REPRODUCTIVE BIOLOGY OF WAHOO, *ACANTHOCYBIUM SOLANDRI* (CUVIER, 1832), OF EASTERN ATLANTIC

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SUMMARY

This study analyses samples acquired under three Short-Terms Contracts from the ICCAT Small Tuna Year Program (SMTYP 2018 to 2021). We present de reproductive biology of Wahoo (WAH), from East Atlantic (AT-NE/BIL94B and AT-SE/BIL97). Our results indicate that the WAH have a protracted spawning season in the area (from March to October), picking in August-September. The L50 for females was estimated in 94.78 cm SFL. All these results are in agreement with those of the western Atlantic Wahoo.

RESUMEN

Este estudio analiza muestras adquiridas en el marco de tres Contratos a corto plazo del Programa anual de pequeños túnidos de ICCAT (SMTYP 2018 a 2021). Presentamos la biología reproductiva del Wahoo (WAH), del Atlántico este (AT-NE/BIL94B y AT-SE/BIL97). Nuestros resultados indican que el WAH tiene una temporada de puesta prolongada en el área (de marzo a octubre), con su pico reproductivo en agosto-septiembre. El L50 para hembras se estimó en 94,78 cm SFL. Estos resultados están de acuerdo con los del Atlántico occidental.

RÉSUMÉ

Cette étude analyse des échantillons acquis dans le cadre de trois contrats à court terme du Programme annuel ICCAT pour les thonidés mineurs (SMTYP 2018 à 2021). Nous présentons la biologie de la reproduction du Wahoo (WAH), de l'Atlantique Est (AT-NE/BIL94B et AT-SE/BIL97). Nos résultats indiquent que les WAH ont une saison de ponte prolongée dans la zone (de mars à octobre), cueillette en août-septembre. Le L50 pour les femmes a été estimé à 94,78 cm SFL. Tous ces résultats sont en accord avec ceux du Wahoo de l'Atlantique Ouest.

KEYWORDS

Wahoo; reproductive biology;
spawning season; sexual maturity; GSI; East Atlantic

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1. Introduction

Acanthocybium solandri (Cuvier, 1831) is a pelagic and oceanic species occurring in tropical and subtropical waters worldwide with a highly migratory behaviour (Collette and Nauen 1983; McBride et al., 2008). Wahoo (WAH) is one of the most important species caught in tropical oceans, being fished directly and bycatch in tuna longline and purse seine fisheries (Oxenford et al., 2003; Viana et al., 2013). It is valuable to many subsistence fisheries and highly prized as recreational sportfish (Zischke, 2012). Fisheries targeting WAH are increasingly common worldwide, enhancing the need for more accurate data on its biological aspects (Brown-Peterson et al., 2000; Oxenford et al., 2003).

spawning season generally associated with increases in water temperature (Brown-Peterson et al., 2000; Jenkins and Mc Bride, 2009; Zischke et al., 2013). Since the 1970s, examination of the gonads of WAH has been used to investigate temporal and spatial peaks in reproductive activity. Wahoos have asynchronous oocyte development, with mature individuals following iteroparous spawning behaviour (Zischke, 2012). Much information is available on the wahoo biology, distribution and population characteristics from different parts of the world (Brown-Peterson et al., 2000; Oxenford et al., 2003; McBride et al., 2008; Viana et al., 2013). However, biological information on wahoo from de eastern Atlantic has never been reported.

This study analyses samples acquired under three Short-Terms Contracts from the International Commission for the Conservation of Atlantic Tunas (ICCAT) Small Tuna Year Program (SMTYP). From 2018 to 2021, biological samples were collected for growth, reproduction and stock structure studies on Atlantic WAH. Knowledge of these life history parameters is crucial to implement management strategies for WAH fisheries (Anon 2019).

2. Material and Methods

467 WAH coming from different fisheries from Northeast Atlantic (Purse seine and Bait boat in Canary Islands, Spain. AT-NE/BIL94B. N = 351) and Southeast Atlantic (Gillnet: Drift net in Côte d'Ivoire. AT-SE/BIL97. N = 116) are included in the present work. Due to the lack of genetic differentiation in the Atlantic Wahoo (Ollé et al., 2021), we have analysed all the samples as a single stock.

Immediately after landing, the round weight (RW, kg), the straight fork length (SFL, to the nearest 0.1 cm) and the gonad weight (GW, to the nearest g) were measured. When possible, sex was determined by visual inspection. In other cases, the sex was determined or corrected during the microscopic analysis.

Assuming no systematic differences in ovarian homogeneity throughout the whole ovary, including between the two ovarian lobes (Otsu and Uchida 1959, Stequert and Ramcharrun 1995), a cross-section (2-3 cm wide) from the central part of one of the lobes was fixed in 10% formalin, or Bouin's fluid for four h and then preserved in 70% ethanol for later analysis. This tissue was later rinsed, dehydrated in ethanol, embedded in paraffin, thin-sectioned to 10 µm, and stained with Mallory's trichrome stain. Histology slides were viewed under transmitted light at different magnifications with a compound microscope and digital camera.

2.1 Gonad staging analysis

The microscopic maturity stating of gonads was based on a modification of the criteria of Schaefer (1998) and Farley et al. (2013). The most advanced group of oocytes (MAGO) present in each WAH ovary was assigned to one of seven categories listed in **Table 1**.

The microscopic maturity staging of gonads was based on histologic analysis of 213 individuals (195 females and 18 males).

2.2 Spawning season

We used the Gonadosomatic index (GSI) to determine the spawning season timing. GSI helps monitor monthly changes in gonad development that indicate reproductive activity. In addition, the spawning season and annual maturity cycle have been analysed using the proportion of gonads stages by month.

To calculate GSI the following equation (Gibson and Ezzy, 1980) was used.

$$GSI = \frac{GW}{RW - GW}\ x\ 100$$

where GW is gonad weight and RW is round weight of the sampled individual.

For the estimates of the monthly mean GSI values, we used the available information for 352 fish, and for the mean GSI by gonad stage, we used all the samples with microscopic gonad stage assigned (n = 213).

2.3. Maturity Ogives

The Maturity at length ogive was fitted as generalized linear models (GLM) to binary maturity status with a logit 'link' function. The maturity stage ('mature', 'immature') was handled as a binomial response variable with a 'logit' link function and modelled as a function of FL (cm). For a range of sizes between 61.8 – 166.3 cm. The statistical significance of the difference in maturity ogives between sexes was done using an analysis of deviance. R version 4.0.3 (2020-10-10) was used for the analysis.

Length at maturity (length at 50% of the fish have reached maturity) was estimated from the parameters of the fitted logistic model (L50 = -α/β). Confidence intervals (95%) for the estimated length at maturity (L50) were obtained by non-parametric bootstrapping techniques.

3. Results

3.1 Gonad staging analysis

213 WAH, 153 individuals from Northeast (128 females and 14 males) and 61 from Southeast Atlantic (57 females and four males from Côte d'Ivoire) were examined under a microscope, and the microscopic maturity stage was assigned. Most of the gonads were mature, inactive post-spawning phase (Stage V. 66%): 44% in regenerating phase (Vb) and 22% in regressing one (Va). 9.7% of individuals were in active stages (3.7% in Spawning capable phase, and 6% in the spawning stage). A summary of the number of fish by gonad stage is presented in **Table 2**. **Figure 1** shows different images of ovaries in the different gonad stages found in this study.

Figure 2 shows the mean GSI by gonad stage. The stage III (Spawning capable) showed the highest GSI mean value.

3.2 Spawning season

We observed active WAH (Stages III and IV) from June to October and March (We have not obtained samples from April and May). Spawning fish were observed in March and July to October (**Table 3**).

The average monthly GSI reached a high of 2,55 in August and a low of 0,49 in February. Data on mean monthly GSI indicates an upward trend from January to August and a downward trend from August to December (**Figure 3**). We only have one sample in July, a male specimen in gonad stage IV. **Figure 4** shows the monthly relative frequency of ovarian stages. The results on the pawning season using GSI analysis agree with those using the monthly proportion of gonad stages.

Our results indicate that the WAH have an ample spawning season in the area (from March to October). The spawning peak is in August-September.

3.3 Maturity Ogives

The analysis of L50 has been done for sexes-combined and females using the microscopic data (**Table 4**). We have not estimated the ogive for males due to the small sample size (N = 18).

The sizes of females analyzed ranged from 61.8 – 166.3 cm SFL, and the L_{50} resulted in 94.78 cm SFL. The smallest mature female (L_{MAT}) was 84.7 cm SFL. The largest immature female was 97 cm SFL.

Figure 5 shows the maturity ogive for females using the microscopic data. The confidence intervals are marked in grey.

4. Discussion

The Wahoo has been fished in the eastern Atlantic Ocean for the past three decades without any stock management or assessment. Though the WAH is of great economic importance in the area, there is a lack of knowledge about its biology in the eastern Atlantic.

Our study of the gonad stage by months and the GSI analysis indicate that Eastern Atlantic is a spawning area for Wahoo. We have found spawning females offshore the Côte d'Ivoire coast and in the Canary Islands.

Regarding spawning seasons, Zischke et al. (2013) described spawning season during de Austral spring and summer (from October to February) In eastern Australia. Gao et al. (2020), in the Western and Central Pacific Ocean, described a peak GSI for wahoo in November.

In the tropical eastern Atlantic Ocean, Kindong et al. (2022) conclude that WAH may be spawning in winter (December-January). In their study, no WAH females were recorded in September, and only two individuals in August (one mature-active and the other mature-inactive). They explain that the decline in the GSI in March-November could be attributed to fewer samples available, changes in regional temperatures or food availability.
Our results on monthly variation of the mean GSI values, peaking in August, and the results obtained from the monthly relative frequency of ovarian stages indicated that the WAH has a protracted spawning season (from March to October) in the eastern Atlantic, peaking in August and September. These results agree with those from the Atlantic coast of Florida and the northern Bahamas (Jenkins and Mc Bride, 2009). Nevertheless, our temporal coverage of the sampling of Wahoo requires additional sampling effort. We have no analysed samples from April and May and poor sample coverage in January, June and July. The main differences between Kindong et al. (2022) and our results could be attributed to deficient spatial/temporal sampling coverages and applying of different maturity scales.

The size at first sexual maturity is a parameter of great importance for fish stock management. In the Western Atlantic: Brown-Peterson et al. (2000) estimated an LMAT = 97.5 cm and an L50 = 102 cm FL (Northern Gulf of México and Bahamas); Jenkins and Mc Bride (2009) obtained an LMAT = 88 cm and L50 = 92.5 cm FL; In Bermuda, Oxenford et al. (2003) suggested a size at first maturity of 95 cm for females; In North Carolina Hogarth (1976) calculated an LMAT = 101 cm TL. and Viana et al. (2013), in Saint Peter and Saint Paul Archipelago (Brazil), found an L50 of 110 cm FL. Our results (LMAT = 84.7 cm SFL and L50 = 94.78 cm FL for females) agree with Oxenford et al. (2003) and Jenkins and McBride (2009). Kindong et al. (2022) reported an LMAT = 72 cm FL, the smallest ever observed, and L50 = 89.6 cm FL for females. They provide the same L50 as Figuerola-Fernández et a. (2008) in Costa Rica.

More efforts are needed to solve the spatial and temporal gaps in the sampling for the reproduction of WAH in the eastern Atlantic. Improvements in reproductive parameter estimates will aid in better understanding the productivity of WAH populations and effectively managing its stocks.

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Table 1. Microscopic maturity stating of gonads based on a modification of the criteria of Schaefer (1998) and Farley et al. (2013).

STAGE	Maturity Status	Gonad Stage	MAGO and POFs	ATRESIA	Maturity Markers
I	Inmature	Inmature	Previtellogenic. No POFs	No atresia	Absent
IIa	Inmature	Developing	Early vitellogenic. No POFs	No atresia	Absent
IIb	Mature	Developing	Early vitellogenic. No POFs	Late stages of atresia	Present
III	Mature	Spawning capable	Advanced vitellogenic. No POFs	α and β atresia may be present	Posible
IV	Mature	Spawning	Fs; Migratary nucleus ± POFs; Hidrated ± POFs	α and β atresia may be present	Posible
Va	Mature	Regresing	Previtelogenic or Vitelogenic	The majority (>50%) of vitellegenic are in α and β atresia	Present
Vb	Mature	Regenerating	Previtelogenic	Late stages of atresia may be present	Present

Table 2. Gonad stage for the analysed individuals.

Gonad Stage	I	IIa	IIb	III	IV	Va	Vb	Total
N	34	2	15	8	13	47	94	213

Table 3. Gonad stage by month for the analysed individuals.

	I	IIa	IIb	III	IV	Va	Vb	Total (Month)
1	N/A	N/A	N/A	N/A	N/A	N/A	**8**	**8**
2	N/A	N/A	**5**	N/A	N/A	N/A	**14**	**19**
3	**11**	**2**	**4**	N/A	**2**	**1**	**5**	**25**
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**N/A**
6	**1**	N/A	**1**	**1**	N/A	N/A	N/A	**3**
7	N/A	N/A	N/A	N/A	**1**	N/A	N/A	**1**
8	**3**	N/A	**1**	**1**	**2**	**11**	**1**	**19**
9	**13**	N/A	**4**	**6**	**7**	**31**	**11**	**72**
10	N/A	N/A	N/A	N/A	**1**	**2**	**31**	**34**
11	**4**	N/A	N/A	N/A	N/A	**2**	**16**	**22**
12	**2**	N/A	N/A	N/A	N/A	N/A	**8**	**10**
Total (Stage)	**34**	**2**	**15**	**8**	**13**	**47**	**94**	**213**

Table 4. Maturity Ogives.

	N	Size Range	Countries	L_{50}	Cl 5%	Cl 95%
Sex combined	213	61.8-166.3	SP, CIV	94.76	92.54	96.61
Females	195	61.8-166.3	SP, CIV	94.78	92.37	96.56

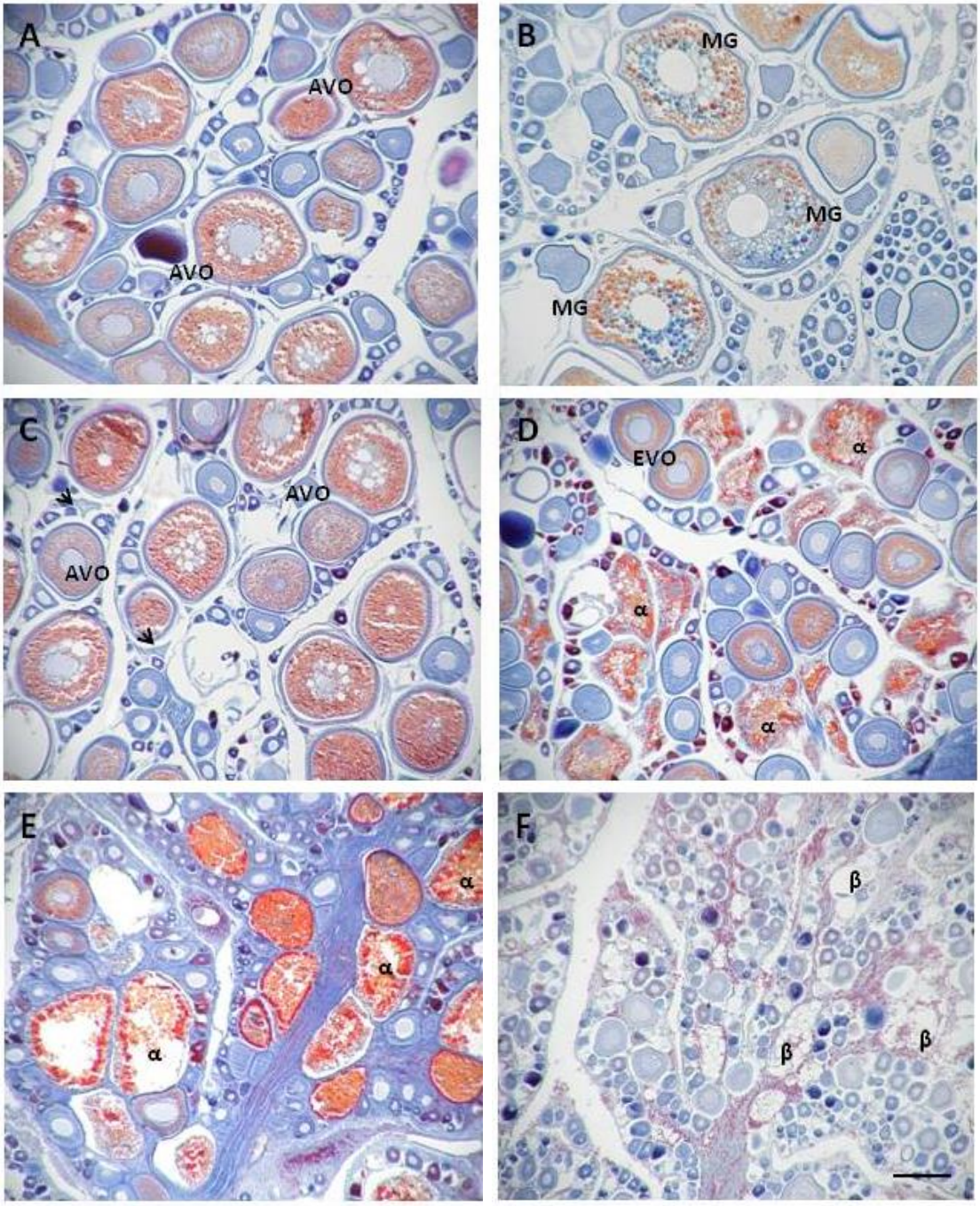

Figure 1. A: Image of a Spawning Capable ovary (Stage III). B: Image of a spawning ovary (stage IV) with Migratory nucleus oocytes (MG) as MAGO. C: Image of a spawning ovary (stage IV) with AVO as MAGO and post-ovulatory follicles (arrows). D: Image of an initial regressing stage ovary (stage Va) with more than 50% of Vitellogenic oocytes in α atresia (α). EVO = Early Vitellogenic Oocytes. E: Image of a regressing ovary (stage Va) with the majority of Vitellogenic oocytes in α atresia (α). F: Image of an advanced regressing ovary (stage Va) with some rest of β atresia (β). (bar = 400µm).

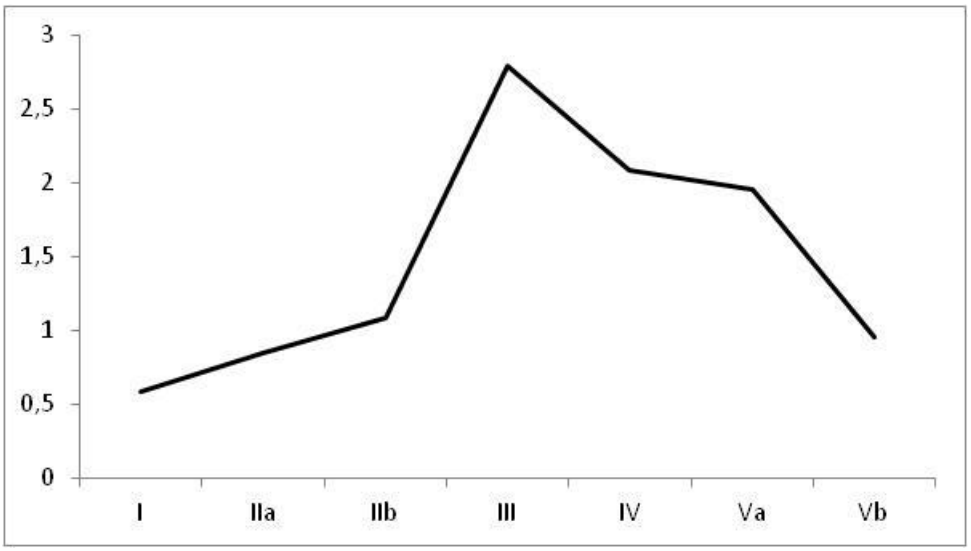

Figure 2. The plot shows the mean GSI by gonad stage. The maximum GSI was found in Spawning capable female (Stage III).

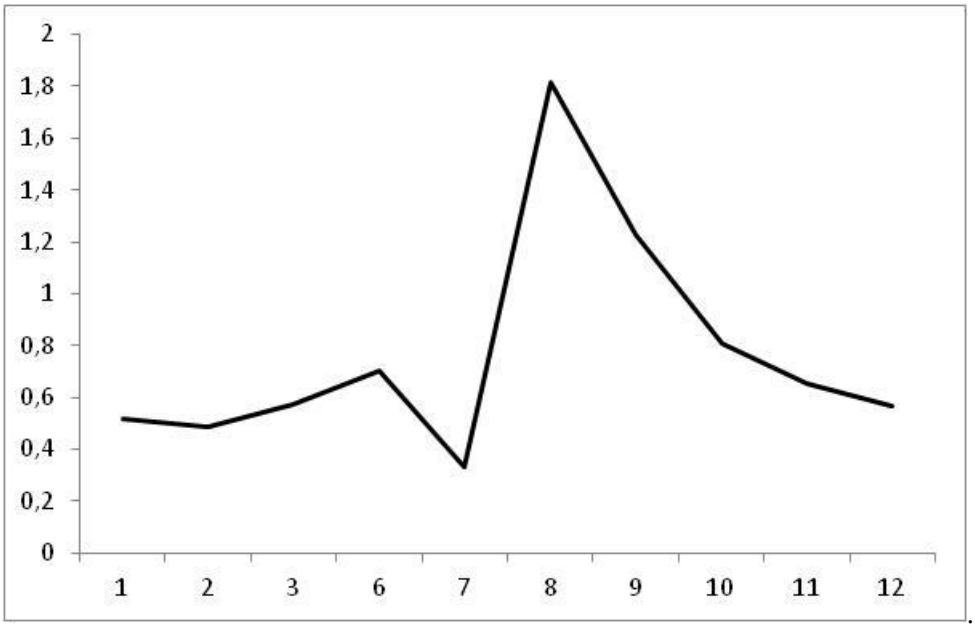

Figure 3. Monthly average GSI. The maximum GSI was found in August.

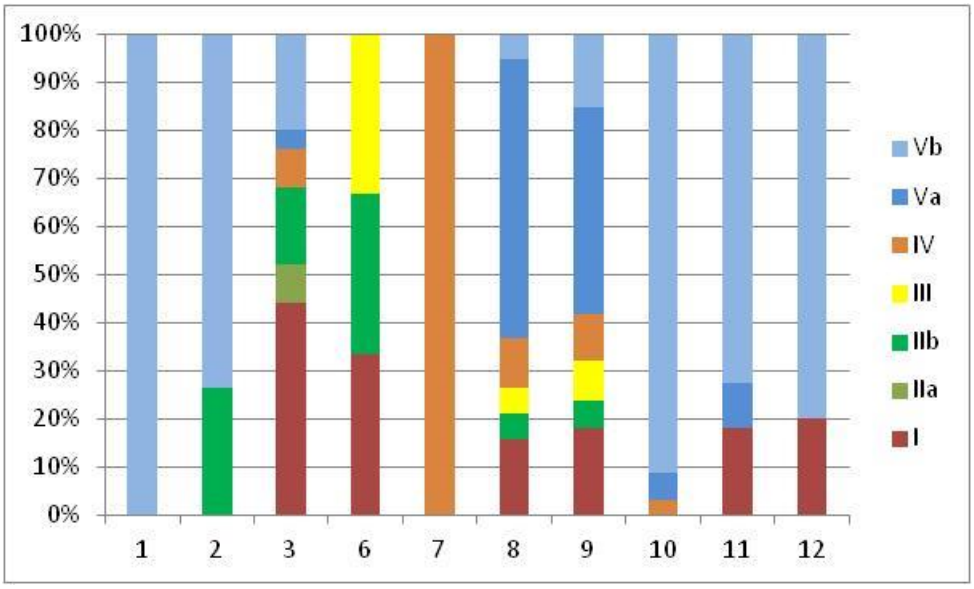

Figure 4. Monthly relative frequency of gonad stages or maturity classes found by microscopic examination.

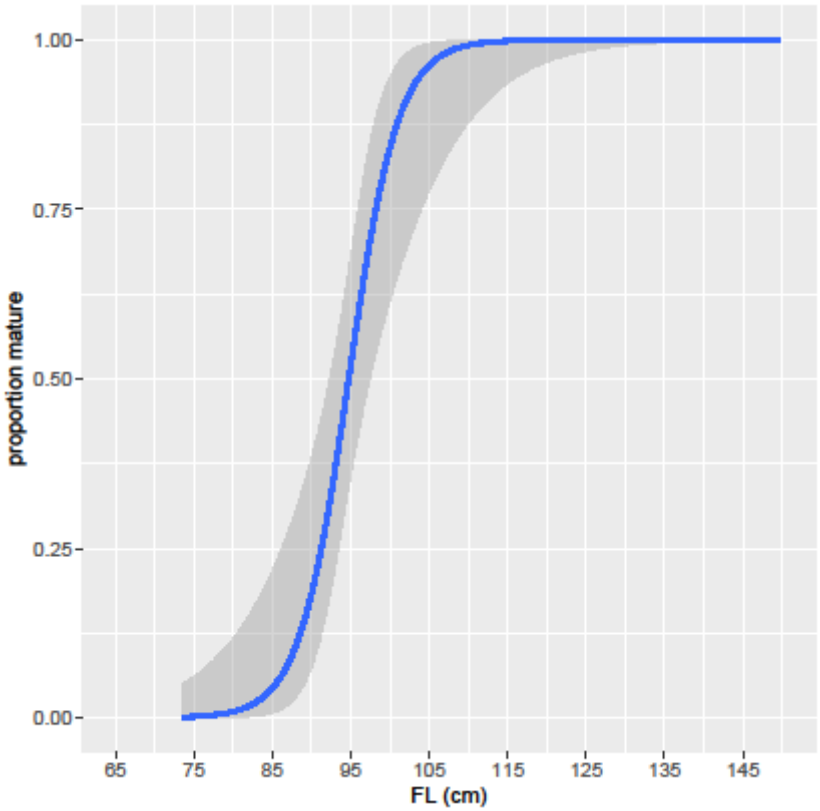

Figure 5. The plot shows the Maturity ogive for females using the microscopic data. The confidence intervals are marked in grey.