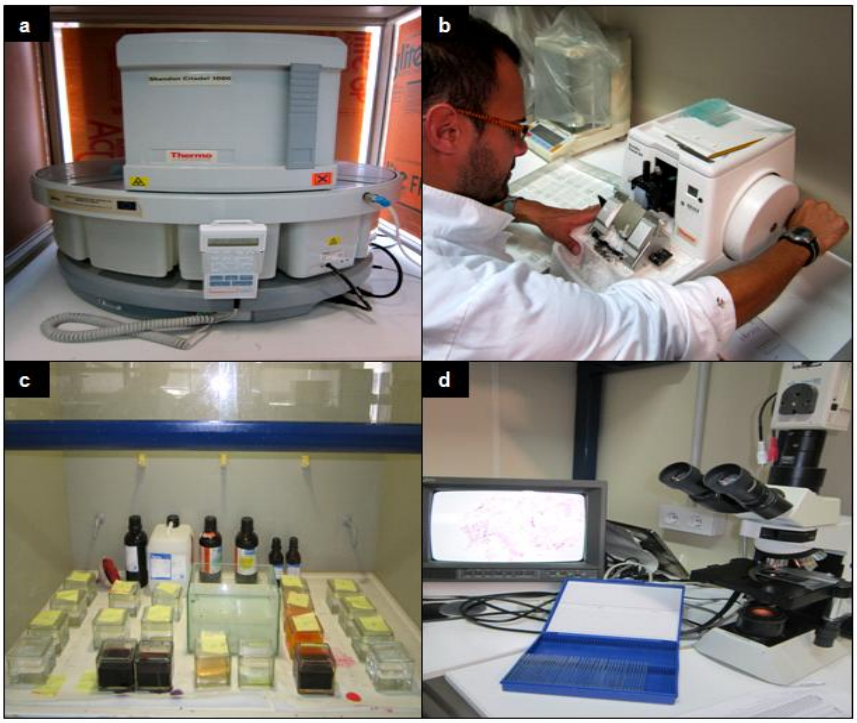

Fig. 9. Histological analysis processes: *(*a) automatic dehydrator, (b) manual microtome, (c) manual staining of samples and (d) histological observation under the microscope.

Table 1. Dehydration protocol of tissue samples used for *M. compressus.*

Reagents	Time (hours)
1.- Alcohol al 70%	1.- 3 hours
2.- Alcohol al 90-96%	2.- 2 hours
3.- Alcohol al 90-96%	3.- 2 hours
4.- Alcohol al 90-96%	4.- 1 hour
5.- Alcohol al 100%	5.- 1 hour
6.- Alcohol al 100%	6.- 2 hours
7.- Alcohol al 100%	7.- 2 hours
8.- Isoparaffin	8.- ½ hour
9.- Isoparaffin	9.- ½ hour
10.- Isoparaffin	10.- 1 hour
11.- Paraffin	11.- 3 hours
12.- Paraffin + vacuum	12.- 7 hours + 2 hours

Table 2. Staining protocol of tissue samples used for *M. compressus*.

Reagents	Time (minutes)
1.- Isoparaffin	1.- 2 minutes
2.- Isoparaffin	2.- 2 minutes
3.- Alcohol al 100%	3.- 2 minutes
4.- Alcohol al 100%	4.- 2 minutes
5.- Alcohol al 70%	5.- 2 minutes
6.- Distilled water	6.- 2 minutes
7.- Distilled water	7.- 2 minutes
8.- Distilled water	8.- 2 minutes
9.- Hematoxylin	9.- 15 minutes
10.- Alcohol hydrochloric	10.- 4 quick passes *
11.- Agua amoniacal	11.- 15 quick passes *
12.- Eosin	12.- 4 minutes
13.- Alcohol al 96%	13.- 2 minutes
14.- Alcohol al 96%	14.- 2 minutes
15.- Alcohol al 100%	15.- 2 minutes
16.- Alcohol al 100%	16.- 2 minutes
17.- Isoparaffin	17.- 2 minutes
18.- Isoparaffin	18.- 2 minutes
19.- Isoparaffin	19.- 2 minutes

The classification of the different phases or stages of oocyte development in females of *M. compressus* was based on the criteria established by Wallace and Selman (1981) and West (1990) (Table 3). The cellular organization of the testes and spermatogenesis in male was established according Grier (1981) (Table 4).

Table 3. Stages of ovarian development in females of *M. compressus* (Adapted from West, 1990).

Steps	Description
Previtellogenesis	
1. - Oogonium (OO)	Oocytes with small high ratio between the nucleus and cytoplasm. Well developed nucleus and basophilic cytoplasm.
2. - Perinuclear oocytes (PO)	Basophilic oocytes with many peripheral nucleoli and theca cells coated well defined.
Vitellogenesis	
3. - Vitellogenic oocytes with primary yolk vesicles (YPO)	First vesicle oocytes with yolk in the cytoplasm (cortical alveoli). Numerous nucleoli in the peripheral region of the core.
4. - Vitellogenic oocytes with primary yolk vesicles (YSO)	Oocytes with eosinophil granules in the cytoplasm and increased lipid vacuoles. Oocyte envelope presents a highly visible radiated inner layer of basophilic affinity, on which there are two layers eosinophilic.
5. - Vitellogenic oocytes with primary yolk vesicles (YTO)	Oocytes enveloped core radiated and disappearance. Yolk granules filling most of the surface of the oocyte. Partial melting of some yolk granules in cytoplasm.
6. - Mature eggs (H)	Ovaries with mature oocytes characterized by being completely filled with yolk.
7. - Postovulatory and atretic follicles (POF, AF)	Presence of empty postovulatorias structures called postovulatory follicles in reabsorption processes (atretic oocytes).

Table 4. Gonadal development in males of *M. compressus* (Adapted from Grier, 1981).

Steps	Description
1. - Spermatogonia (ESP)	The core has a clear appearance after staining and the cytoplasm shows a patch of dense fibrillar granular material called "cloud", usually near the nuclear membrane.
2. - Spermatocytes (ESPT)	Appearance of spermatocytes I and II by mitosis and meiosis cell spermatogonia respectively. Spermatocytes have rounded shape with large oval nucleus. Evidence of the start of the second meiosis in the presence of spermatids, characterized by presenting a rounded shape basophilic cytoplasm and nucleus reduced.
3. - Spermatids (ESPM)	Presence of spermatocytes and spermatids in the testes. Appearance of sperm cytodifferentiation of spermatids. Sperm have elongated and strong staining by hematoxylin-eosin.
4. - Sperm (ESPZ)	Testicles have only mature sperm.

The sexual pattern was established taking into account the sex determination. The sex proportion or sex ratio (male: female) was estimated taking into account the relationship between the number of males and females. We also analyzed the sex ratio in quarters and set size ranges to differentiate the sex ratio in young, adult and old. The sex ratio was tested statistically using a non parametric Pearson X^2 test (α=0.05) to detect significant deviations from the expected ratio 1:1.

The spawning period is determined from monitoring the temporal variation in the gonadosomatic index (GSI), calculated for each specimen as IGS=(gonad weight/gutted weight)•100 (Anderson y Gutreuter, 1983), and the estimation of the temporal evolution of the frequency of maturity stages.

The size at first maturity (*Lm*) were determined as the proportion of reproductively active individuals in each size class (stages III, IV and V) by fitting a logistic ogive:

$$P = \frac{100}{1 + e^{-r(Lt-Lm)}}$$

where *P* is the percentage of mature individuals in each size range, *Lt* is the total length (mm), *Lm* is the length at first maturity (mm), *r* is a parameter of the model (Saila et al., 1988). The function was fitted to the data using the Levenberg-Marquardt algorithm for non-linear parametric estimation. The proportion of mature individuals was calculated on the basis of sexual maturity stages established macroscopically and histologically.

3. RESULTS

3.1. Descriptors

In the sample examined of *M. compressus* (n=78), 52 individuals were determined histologically as males, 25 as females, and 1 damaged individual could not be assigned to any sex. Sex determinations through visual examination were confirmed by histological analysis in 75.33% of cases. While determinations of sexual maturity for each individual, mature or immature, were successful in 93.51% of cases.

The size range of the entire sample varied between 308 and 611 mm LT (Fig. 10). The PT ranged between 54.66 and 598.80 g. The analyzed showed no significant difference in the mean between males LT (467.38 mm) and females (474.16 mm) (*t*-test, *t*=-0.407, p-value=0.685) and not in the middle between PT males (241.83 g) and females (240.06 g) (*t*-test, *t*=0.062 and p-value=0.950). The size of males ranged between 331 and 611 mm LT (Fig. 11 a) and PT between 75.00 and 598.80 g. In females, ranged in size between 308 and 570 mm LT (Fig. 11 b) and the PT between 54.66 and 415.86 g. No significant differences were found in the range of total lengths (LT) (non parametric Kolmogorov-Smirnov *Z* test, Z=1.062 and p-value=0.209) and total weight range (PT) between the sexes (non parametric Kolmogorov-Smirnov *Z* test, Z=0.812 and p-value=0.524).

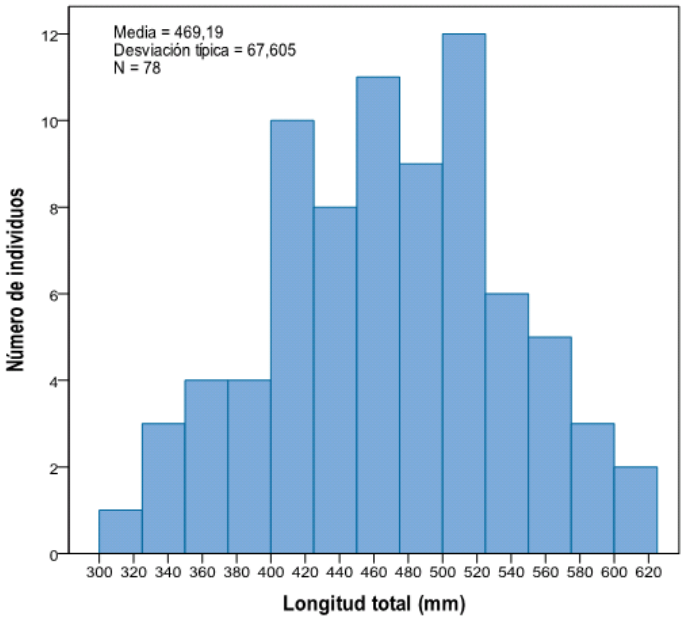

Fig. 10. Size frequency distribution for the whole sample (n=78).

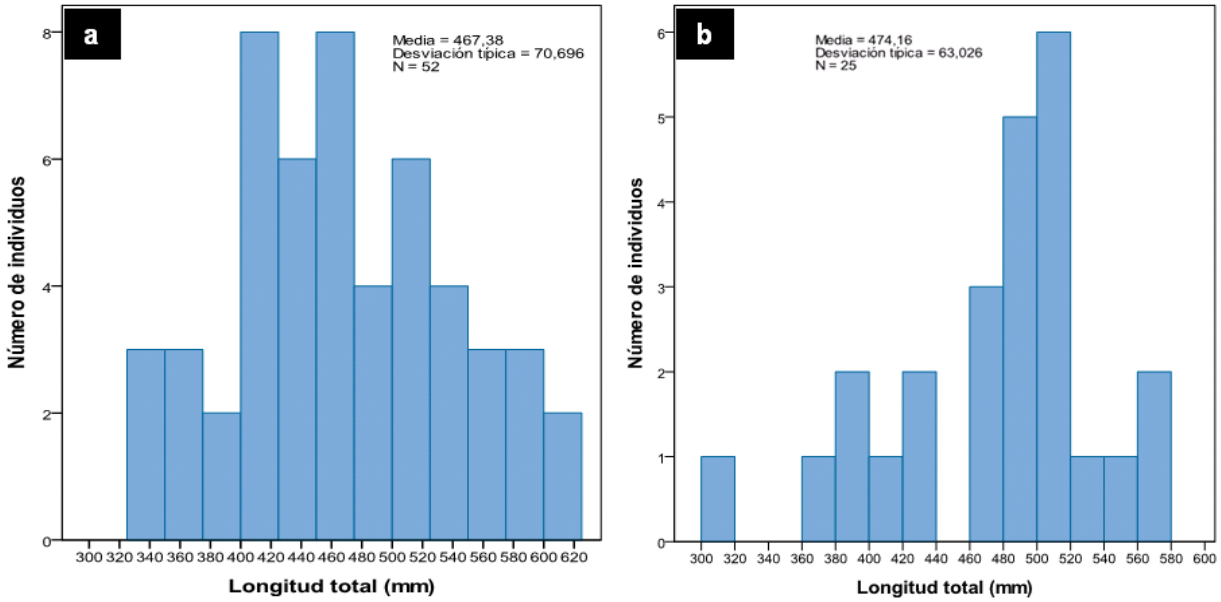

Fig. 11. Size frequency distribution: (a) for males (n=52) and (b) females (n=25).

3.2. Length-weight relationship

The parameters defining the relationship between the total length (LT) and total weight (TW) in the whole sample (Fig. 12) and by sexes (Fig. 13) are shown in Table 5. The analysis of the parameter b (allometric coefficient) by applying the Student *t* test showed a positive allometric length-weight relationship in the whole sample, males and females (t-value>$t_{0,05,n-2}$ =1,993).

Table 5. Parameters of the length-weight relationship for males, females and the total sample: *n* is the number of copies, *a* is a parameter of the equation, *b* is the allometric coefficient, r^2 is the correlation coefficient, $\sigma(b)$ is the standard deviation of the parameter *b* and *t-value* corresponds to the estimated value of *t*..

	n	*a*	*b*	$\sigma(b)$	r^2	*t-valor*
Males	52	0,0000002592	3,345	0,094	0,962	35,518
Females	25	0,0000003500	3,291	0,147	0,956	22,401
Total	77	0,0000002907	3,325	0,079	0,960	42,162

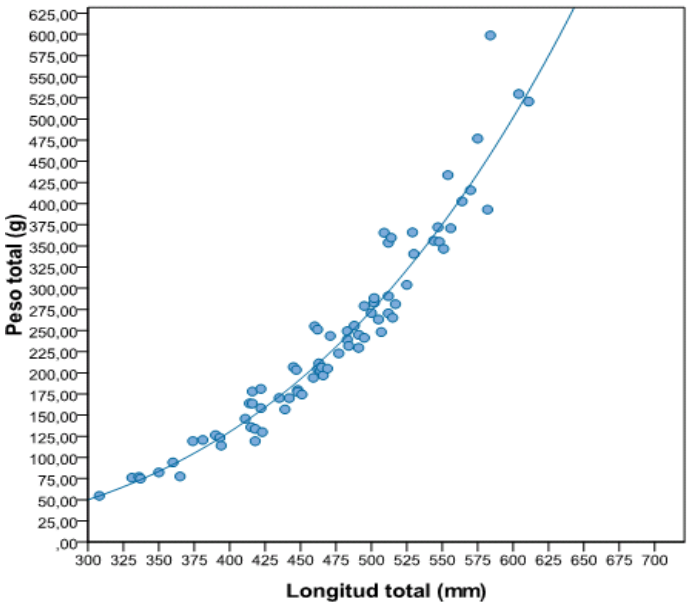

Fig. 12. Length-weight relationship in the whole sample (*n* =77).

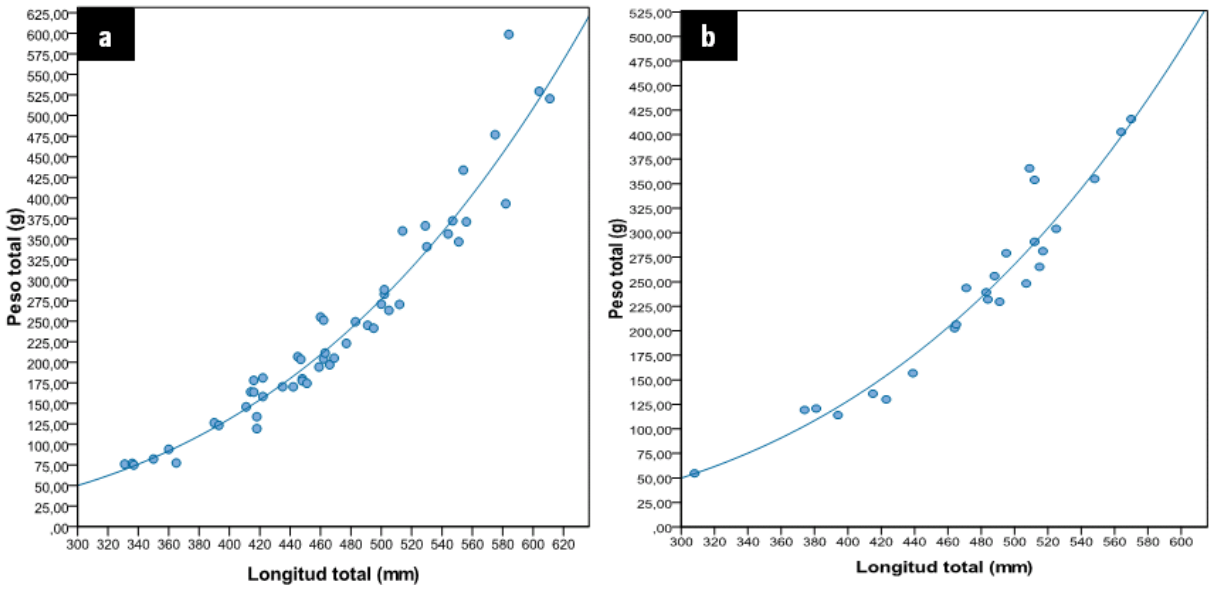

Fig. 13. Length-weight relationship**:** (a) for males (*n*=52) and (b) females analyzed (*n*=25).

3.3. Biometric parameters

The morphometric parameters in whole sample and sexes separated, expressed as percentage of LT and LC, are shown in Table 6. No significant differences were found in all of the measures taken between the sexes (*t*-test, p-value> 0.025). The results of *t*-test are presented in Table 7.

The meristic study of whole sample reveals that the number of lateral line pored, distinctive feature in Myrocongridae family, differs for each side of the body in 75.70% of cases (Fig. 14). The number of lateral line pores on each side, for total specimens sampled and sexes separated, also shown in Table 6. No significant differences in the number of lateral line pores between both sides for the total sample and by sexes (non parametric Wilcoxon of signed ranks samples: sample, p-value=0,912; males, p-value=0,577; females, p-value=0,441).

Table 6. Meristic and morphometric data of *M. compressus* in the whole sample, sexes separeted and specimens described by Smith (1984).

	Smith (1984)	Present paper		
Myroconger compressus		**Total**	**Males**	**Females**
Total length (mm)	366	308 - 611	331 - 611	308 - 570
Meristic data				
Nº lateral lines pores (left)	5 – 7	3 - 9	4 - 9	3 - 9
Nº lateral line pores (right)		3 - 8	3 - 8	4 - 8
Pectoral rays	16	15 - 20	16 - 20	15 - 20
Dorsal rays before level of anus	?	104 - 114	104 - 111	104 - 114
Total anal rays	?	288 - 324	288 - 324	288 - 306
Radios anales totales	?	184 - 238	184 - 238	199 - 236
Predorsal vertebrae	?	6 - 8	6 - 7	6 - 8
Preanal vertebrae	47	48 - 52	48 - 52	49 - 51
Precaudal vertebrae	52	54 - 62	54 - 62	57 - 60
Total vertebrae	131	130 - 135	130 - 135	132 - 133
Morphometric data (%LT)				
Preanal length	45	41,61 - 47,95	41,61 - 47,61	43,32 - 47,95
Predorsal length	12	10,75 - 14,75	11,12 - 14,75	10,75 - 14,45
Head length	14	13,04 - 17,47	13,04 – 16,49	13,31 – 17,47
Body depth at anus level	-	5,79 - 10,51	5,79 – 9,18	7,08 – 10,51
Body depth at gill opening	-	6,53 - 10,36	6,53 - 10,36	6,77 - 10,02
Trunk length	-	28,31 - 33,40	28,31 – 32,73	29,86 – 33,40
Caudal fin length	-	30,41 - 58,39	30,41 - 58,39	52,27 – 56,69
Morphometric data (%LC)				
Snout length	24	17,72 - 32,81	17,72 – 32,81	20,01 – 29,33
Ocular diameter	12 - 14	12,56 - 17,97	12,56 – 17,97	13,46 – 16,80
Interorbital distance	-	16,67 - 25,35	16,67 - 25,16	17,68 - 25,35
Upper jaw length	48	38,39 - 56,83	38,39 - 56,83	42,01 – 50,20
Interbranchial distace	10 - 12	10,90 – 18,02	10,90 – 17,29	11,70 - 18,02
Pectoral fin length	19 - 22	18,44 – 32,03	18,44 – 32,03	22,37 – 30,88

Tabla 7. Results of *t*-tests applied to the total morphometric parameters.

t-tests	*t*	*gl*	p-value
Preanal length	-0,953	69	0,344
Predorsal length	0,175	69	0,861
Head length	-0,223	75	0,824
Body depth at anus level	-1.172	68	0,245
Body depth at gill opening	-0,285	75	0,776
Trunk length	-0,919	68	0,361
Caudal fin length	-0,405	68	0,687
Snout length	0,311	69	0,756
Ocular diameter	-0,044	69	0,965
Interorbital distance	-0,346	68	0,730
Upper jaw length	-0,103	68	0,918
Interbranchial distace	-0,875	68	0,385
Pectoral fin length	-1,843	68	0,070

The formula of the pectoral fin in the whole sample and by sexes separated is indicated in Table 6. No significant differences in the number of pectoral rays between both sexes (Mann-Whitney U-test for independent samples, p-value=0.608). In Figure 15 details the pectoral fin rays in *M. compressus*.

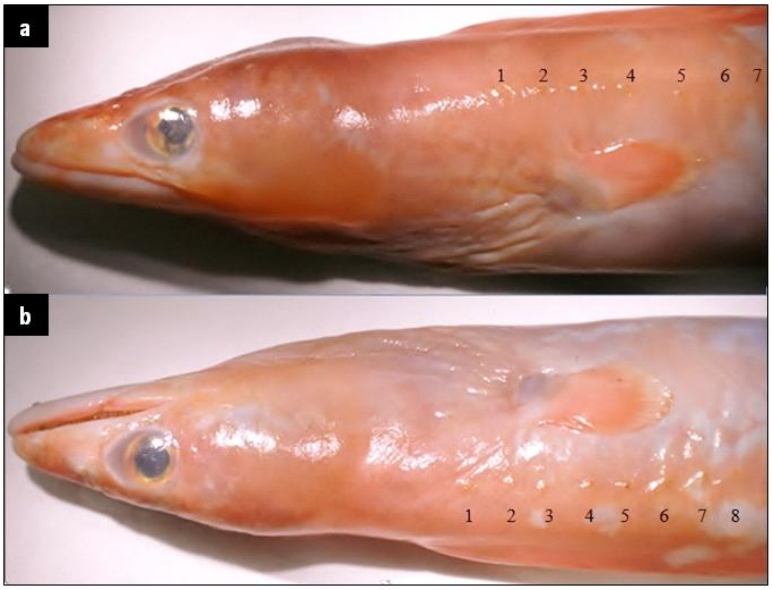

Fig. 14. Details of the number of lateral line pores on each side in *M. compressus*: (a) left flank and (b) right flank.

Fig. 15. Detail of pectoral fin rays in *M. compressus*.

The radiographic study of the subsample of *M. compressus* (n=12) revealed that a copy had incomplete caudal fin (Fig. 16). The formulas vertebral and radial (Fig. 18) are shown in Table 6. No significant differences were found between the vertebral and radial formulas by sexes separated (Mann-Whitney U and medium tests for independent samples, p-value>0.05). Table 8 shows the results of the nonparametric test applied in radial and vertebral formulas.

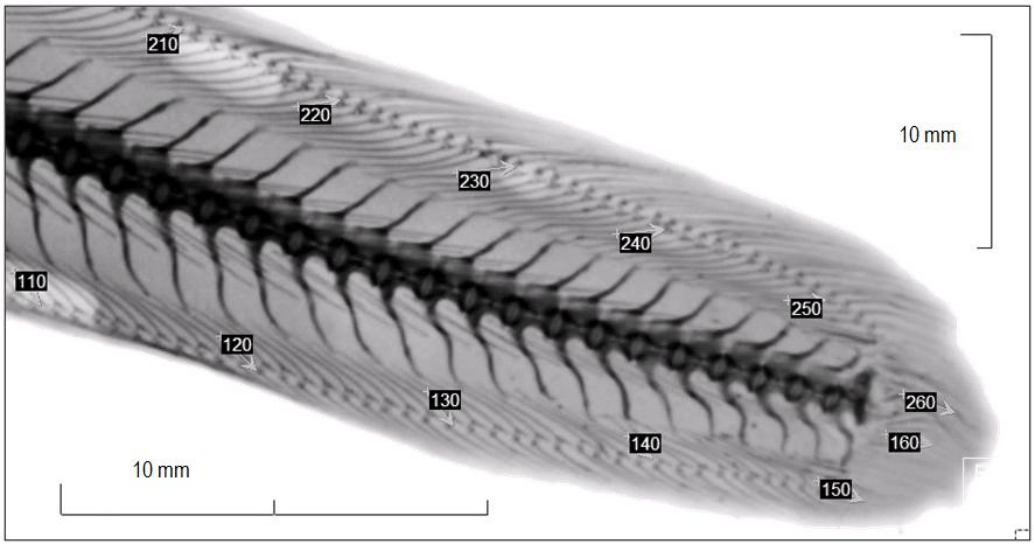

Fig. 16. Detail of a one case with caudal fin sectioned in *M. compressus*.

Table 8. Results of the nonparametric test applied in radial and vertebral formulas.

	Mann-Whitney U test for independent samples (p-value)	Medium test for independent samples (p-value)
Dorsal rays before level of anus	0,796	0,545
Total anal rays	0,474	1,000
Radios anales totales	0,683	0,545
Predorsal vertebrae	0,540	0,333
Preanal vertebrae	0,726	1,000
Precaudal vertebrae	0,795	1,000
Total vertebrae	1,000	1,000

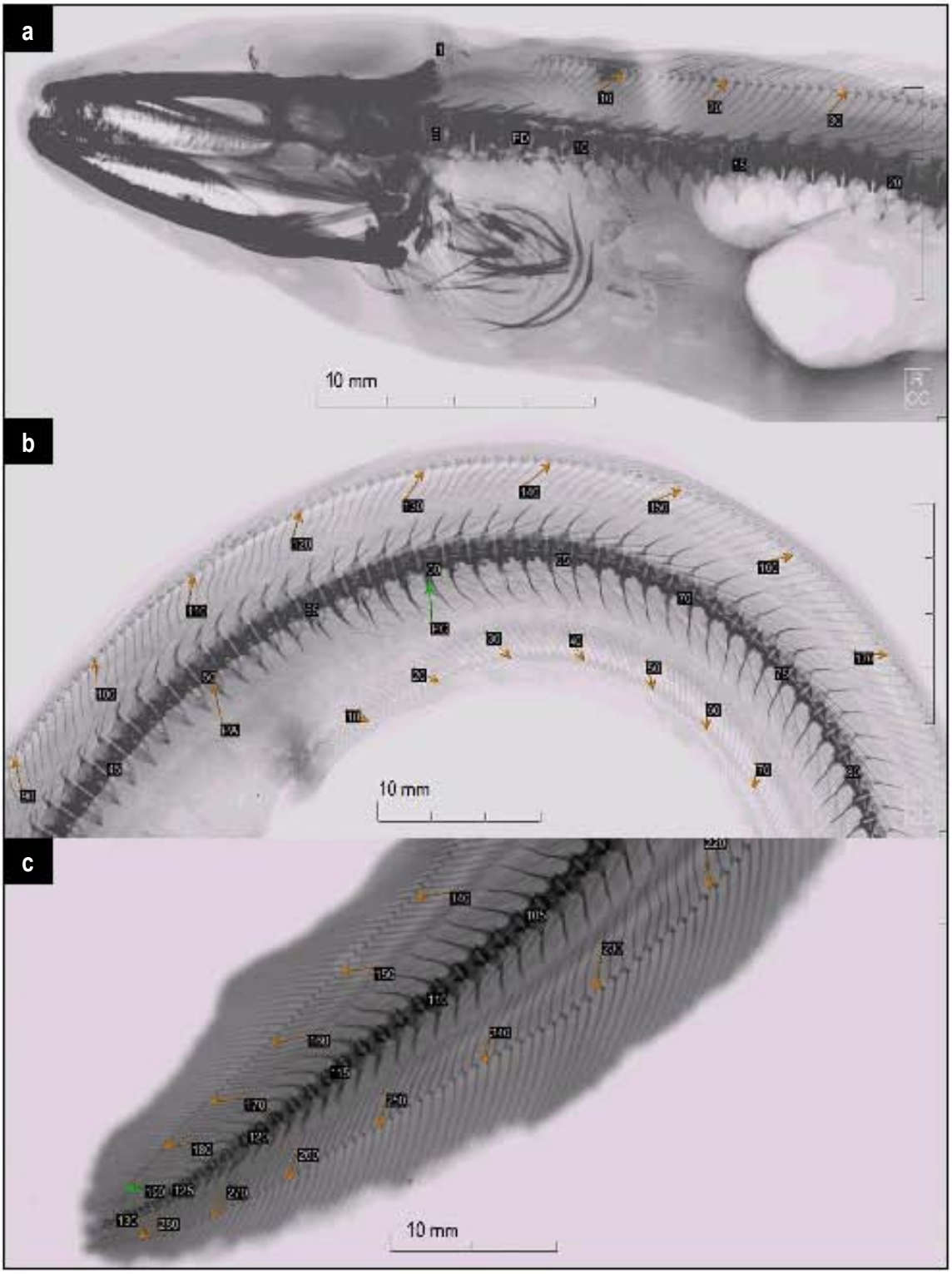

Fig. 17. Radiographic analysis in a specimen of *M. compressus* into several sections: head (a), trunk (b) and caudal fin (c).

3.4. Vertical distribution

The analysis of the vertical distribution of the sample (n_{valid}=74) revealed that 15 individuals, 11 males and 4 females, were captured less than 175 m deep, with a percentage of 66,67% mature. Between 175 and 250 m were captured 19 individuals (52,63% mature), where 12 were males and 7 females. More than 250 m were recorded 40 sacks, 26 males and 14 females, with 50% of mature individuals. The sex ratio by depth stratum (Table 9) showed significant differences in stratum 3 (> 250 m) for males (non parametric Pearson X^2-test, $\chi^2=7.78>\chi^2_{0.05,\ 1}=3,84$). The analysis of the percentage of mature fish by depth stratum (Table 10) showed no significant difference in the percentage of immature in any of the cases ($\chi^2>\chi^2_{0.05,\ 1}=3,84$).

Tabla 9. Sex-ratio por estrato de profundidad.

Depth (m)	Males	Females	Sex-ratio	X^2-test	n
<175	11	4	1:0,36	3,27	15
175-250	12	7	1:0,58	1,32	19
>250	26	14	1:0,51	7,78	40

Tabla 10. Porcentaje de individuos maduros por estrato de profundidad.

Depth (m)	Matures	Immatures	% Matures	X^2-test	n
<175	10	5	66,67	1,67	15
175-250	10	9	52,63	0,05	19
>250	20	20	50,00	0	40

3.5. Sexual tipology

M. compresus doesn't present external evidence to suggest sexual dimorphism. Extraperitoneally gonads are located in the roof of the visceral cavity and in the ventral position of the vetebral spine, partially adhered to the bladder. Males have elongated testicles with colour white to cream, while in females, the ovaries are saccular and elongated with colour orange to brown. In both sexes lobes are similarly developed and linked by a connective tissue.

Histological examination determined the existence only of testicular tissue (Fig. 18, a) and ovarian tissue (Fig. 18, b), no evidence of hermaphroditism or sex reversal.

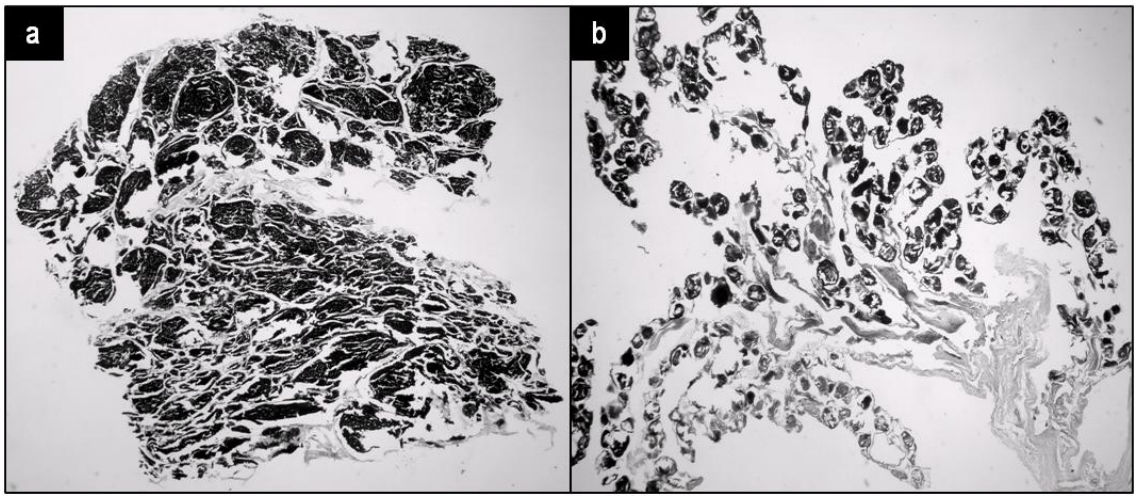

Fig. 18. Histological Analysis of *M. compressus*: (a) cross section of a testis (4x) and (b) cross section of an ovary (4x).

The gonads weight varied from 0.05 to 21.94 g for the entire sample. In males, the testes weight ranged between 0.05 and 8.01 g while in females, the ovary weight ranged from 0.28 to 21.94 g. The average weight of the gonads showed significant differences between the sexes (Mann-Whitney U-test for independent samples, p-value=0). The average gonadal weights for each sexual maturity state in males and females are shown in Table 11.

Table 11. Average gonadal weights for each sexual maturity state in males and females of *M. compressus*.

Gonadal weight (g)	I	II	III	IV	V
Males	-	0,61	1,75	6,54	-
Females	-	0,87	3,68	9,01	-
Total	-	0,64	2,36	8,68	-

3.6. Sex-ratio

The sex ratio (male: female) was 1: 0.48. Both sexes aren´t represented in the same proportion and the hypothesis of sex ratio 1:1 was rejected (non parametric Pearson X^2-test, $\chi^2=9,47 > \chi^2_{0.05,1}=3,84$). The analysis of the sex ratio by quarter (Table 12) doesn´t showed significant differences in the expected ratio 1:1 into the period analyzed. The sex ratio by size range (Table 13) showed significant differences for juveniles with sizes between 310 and 450 mm (non parametric Pearson X^2-test, $\chi^2=10,13 > \chi^2_{0.05,1}=3,84$).

Table 12. Number of male and female by quarter and total.

Quarter	Males	Females	Sex-ratio	χ^2 test
1	10	3	1:0,30	3,77
2	9	3	1:0,33	3,00
3	33	19	1:0,58	3,77
Total	52	25	1:0,48	9,47

Table 13. Number of male and female by size range.

Size range (mm)	Males	Females	Sex-ratio	χ^2 test
310-450	25	7	1:0,28	10,13
470-530	17	15	1:0,88	0,13
550-610	10	3	1:0,30	3,77
Total	52	25	1:0,48	9,47

3.7. Reproductive period

Analysis of sexual maturity stages revealed that all states of gonadal development were observed in males and females in the overall sample, except the states I and V. The proportion of sexual maturity stages in the sample and by sexes separated varied according to the quarter temporarily analyzed (Fig. 19, 20a and 20b). The males at rest (stage II) were observed in all quarters analyzed. Resting females were observed only in the quarter 3. Males with mature gonads (stage III) were observed in all quarters. Mature females were observed only in the quarter 3. Mature and spawning males (stage IV) were observed in quarters 1 and 2. Mature and spawning females were observed in all quarters.

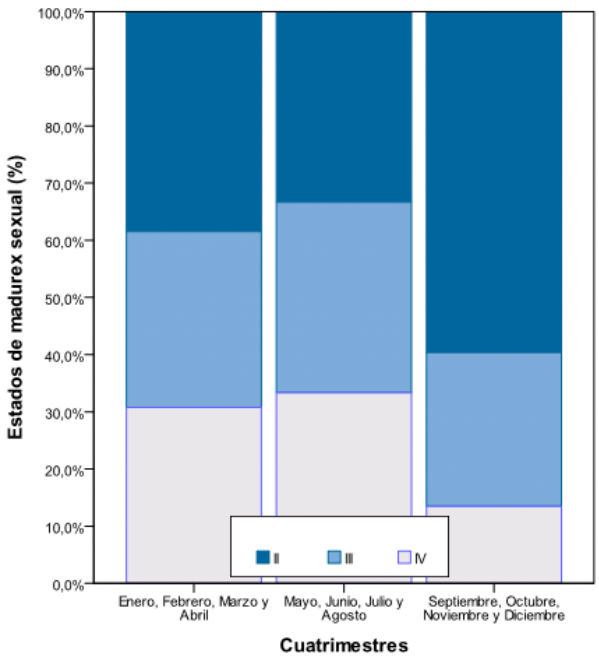

Fig. 19. Percentage evolution of sexual maturity stages per quarter in the whole sample of *M. compressus* (n = 77).

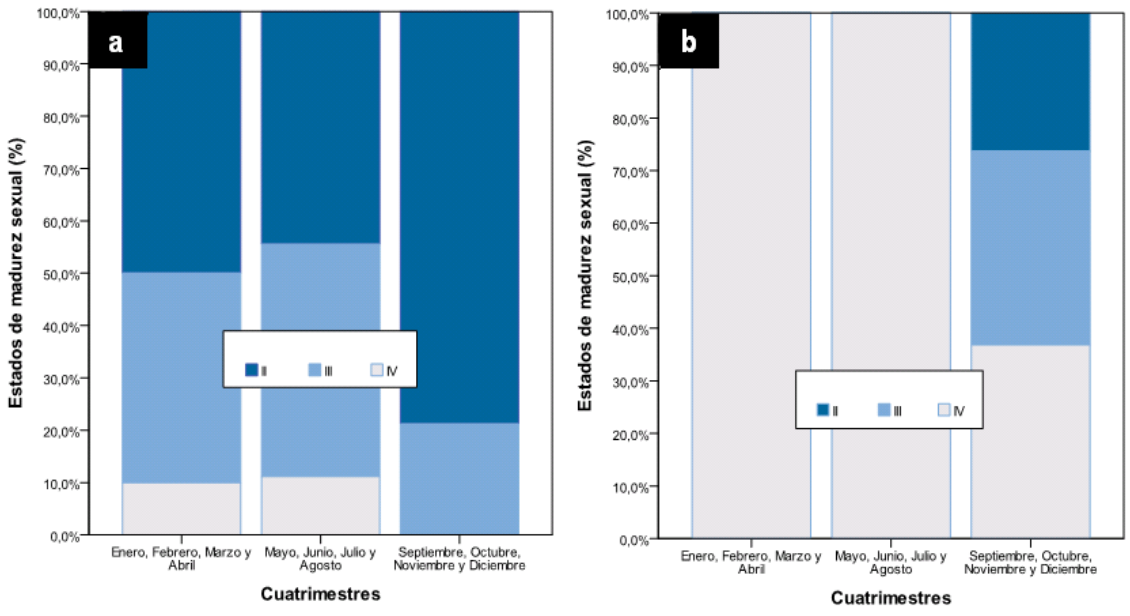

Fig. 20. Percentage evolution of sexual maturity stages by quarter: (a) for males (n=52) and (b) females (n=25).

IGS medium evolution for the entire sample (n=77) during the analyzed quarters ranged between 0.85 and 2.40%. (Fig. 21). In males, the IGS medium values ranged between 0.34 and 0.92% (Fig. 22 a), while in females, the IGS medium values varied between 1.74 and 7.13% (Fig. 22 b).

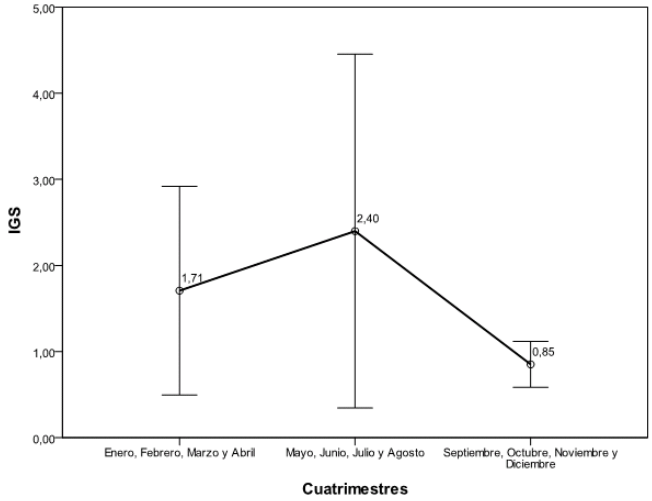

Fig. 21. Quarterly evolution of average IGS for the sample of *M. compressus* (n=77).

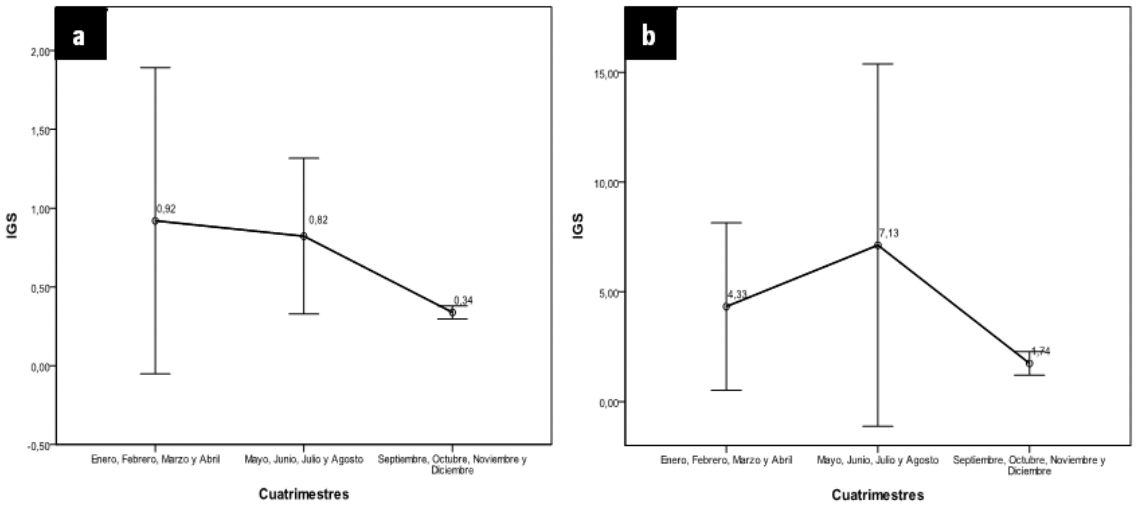

Fig. 22. Quarterly evolution of average IGS in *M. compressus*: (a) for males (n=52) and (b) females (n=25).

The individual values of the IGS in the whole sample per quarter ranged from 0.04 to 10.97% (Fig. 23), reaching a peak in quarter 2. In the case of male, IGS values ranged between 0.04 and 4.77% (Fig. 24 a). In females, IGS values registered ranged from 0.30 to 10.97% (Fig. 24 b).

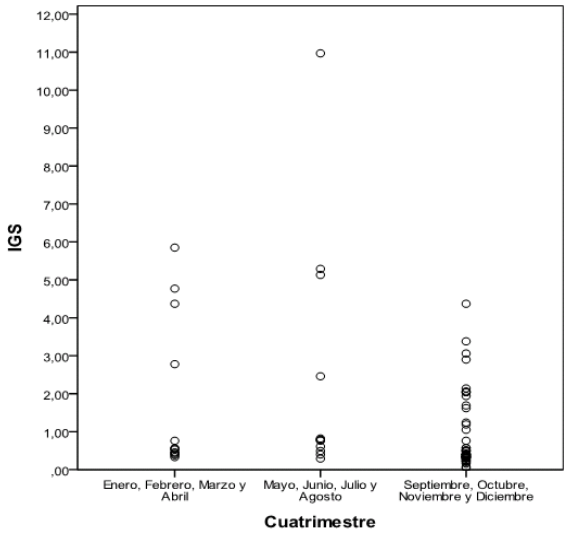

Fig. 23. Quarterly evolution of IGS individual values in whole sample of *M. compressus* (n=77).

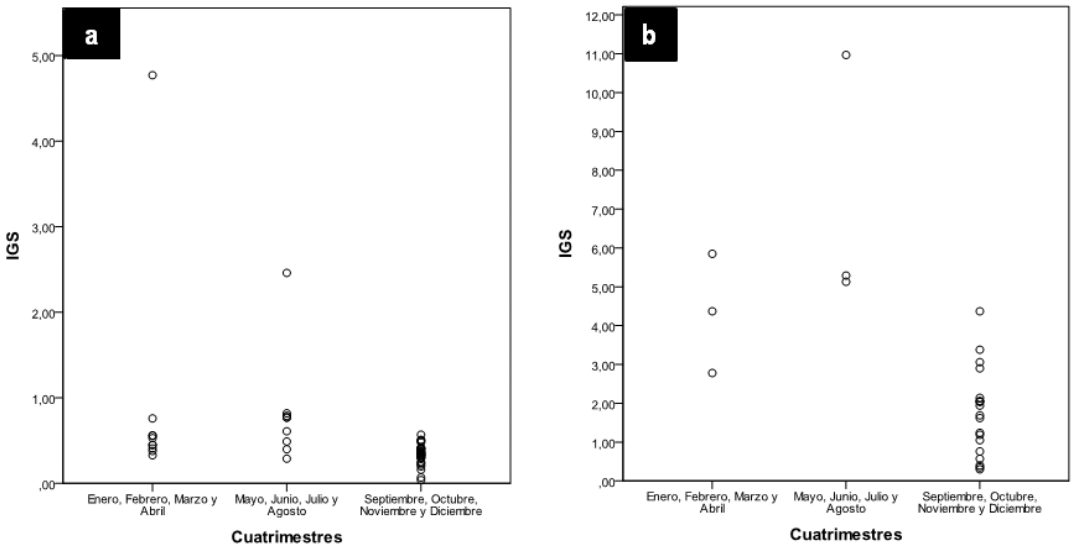

Fig. 24. Quarterly evolution of IGS individual values in *M. compressus*: (a) for males (n=52) and (b) females (n=25).

Examination of gonadal development stages histologically established determined that immadure or resting males with spermatocytes (Fig. 25) were observed during the three quarters analyzed. Mature males with presence of spermatids were observed in all quarters. Mature and spawning males with presence of spermatids and spermatozoa were observed in semesters 1 and 2.

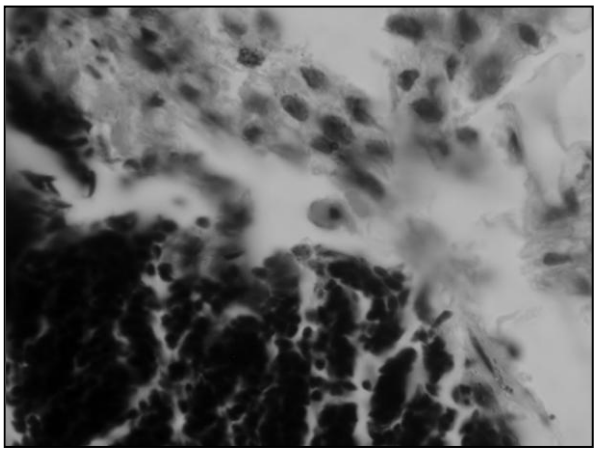

Fig. 25. Detail of spermatocytes 1 and 2 (100x) in *M. compressus.*

Females in previtellogenesis phase being characterized by the presence of perinuclear oogonia and polygonal oocytes (Fig. 26), were observed only in the quarter 3. Oocytes at various stages of vitellogenesis phase (Fig. 27) were observed in the quarters 1 and 3. Vitellogenic oocytes with primary yolk vesicles (YPO) and secondary (YSO) were observed in quarter 3. Vitellogenic oocytes with tertiary yolk vesicles (YTO) were observed in quarters 1 and 3. Mature eggs (H) were observed in all quarters analyzed (Fig. 28 a). Some mature eggs present oil droplets (Fig. 28 b).

Oocytes with signs of atresia were observed in 5 of the 25 females examined at different stages of development (Fig. 29). A single specimen was observed with atretic oocytes in previtellogenesis phase and the remaining four were observed in advanced vitellogenesis phase. All females with atretic oocytes were recorded in quarter 3.

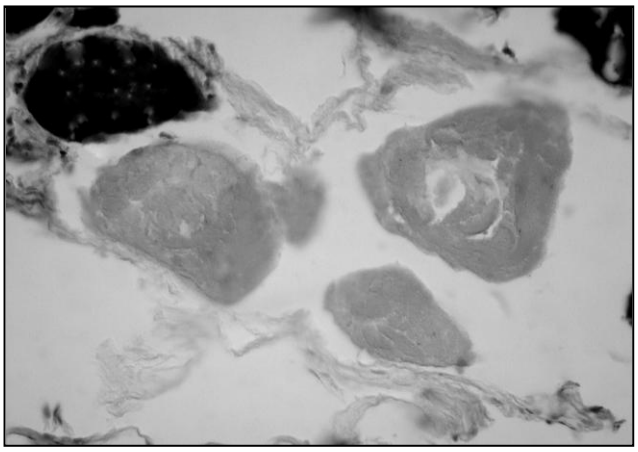

Fig. 26. Details of perinuclear oocytes (40x) in *M. compressus.*

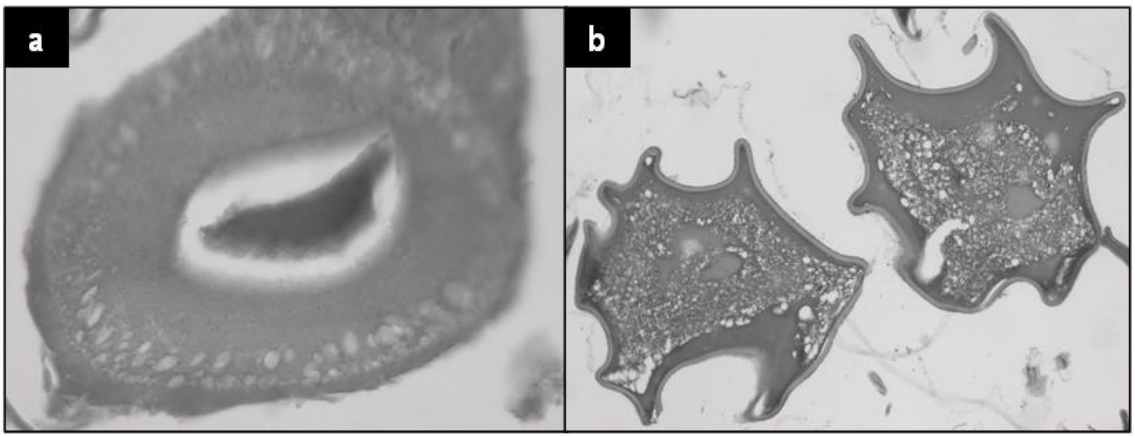

Fig. 27. Detail of vitellogenic oocytes in *M. compressus*: (a) primary vesicle oocytes YPO (40x), (b) and tertiary vesicle oocytes YTO (10x).

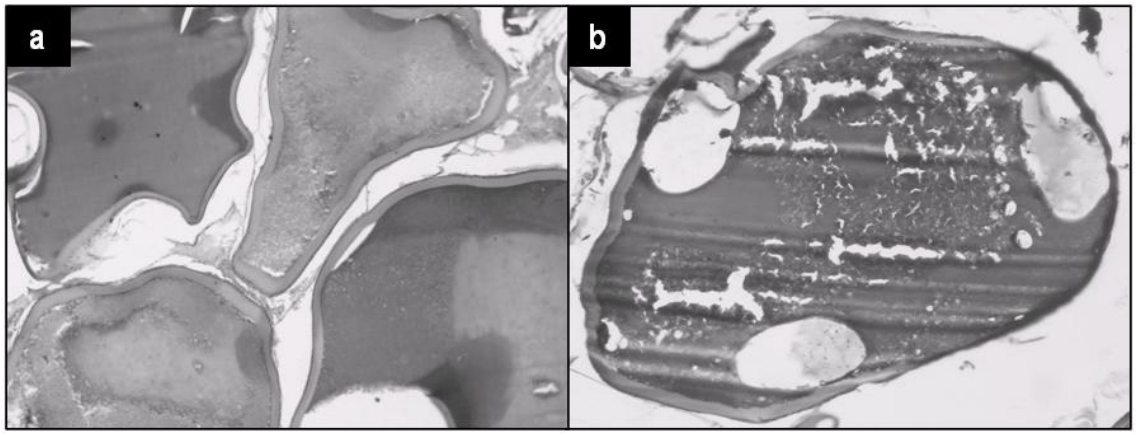

Fig. 28. Detail of mature eggs (H) in *M. compressus*: (a) mature eggs (10x) and (b) mature egg with oil droplets (10x).

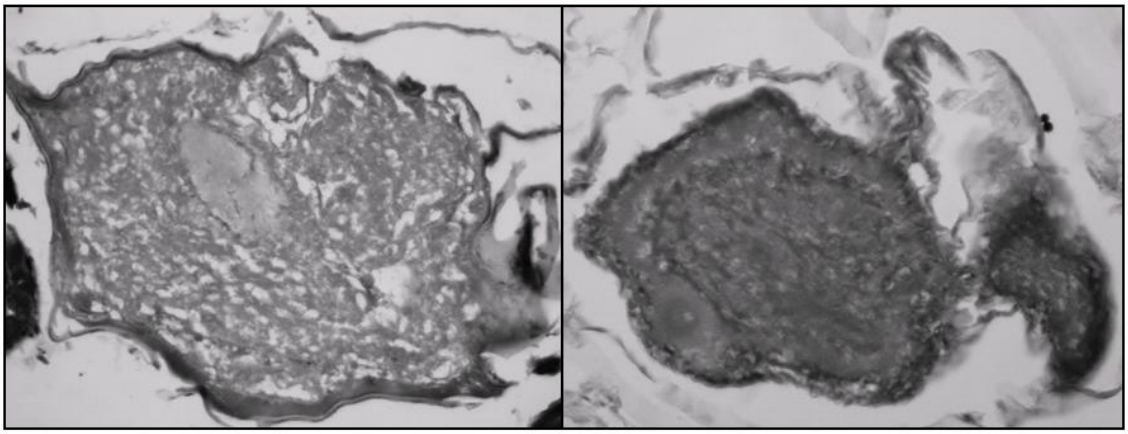

Fig. 29. Detail of oocytes with signs of atresia (40x) in *M. compressus*.

3.8. Sexual maturity

The sexual maturity ogives, estimated on the basis of sexual maturity stages (III, IV and V), for the entire sample are presented in Figure 30. The size at first maturity or length at which 50% of individuals are sexually mature (Lm50) was 476 mm for the states established histologically and 497 mm for the states assigned macroscopically.

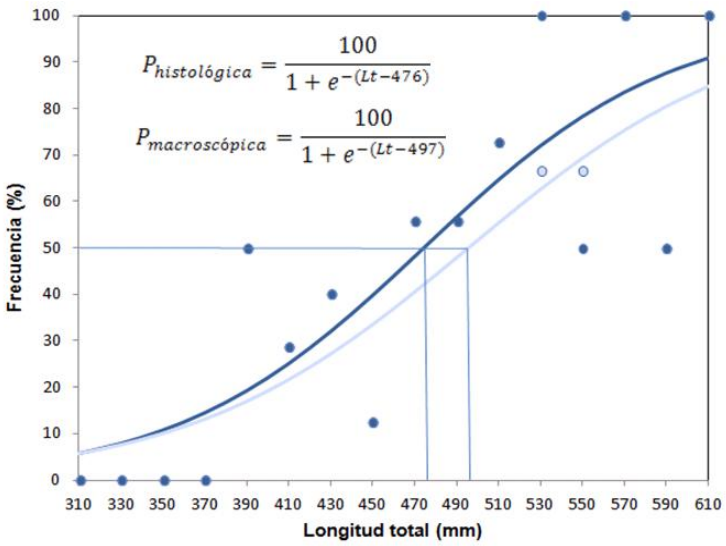

Fig. 30. Maturity sexual ogives in *M. compressus* based on sexual maturity stages (III, IV and V) established histologically and macroscopically.

4. DISCUSSION

This paper extends the known biometric information and provides new data on the reproductive biology of *M. compressus*, who just had a redescription of the holotype and an incomplete specimen (Smith, 1984, 1989), whose corresponding sizes were 538 and 253 + mm LT. The sample consists of full material is known about the species to date and provides a wide range of sizes and biological specimens in reference collections (2 copies in the Municipal Museum of Funchal, and MMF41910 MMF41909).

The size frequency distribution for the total sample and by sex separated showed a characteristic pattern of dioecious species or gonocóricas which was subsequently confirmed by the histologic findings. Statistical analysis of some descriptors such as length and total weight showed no significant difference between both sexes for medium and range values.

The length-weight relationship in the whole sample was defined by the parameters a= 0.0000002907 and b=3.325. The study of allometric coefficient revealed positive allometry between total length (LT) and total weight (PT) in the whole sample and by sexes separated. This allometry type have been observed in other species of Anguiliformes as *Conger conger* (Filiz and Bilge, 2004).

Macroscopic examination of the specimens studied found no evidence to suggest sexual dimorphism in *M.compressus*. The biometric analysis confirmed that no morphological differences between males and females, as deduced from the results obtained in the test applied to all meristic and morphometric parameters analyzed. This feature has also been observed for other species of Anguilliformes as *Ophichthus rufus* (Casadevall i Masó, 1991).

The radiological study completed the vertebral formulas and provides first information about radial formulas in these eels. Table 14 compares the biometric data obtained in *M. compressus* with other species belonging to the family Myrcongridae. It is noted that predorsal vertebrae doesn´t discriminate this species with others described. However preanal and precaudal vertebrae can be used to discriminate the species of the others described.

There isn´t too information on the vertical distribution of this species, although there are records capture these eels at depths between 100 and 1000 meters (Gonzalez et al., 2004, Menezes et al., 2004 and Gonzalez and Tariche, 2009). The results obtained in this study provide the first data on the vertical distribution of this species by sexes separated and sexual maturity.

Table 14. Biometrics data compared to different species belonging to the family Myrocongridae.

	Present paper	Castle (1991)	Castle y Beárez (1995)		Karmovskaya (2006)	Paiva et al. (2011)
Fam. Myrocongridae	***M. compressus***	***M. gracilis***	***M. nigrodentatus***	***M. prolixus***	***M. seychellensis***	***Myroconger sp.***
Total length (mm)	308 - 611	484	366	383	450	431
Meristic data						
Nº line lateral pores	3 - 9		6	11	4	5
Pectoral rays	15 - 20	16	16-17	15-16	-	-
Dorsal rays before anus level	104 - 114	134	100	156	-	-
Total dorsal rays	288 - 324	349	298	398	300	-
Total anal rays	184 - 238	229	213	239	163	-
Predorsal vertebrae	6 - 8	7	6	5	7	4
Preanal vertebrae	48 - 52	53	43	57	56	48
Precaudal vertebrae	54 - 62	65	50	71	68	-
Total vertebrae	130 - 135	139	123	147	130	125
Mrphometric data (%LT)						
Preanal length	41,61 - 47,95	44,50	45,60	45,40	50,70	47,30
Predorsal length	10,75 - 14,75	9,90	13,60	10,30	12,20	13,90
Head length	13,04 - 17,47	10,90	17,40	11,80	14,20	14,90
Body depth at anusl evel	5,79 - 10,51	5,10	7,50	4,60	6,40	6,40
Body depth at gill opening	6,53 - 10,36	-	-	-	-	-
Trunk length	28,31 - 33,40	-	-	-	36,40	-
Caudal fin length	30,41 - 58,39	-	-	-	-	-
Morphometric data (%LC)						
Snout length	17,72 - 32,81	23,00	21,00	27,10	25,80	24,90
Ocula diameter	12,56 - 17,97	15,00	15,10	13,90	11,70	12,70
Interorbital distance	16,67 - 25,35	18,20	18,90	20,90	20,30	24,40
Upper jaw lengh	38,39 - 56,83	45,40	41,90	49,50	47,60	49,80
Interbranchial distance	10,90 -18,02	11,20	18,10	8,40	10,90	24,40
Pectoral fin length	18,44 - 32,03	20,10	22,10	17,80	18,70	16,60

The vertical distribution by sexes separated in the three bathymetric strata studied, does not suggest a segregation of sexes in depth. The numbers of capture are recorded in greater proportion in depth stratum 3 (> 250 m), showing a progressive increase in the number of captures males and females with depth. Their increased presence in these bathymetric levels is undoubtedly linked to the presence in these depths of large biomass pandalids shrimp that likely constitute a major part of their diet (González y Tariche, 2009).

The percentage of mature decreased with depth, registering 66.67% of sexually mature individuals in stratum 3. The X^2 test analysis showed no significant difference in the proportion of mature and immature in any of the studied depth strata. The sex ratio by depth strata differed significantly only in stratum 3 (> 250 m), but the high proportion of males in each stratum reflects the low fiability of the X^2 test for muestreales sizes less than 30 cases. These results differ from those obtained for other species as Conger conger Anguilliformes where if there has been a vertical displacement of the sexes (Cau and Manconi, 1983). In order to study the actual distribution of the species and taking into account that catches of these eels come from the bycatch of the soldier shrimp fishery prospective (*Plesionika edwardsii*) in Cape Verde waters, whose operability range is restricted between 100 and 350 deep, should dispose a larger sample size with capture data at higher levels deep.

The study of the reproductive biology of *M. compressus* (typology sexual, reproductive strategy, sexual maturity and reproductive period) represents the first document in this field on the species, *Myroconger* genus and Myrocongridae family . Histology results confirmed that *M. compressus* has separate sexes, with no evidence of sex reversal or hermaphroditism. Gonadal weights presented significant differences between the sexes, being higher in females. This pattern has been observed in most of the species of Anguilliformes.

The sex ratio showed significant differences in the overall sample, the ratio was 1:0,48 favor of males. The low proportion of females found may be associated with factors such as the selectivity of traps used for catching, or behavioral changes in males of *M. compressus*, where aggressive males may restrict the likelihood that smaller size animals and females entering the traps. The sex ratio per quarter does not reflect significant differences in the expected 1:1 ratio, although it is important to note that the low number of available data ago necessary to confirm this.

The values of sex ratio by size range showed significant differences between juveniles of small sizes (310-450 mm) for males, while adults of average size (470-530 mm) showed no differences in proportion of sexes. Large size older individuals did not differ in sex ratio, although we can not conclude that there are no differences in the sex ratio (n <30).

The spawning season of *M.compressus* in Cape Verde waters appears to extend over the whole year, with a peak of spawn into the summer months. During the study period there were analyzed mature males and females in all quarters. Mature and spawning males recorded in quarters 1 and 2, while mature and spawning females were observed throughout the year. The observations of the evolution of sexual maturity stages showed a higher percentage of individuals in III and IV states for quarters 1 and 2.

The values of the gonadosomatic index (GSI) were observed higher in the case of females than in males. This is because females invest more energy during reproduction to produce the vitelogénicas reserves of eggs. IGS analysis (%) per quarter indicated higher levels in quarter 2. This suggests an increase in reproductive activity coinciding with the summer months where there is more food available.

Peak of spawn in *M. compressus* coincides with the reproductive period of others Anguilliformes that sharing the same habitat as *Gnathopis mystax* and *Conger conger* whose spawn are in summer (Muus and Nielsen, 1999; Relini et al., 1999; Vallisneri et al., 2007) and from July to August (Casadevall i Maso, 1991) respectively.

Eggs of *M. compressus* showed inclusions of oil drops in oocytes with advanced stages of vitellogenesis. Generally, this oil drops fusioned in mature egg stage. The presence of these structures indicates growth of larval in pelagic phase and has been described in other Anguilliformes as *Gnathophis mystax* (Marinaro, 1971) and *Ophichthus rufus* (Sparta, 1937).

In the case of sexual maturity, size at first maturity (Lm) or length at which 50% of individuals are mature was established at 476 mm. This size, calculated by histological allocating of sexual maturity stages, was 19 mm less than the size at first maturity obtained from the states of sexual maturation granted macroscopically (497 mm). This difference reflects the difficulty of correctly classifying visually of sex and sexual maturity stages in early stages of development of the gonads.

Currently, *M. compressus* is not subject to overfishing. Catches of these eels are restricted to deep prospecting in water with different types of traps where they are captured as bycatch, mainly directed to soldier shrimp catches (*Plesionika edwardsii*). This work sheds new insights into the biology of the species, providing for the first time information on the reproductive aspects.

Would require further study with a larger sample size in order to establish other eco-biological parameters. Thereby, could be adopted fisheries management measures governing the future bycatch in fisheries in Cape Verde waters.

5. CONCLUSIÓN

1. It is confirmed that *M. compressus* is a gonochoric species.

2. *M. compressus* no present sexually dimorphic.

3. The length-weight relationship for both sexes has positive allometric between total length (LT) and total weight (PT).

4. The species shows no evidence to suggest sex segregation in depth.

5. *M. compressus* presents a pelagic spawn in all the year with a small peak in summer months.

6. The sex ratio of *M. compressus* presents significant differences in favor of males (1:0,48).

7. IGS values (%) are higher in females than in males.

8. *M.compressus* presents a sexual maturity at 476 mm. The error made in determining the sex and maturity stages visually amounted to 24,67% and 6,49% respectively.

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