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FIRST STEP FOR IMPLEMENTATION OF VISUAL ASSESSMENT OF THE MESENTERIC FAT CONTENT OF HORSE MACKEREL, *TRACHURUS TRACHURUS* (LINNAEUS, 1758), IN THE PORTUGUESE COAST

Ana Maria Costa

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35

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FIRST STEP FOR IMPLEMENTATION OF VISUAL ASSESSMENT OF THE MESENTERIC FAT CONTENT OF HORSE MACKEREL, *TRACHURUS TRACHURUS* (LINNAEUS, 1758), IN THE PORTUGUESE COAST

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ABSTRACT

The objective of this study was to visually obtain the amount of mesenteric fat content and its relationship with length and maturity cycle of horse mackerel in three different regions. Between January and December 2015, a total of 3124 individuals (1467 males, 1439 females and 218 unsexed or indeterminate) were collected at Matosinhos, Peniche and Portimão fish auctions, with total lengths between 11.1 and 43.9 cm. A sex ratio of 1:0.98 in favor of males was obtained, with small non-significant differences in fat content between sexes. A significant inverse relationship was found between the amount of mesenteric fat and the phase of the maturity cycle, corresponding also to a significantly relationship between fat and fish condition. During the spawning season, in the 1st quarter of the year, most of the fish had practically no mesenteric fat, whereas in the resting season, corresponding to the summer months, the individuals presented the highest fat content. During the summer months the leanest specimens were recovering, while the highest fat content was recorded in maturing individuals. These observations were common to the three zones studied. The visual assessment of the amount of mesenteric fat is a quick and easy technique, well-suited for use at sea, in opposition to the determination of lipid content, which is more expensive and time consuming.

Key words: *Trachurus trachurus*, mesenteric fat, visual assessment, Portuguese coast

RESUMO

Título: Primeira abordagem da avaliação do teor em gordura visceral de carapau branco (*Trachurus trachurus*) (Linnaeus, 1758) na costa portuguesa

O objetivo deste estudo foi obter visualmente a quantidade mensal de gordura visceral e sua relação com o comprimento dos indivíduos e o ciclo de reprodução do carapau nas três zonas estudadas. Entre Janeiro e Dezembro de 2015 foram recolhidos nas lotas de Matosinhos, Peniche e Portimão um total de 3124 indivíduos (1467 machos, 1439 fêmeas e 218 indeterminados), com comprimentos totais entre 11,1 e 43,9 cm. Obteve-se uma proporção sexual de 1:0,98 em favor dos machos, com pequenas diferenças não significativas do teor em gordura entre sexos. Foi encontrada uma relação inversa significativa entre a quantidade de gordura visceral e o ciclo de maturação, correspondendo a uma relação direta também significativa entre a gordura e a condição do peixe. Durante a época de desova, no 1º trimestre do ano, a maioria dos peixes praticamente não apresentava gordura visceral, enquanto na época de descanso, correspondente aos meses de verão, os indivíduos apresentavam o maior teor de gordura. Os exemplares mais magros encontravam-se em recuperação, enquanto que o teor em gordura mais elevado foi registado nos indivíduos em maturação. Estas observações foram comuns às três zonas estudadas. A atribuição visual da quantidade de gordura visceral é uma técnica rápida e fácil, bem adequada para uso no mar, em oposição à determinação do conteúdo lipídico, que é mais cara e demorada.

Palavras-chave: *Trachurus trachurus*, gordura visceral, avaliação visual, costa Portuguesa

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INTRODUCTION

Horse mackerel, *Trachurus trachurus* (Linnaeus, 1758) is one of the most abundant and commercially most important pelagic species (after sardine, *Sardina pilchardus*, and Atlantic chub mackerel, *Scomber colias*) in the catches of the Portuguese fishing fleet (INE, 2020). It is caught along the entire coast, with several fishing gears (trawl, purse seine and polyvalent gears) and in 2019, with 17 167 tons landed, represented around 14.4% of the total 119 534 tons of marine fish cached (INE, 2020).

The Iberian stock of *Trachurus trachurus* (ICES subareas 27.9a and 27.8c) spawns from September to June, with a peak in February (ICES, 2017). Off the west coast of Portugal (ICES subarea 27.9), horse mackerel has a prolonged spawning season, from November to April (Borges and Gordo, 1991), very similar to the one found north of Spain (Abaunza *et al.*, 2003). Barraca (1964) from fish caught off Lisbon and Borges and Gordo (1991), working with samples from the entire coast of Portugal, determined the spawning season to last from December-January to June. Borges *et al.* (1977) and Arruda (1982, 1984) studied samples from the northern and central regions of Portugal and found that the spawning period was between February and August, with a peak from March to June, while for the southern part of the coast, the spawning period was considerably longer and extended from September to May. The most recent studies indicate that in Portugal the spawning season lasts from December to April, with a main peak in January-March (Costa, 2001; Santos *et al.*, 2001).

Lipid reserves are particularly important in growth, survival and maturity/gonad development of fishes (Adams, 1999). Lipid storage in horse mackerel mainly occurs as subcutaneous fat, but also in the viscera and embedded in the muscle (Bandarra *et al.*, 2001). Subcutaneous fat can be an important source used by the fish during the phase of gametogenesis (Hardy and Keay, 1972).

Like other pelagic species horse mackerel presents some seasonal variations of lipids related to the reproductive cycle and environmental factors (Bandarra *et al.*, 2001). The knowledge of the effect of these fluctuations is important to understand the spawning success of the species, which is one of the mechanisms affecting subsequent recruitment success of the population (Van der Lingen and Hutchings, 2005).

The analysis of the total lipids present in the muscle of individual fish is not only expensive and time-consuming but also almost impractical to conduct at sea (Van der Lingen and Hutchings, 2005). Although there are currently portable lipid content meters, called Fatmeter, which are affordable and easy to use at sea, the visual assessment of mesenteric fat is a rapid technique to determine the condition of pelagic fish, with the advantages of being quick and easy to apply, requires no

specialized equipment and is cheap, therefore well-suited for use at sea (Van der Lingen and Hutchings, 2005). The amount of mesenteric fat in the viscera by visual observation and the lipid content using the Soxhlet method were compared for the sardine (*Sardina pilchardus*) of the Middle Adriatic (Mustać and Sinovčić, 2009) and the results showed the same trend, meaning that the visual assessment of mesenteric fat can be sufficiently accurate for obtaining the fish condition, rather than the more complicated Soxhlet method, for cases when precise values of fat content are not needed (Mustać and Sinovčić, 2009).

Regarding horse mackerel, and after a detailed bibliographic revision, it was verified that the only study on fat content for the Portuguese coast is from Bandarra *et al.* (2001). These authors recorded for this area the maximum total lipids in August and January, with a minimum in February, which can be explained by the fact that spawning of horse mackerel in Portuguese waters occurs, as previously mentioned, during winter (Costa, 2001; Santos *et al.*, 2001). Based on the literature found on this subject, we see that the minimum values of mesenteric fat obtained by lipid analysis are recorded in the spawning season, corresponding to the months of January-February in the Northeast Atlantic (Van Damme *et al*., 2014) and in particular on the Portuguese coast (Bandarra *et al*., 2001) and in the summer months in the North Eastern Mediterranean Sea (Celik, 2008).

Horse mackerel is a widely consumed species in Portugal and the consistent presence, all year long, of polyunsaturated ω3 components provides the intake of this element throughout the year, as opposed to sardine which gains importance only during the phase when it is high in fat (Bandarra *et al.*, 2001).

The aim of this study was to study the variation on the mesenteric fat content in horse mackerel, *T. trachurus*, males and females associated with the reproduction cycle based on the gonads maturity stages and with the time of the year. During the present study also the mesenteric fat content on individuals from different regions (north, center and south) and from different length classes will be evaluated. In the future, this work should be repeated and accompanied by chemical tests to validate the results obtained and even establish a new mesenteric fat scale for horse mackerel.

MATERIAL AND METHODS

Horse mackerel samples, 3124 individuals (1467 males, 1439 females and 218 unsexed or indeterminate) have been collected off the Portuguese coast (between 41º 49' latitude North and 36º 57' longitude West) in the ports of Matosinhos (north), Peniche (center) and Portimão (south) (Fig. 1), from landings samples by trawl and polyvalent gears, based on a monthly sampling scheme. The current study samples are from the period between January and December 2015.

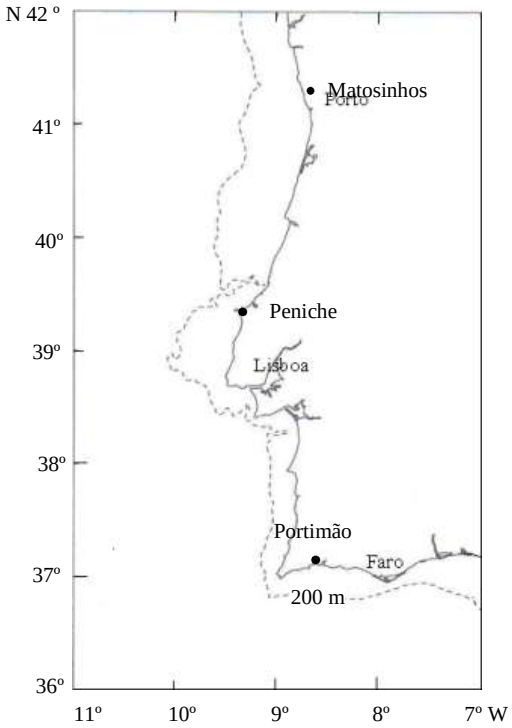

Figure 1 – Location of the sampling ports

Figura 1 – Localização dos portos de amostragem

An average of 260 fish were sampled each month and from each individual total length (TL, 0.1cm accuracy), total weight (TW, 0.01g accuracy) and gutted weight (GW, 0.01g accuracy) were recorded; sex and maturity stages were macroscopically assigned, based on the shape and appearance of the gonads. The assignment of the maturity stage was made according to the 6-stages scale by Walsh *et al.* (1990). (Table 1).

Table 1 – Horse mackerel maturity scale (Walsh *et al.*, 1990)

Tabela 1 – Escala de maturação do carapau (Walsh *et al*., 1990)

Maturity stage		Females	Males
1	Immature	Gonads small. Ovaries wine red and clear, torpedo shaped.	Gonads pale, flattened and transparente.
2	Begining of the development	Gonads occupying ¼ to ¾ of the body cavity. Opaque eggs visible in ovaries giving pale pink to yellowish colouration, largest eggs without oil globule.	Testes off-white, milt not running.
3	Late ripening/partly spent (early)	Gonads occupying ¾ to almost filing body cavity. Ovaries yellow to orange with the presence of opaque eggs. Largest eggs may have oil globules	Testes creamy white.
4	Ripe	Ovaries characterized by externally visible hyaline eggs no matter how few or how early the stage of hydration. Ovaries with hyaline eggs only in the lumen are not included. Ovary size variable from full to ¼.	Testes filling body cavity, milt freely running.
5	Partly spent (late)	Gonads occupiyng ¾ to ¼ body cavity. Ovaries slacker than in stage 3 and often bloodshot. It may have residual eggs (opaque and a few hyalines) in the gonad.	Testes with sperm remains and shrivelled at anus end.
6	Spent / Recovering spent	Gonads occupyind ¼ or less of body cavity. Ovaries reddish and often murky in appearance, sometimes with a scattering or patch of opaque eggs.	Testes opaque with brownish tint and no trace of milt.

The sex-ratio, i.e. the proportion of males and females in the samples was calculated. The identification of the phase of reproductive cycle in each month, was made according to the monthly distribution of the maturity stages observed on the samples. The gonadosomatic index, was determined using the following equation: GSI=Wg/GW*100, with Wg as the gonad weight (grammes) and GW the gutted weight (grammes). The condition factor was determined using Fulton's equation (Fulton, 1902): $K=GW/L^{b}*100$, where GW is the gutted weight (grammes), L is the total length of the fish (centimeters) and *b* is the slope of the length-weight relationship. These indices were calculated for each one of the sampled individuals and furthermore a mean index by month was also estimated.

The amount of mesenteric fat in the body cavity was classified using an empiric scale (Table 2) where each stage depends upon the amount of fat around the gonads and associated with the intestine and stomach, based on the empiric mesenteric fat scale content applied to sardine (Krvarić and Mužinić, 1950).

Table 2 – Mesenteric fat scale applied to *T. trachurus* of the Portuguese coast (according to Krvarić and Mužinić, 1950)

Tabela 2 – Escala de gordura visceral aplicada ao *T. trachurus* da costa portuguesa (de acordo com Krvarić and Mužinić, 1950)

Stage	Description	Plate nr.
1 Lean	Without fat on the digestive tract	1
2 Little fat	A visible fat cord wrapping the digestive tract	2
3 Very fat	Fat involves the entire digestive tract and the abdominal cavity	3

The coefficient of variation (CV) was applied to achieve the precision of the classifications.

The mesenteric fat content was analyzed by length (applying classes with 5 cm range: ≤ 20 cm, 21-25 cm, 26-30 cm and ≥ 31 cm), studied areas, month, maturity stage and fish condition. The results obtained in each one of the three different areas were compared among them to evaluate if there was any pattern of distribution of the fatter or leaner individuals and the results are presented as the proportion of the individuals with each mesenteric fat stage. Given the assumptions that the data are random and independent, with a normal distribution and homogeneous variances, qui square and ANOVA tests were performed, with the SPSS software Social Science Statistics

(https://www.socscistatistics.com), to examine potential statistically significant differences in the mesenteric fat content by sex, length class, fish condition and geographical area.

RESULTS

Monthly length distribution

Figure 2 shows the distribution of total length for both sexes of the sampled individuals by month and port.

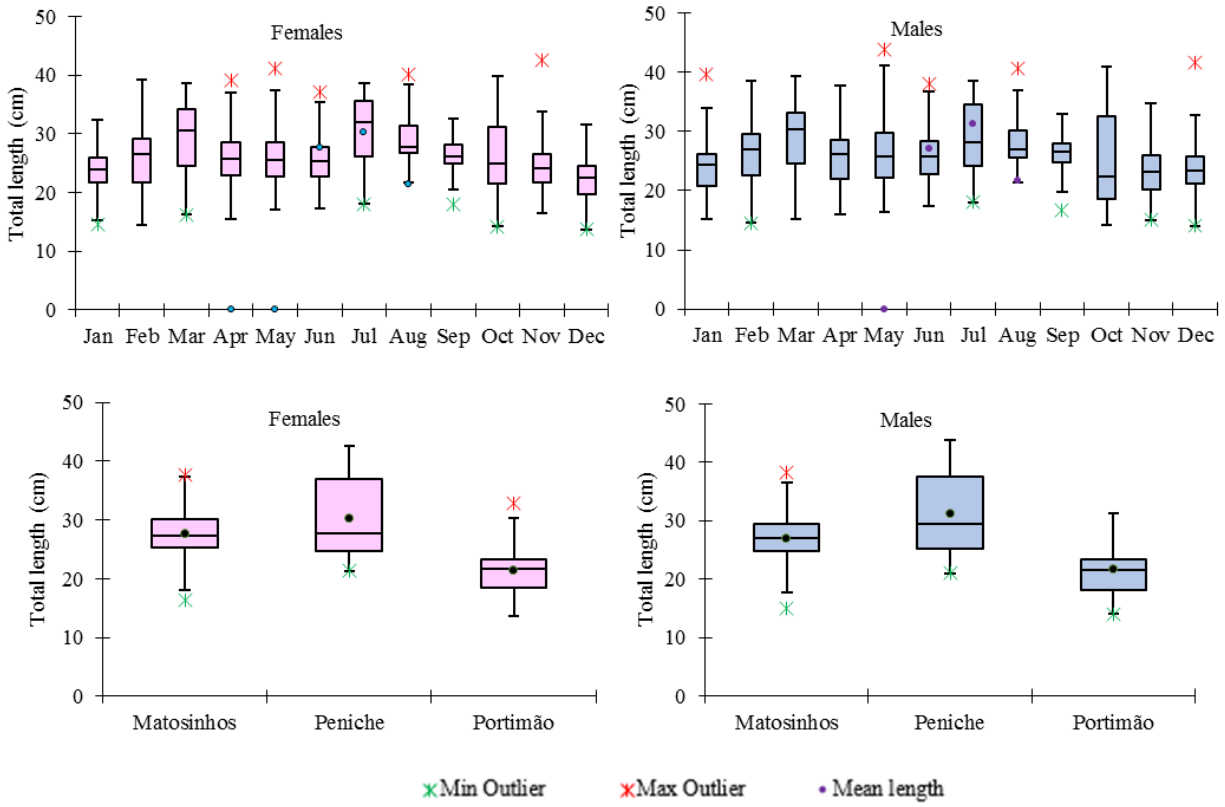

Figure 2 – Length distribution of *T. trachurus* in 2015 by month and port

Figura 2 – Distribuição mensal de comprimentos de *T. trachurus* em 2015 por porto

Mesenteric fat stages assessment

The mesenteric fat content of all specimens was assigned and the corresponding coefficient of variation was obtained with the formula CV=(σ/μ)*100, where σ is the standard deviation and μ is the mean of all the mesenteric fat stages assigned. The results obtained are in Table 3.

Table 3 – Coefficient of variation of observed mesenteric fat content

Tabela 3 – Coeficiente de variação do conteúdo em gordura visceral observada

DP	Média	CV (%)
0.78	1.83	0.43

Sex ratio and mesenteric fat content per sex

From the total 3124 individuals sampled, 2906 specimens (1467 males and 1439 females) were analyzed to determine the sex-ratio. Through the obtained results it can be observed that the sex ratio was always near 1:1 (Figure 3), with a proportion of 1:0.98 in favor of males.

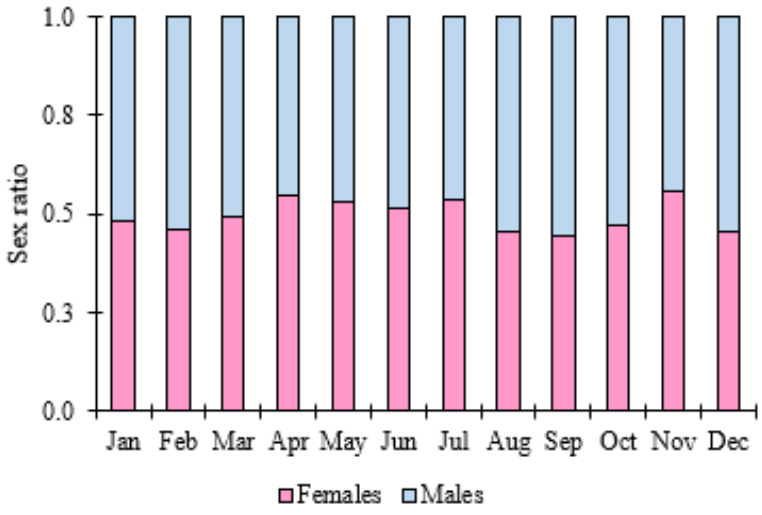

Figure 3 – Sex ratio of *T. trachurus* caught in the Portuguese coast between January and December 2015

Figura 3 – Sex ratio do *T. trachurus* capturado na costa Portuguesa entre Janeiro e Dezembro de 2015

Considering both sexes, there was a non-significant difference in the amount of mesenteric fat (χ^2 = 1.44), with a 95% CI of [0.03, 0.06].

Mesenteric fat content per month and fish length

Figure 4 shows the monthly variation in the mesenteric fat content of each length class for both sexes.

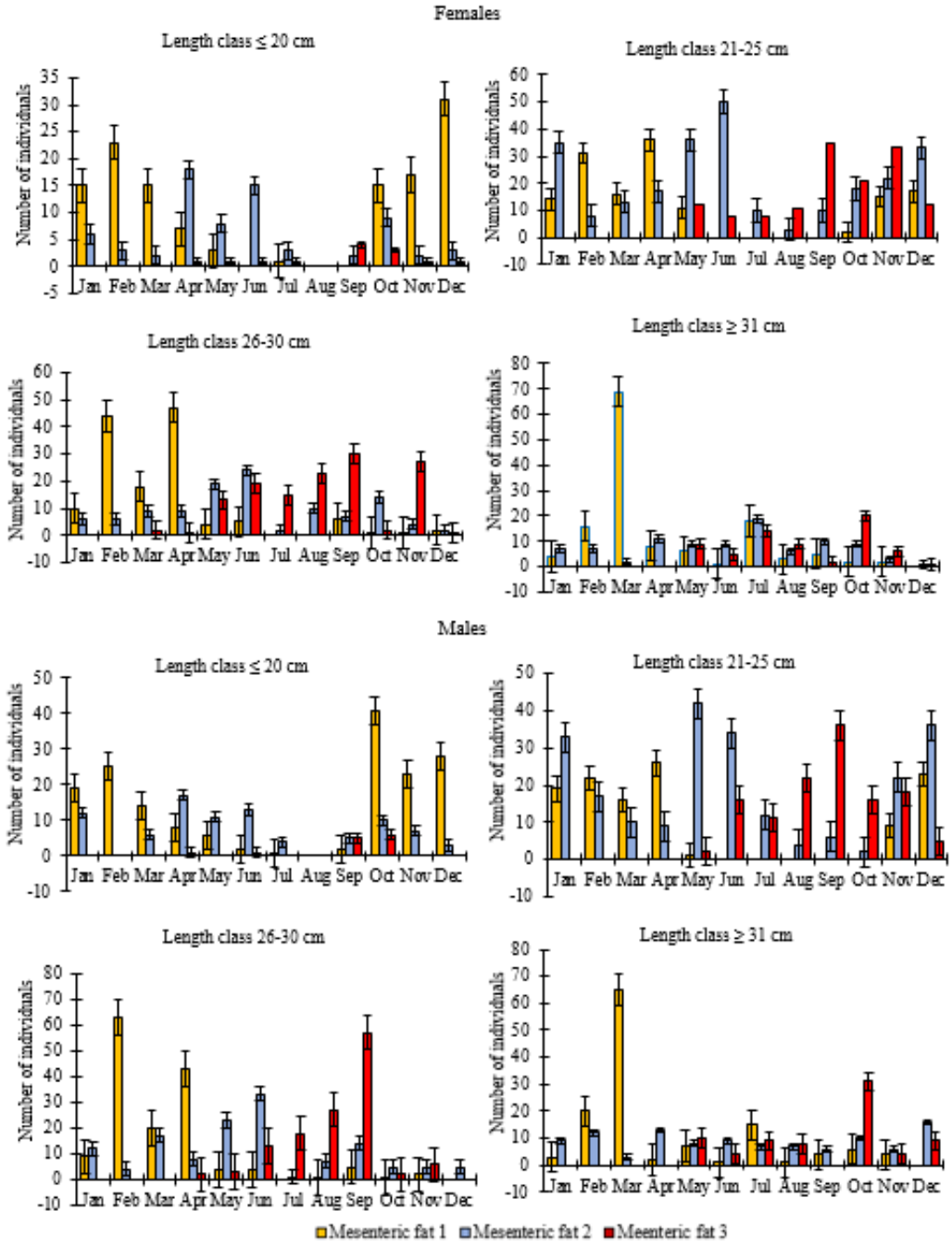

Figure 4 – Mesenteric fat stages of both sexes per length class and per month

Figura 4 – Distribuição mensal dos **e**stados de gordura visceral de ambos os sexos por classe de comprimento

This figure shows that in the first quarter a large number of individuals presented low mesenteric fat content in all length classes. In the last quarter there was also a high number of specimens with small amounts of mesenteric fat, belonging to the classes with less than 25 cm. The summer months from June to September were the ones with the highest number of fish with the greatest amount of mesenteric fat, in particular the specimens of the length classes above 21 cm.

A qui-square test was performed to compare the total amount of all stages of mesenteric fat content in both sexes, considering all length classes, which showed no significant differences: (χ^2 = 1.4438).

At the same time, ANOVA tests were performed to compare the total mesenteric fat content of each sex of all length classes, which showed no significant differences neither in females (F = 2.67) nor in males (F = 0.55). However, considering all individuals of each length class, the result shows significant differences (F = 3.94); the Tukey HSD test (Q test) indicates that the significant difference is between the ≤ 20 cm and 21-25 cm length classes (q = 4.62).

Finally, the same levels of mesenteric fat in the different length classes were compared for each sex and the ANOVA tests resulted in significant differences in female's mesenteric fat 2 (F = 7.167) and mesenteric fat 3 (F = 5.383) and in mesenteric fat 2 in males (F = 3.27), explained by the following results of the Q test:

Sex	Mesenteric fat level	Length classes	q-stat	p-value
Females	2	≤ 20 cm : 21-25 cm	5.80	0.00101
		21-25 cm : 26-30 cm	4.67	0.01011
		26-30 cm : ≥ 31 cm	5.29	0.00293
	3	≤ 20 cm : 26-30 cm	5.41	0.00303
		≤ 20 cm : ≥ 31 cm	4.08	0.03336
Males	2	≤ 20 cm : ≥ 31 cm	0.01	0.00000

Reproductive cycle

The reproductive cycle of a fish species can be described by the monthly distribution of the maturity stages and the gonadosomatic index.

The occurrence per month of each maturity stage of males and females combined is shown in Figure 5 and in Figure 6 are the monthly values of GSI of both sexes.

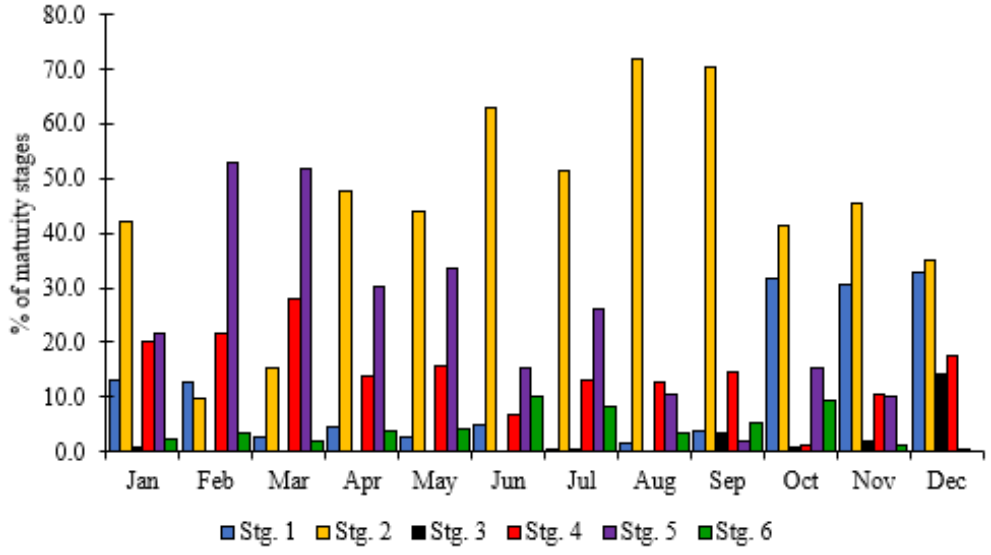

Figure 5 – Distribution by month of the percentages of the maturity stages of *T. trachurus*

Figura 5 – Distribuição mensal das percentagens dos estados de maturação de *T. trachurus*

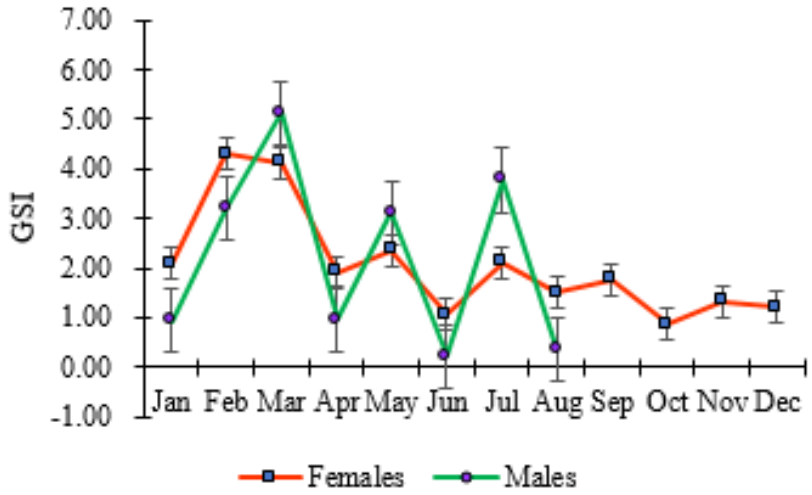

Figure 6 – Monthly values of horse mackerel GSI of both sexes

Figura 6 – Valores mensais do IG de ambos os sexos

Comparing the monthly distributions of the gonadosomatic index and the percentage of maturity stage 4, spawning stage, of sexes combined (Figure 7) we can confirm that the spawning season of horse mackerel occurs mostly in the first quarter of the year, although spawning individuals are found throughout the year.

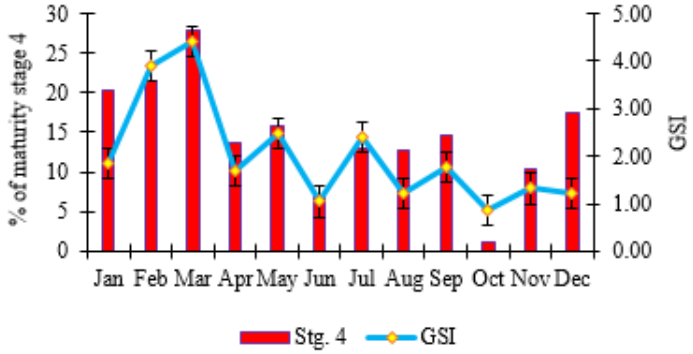

Figure 7 – Spawning season identified by the GSI and the maturity stage 4

Figura 7 – Época de desova identificada pelo IG e pelo estado de maturação 4

Mesenteric fat content vs reproductive cycle

The highest percentage of the leanest specimens was found in the first 4 months of the year, particularly in February and March (spawning season). From May onwards, the proportion of fatter fishes increased considerably, and in the third quarter most fish presented great amounts of mesenteric fat, as shown in Figure 8.

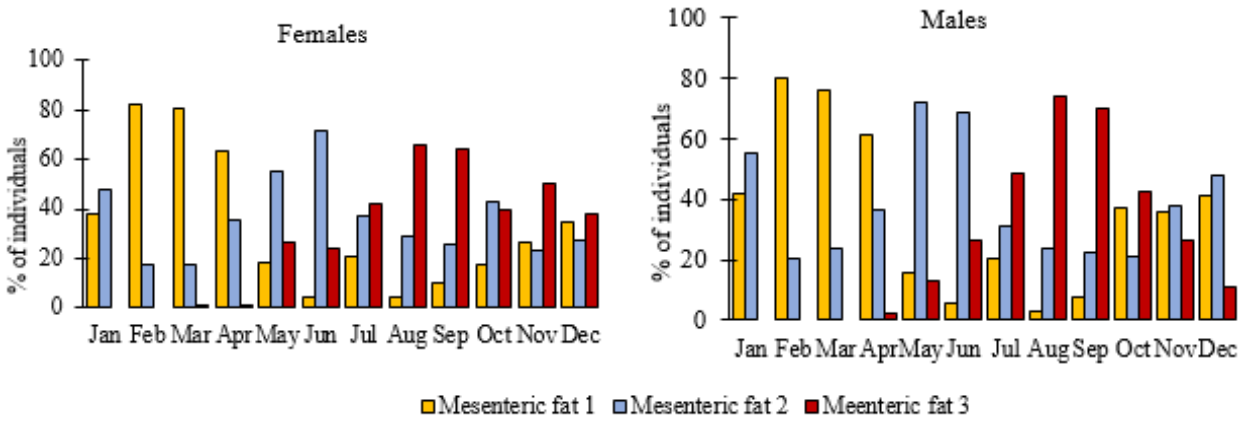

Figure 8 – Percentage of fish with each stage of mesenteric fat by month

Figura 8 – Percentagem mensal de indivíduos com cada estado de gordura visceral

The relation between mesenteric fat and fish maturity stage was evaluated and it was verified that the highest percentage of individuals with higher mesenteric fat content were those in the beginning of the development (maturity stage 2) (Figure 9).

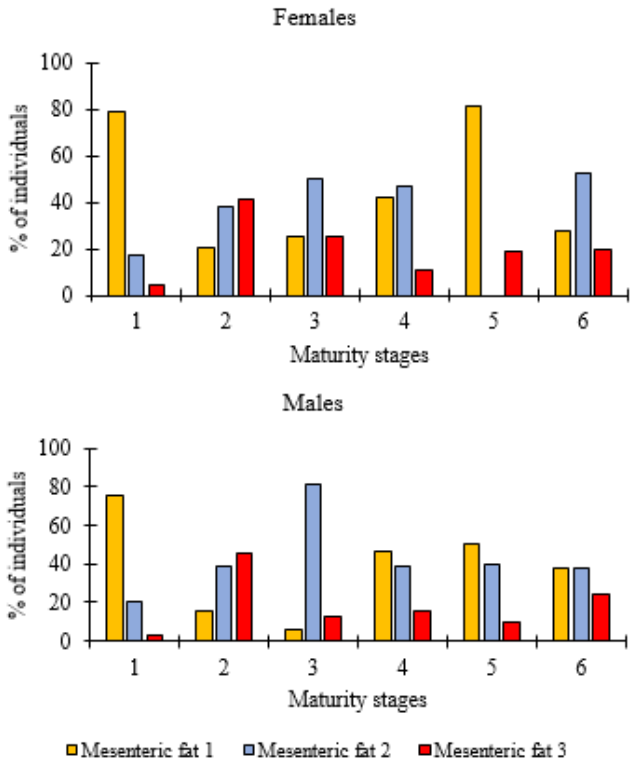

Figure 9 – Mesenteric fat content by sex and maturity stage of horse mackerel

Figura 9 – Conteúdo em gordura visceral por sexo e estado de maturação de carapau

To complement the analysis of the fat content in the horse mackerel reproductive cycle, the GSI was compared with the monthly percentage of individuals with the maximum mesenteric fat content (mesenteric fat 3). In females the highest amount of mesenteric fat 3 in the abdominal cavity was registered between May and December, when the gonadosomatic indices were lower. In males, May and August were the months with higher amounts of mesenteric fat, while from September to December fish became thinner, without presenting stage 3 mesenteric fat (Figure 10).

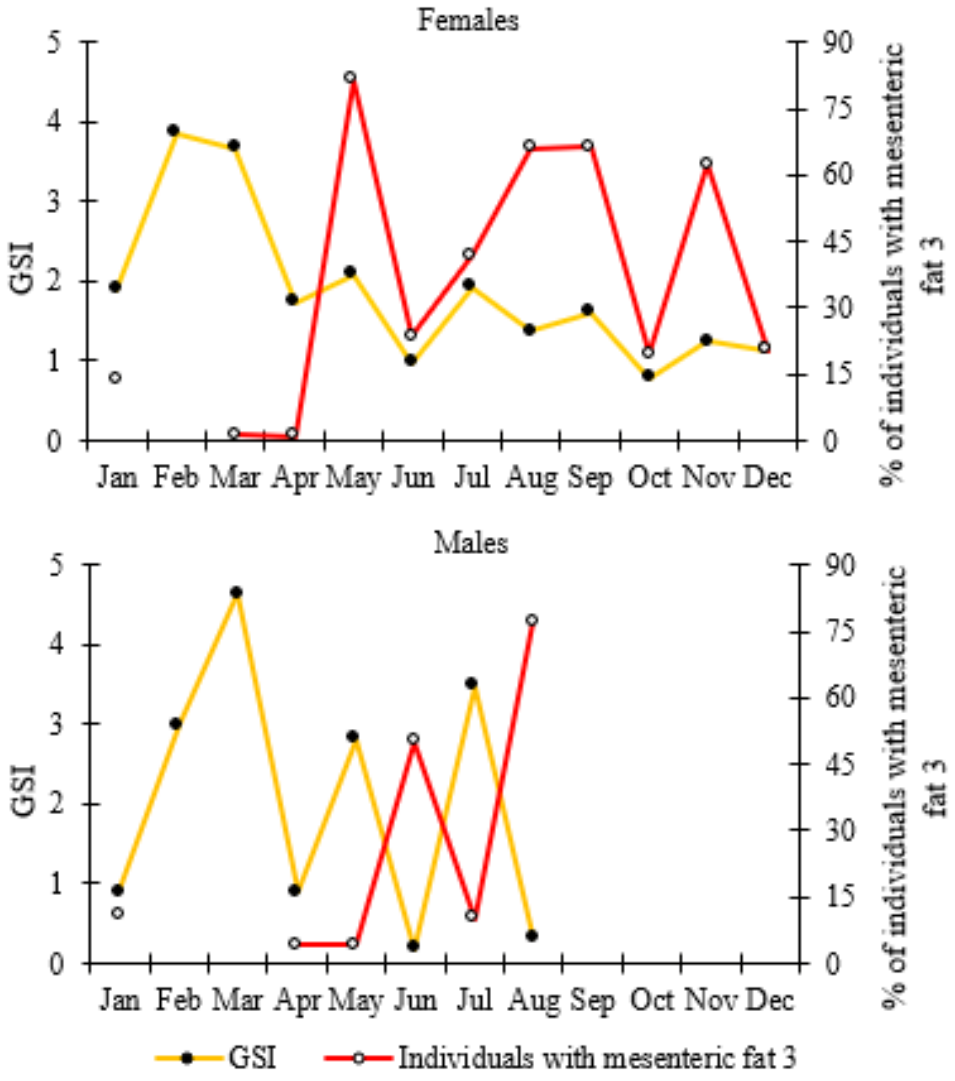

Figure 10 – Distribution of the percentage of GSI and individuals with mesenteric fat 3 by month

Figura 10 – Distribuição mensal da percentagem do IG e de indivíduos com gordura visceral no estado 3

The ANOVA tests applied to the monthly available data from total mesenteric fat (all stages combined) showed significant differences between GSI and the percentage of mesenteric fat in almost every month (Table 4).

Table 4 – Results of the ANOVA tests performed to the monthly data of GSI and the content of mesenteric fat 3 (%) of female *T. trachurus*

Tabela 4 – Resultados dos testes ANOVA aplicados aos dados mensais do IG e do conteúdo em gordura visceral no estado 3 (%) das fêmeas de *T. trachurus*

Month	Females			Males		
	Nr.of fish	*F* value	Correlation type (p<0.05)	Nr.of fish	*F* value	Correlation type (p<0.05)
Jan	111	0.46	Not significant	28	29.41	Significant
Feb	126	109.49	Significant	72	133.4	Significant
Mar	143	120.13	Significant	56	405.59	Significant
Apr	152	4.29	Significant	47	2.50	Not significant
May	129	0.00	Not significant	25	8.10	Significant
Jun	136	122.52	Significant			(1)
Jul	91	2.55	Not significant	20	35.45	Significant
Aug	65	48.10	Significant	22	446.41	Significant
Sep	68	20.59	Significant			(1)
Oct	41	57.06	Significant			(1)
Nov	61	59.77	Significant			(1)
Dec	69	16.87	Significant			(1)

(1) - Without gonad weight

Condition of the fish

The condition factor values obtained with sexes combined also helps to identify the spawning season: the lowest values of Fulton's index were recorded in January and February, followed by an increase thereafter, until reaching their maximum in August-September, decreasing again until December (Figure 11).

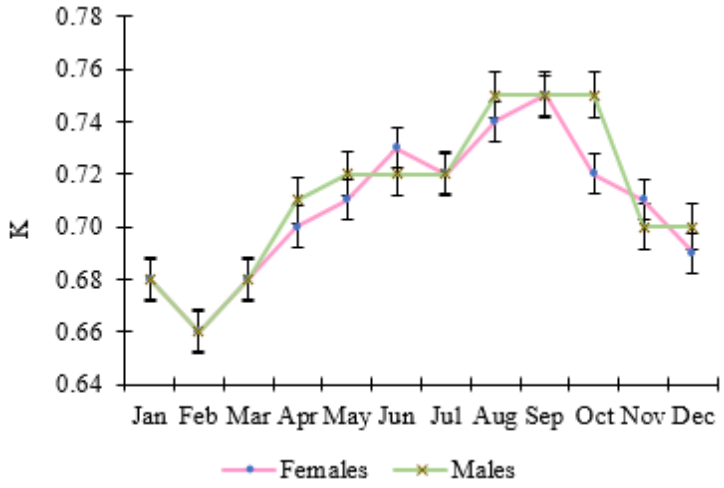

Figure 11 – Monthly values of horse mackerel condition factor

Figura 11 – Valores mensais do factor de condição do carapau

Applying an ANOVA test to compare the condition index (K) and the mesenteric fat content (Figure 12) it was found a statistically significant positive correlation ($F = 4847.17$) between them, with a CI of 0.962-1.018. In January and February there was no mesenteric fat 3 in the viscera, corresponding to the lowest condition of the fish, while between July and September the fish condition and the mesenteric fat content reached their higher values.

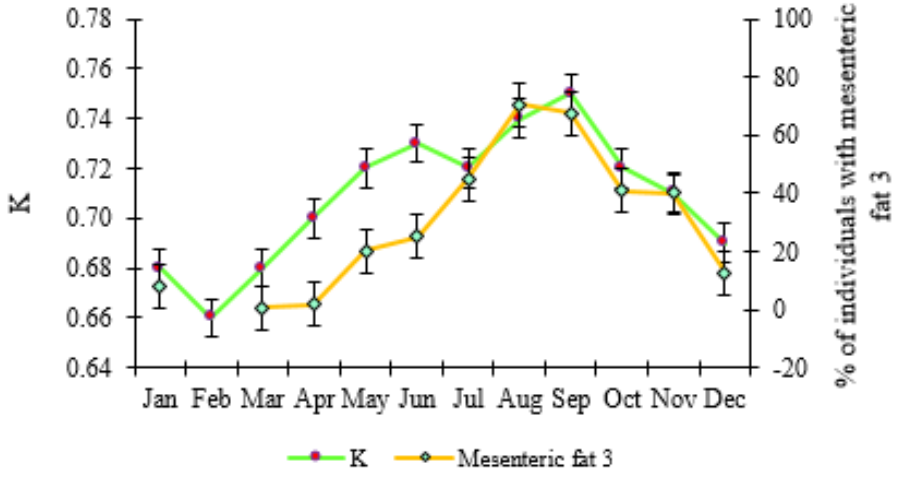

Figure 12 – Monthly distribution of the condition index (K) and percentage of fish with higher mesenteric fat content (stage 3)

Figura 12 – Distribuição mensal do índice de condição (K) e da percentagem de peixes com o teor mais elevado de gordura visceral (estado 3)

Figure 13 shows that, for sexes combined, during the main spawning season of horse mackerel, corresponding to the first quarter, and particularly in February-March, the gonadosomatic index presented the highest values (GSI = 3.89-4.40), while the condition factor was quite low (K = 0.66-0.68). At the same time, the lowest GSI (0.87) and the highest K (0.75) were recorded during the resting period, in October and September, respectively. The ANOVA test performed with the mean monthly results of GSI and K confirm that the differences found in the distribution of the two indices are significant (F = 11.66; CI (1.223, 1.377)).

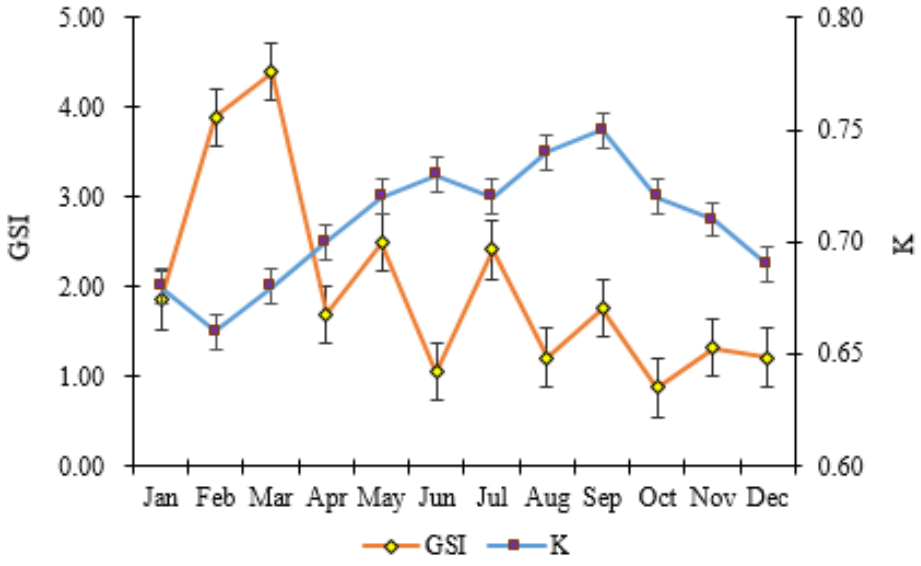

Figure 13 – Monthly distribution of horse mackerel GSI and K

Figura 13 – Distribuição mensal dos valores do IG e do K do carapau

Spatial distribution of mesenteric fat content

Figure 14 shows the monthly variation of the most abundant mesenteric fat content stage in relation to the mean length of the individuals and the correspondent maturity stage.

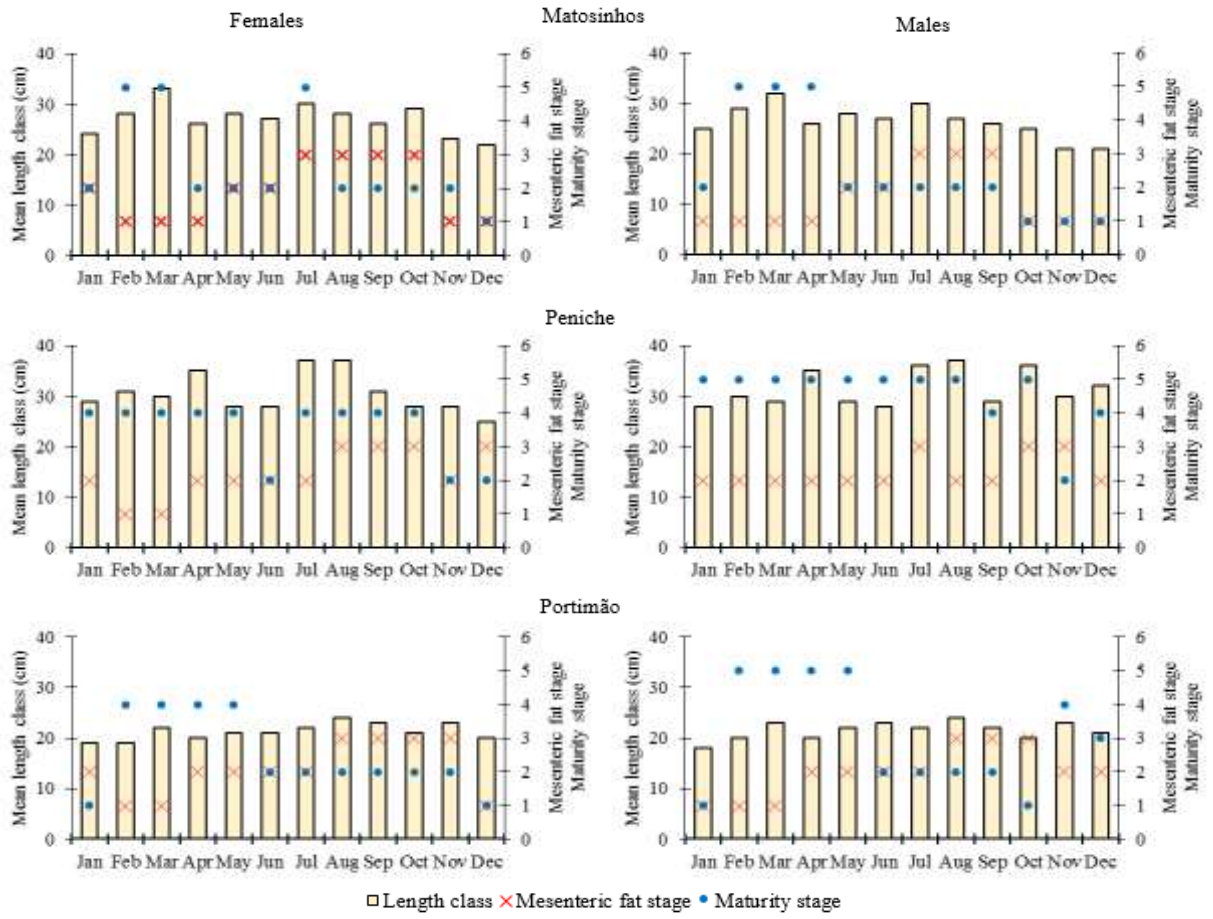

Figure 14 – Mesenteric fat content in relation to mean length and maturity stage, by sampling port

Figura 14 – Relação entre o teor em gordura visceral, o comprimento médio e o estado de maturação por porto

In order to understand if there were significant differences in terms of mesenteric fat content between males and females over the months, a chi-square test was performed, with a significance level of 0.05, to compare the same mesenteric fat levels of males and females from each port.

The applied test indicates that the differences are not significant when considering the total mesenteric fat (Matosinhos – $\chi^2 = 1.870$; Peniche – $\chi^2 = 4.799$; Portimão – $\chi^2 = 4.678$), but analyzing each fat stage by port, significant differences are found in stage 1 ($\chi^2 = 6.605$). A new analysis showed that these differences are between Matosinhos and Peniche ($\chi^2 = 6.539$) and between Peniche and Portimão ($\chi^2 = 4.680$).

DISCUSSION

Sex ratio variations are related to unequal growth rates of growth and mortality (Turner *et al.*, 1983). In our study the sex ratio was very close to 1:1 and the slight predominance of males in winter months and females in spring may have depended on feeding habits, environmental conditions or spawning behaviors. Ouattara et al. (2015) in a study with anchovy from Ivory Coast reported that in winter and with certain atmospheric conditions, females migrate to specific areas, making their capture difficult, which may also explain this 1:1 difference in the sex ratio obtained in this study.

The production and deposition of lipids such as triacylglycerols in the liver, muscles, mesentery or lateral line is responsible for the temporary storage of energy in fish (Hadley, 1985, in Cikeš and Zorica, 2012). Mesenteric fat is the first to be deposited with food intake (McPherson *et al*., 2011) and decreases significantly at the beginning of gametogenesis, being depleted during maturation (Bandarra et al., 2001). This mesenteric fat cycle is reflected in the lower energy content of adult horse mackerel during the winter, when the individuals use the mesenteric fat as an energy store and, at the same time, the gonads enlarge in preparation for spawning. In the summer months, the fish feed and accumulate mesenteric fat again (Cabral and Murta, 2001). The evaluation of the mesenteric fat content carried out in this work and its relationship with the GSI and K helps to characterize the spawning season of horse mackerel on the Portuguese coast: low mesenteric fat content, high values of the gonadosomatic index, the distribution of the spawning stage and the lower values of the condition factor indicate that the peak of the active phase of the reproductive cycle is reached in February-March. In opposition, during the resting season, May to November, the amount of mesenteric fat reaches its maximum values, corresponding to the minimum values of GSI and maximum values of the condition factor.

Similar results were obtained by Bandarra *et al.* (2001) which obtained the percentage of lipids present in horse mackerel from Peniche. These authors also refer that the highest fat content was recorded in August and the lowest in February. Also, Lockwood and Johnson (1977) had already indicated for horse mackerel the peak of mesenteric fat level in autumn, corresponding to the resting season, and the lowest values in the spawning season.

Also for other areas and for other species the results are identical to those obtained by us, presenting the opposite fat cycle to the sexual cycle. In North Eastern Mediterranean Sea higher lipid content was observed in autumn for chub mackerel and horse mackerel, while the lowest lipid content was observed in winter period (Celik, 2008). In the Eastern Middle Adriatic sardines attained highest condition values in the sexually inactive phase of the sexual cycle, during the summer months and the beginning of autumn, containing the lowest values in February (Mustać and Sinovčić, 2009).

However, knowing that the amount of mesenteric fat in different species is affected by several factors, such as, water temperature, food availability, geographic location or reproductive status, the studies conducted in different parts of the world could lead to different results.

As for the distribution of mesenteric fat content by sampling area, it appears that in general there are no differences between the three regions. This could be due to the fact that environmental conditions and food availability, which as indicated are two of the most important factors in the condition of the fish, do not differ much between different locations.

However, the results of a more detailed analysis of the various levels of mesenteric fat in the Peniche region shows different results from the other two areas with regard to the presence of thinner individuals. This is the region with the largest specimens and the greatest length ranges, which may be the reason for having individuals with slightly higher fat contents than in other regions.

Fish biology research, including fish reproduction and feeding studies, are often based on visual techniques, such as the maturity stage of the gonads, depending on the macroscopic appearance (e.g., Abaunza *et al.*, 1995), or the assessment of the stomach fullness (e.g., Cabral and Murta, 2001). These techniques are widely accepted research tools and the accuracy of the visual mesenteric fat staging technique, as demonstrated for instance by van der Lingen and Hutchings (2005) and Mustać and Sinovčić (2009), suggest that the usage of this method may also become widespread.

Throughout this work, individuals with the same mesenteric fat content but in different maturity stages were identified (Plate 4), as well as individuals who, being in the same phase of the reproductive cycle, had different mesenteric fat levels. This may be due to natural variation in the population (Fernandéz-Jover *et al*., 2007) and to the fact that, as horse mackerel is a species with an extended spawning season, gonads can be found in the same stage of development throughout the year, even with different mesenteric fat content.

Although the technique of visually assigning the mesenteric fat stage requires the sacrifice of the fish, preventing this quantification to be monitored over time, the accuracy of this technique allows its application at sea for the evaluation of a large number of fish, spread over wide areas of study.

In spite of precise measurements of fish lipid content, either in laboratory or using a fatmeter, represent the ideal method of assessing the condition of the pelagic fish, the visual assessment of fat content can be applied particularly in studies on spatial variability of spawners and how this may be related to environmental conditions and food availability and subsequent egg production (Van der Lingen and Hutchings, 2005). Knowing that recruitment success is partially dependent on parental status, as has been suggested for pelagic (e.g., Far Eastern sardine, Kawasaki and Omori, 1995; Morimoto, 1996) and demersal (e.g., Barents Sea cod *Gadus morhua*, Marshall *et al.*, 1999) fish stocks this technique may prove to be of great importance.

In biological models that intend to investigate the effect of various biological parameters, such as spatio-temporal spawning patterns (Huggett *et al*., 2003) and egg buoyancy (Parada *et al*. 2003), in the recruitment of the species the data of the amount of mesenteric fat, which can condition the increase in the quality and/or quantity of eggs, could be incorporated. In this case, the collection of these data in surveys taking place at the spawning season may have important implications for species assessment (van der Lingen and Hutchings, 2005).

Regarding the mesenteric fat content of Portuguese horse mackerel, there are no references in the literature to its visual determination. There is only one study on the seasonal variation in the chemical composition of horse mackerel (*T. trachurus*), obtained from the analysis of total lipids and fatty acids (Bandarra *et al.*, 2001), where the authors refer that this species is all year long an adequate element of the traditional Portuguese diet, and contributes to the ω3 intake, as opposed to sardine (*S. pilchardus*), which gains importance only during the phase when it is high in fat.

However, the fact that our results are consistent with those of Bandarra *et al.* (2001) allows us to say that this method seems to be sufficiently reliable to be applied routinely in helping the identification of the spawning season of the *Trachurus trachurus* of the northeast Atlantic and also that there was no change in the main spawning season of horse mackerel of the Portuguese coast.

As stated before, this type of study should be repeated and complemented with biochemical analysis, which would validate the information obtained here, and even develop a specific mesenteric fat scale for horse mackerel. The monitoring of the horse mackerel mesenteric fat is important to determine whether the same trend will continue over a long period of time, especially with regard to global climate change.

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REFERENCES

Abaunza, P., Fariña, A.C., Carrera, P. 1995. Geographic variations in sexual maturity of the horse mackerel, *Trachurus trachurus*, in the Galician and Cantabrian Shelf. *Scientia Marina* 59, 211-222.

Abaunza, P., Gordo, L., Karlou-Riga, C., Murta, A., Eltink, A.T.G.W., García Santamaria, M.T., Zimmermann, C., Hammer, C., Lucio, P., Iversen, S.A., Molloy, J., Gallo, E., 2003. Growth and

reproduction of horse mackerel, *Trachurus trachurus* (carangidae). *Reviews in Fish Biology and Fisheries* 13, 27-61.

Adams, S.M., 1999. Ecological Role of Lipids in the Health and Success of Fish Populations. In: Arts M.T., Wainman B.C. (eds) Lipids in Freshwater Ecosystems. Springer, New York, NY. https://doi.org/10.1007/978-1-4612-0547-0_8

Arruda, L.M., 1982. Aspectos da biologia de *Trachurus trachurus* (Linnaeus 1758) vivendo ao longo da costa portuguesa: as populações, o crescimento e a maturação sexual. Dissertação apresentada à FCL, 407 pp.

Arruda, L.M., 1984. Sexual maturation and growth of *Trachurus trachurus* (L.) along the Portuguese coast. *Investigacion Pesquera*, 48, 419-430.

Bandarra, N.M., Batista, I., Nunes, M.L., Empis, J.M., 2001. Seasonal variation in the chemical composition of horse-mackerel (*Trachurus trachurus*). *European Food Research and Technology* 212, 535-539.

Barraca, I.F., 1964. Quelques aspects de la Biologie et de la pêche du chinchard, *Trachurus trachurs* (L.) de la côte portugaise. *Notas e Estudos do Instituto de Biologia Marítima*, 29, 45 pp.

Borges, M.F., Gordo, L.S., 1991. Spatial distribution by season and some biological parameters of horse mackerel (*Trachurus trachurus* L.) in the Portuguese continental waters (Division IXa). ICES CM 1991/H:54.

Borges, F., Dinis, H., Monteiro, C., 1977. Résultats préliminaires sur la ponte, composition des tailles et état du stock du chinchard (Trachurus trachurus L.) de la côte continentale portugaise. ICES CM 1977/J:14.

Cabral, H.N., Murta, A.G., 2001. The diet of blue whiting, hake, horse mackerel and mackerel off Portugal. *Journal of Applied Ichthyology* 18, 14-23.

Celik, M., 2008. Seasonal changes in the proximate chemical compositions and fatty acids of chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*) from the north eastern Mediterranean Sea. *International Journal of Food Science and Technology*, 43, 933-938.

Cikeš Keč, V., Zorica, B., 2012. Mesenteric fat and condition of chub mackerel, *Scomber colias* in the Adriatic Sea. *Ribarstvo*, 70 (1): 19-30.

Costa, A.M., 2001. Contribuição para o estudo da fecundidade temporal e espacial do carapau (*Trachurus trachurus* L.) na costa portuguesa. Dissertação original apresentada para acesso à Categoria de Investigador Auxiliar. IPIMAR, 2001, 180 pp.

Fernandéz-Jover, D., Jimenez, J.A.L., Sanchez-Jerez, P., Bayle-Sempere, J., Casalduero, F.G., Lopez, F.J.M., Dempster, T., 2007. Changes in body condition and fatty acid composition of wild Mediterranean horse mackerel (*Trachurus mediterraneus*), Steindachner, 1868) associated

to sea cage fish farms. *Marine Environmental Research*, 63 (1): 1-18.

Fulton TW (1902) The rate of growth of fishes. 20th Annual Report of the Fishery Board of Scotland 1902 (3):326–446

Hardy, R., Keay, J.N., 1972. Seasonal variations in the chemical composition of Cornish mackerel, *Scomber scombrus* (L), with detailed reference to the lipids. *Journal of Food Technology* 7, 125-137.

Huggett, J. A., Fréon, P., Mullon, C., P. Penven, 2003. Modelling the transport success of anchovy *Engraulis encrasicolus* eggs and larvae in the southern Benguela: the effects of spatio-temporal spawning patterns. *Marine Ecology Progress Series* 250, 247–262.

ICES, 2017. Report of the Benchmark Workshop on Pelagic Stocks. ICES CM 2017/ACOM:35.

INE, 2020. Instituto Nacional de Estatística - Estatísticas da Pesca: 2019. Lisboa: disponível na www: <url:https://www.ine.pt/xurl/pub/435690295>. ISSN 0377-225-X. ISBN 978-989-25-0540-4.

Kawasaki, T., Omori, M., 1995. Possible mechanisms underlying fluctuations in the Far Eastern sardine population inferred from time series of two biological traits. *Fisheries Oceanography* 4, 238–242.

Krvarić, J., Mužinić, R., 1950. Investigation into the fat content in the sardine tissues (*Clupea pilchardus* Walb.). *Acta Adriatica* 33, 1-26.

Lockwood, S.J., Johnson, P.O., 1977. Horse mackerel. *Laboratory leaflet*, 38, 17 pp.

Marshall, C.T., Yaragina, N.A., Lambert, Y., Kjesbu, O. S., 1999. Total lipid energy as a proxy for total egg production by fish stocks. *Nature* 42, 288–290.

McPherson,L., Slotte, A., Kvamme, C., Meier, S., Tara Marshall, C., 2011. Inconsistencies in measurement of fish condition: a comparison of four indices of fat reserves for Atlantic herring (*Clupea harengus*). *ICES Journal of Marine Science*, 68 (1): 52–60.

Morimoto, H., 1996. Effects of maternal nutritional conditions on number, size and lipid content of hydrated eggs in the Japanese sardine from Tosa Bay, southwestern Japan, in Watanabe, Y., Yamashita, Y. and Y. Oozeki (Eds), Survival Strategies in Early Life Stages of Marine Resources. A. A. Balkema, Rotterdam, pp. 3–12.

Mustać, B., Sinovičić, G., 2009. Comparison of mesenteric and tissue fat content in relation to sexual cycle of the sardine, *Sardina pilchardus* (Walb., 1792), in the eastern Middle Adriatic fishery grounds (Croatia). *Journal of Applied Ichthyology* 25, 595–599.

Ouattara, S.; Bamba, Y.; Karamoko, M. e Fantodji, A., 2015. Aspects macroscopiques de la reproduction de *Engraulis encrasicolus* (Pisces, Engraulidae) sur le littoral-ouest de la Côte d'Ivoire. *Afrique SCIENCE*, 11 (3): 101-114.

Parada, C., Van der Lingen, C.D., Mullon, C., Penven, P., 2003. Modelling the effect of buoyancy on the transport of anchovy (*Engraulis capensis*) eggs from spawning to nursery grounds in the southern Benguela: an IBM approach. *Fisheries Oceanography* 12, 170–184.

Santos, A.M.; Borges, M.F. e Groom, S., 2001. Sardine and horse mackerel recruitment and upwelling off Portugal. *ICES Journal of Marine Science,* 58: 589-596.

Turner, S.C., Grimes, C.B., Able, K.W., 1983. Growth, mortality, and age ⁄ size structure of the fisheries for the tilefish, *Lopholatilus chaemaelonticeps*, in the middle Atlantic-Southern New England region. *Fishery Bulletin* 81, 751–763.

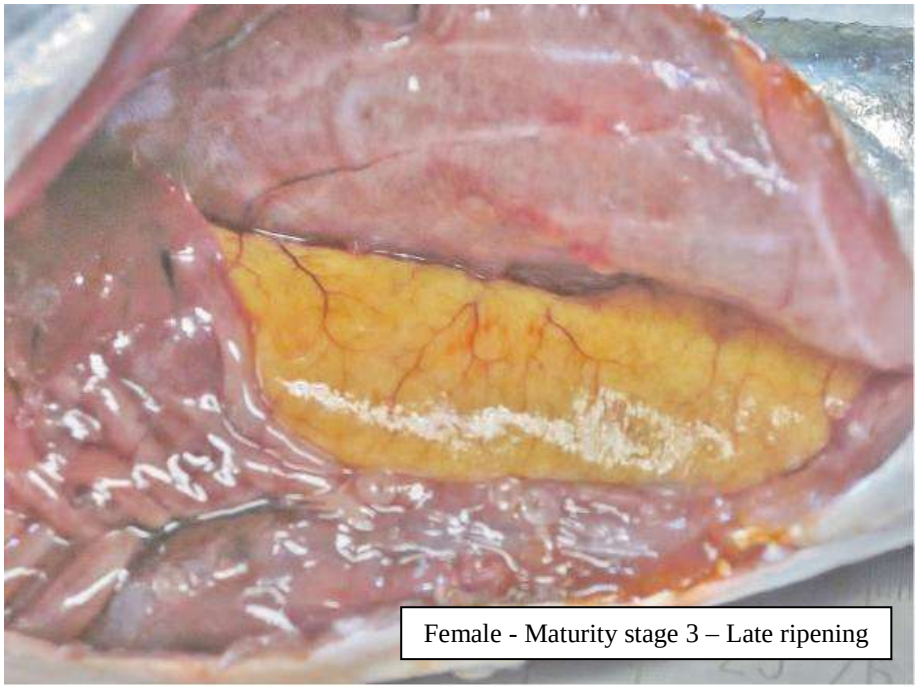
Van Damme, C., Thorsen, A., Fonn, M., Alvarez, P., Garabana, D., O'Hea, B., Perez, J.R., Dickey-Collas, M., 2014. Fecundity regulation in horse mackerel. *ICES Journal of Marine Science*, 71, 546-558.

Van der Lingen, C.D., Hutchings, L., 2005. Estimating the lipid content of pelagic fish in the southern Benguela by visual assessment of their mesenteric fat. *African Journal of Marine Science* 27, 45-53.

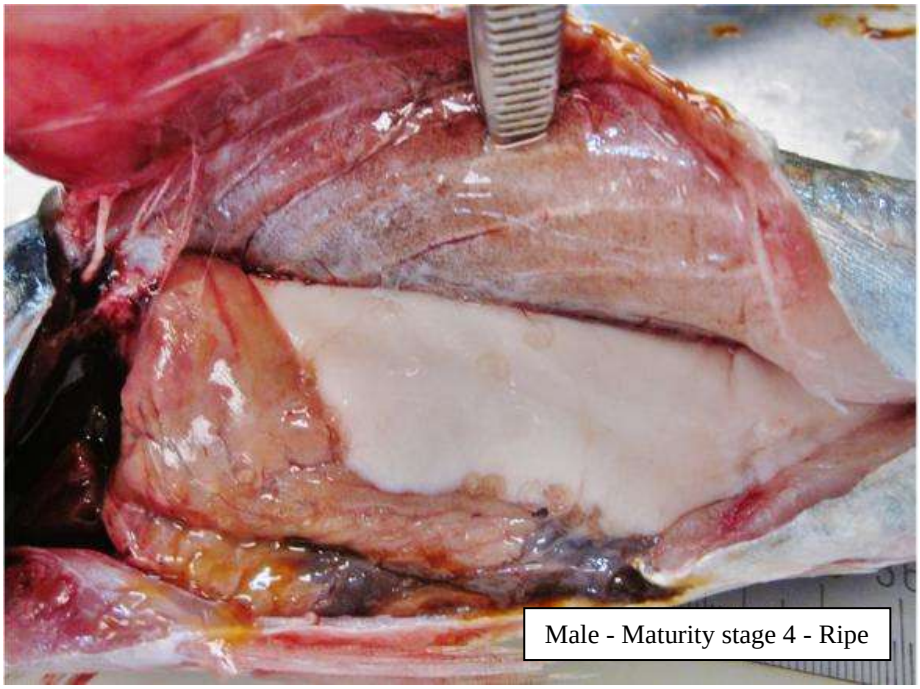
Walsh, M., Hopkins, S. P., Witthames, P.; Greer-Walker, P. and Watson, J., 1990. Estimation of total potential fecundity and atresia in the western mackerel stock, 1989. ICES CM 1990/H:31.

Plate 1 – Mesenteric fat stage 1

Quadro 1 – Estado 1 de gordura visceral



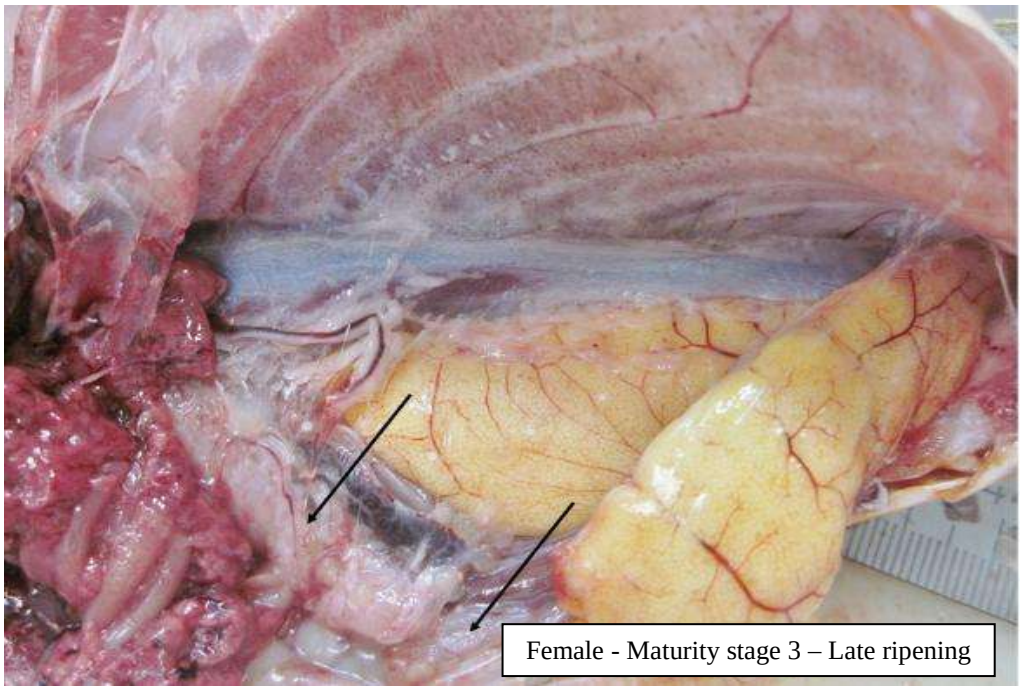
Female - Maturity stage 3 – Late ripening



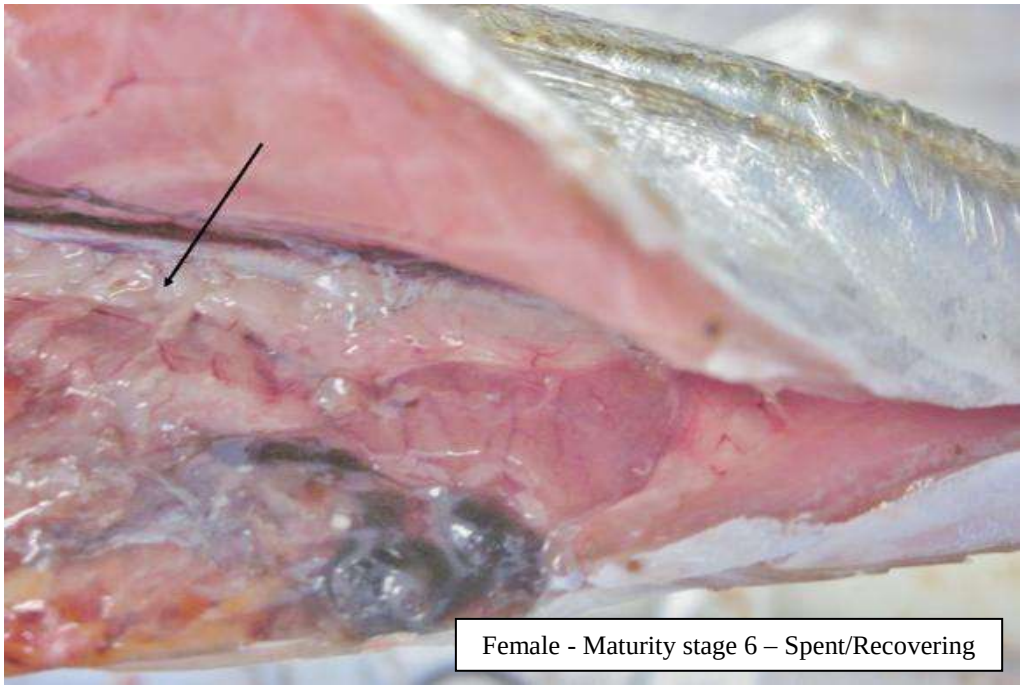
Male - Maturity stage 4 - Ripe

Plate 2 – Mesenteric fat stage 2 (black arrows indicate presence of mesenteric fat)

Quadro 2 – Estado 2 de gordura visceral (as setas pretas indicam a presença de gordura)



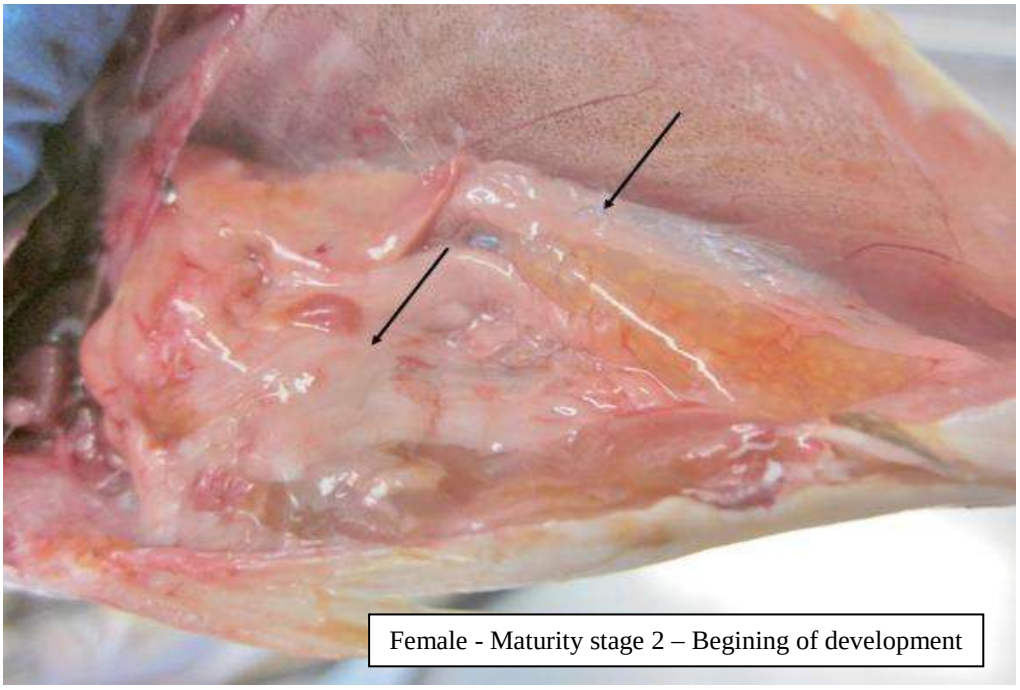
Female - Maturity stage 3 – Late ripening



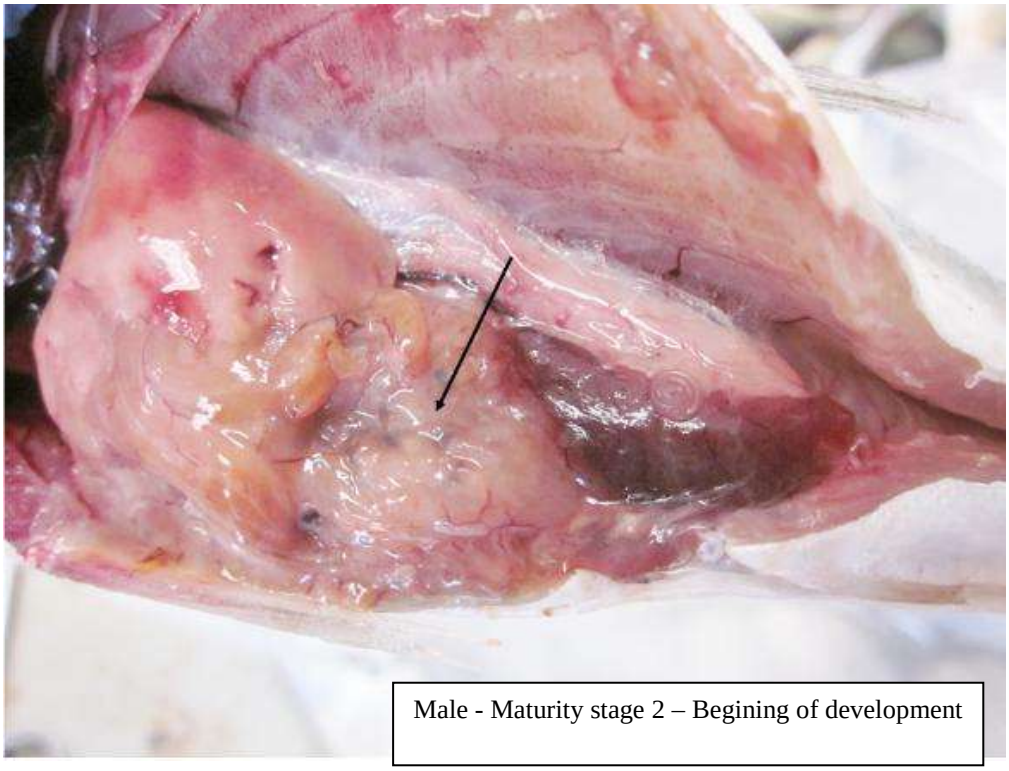
Female - Maturity stage 6 – Spent/Recovering

Plate 3 – Mesenteric fat stage 3 (black arrows indicate presence of mesenteric fat)

Quadro 3 – Estado 3 de gordura visceral (as setas pretas indicam a presença de gordura)



Female - Maturity stage 2 – Begining of development



Male - Maturity stage 2 – Begining of development

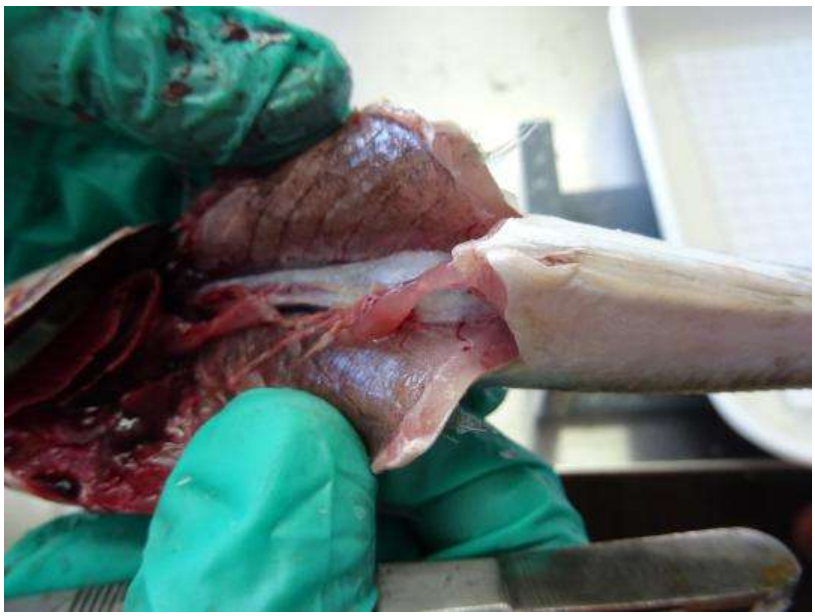
Plate 4 – Some examples of the same mesenteric fat stage in different maturity stages

Quadro 4 – Alguns exemplos do mesmo estado de gordura visceral em diversos estados de maturação

Mesenteric fat 1

Female – Maturity stage 1

Female – Maturity stage 2



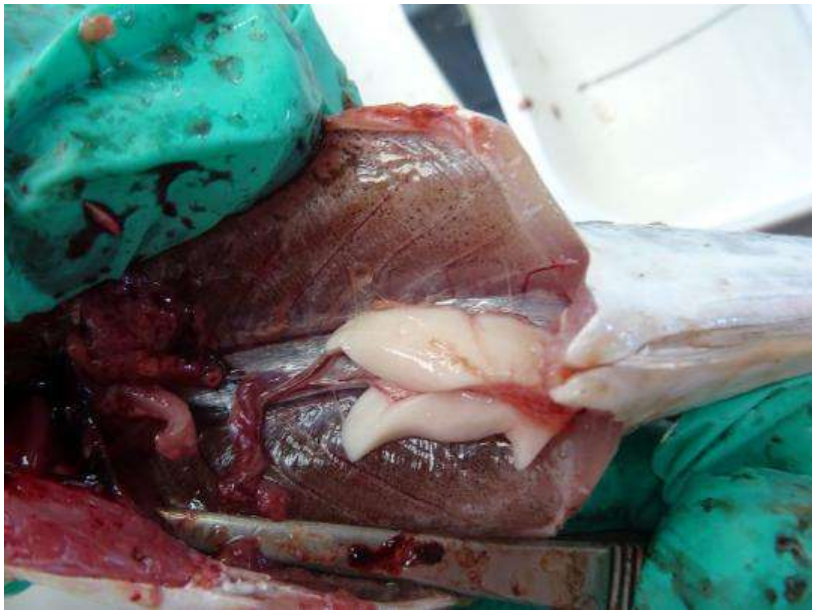
Female – Maturity stage 3

Female – Maturity stage 5

Male – Maturity stage 1

Male – Maturity stage 2

Male – Maturity stage 3

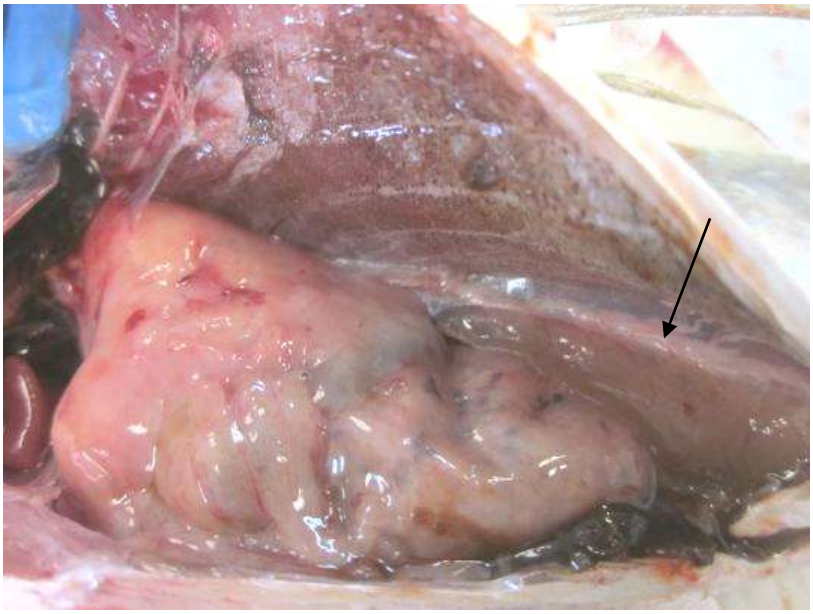


Male – Maturity stage 5

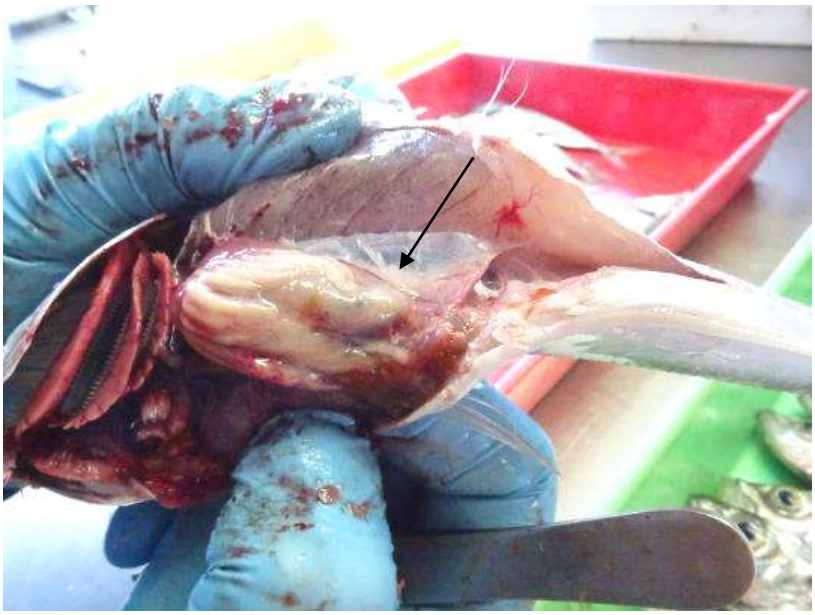
Mesenteric fat 2 (black arrow indicates presence of mesenteric fat)

Female – Maturity stage 2

Female – Maturity stage 5

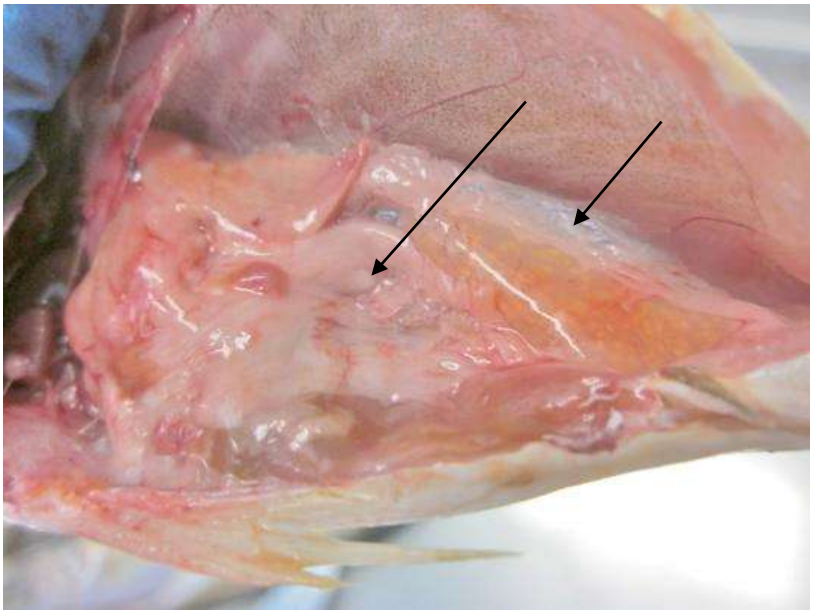


Male – Maturity stage 2

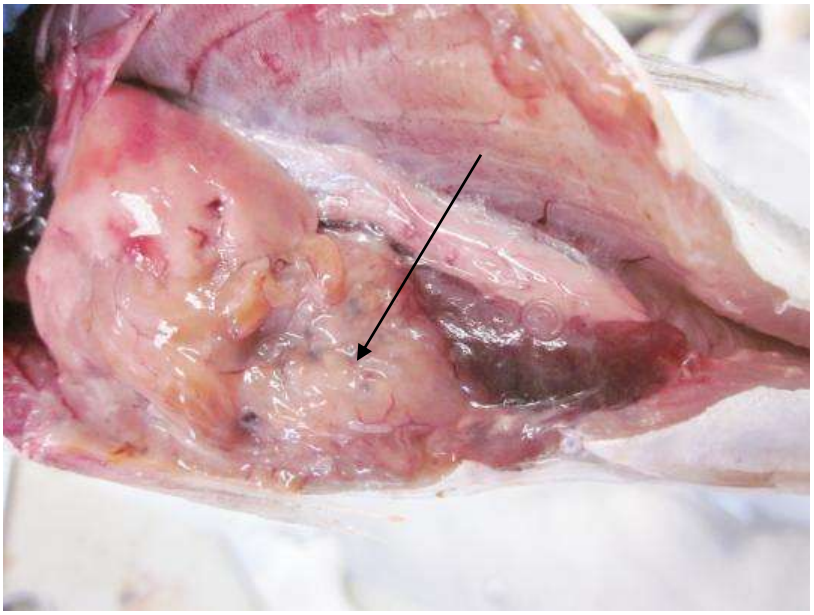


Mesenteric fat 3 (black arrows indicate presence of mesenteric fat)

Female – Maturity stage 2



Male – Maturity stage 5

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