

JULIANA CRISTINA FERREIRA RODRIGUES

**Age, growth and reproductive biology of
the tub gurnard (*Chelidonichthys
lucerna*) in North-East Portugal**



UNIVERSIDADE DO ALGARVE

Faculdade de Ciências e Tecnologia

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Dissertação efetuada sob a orientação científica do
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do Prof. Doutor Karim Erzini (Coorientador: UAlg/CCMAR)



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Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

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(Assinatura)

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Resumo

Chelidonichthys lucerna, ou cabra-cabaço como é vulgarmente conhecida em Portugal, é uma espécie piscícola marinha e demersal pertencente à família *Triglidae*. Os indivíduos pertencentes a esta família são vulgarmente denominados como ruivos. Nas águas do Atlântico Nordeste existem oito espécies identificadas, embora apenas seis sejam frequentemente comercializadas, sendo *C. lucerna* uma dessas espécies. Esta espécie tem uma distribuição geográfica bastante ampla, sendo que pode ser encontrada no Oceano Atlântico, à exceção das regiões arquipelágicas da Madeira e dos Açores, e ainda nos mares Mediterrâneo e Negro. Ocorre em águas pouco profundas, entre os 20 m e os 300 m, e com temperaturas compreendidas entre os 8°C e os 24°C. Durante a primavera e o verão, encontram-se em águas mais rasas, mas no inverno migram para águas ligeiramente mais profundas. Esta espécie tem características morfológicas e merísticas marcantes, em particular a coloração das suas barbatanas, que a permitem distinguir das restantes espécies congênicas. Relativamente à alimentação, *C. lucerna* apresenta um comportamento oportunista, alimentando-se de diferentes tipos de presa ao longo do ciclo de vida. Enquanto os juvenis desta espécie preferem alimentar-se de crustáceos, os organismos adultos alimentam-se preferencialmente de outros peixes. No início da maturação sexual, os indivíduos maiores tendem a migrar para maiores profundidades, alterando o seu regime alimentar. A alimentação também sofre alterações, dependendo da estação do ano, sendo que preferem alimentar-se de peixes no inverno e de crustáceos no verão. Não existem, contudo, diferenças registadas entre a alimentação de machos e fêmeas. *C. lucerna* é uma espécie de crescimento rápido e de vida relativamente longa. Geralmente, as fêmeas são maiores e mais velhas que os machos, sendo comum a ausência de machos nas classes de idade mais avançadas. Relativamente à reprodução, é comum que os machos atinjam a maturidade sexual mais cedo e com menor tamanho, até porque estes apresentam um crescimento mais rápido. Vários estudos apontam para uma época de reprodução bastante extensa, podendo ocorrer ao longo de todo ano, embora com picos de intensidade em épocas particulares, dependendo da localização geográfica. Em termos de proporção sexual é frequente ser encontrado um maior número de fêmeas em relação aos machos na coluna de água. Quanto à pesca, uma grande parte das espécies da família *Triglidae* é rejeitada ainda no mar, uma vez que têm um valor comercial reduzido. No entanto, dentro das espécies desta família, *C. lucerna* é a mais abundante e a que apresenta um maior valor comercial. Embora esta espécie não seja uma espécie-alvo de várias pescarias, é frequentemente uma captura acessória em arrastos de portas. Para a realização deste estudo, um total de 244 indivíduos foram considerados: 180 indivíduos amostrados bimensalmente, entre junho de 2018

e maio de 2019, e capturados pela frota artesanal a operar ao largo de Matosinhos, Nordeste de Portugal, com recurso a redes de emalhar e de arrasto de vara; mais 64 indivíduos provenientes de uma campanha do IPMA que teve lugar durante os meses de janeiro e fevereiro de 2019, capturados através de redes de arrasto de portas. Os indivíduos foram medidos (comprimento total), pesados (inteiros e eviscerados) e os seus índices gonadossomático e hepatossomático foram obtidos. Foi feita a estimativa de idades dos animais por leitura dos anéis de crescimento anual dos otólitos *sagittae*. Fez-se inicialmente a identificação macroscópica do sexo e estadio de desenvolvimento gonadal dos indivíduos, posteriormente confirmado com recurso a cortes histológicos. O comprimento total das fêmeas e machos variou entre 12,3 – 46,2 cm e 13,3 – 30,3 cm, respetivamente. A relação peso-comprimento foi definida separadamente para ambos os sexos, indicando um crescimento alométrico positivo para as fêmeas ($W = 6,39 e^{-6} L^{3,13}$) e um crescimento isométrico para os machos ($W = 8,89 e^{-6} L^{3,02}$). Um total de 225 otólitos foram lidos com sucesso e as idades dos peixes variaram entre 0 e 8 anos, sendo que para as fêmeas as idades variaram entre 0 e 8 anos, e para os machos as idades variaram entre 0 e 4 anos. As bordas dos otólitos também foram analisadas e foi possível verificar uma maior percentagem de bordas opacas nos meses de maio, julho e setembro (primavera-verão), enquanto que uma maior percentagem de bordas translúcidas foi verificada nos meses de novembro, janeiro, fevereiro e março (outono-inverno), sugerindo uma deposição anual dos *annuli*. Durante as amostragens, o número de fêmeas foi sempre superior ao número de machos, apresentando uma proporção sexual de 1.00:0.31. Apenas foi possível encontrar indivíduos imaturos nos meses de maio, julho e setembro. A época de reprodução foi estimada com base numa combinação entre a análise dos valores dos índices gonadossomático e hepatossomático, assim como a identificação do grau de desenvolvimento das gónadas dos indivíduos. Na costa norte portuguesa, a reprodução ocorre preferencialmente entre os meses de novembro e março, com um pico em janeiro. Também foi possível observar um maior número de estômagos vazios durante a época de reprodução, sugerindo que os indivíduos suspendem a sua alimentação na época pré-reprodutiva. O fator de condição parece ser influenciado pela época de reprodução e variou entre 0,80 e 0,89 para maio e setembro, respetivamente. Os parâmetros da equação de crescimento de von Bertalanffy apresentaram diferenças significativas entre machos e fêmeas, sendo estimados como $L_{\infty} = 33,3$ cm e $k = 0,42$ anos⁻¹ para machos e $L_{\infty} = 54,1$ cm e $k = 0,14$ anos⁻¹ para fêmeas. Os valores do comprimento (e idade) de primeira maturação também apresentaram diferenças entre machos e fêmeas, sendo estes estimados como 18,3 cm (e 0,61 anos) e 20,3 cm (e 0,71 anos) para fêmeas e machos, respetivamente.

Palavras-chave: *Triglidae*, proporção sexual, parâmetros de crescimento de von Bertalanffy, comprimento médio de maturação, idade média de maturação

Abstract

The tub gurnard, *Chelidonichthys lucerna*, is an important commercial marine demersal fish species belonging to the *Triglidae* family, which can be commonly found in the north-eastern Atlantic, in the Mediterranean Sea and in the Black Sea. Within the gurnards, *C. lucerna* is the most important species and the one with the greatest economic value in the Portuguese coast. In this study, age, growth, sex and gonadal maturation of *Chelidonichthys lucerna* were determined for the first time in a southern NE Atlantic region, in order to provide essential ecological data on the species. A total of 244 specimens of *C. lucerna* combined between bi-monthly artisanal fishery captures that took place between June 2018 and May 2019, and samples collected in January-February 2019 from a research survey, both in northern Portugal. Total length for males ranged from 13.3 to 30.3 cm and for females from 12.3 to 46.2 cm. The length-weight relationship for males and females combined was defined as: $W = 5.2 e^{-6} L^{3.19}$, indicating a positive allometric growth. The maximum age observed was 4 for males and 8 for females. According to the variation of GSI values and through the histological gonadal development, it was possible to define a protracted spawning season from November to March, with a peak in January. The condition factor was related with the reproduction period and varied seasonally, with minimum and maximum values recorded in May and September, respectively. A high number of empty stomachs was also recorded during the reproduction period, suggesting a behavioural feeding regime change. The overall female to male sex-ratio observed was 1.00:0.31. The von Bertalanffy growth parameters were estimated as $L_{\infty} = 33.3$ cm and $k = 0.42$ year⁻¹ for males and as $L_{\infty} = 54.1$ cm e $k = 0.14$ year⁻¹ for females. Males mature at smaller lengths and younger ages ($L_{50} = 18.2$ cm, $A_{50} = 0.61$ years) than females ($L_{50} = 20.3$ cm, $A_{50} = 0.71$ years).

Keywords: *Triglidae*, sex-ratio, von Bertalanffy growth parameters, length at maturity, age at maturity

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1. Introduction

1.1. Fish Ecology

Gurnards or sea robins are small or medium-sized fish that belong to the *Triglidae* family (Fischer *et al.*, 1981). They can be found in different substrates, namely muddy, detritus, rocky, rubble and reef-type bottoms, in waters shallower than 500 meters (Fischer *et al.*, 1981; Papaconstantinou, 1983; Olim and Borges, 2006). They inhabit the continental and insular shelves of tropical and temperate waters around the world (Richards and Jones, 2002; Olim and Borges, 2006).

Gurnards have an elongated body with a large, bony and spiny head. Their colour is variable, but the predominant is red with some grey with a pale belly. Their pectoral fins, where strong colours are usually found, are large and have distinctive marks (Fischer *et al.*, 1981). They also have three free pectoral rays that are used for body support and to search for food in the bottom (Fischer *et al.*, 1981; Muñoz *et al.*, 2002).

Eight species of gurnards occur in the Eastern Atlantic: *Chelidonichthys cuculus* (Linnaeus, 1758), *Chelidonichthys lastoviza* (Bonnaterre, 1788), *Chelidonichthys lucerna* (Linnaeus, 1758), *Chelidonichthys obscurus* (Walbaum, 1792), *Eutrigla gurnardus* (Linnaeus, 1758), *Lepidotrigla cavillone* (Lacepède, 1801), *Lepidotrigla dieuzeidei* (Blanc & Hureau, 1973) and *Trigla lyra* (Linnaeus, 1758) (Hureau, 1986). In the North-East (NE) Atlantic, only six species are frequently commercialized (Rocha *et al.*, 2018), since *L. cavillone* and *L. dieuzeidei* have no commercial value and are discarded because of their small size (Rocha, 2007).

The tub gurnard (*Chelidonichthys lucerna*, Linnaeus, 1758), previously named as *Trigla lucerna*, is a marine, demersal species with a relatively wide geographical distribution in the NE Atlantic, being found from Norway to Mauritania and south of Ghana (Vallisneri *et al.*, 2011; Roncarati *et al.*, 2012; Uyan and Turan, 2017). It can be also found in the Mediterranean Sea and in the Black Sea (Griffiths *et al.*, 2007; Nunoo *et al.*, 2015; Froese and Pauly, 2018) (Fig. 1). However, there are no records of this species in Madeira or Azores archipelagos (Froese and Pauly, 2018). *C. lucerna* is a species with a coastal and benthic distribution, usually found at shallow depths, generally between 20 and 300 meters, but is more frequently caught between 20 and 150 meters (Işmen *et al.*, 2004; Griffiths *et al.*, 2007; ICES, 2010). During spring and summer, they are found in shallower waters, but in winter they migrate to greater depths (Tsimenides *et al.*, 1992). It can be found in waters with temperatures ranging between 8°C and 24°C (Froese and Pauly, 2018).



Figure 1: Distribution map of *Chelidonichthys lucerna* in the NE Atlantic, Mediterranean and Black Seas. (Source: <https://www.aquamaps.org/>. Downloaded in 2 January 2019).

The body of *C. lucerna* (Fig. 2) is covered by small cycloid scales, the head is large and elongated, with big eyes located on the top of the head. The lateral line is smooth and devoid of spiny scales. The body coloration varies from orange to brown on the back of the head and across the upper body and yellowish on the rest of the body. This species can be distinguished from the other gurnards because of their coloured pectoral fins oscillating between blue and violet with some yellow and blue spots that may disappear with age. Their pectoral fins also have a large black spot on the inner face (Allué *et al.*, 1981; Fischer *et al.*, 1981; Martins and Carneiro, 2015).

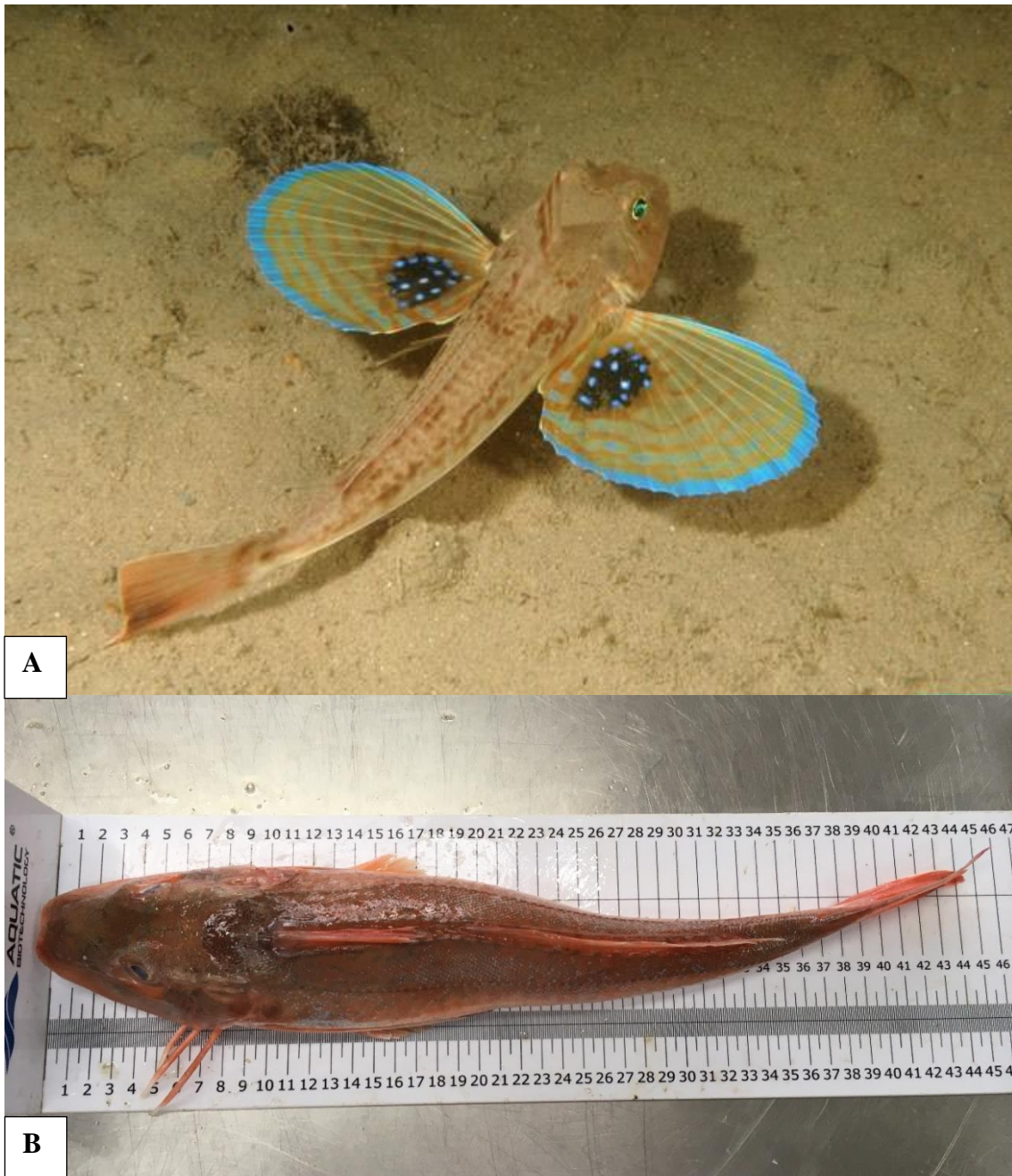


Figure 2: **A)** A photograph of a specimen of *Chelidonichthys lucerna*. (Source: <https://doris.ffessm.fr/Especies/Chelidonichthys-lucerna-Grondin-perlon-875>. Downloaded in 26 July 2019). **B)** A photograph of a 45.4 cm tub gurnard female taken during the November 2018 sampling.

Several studies showed that this species is opportunistic, their trophic spectrum is quite wide and their feeding habits are not species-specific (Montanini *et al.*, 2008; Stagioni *et al.*, 2012). Their diet is mainly based on epibenthic crustaceans and nectobenthic fish, changing during their life cycle, according to their ontogenetic growth (Caragitsou and Papaconstantinou, 1990; Colloca *et al.*, 1994; Morte *et al.*, 1997; Stagioni *et al.*, 2012). While the juveniles prefer

crustaceans, the adults prefer fish (Vallisneri *et al.*, 2011). As individuals became larger, they show a decrease in the number of prey ingested, but an increase in prey weight and size (Colloca *et al.*, 1994). Moreover, an abrupt change in the feeding strategy, when the individuals reach lengths between 14 and 16 cm in Central Mediterranean and at around 18 cm in North-East Mediterranean, which coincides with the first maturity, has been described; this probably occurs because of the higher requirement of energy for gonadal development and reproduction (Colloca *et al.*, 1994; Montanini *et al.*, 2008). Despite this, depending on the location, the feeding regime of the gurnards varies according to the availability of food (Colloca *et al.*, 1994). Their diet also varies according to the season, since they preferentially feed on fish in winter and on crustaceans in summer (Stagioni *et al.*, 2012). However, there are no differences between the feeding regimes of males and females (Stagioni *et al.*, 2012).

Generally, the feeding rate decreases during the spawning season (Caragitsou and Papaconstantinou, 1990). But this pattern was not found for all members of the *Triglidae* family. *C. lastoviza* and *C. obscurus*, for instance, showed a reduction of empty stomachs in spring and summer, the period that corresponds to the spawning season (Boudaya *et al.*, 2007). In the western Mediterranean, it has been reported that the number of empty stomachs for *C. lucerna* remained constant during all the year which indicates that reproductive processes do not influence its feeding behaviour (Morte *et al.*, 1997).

Various studies indicate that the members of *Triglidae* family are species with relatively fast growth and are moderately long-lived (Işmen *et al.*, 2004; Boudaya *et al.*, 2008). Despite this, there are differences between males and females, since females attain larger sizes and live longer than males (Table 1) (Papaconstantinou, 1984; Tsimenides *et al.*, 1992; Boudaya *et al.*, 2008).

Data collected by Papaconstantinou (1984), and İlhan and Toğulga (2007), in Thermaikos Gulf, Greece, and in İzmir Bay, Turkey, respectively, did not find any males in the oldest age groups, indicating that females live longer than males.

Recently, a growth study about *C. lucerna* (McCarthy and Marriott, 2018) demonstrated that k , the von Bertalanffy growth parameter, is greater for males (0.36 year^{-1}) than for females (0.26 year^{-1}) which indicates that males grow faster than females, as observed earlier (Papaconstantinou, 1984). Moreover, Papaconstantinou (1984) reported that in Greek waters, tub gurnard females and males attained, respectively 30% and 55% of their maximum adult size during the first year of life. In the Gulf of Gabès, Tunisia, Boudaya *et al.* (2008)

demonstrated that females and males attained 48% and 75% of their maximum adult size during the first year of life, respectively. In Egyptian waters, El-Serafy *et al.* (2015) report that the males of *C. lucerna* attained 62% of their maximum size in the first year of life, while females only attained 52%.

Table 1: von Bertalanffy growth parameters and maximum estimated age for females (F) and males (M) of *Chelidonichthys lucerna* in different studies. L_{∞} is the asymptotic length, t_0 corresponds to the theoretical age (year) when fish length is zero and k corresponds to the growth coefficient (year⁻¹).

Study	Location	Sex	L_{∞}	k	t_0	Maximum estimated age
Baron, 1985	Bay of Douarnenez, France (NE Atlantic)	F	66.8	0.320	- 0.460	14 years old
		M	48.4	0.462	- 0.410	13 years old
İşmen <i>et al.</i> , 2004	Bay of İskenderun, Turkey (Eastern Mediterranean)	F	45.6	0.223	- 0.602	4 years old
		M	36.0	0.309	- 0.478	3 years old
İlhan and Toğulga, 2007	İzmir Bay, Turkey (Eastern Mediterranean)	F	49.1	0.186	- 1.484	5 years old
		M	31.4	0.447	- 0.886	3 years old
Boudaya <i>et al.</i> , 2008	Gulf of Gabès, Tunisia (Western Mediterranean)	F	46.2	0.050	- 3.030	9 years old
		M	46.1	0.060	- 1.320	7 years old
El-Serafy <i>et al.</i> , 2015	Alexandria, Egypt (Eastern Mediterranean)	F	32.4	0.255	- 1.090	5 years old
		M	29.8	0.274	- 1.360	4 years old
McCarthy and Marriott, 2018	Northwest Wales, UK (North-East Atlantic)	F	50.7	0.260	- 0.330	7 years old
		M	43.9	0.360	- 0.170	5 years old

Previous studies that took place in different geographic areas, showed that *C. lucerna* females predominate over males. For example, in Turkish waters, this ratio (F:M) was defined as 1.40:1.00 and 1.00:0.52, in Bay of İskenderun and İzmir Bay, respectively (İşmen *et al.*, 2004; İlhan and Toğulga, 2007). In Egyptian waters, El-Serafy *et al.* (2015) showed that the sex-ratio was 1.67:1.00.

In Thermaikos Gulf (Greece), there was a decrease in number of females compared to the number of males in spring, that can be justified by the early departure of females to the spawning and nursery areas (Papaconstantinou, 1984). This pattern can also be found in the

Bay of İskenderun, where in December more males than females were found, and this corresponds to the beginning of the spawning season in this area (Işmen *et al.*, 2004).

According to different studies, such as in the waters of the Mediterranean, males of tub gurnard reach maturity with a smaller size and earlier than females (Papaconstantinou, 1984; Işmen *et al.*, 2004; İlhan and Toğulga, 2007) (Table 2). This is a common feature among different fish species, representing an advantage for females because in that way, they can have higher fecundity, produce larger eggs with higher survival rates and have access to best spawning sites due to the large body size (Boudaya *et al.*, 2008; Vallisneri *et al.*, 2012). In Turkish waters, the males and females reach maturity at around 18.0 cm (2 years) and 20.0 cm (2 years), respectively (Işmen *et al.*, 2004). In Gulf of Gabès, Tunisia, maturity is reached at 19.2 cm (1.3 years) for males and 21.6 cm (2.9 years) for females (Boudaya *et al.*, 2008). In the Adriatic Sea, the males reach maturity at 22.1 cm and females at 24.3 cm (Vallisneri *et al.*, 2012). In Egyptian waters, maturity is reached at 15.0 cm (1.21 years) and 15.2 cm (1.4 years) for males and females, respectively (El-Serafy *et al.*, 2015). However, a recent study that took place in the NE Atlantic, reported that females attained maturity in smaller sizes and younger ages than males. L_{50} and A_{50} values were presented as 27.7 cm and 2.7 years old for females and 29.1 cm and 2.8 years old for males (McCarthy and Marriott, 2018).

Moreover, El-Serafy *et al.* (2015) reported that, in Egyptian Mediterranean waters, fish less 13 cm were immature, and fish longer than 20 cm are completely mature. It was also reported by Papaconstantinou (1984) that this species follow a common pattern, reaching 50% of their maximum size before sexual maturation.

Table 2: Length (L_{50}) and age (A_{50}) at first maturity of males (M) and females (F) of *Chelidonichthys lucerna* in different geographic locations.

Study	Location	Sex	L_{50}	A_{50}
Papaconstantinou, 1984	Thermaikos Gulf, Greece (Eastern Mediterranean)	F	31.7 cm	4 years old
		M	26.0 cm	3 years old
Işmen <i>et al.</i> , 2004	Bay of İskenderun, Turkey (Eastern Mediterranean)	F	20.0 cm	2 years old
		M	18.0 cm	2 years old
Eryilmaz and Meriç, 2005	Sea of Marmara (North-East Mediterranean)	F	19.0 cm	3 years old
		M	18.5 cm	3 years old
İlhan and Toğulga, 2007	İzmir Bay, Turkey (Eastern Mediterranean)	F	19.0 cm	Not available
		M	17.7 cm	Not available
Boudaya <i>et al.</i> , 2008	Gulf of Gabès, Tunisia (Western Mediterranean)	F	21.6 cm	2.9 years old
		M	19.2 cm	1.3 years old
Vallisneri <i>et al.</i> , 2011	Adriatic Sea (North-East Mediterranean)	F	25.5 cm	Not available
		M	23.8 cm	Not available
Vallisneri <i>et al.</i> , 2012	Adriatic Sea (North-East Mediterranean)	F	24.3 cm	Not available
		M	22.1 cm	Not available
El-Serafy <i>et al.</i> , 2015	Alexandria, Egypt (Eastern Mediterranean)	F	15.2 cm	1.4 years old
		M	15.0 cm	1.2 years old
McCarthy and Marriott, 2018	Northwest Wales, UK (North-East Atlantic)	F	27.7 cm	2.7 years old
		M	29.1 cm	2.8 years old

The Atlantic and Mediterranean tub gurnards appear to grow at different rates. *C. lucerna* found in the Mediterranean do not attain as large a size as the Atlantic ones and they also mature at smaller size, probably due to the differences in water temperatures (McCarthy and Marriott, 2018).

Among the fish of the *Triglidae* family, a protracted spawning period is a common feature (Boudaya *et al.*, 2008). Thus, the reproduction occurs throughout the year, but with greater incidence at certain times in different regions (Papaconstantinou, 1984) (Table 3). In Turkish waters, for instance, spawning takes place from December to May (Işmen *et al.*, 2004); in the Aegean Sea, reproduction takes place between December and May (İlhan and Toğulga, 2007);

in the Gulf of Gabès it occurs from January to February (Boudaya *et al.*, 2008); and in the Egyptian waters it takes place from November to February (El-Serafy *et al.*, 2015).

Table 3: Spawning season for *Chelidonichthys lucerna* reported in several geographical locations within the Mediterranean Sea.

Study	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Papaconstantinou, 1984 (Eastern Mediterranean)												
Işmen <i>et al.</i> , 2004 (Eastern Mediterranean)												
Eryilmaz and Meriç, 2005 (North-East Mediterranean)												
İlhan and Toğulga, 2007 (Eastern Mediterranean)												
Boudaya <i>et al.</i> , 2008 (Western Mediterranean)												
El-Serafy <i>et al.</i> , 2015 (Eastern Mediterranean)												

Although the Atlantic and Mediterranean tub gurnards have different growth and reproductive biology strategies, the spawning periods in these areas occurs almost at the same temporal window (Papaconstantinou, 1984; McCarthy and Marriott, 2018).

During the early life history stage *C. lucerna* has a pelagic phase: the eggs and the larvae are pelagic, and at around 30 mm the larvae become benthic (Dulčić *et al.*, 2001; Vallisneri *et al.*, 2012; Castellani and Edwards, 2017).

Shallow inshore waters with depths ranging from 10 to 30 m and soft-bottoms, as well as estuarine areas and the mouth of the rivers, are considered nursery areas for *C. lucerna*, and the presence of the younger individuals in these areas is related with the abundance of food (Papaconstantinou, 1984; Serena *et al.*, 1998).

1.2. Tub gurnard fisheries

C. lucerna is one of the most abundant and largest gurnards, and consequently one of the most important commercial species, especially for the European fishing nations that border the Atlantic Ocean and Mediterranean Sea (Hureau, 1986). This species was classified as a potential new species for commercial exploitation in the NE Atlantic in 2006, along with other gurnard species (ICES, 2006). At present, there is no minimum landing size, allowed quotas, fishing closure seasons, or other fishery regulations. Smaller specimens are used for baiting traps to harvest large crustaceans such as lobsters and crabs (ICES, 2013), while the larger ones (> 20 cm) are used for human consumption (Fischer *et al.*, 1981; ICES, 2013).

While most gurnards are not targeted by fishing fleets, they are often caught as by-catch in bottom-trawlers (Fischer *et al.*, 1981). *C. lucerna*, in particular, is caught by the trawler fleets, such as in Spain and Egypt, and through artisanal fleets in other areas where they are present (Griffiths *et al.*, 2007). The main fishing gears used to catch *C. lucerna* are bottom trawls, beam trawls, gillnets, trammel nets, longlines, handlines and beach seines (Griffiths *et al.*, 2007; Rocha *et al.*, 2018).

There has been a steady increase in the landed catches over the last years (McCarthy and Marriott, 2018). A significant decrease in the world commercial catches of this species was observed between 2007 and 2010, ranging from 4255 to 1473 tonnes, respectively. Thereafter, the catches increased during the last years, reaching 3567 tonnes in 2012, 4600 tonnes in 2014 and 8056 tonnes in 2016 (Fig. 3).

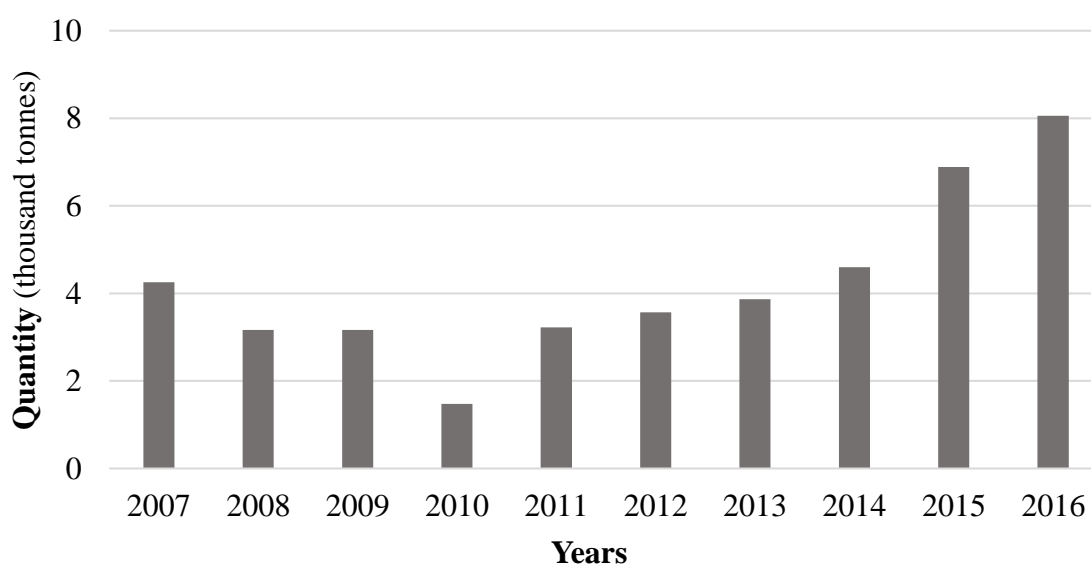


Figure 3: Global capture production of *Chelidonichthys lucerna* in thousand tonnes (Adapted from: <http://www.fao.org/fishery/species/2530/en>. Downloaded in 25 July 2019).

In the Portuguese fish markets, gurnards are often sold under a single commercial category (overall common name: “Ruivos”), meaning that they are not sorted by species (Feijó *et al.*, 2008). According to the Portuguese fishing statistics, between 2009 and 2019, there have been some fluctuations in catches concerning the gurnards; the minimum landings recorded were in 2018 (322 tonnes) and the maximum was in 2014 (432 tonnes) (INE, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020). Furthermore, many fish in the *Triglidae* family are frequently caught by trammel nets in artisanal fisheries, but almost of them are discarded at sea, since they have no commercial value (Olim and Borges, 2006; Batista *et al.*, 2009).

The most exploited species in Portugal are *C. lucerna*, *C. cuculus* and *C. obscurus* (Rocha *et al.*, 2018). But, *C. lucerna* is the most abundant and with higher commercial value (Rocha *et al.*, 2018).

In Portugal, there are no studies about age, growth or reproduction available on this species. However, there is one recently published study on the population structure, using otolith shape and elemental signatures, that showed that *C. lucerna* is apparently a unique, although not necessarily homogenous, single population-unit in mainland Portugal (Ferreira *et al.*, 2019).

Thus, the main objectives of this work are to determine the age, growth and reproductive biology of *C. lucerna* captured in northern Portugal. Ultimately, the aim of the study is to test whether these basic life history parameters, presently unknown for this species in this geographic location, differ from the other fishery grounds, namely in the western Mediterranean, Adriatic Sea and in the Atlantic around the British Isles. This study will be important for further comparisons of these biological traits with studies carried out in other locations. Moreover, the gathered information will be useful to assist the fisheries agencies in making decisions for a rational assessment of tub gurnard fisheries.

2. Material and Methods

2.1. Fish Sampling

A total of 547 individuals, with total lengths ranging between 12.3 and 46.2 cm, were collected along this study. Almost all the samples (n = 457) came from the artisanal fleets operating with gillnets and beam trawls along the northern Portugal. Fish were landed and acquired in Matosinhos, during a period of one year, from June 2018 and May 2019. Ninety additional specimens, caught using bottom trawls, came from Daily Egg Production Method (DEPM) survey done by IPMA's (Instituto Português do Mar e da Atmosfera) that took place between January and February 2019.

The individuals collected by the artisanal fleets were divided by 1 cm size classes, ranging from 20 cm to 45 cm of total length (TL). For each individual, the following data were collected: total length (0.1 cm), fresh and eviscerated weight (0.01 g), liver weight (0.01 g), stomach weight (0.01 g), gonad weight (0.01 g), stomach fullness (from empty to bursting: Cunha *et al.*, 2005), sex and gonadal development stage. The sagittal otoliths and gonads were extracted for further analysis.

For the individuals caught in the IPMA survey, ranging from 12 to 46 cm of TL, the data collected were also the total length (0.1 cm), fresh and eviscerated weight (g), stomach fullness, macroscopic identification of sex and maturation stage of the gonads. Individuals for which it was not possible to identify the sex by visual inspection were considered undetermined (U). For these individuals only the sagittal otoliths were collected for further analysis.

For practical purposes, a total of 180 individuals acquired from fishermen in Matosinhos Harbour, 30 per month, every two months, were randomly selected and considered for analysis. In order to have individuals representing the whole TL range for the species, a total of 64 other individuals were also considered for the age estimation: individuals from the campaign (n=52) and some individuals captured in December (n=12).

2.2. Fish Ageing

To estimate the fish age, the sagittal otoliths of *C. lucerna* were removed, washed with distilled water, dried and stored dry in paper envelopes properly labelled for further analysis. The right otoliths were used for the age readings, except when they were lost or damaged.

Two different ageing techniques exist, at present, for *C. lucerna*. The otoliths can be burned for 2 minutes at around 450°C, until a series of brown rings appear; the translucent zones become brown and the opaque zones stay white. Thereafter, the burned otoliths are read in glycerine or in a mixture of glycerine and alcohol (Papaconstantinou, 1981; İşmen *et al.*, 2004); or the age of the fish is determined by immersing the otoliths in a clearing agent, such as histoclear, and observing them using transmitted light under a low power binocular (Marriott *et al.*, 2010; El-Serafy *et al.*, 2015; McCarthy and Marriott, 2018).

In this study, both techniques were preliminary tested but the first method showed better results in terms of visibility of the annual increments. Thus, the otoliths were burned for approximately 2 minutes at 450°C in a muffle furnace. Thereafter, the otoliths were placed in a petri dish, immersed in a mixture of glycerine and alcohol (1:1), and photographed under a stereomicroscope (Meiji Techno EMZ-13TR) at a magnification of 10× to 20× against a black background. The age was determined assuming that one *annulli*, consisting of opaque and translucent zones, was deposited yearly in the otoliths; the opaque zone appears to be deposited during the period of fast growth (summer) and the translucent zone is formed during the period of slower growth (winter) (Papaconstantinou, 1981; Boudaya *et al.*, 2008; El-Serafy *et al.*, 2015; McCarthy and Marriott, 2018). Moreover, in the otoliths of *C. lucerna* it was necessary to consider that three false increments related with critical periods in the life history of the species can be observed. The first two false increments are deposited before the deposition of the first winter increment and correspond to a pelagic and nursery increment, respectively (Boudaya *et al.*, 2008; Colloca *et al.*, 2003). The third false increment can be considered as the maturity increment and is deposited early in sexual development, close to the size of the first sexual maturation (Colloca *et al.*, 2003). The otoliths were later blind read by three experienced readers. The age was accepted when at least two readers agreed on the annual increments counts. When the readers did not agree by the difference of one year, the median was considered as the age of the fish. In case of all the readers disagreed by more than one year the otolith was considered unreadable. The reading precision was estimated using the coefficient of variation (CV). The type of the otolith edge (opaque vs translucent) was also registered.

2.3. Determination of sex

The sex and the maturity stages of *C. lucerna* were firstly determined through macroscopic visualization of the gonads. These observations were confirmed later by histological observation.

Thus, the gonadal maturity stage was macroscopically identified with a number between 1 and 6, with 1 corresponding to an immature fish, 2 corresponding to early ripening, 3 corresponding to late ripening, 4 corresponding to ripe or spawning, 5 corresponding to partly spent and 6 corresponding to a spent or recovering individual (Walsh *et al.*, 1990). The gonads were then stored in plastic flasks in 4% buffered formaldehyde for further histological analysis. The gonads were dehydrated through increasing concentrations of alcohol, then were embedded in paraffin wax and sectioned at 3-7 μm . The sections were stained with hematoxylin-eosin and examined by light microscopy in order to assign sex and maturity stages according to Brown-Peterson *et al.* (2011). A total of 5 stages were defined: (I) immature, (II) developing, (III) spawning capable, and (IV) and (V) correspond to regressing and regenerating, respectively.

The sex-ratio was determined for the selected samples based on the proportion of females relative to males (F:M).

The gonadosomatic index (GSI) and hepatosomatic index (HSI) were determined according to the formulas $GSI = (W_G / W_E) \times 100$ and $HSI = (W_L / W_E) \times 100$. Prior to the analysis, HSI data were $\log(x+1)$ transformed to comply with normality and homogeneity. The Fulton's condition factor (K) was calculated bi-monthly for overall combined samples, based on the equation: $K = (W_E \times 100) / TL^3$. GSI, HSI and K were analysed with One-Way Analysis of Variance (One-Way ANOVA) followed by a Tukey test, if needed ($p < 0.05$), to infer significant differences among seasons.

2.4. Fish growth curve and length/age at first maturity

The allometric growth equation, $W = a \times TL^b$, was used to describe the length-weight relationship (Ricker, 1975) for both males and females. In this equation, a and b are constants, W corresponds to the total weight (g) and TL corresponds to total length (cm) (King, 2007). If the parameter b is equal to 3 it indicates an isometric growth, if this value is less or greater than 3, then the growth will be negative and positive allometric, respectively (Dutta *et al.*, 2012).

The growth was expressed according to the von Bertalanffy growth curve (VBGC), based on the following equation: $L_t = L_\infty \times (1 - e^{-k(t-t_0)})$. L_t corresponds to the total length (cm) at age t , L_∞ corresponds to the theoretical asymptotic total length, k corresponds to the growth coefficient (year^{-1}) and t_0 corresponds to the theoretical age (years) when the fish length is zero. Undetermined individuals were excluded from the growth modelling analyses. To compare the results between males and females the likelihood ratio test and extra sum-of-squares test were performed (Kimura, 1980; Ritz and Streibig, 2008; Ogle, 2016).

Maturity ogives were used to estimate the length (L_{50} and L_{95}) and age (A_{50} and A_{95}) at maturity as the TL and age at which 50 % and 95% of the males and females were mature. Sexual maturity stages were converted to binary maturity determinations (0 = immature, 1 = mature). Only the individuals identified as stage I were considered immatures; the other ones were considered matures. So, the following logistic model was applied: $PM = P_{MAX} [1 + e^{-\ln(19) \{ (1 - \beta_1)(\beta_2 - \beta_1)^{-1} \}}]^{-1}$, with PM corresponding to the proportion of mature at total length or age, β_1 and β_2 corresponding to the fitted parameters that corresponding to L_{50} and L_{95} or A_{50} and A_{95} , respectively, and P_{MAX} corresponding to the asymptote (Harry *et al.*, 2013). β_1 and β_2 parameters were estimated using a bias-reduction generalized linear model with binomial responses and logit-link (Kosmidis, 2014; Harry *et al.*, 2013).

All the age, growth and reproductive analyses (parameter estimations) were performed using the R packages *Agricolae*, *boot*, *brglm*, *FSA*, *MASS*, *psyphy*, and *nlstools* packages (R Development Core Team, 2017). Statistical analyses were performed using R (R version 3.6.1 (2019-07-05)) and SigmaPlot (version 11.0).

3. Results

3.1. Length distribution and Length-Weight Relationship

A total of 244 specimens ranging lengths between 12.3 and 46.2 cm were selected for the analysis (Fig. 4). Of these, 64 were males, 174 females and 3 were of undetermined sex. TL of males ranged between 13.3 and 30.3 cm. The range was greater for females, between 12.4 and 46.2 cm. The most abundant specimens ranged from 23 to 30 cm length classes (56.1 %). The length classes most common for males and females were 27 and 30 cm, respectively.

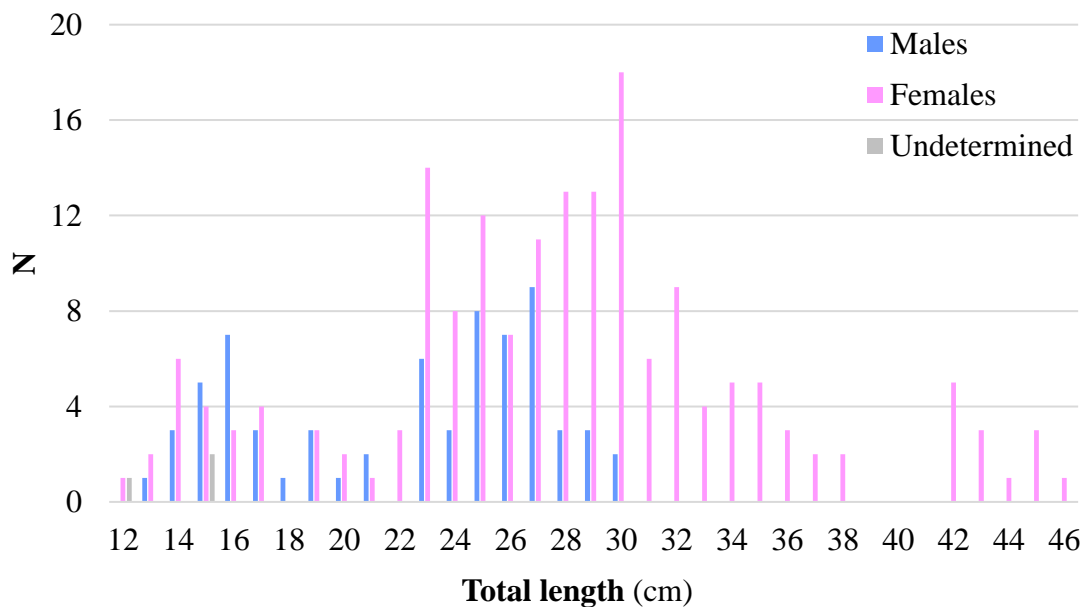


Figure 4: Total length frequency distribution of males, females and undetermined individuals of *Chelidonichthys lucerna*.

The total weight of males and females ranged from 19.0 to 226.5 g and from 16.0 e 990.0 g, respectively. The length-weight relationship was evaluated for males, females and both sexes combined. The equation for the relationship was: $W = 6.61 e^{-6} L^{3.14}$ ($r^2 = 0.98$) for the combined sexes (Fig. 5a). This relationship was also calculated separately for each sex and it was the following: $W = 6.39 e^{-6} L^{3.13}$ ($r^2 = 0.98$) and $W = 8.89 e^{-6} L^{3.02}$ ($r^2 = 0.99$) for females and males, respectively (Fig. 5b, 5c).

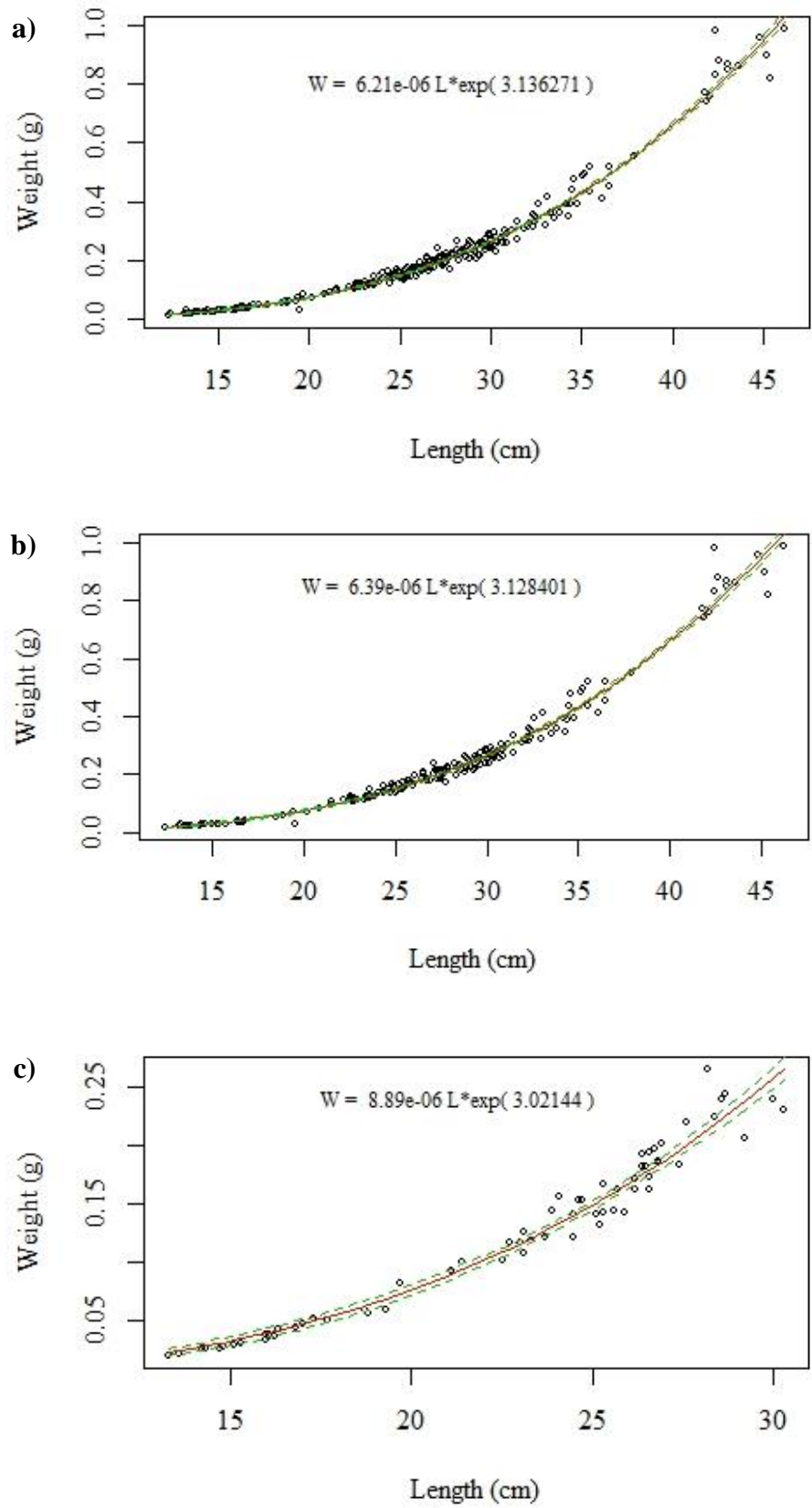


Figure 5: The length-weight relationship of *Chelidonichthys lucerna* samples from the NE Portugal, in Atlantic: **a)** for combined sexes; **b)** for females; **c)** for males.

3.2. Age determination

Of the 244 otoliths selected for age readings, 225 (92.2%) were successfully read and the coefficient of variation showed a high precision in the readings ($CV = 4.69\%$). Age estimation through the burned otoliths ranged from age class 0 to 8 regarding the overall individuals (Fig. 6). Undetermined individuals were only found at age 0. The number of individuals between age classes 5 and 8 was quite small, and no males were found in the older ages. The best represented age classes were the age classes 1 and 2 for females and males, respectively.

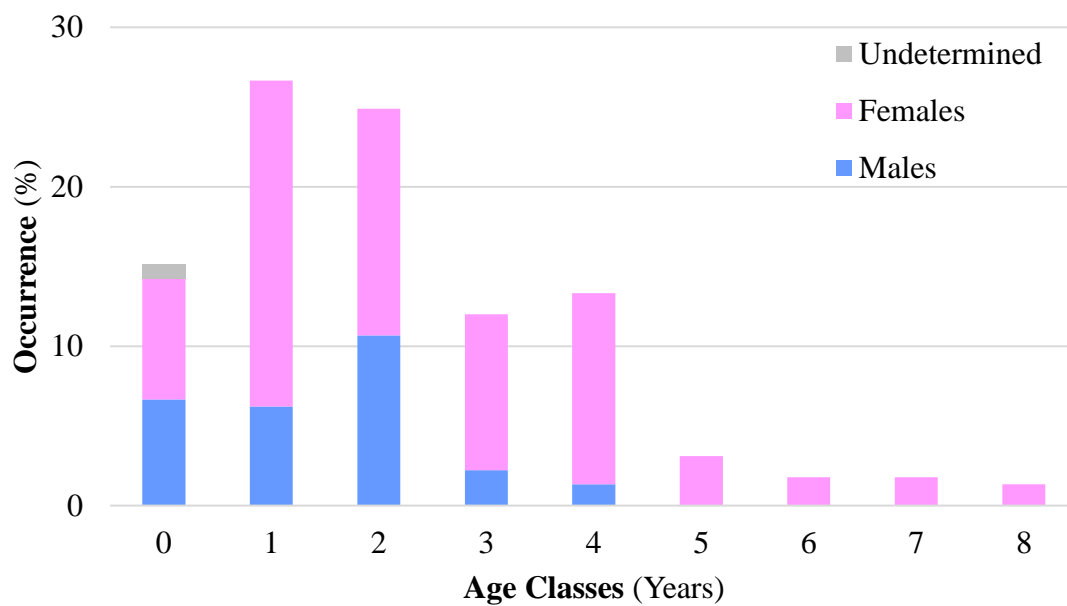


Figure 6: Percentage of individuals distributed by age classes.

After burning, it was possible to notice an improvement in the visibility of the translucent rings and increments, highlighted in brown (Fig. 7).

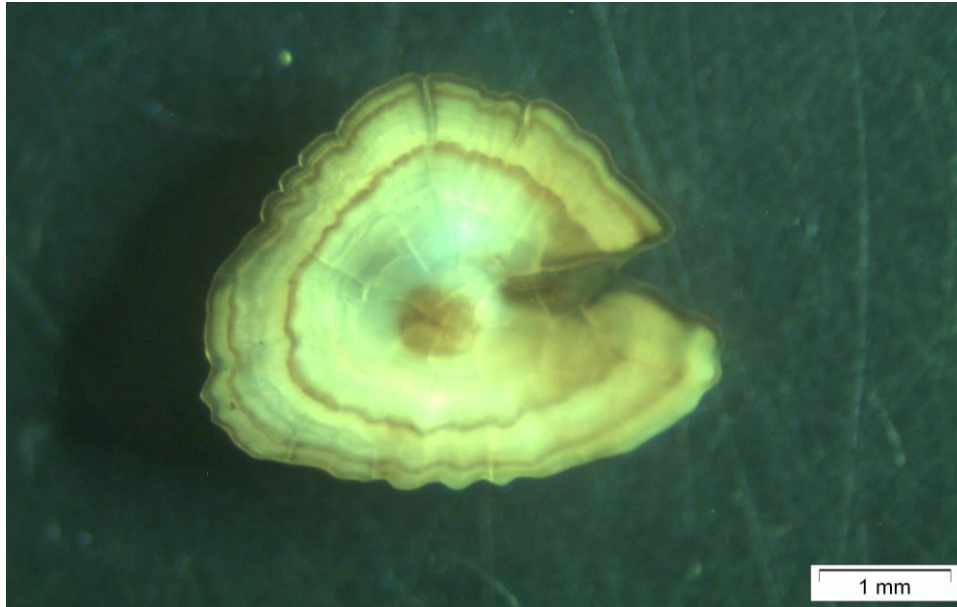


Figure 7: Photograph of a burned otolith from a 24.4 cm *Chelidonichthys lucerna* female aged as 3+ with an opaque margin. Captured in July 17, 2018.

The presence of opaque margins was more pronounced during the months of July, September and May, while the presence of translucent margins was more evident during the months of November, January, February and March. The higher percentage of translucent and opaque margins occurred in January (84.6 %) and in May (58.6 %), respectively.

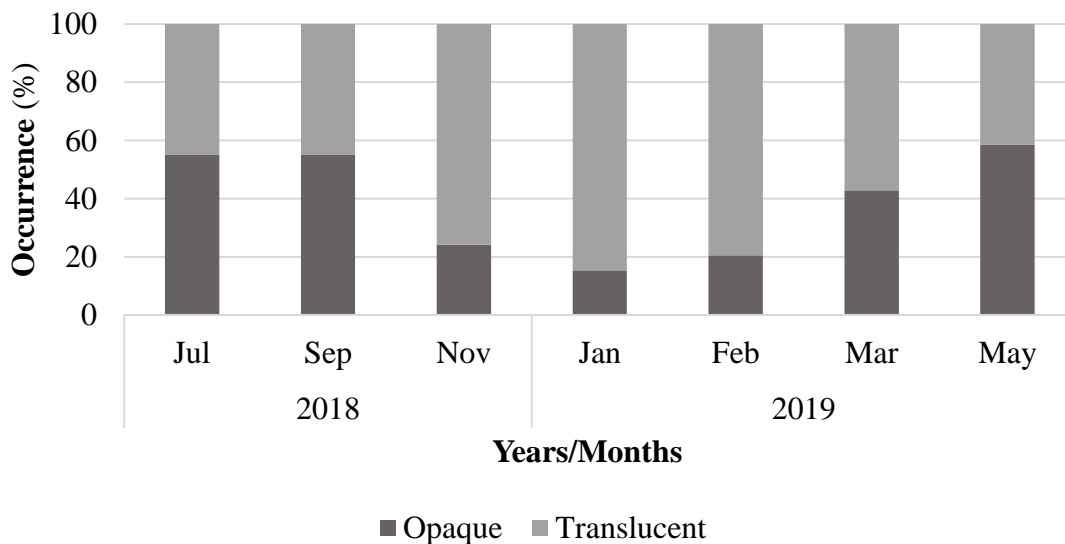


Figure 8: Evolution over time of the edge type variation of the *Chelidonichthys lucerna* otoliths.

3.3. Sex identification and gonadal development

After the macroscopic and histological identification of the sex and gonadal development, it was possible to notice that there were no differences between these two methods regarding the identification of the sex. However, in relation to the identification of the gonadal development the correspondence was only 73.3 % between the visual inspection and the histological identification. So, in order to obtain accurate results, only the histological identification was considered for analysis (Figs. 9, 10, 11).

Immature individuals (I) were only found in July, September and May. The highest percentage of developing individuals, corresponding to stage II, was found in November and May. The highest percentage of spawning capable individuals (III) was found in January (93.3 %). The highest percentage of regressing (IV) and regenerating (V) individuals, were found in the months of November and July, respectively.

It was also possible to observe that most of the fish analysed, except in the month of July, were at stage III, corresponding to spawning capable individuals. In the month of July, most of fish analysed were at regenerating stage (IV). In January, it was only possible to identify spawning capable (III) and regressing (IV) individuals, with spawning capable individuals the most represented.

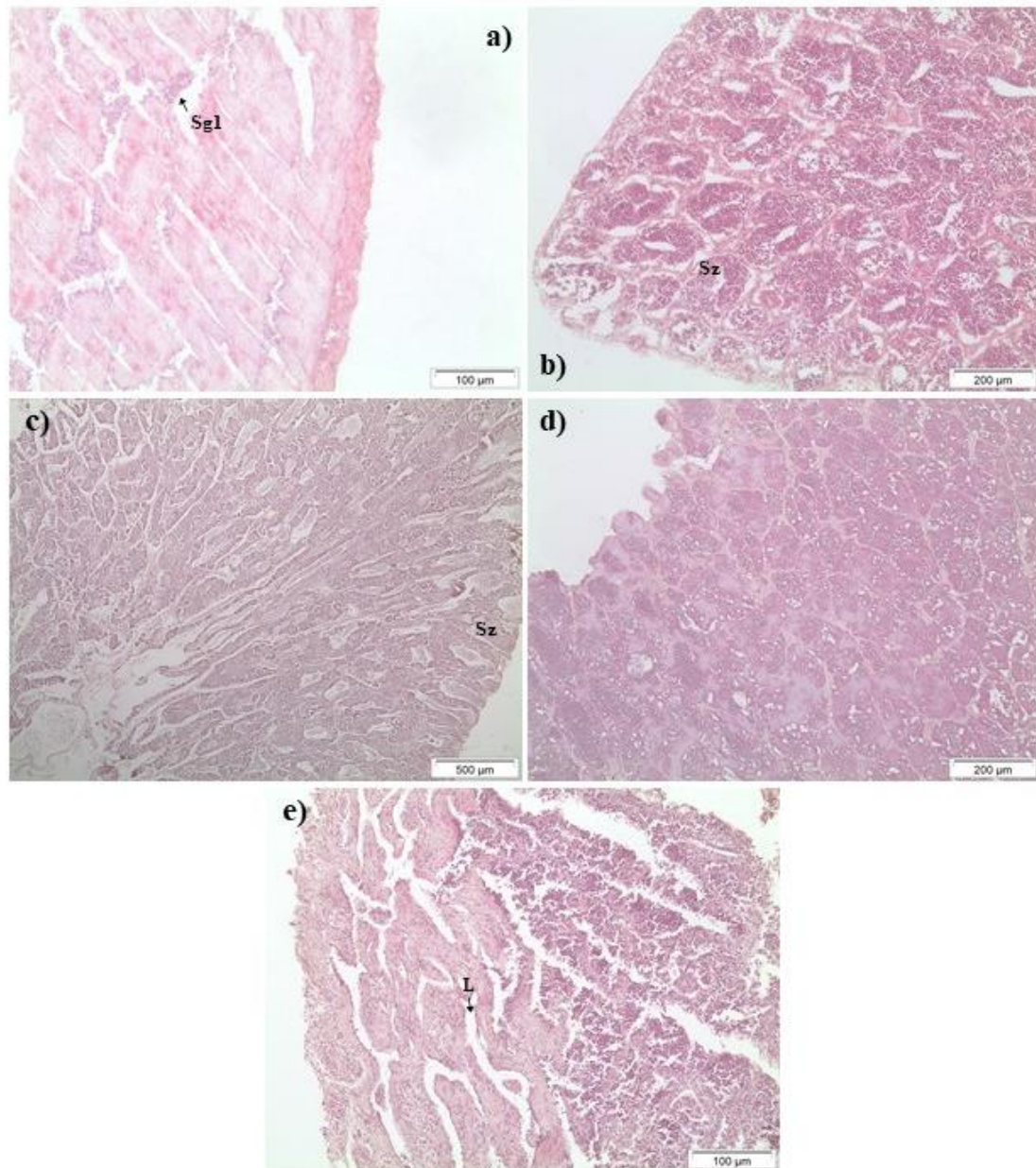


Figure 9: Histological identification of male gonads of *Chelidonichthys lucerna*, according to Brown-Peterson *et al.*, (2011). Gonads corresponding to: **a)** an immature individual, TL=21.4 cm, HE, 400×; **b)** a developing individual, TL=21.1 cm, HE, 100×; **c)** a spawning capable individual, TL=26.4 cm, HE, 40×; **d)** a regressing individual, TL=26.6 cm, HE, 100×; and **e)** regenerating individual, TL=26.8 cm, HE, 400×. Primary spermatozoa (Pg1), spermatozoa (Sz), lumen of lobule (L).

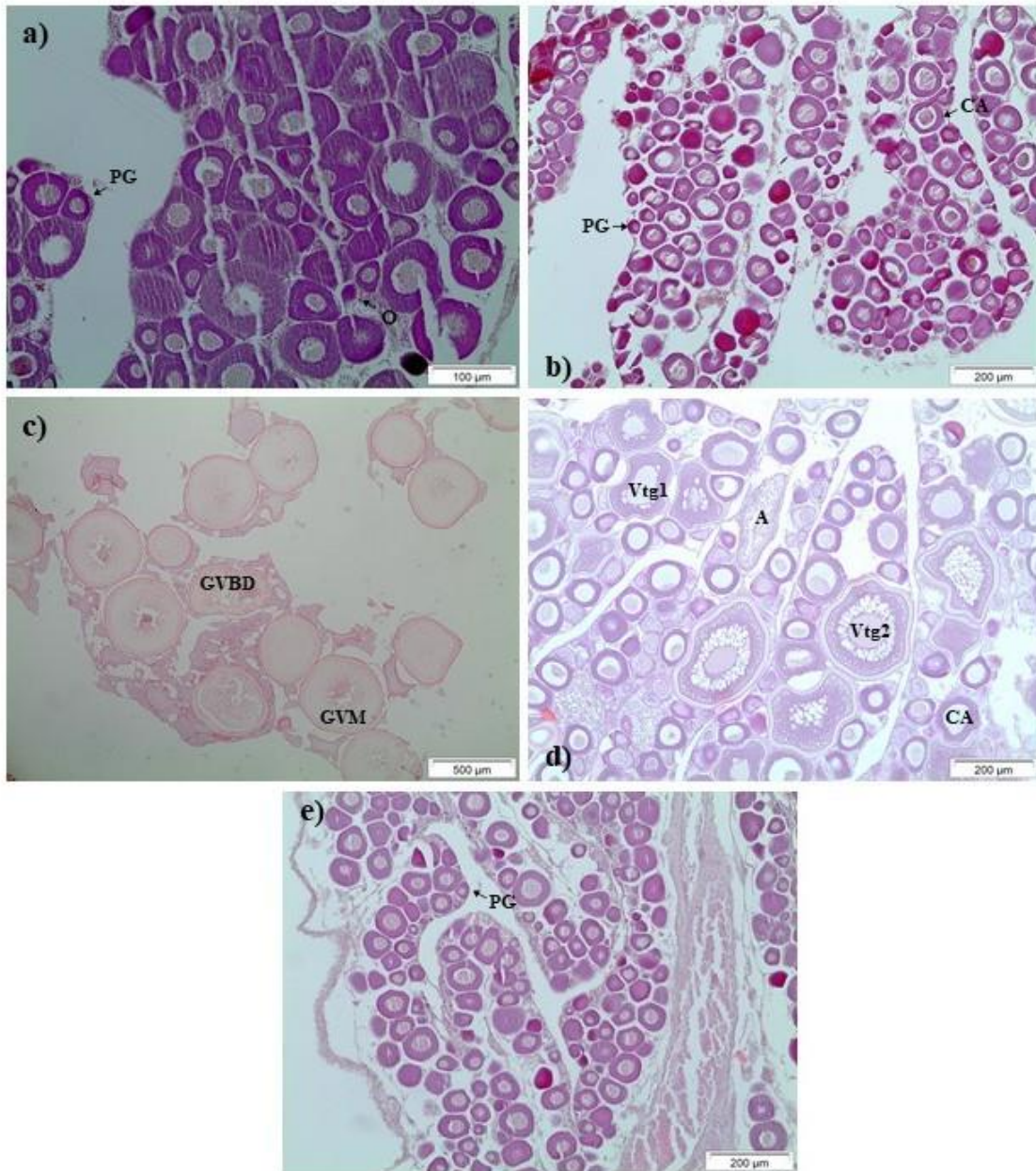


Figure 10: Histological identification of female gonads of *Chelidonichthys lucerna*, according to Brown-Peterson *et al.*, (2011). Gonads corresponding to: **a)** an immature individual, TL=24.9 cm, HE, 400×; **b)** a developing individual, TL=25.5 cm, HE, 100×; **c)** a spawning capable individual, TL=22.4 cm, HE, 40×; **d)** a regressing individual, TL=29.1 cm, HE, 100×; and **e)** regenerating individual; TL=27.5 cm, HE, 100×. Oogonia (O), primary growth oocyte (PG), cortical alveolar oocyte (CA), germinal vesicle breakdown (GVBD), germinal vesicle migration (GVM), atretic oocyte (A), primary vitellogenic oocyte (Vtg1), secondary vitellogenic oocyte (Vtg2).

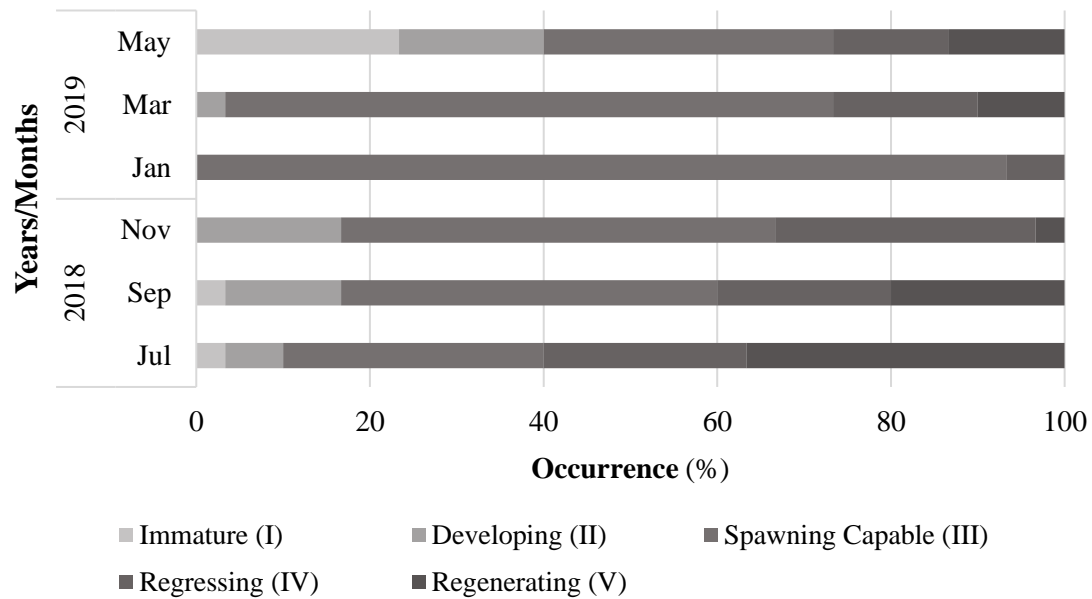


Figure 11: Percentage of individuals of *Chelidonichthys lucerna* in each stage of maturity distributed bi-monthly, between July 2018 and May 2019. These stages were microscopically assigned, based on Brown-Peterson *et al.*, (2011).

The results of Fulton’s condition factor varied between 0.80 and 0.89, with the minimum and the maximum values attained in May and September, respectively (Fig. 12). Significant differences in the values of K were found along the year (One-way ANOVA: $F_{5,174} = 7.572$, $p < 0.01$), namely between the months of September and March, September and May, January and March, January and May, and July and May (Tukey tests, $p < 0.05$).

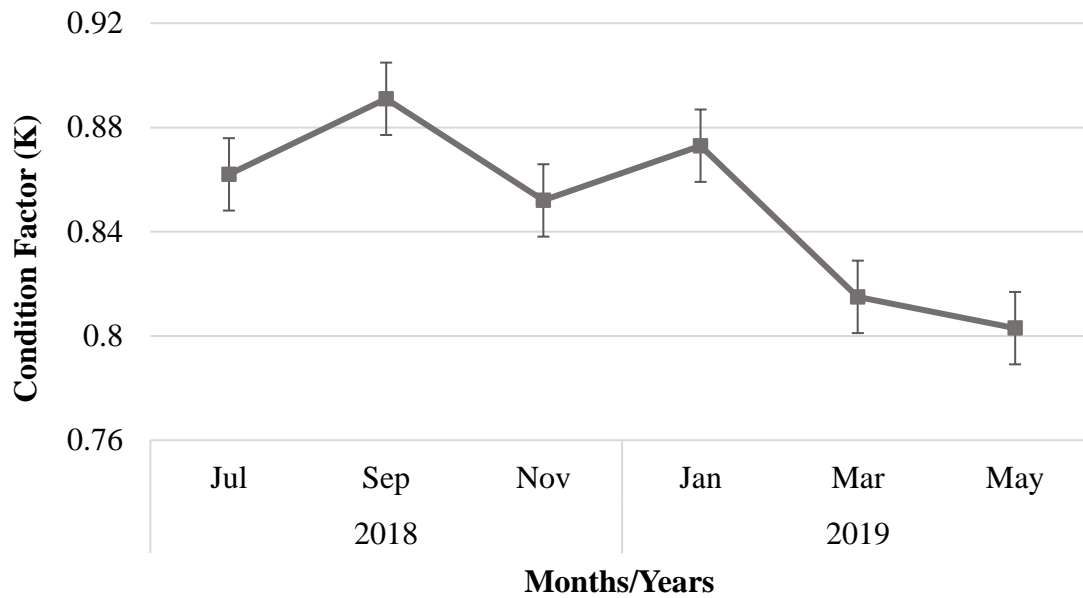


Figure 12: Bi-monthly results of Fulton’s condition factor (K) of *Chelidonichthys lucerna* along the year. Data is presented as mean \pm SE.

GSI values varied significantly along the year (One-way ANOVA: $F_{5,174} = 5.126$, $p < 0.01$), with the minimum and the maximum GSI values (Tukey-tests, $p < 0.05$) calculated in July (2.170) and January (6.920), respectively. The GSI values showed an increase from November to January.

HSI values also varied significantly through the year (One-way ANOVA: $F_{5,174} = 26.856$, $p < 0.01$), and the values ranged from 1.668 and 3.498, with the lowest reached in March and highest reached in July (Tukey-tests, $p < 0.05$). The lowest values of the HSI are presented between November and March.

Regarding the stomach fullness, the month of January presents the largest percentage of empty stomachs, followed by the months of September and March (Fig. 13).

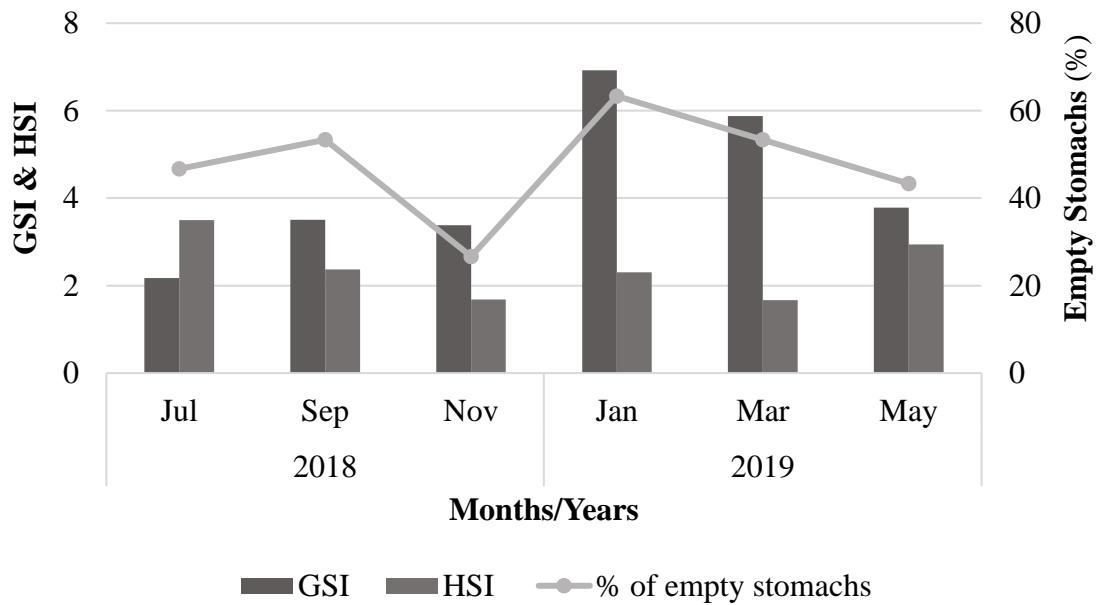


Figure 13: Gonadosomatic (GSI) and hepatosomatic (HSI) indexes and percentage of empty stomachs of *Chelidonichthys lucerna*, distributed bi-monthly, between July 2018 and May 2019.

The overall female to male ratio was determined as 1.00:0.31. The female to male ratios for the bimonthly samples are presented at Table 4. All the bimonthly samples contain more females than males.

Table 4: Sex-ratio (F:M) of *Chelidonichthys lucerna* calculated based on the selected individuals from the samples collected between June 2018 and May 2019.

	Month	Number of females	Number of males	Sex – Ratio
2018	July	26	4	1.00:0.15
	September	25	5	1.00:0.20
	November	23	7	1.00:0.30
2019	January	21	9	1.00:0.43
	March	16	14	1.00:0.88
	May	26	4	1.00:0.15
	Total	137	43	1.00:0.31

3.4. Growth curve and length/age at first maturity

The estimated von Bertalanffy growth parameters for *C. lucerna* in NE Portugal were estimated as: $L_{\infty} = 54.1$ cm, $k = 0.14$ years⁻¹ and $t_0 = -2.89$ years for females and $L_{\infty} = 33.3$ cm, $k = 0.42$ years⁻¹ and $t_0 = -1.49$ years for males (Fig. 14). There were significant differences in all the parameters (L_{∞} , k and t_0) between *C. lucerna* males and females shown by the likelihood ratio test ($\chi^2 = 20.11$, $p = 0.00002$) and extra sum-of-squares test ($F = 6.82$, $p = 0.0002$).

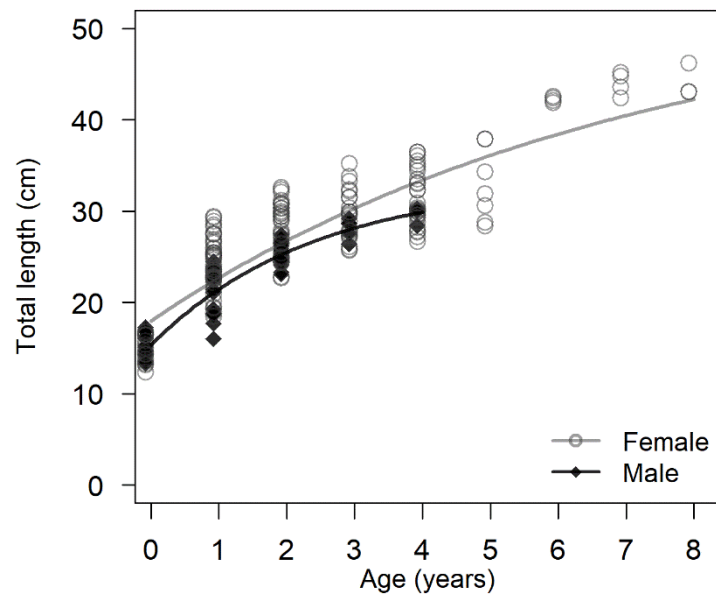


Figure 14: von Bertalanffy curves for males and females of *Chelidonichthys lucerna* in NE Portugal.

Results of this study show that *C. lucerna* females reach 50% maturity at 20.3 cm TL and 0.71 years old. *C. lucerna* males reach 50% maturity at smaller size, 18.3 cm TL, and at younger age, 0.61 years old, than females. Moreover, females reached 95% maturity at 25.1 cm TL and 1.28 years old. Male *C. lucerna* reached 95% maturity at 20.3 cm TL and 1.36 years old (Fig. 15).

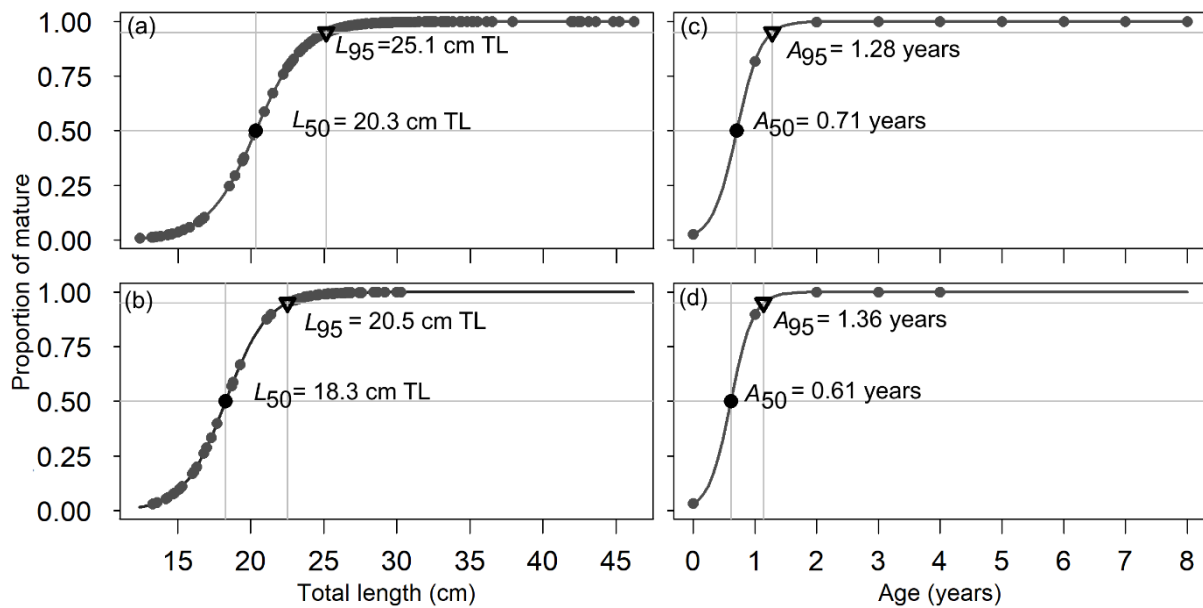


Figure 15: Logistic regression models for the estimated proportion of mature *Chelidonichthys lucerna* relative to total length for females (a) and males (b) and relative to the age of females (c) and males (d) Dark points indicate L_{50} and A_{50} and triangles indicate L_{95} and A_{95} .

4. Discussion

As far as it is known, no studies on age, growth or biology of *C. lucerna* exist in the Iberian waters of the NE Atlantic. The results of this study contribute to the improvement of ecological knowledge of this species in Portugal, since it is an important commercial fish species.

C. lucerna females in northern Portugal, NE Atlantic, reach greater sizes (46.2 cm) than males (30.3 cm). This pattern was also found in other geographical locations. For example, in northwest Wales, NE Atlantic, females were recorded up to 57.5 cm, while males were no longer than 41.0 cm (McCarthy and Marriott, 2018).

In this study, the length-weight relationship was found to be isometric for males ($b = 3.021$) and positive allometric for females ($b = 3.128$) and for combined sexes ($b = 3.136$). In different studies previously performed, it was found that this relationship could be different. For example, Cicek *et al.* (2008) described this relation as isometric for males ($b = 2.988$) and as negative allometric for females ($b = 2.918$) and for combined sexes ($b = 3.240$) in Babadillimani Bight, NE Mediterranean. In 2015, this relation was described as positive allometric both for males ($b = 3.264$) and females ($b = 3.265$) (El-Serafy *et al.*, 2015) in Alexandria, Egypt, Eastern Mediterranean. There are several reasons that can explain the differences in the values of

parameter b, namely the differences on the environment, such as the differences in temperature and salinity, differences in the availability and quality of food, differences in the number of sampled individuals and also differences in sizes of the sampled individuals (Gonçalves *et al.*, 1997; Froese *et al.*, 2011; Özdemir *et al.*, 2019).

In northern Portugal, *C. lucerna* males and females were distributed among the ages 0 – 4 and 0 – 8, respectively, suggesting that females live longer than males. The number of females is also higher than the number of males in all age classes; moreover, no males were recorded in the older age classes. The predominance of females in the older age classes has also been observed in other studies performed in different locations. For example, in the most recent study about age, accomplished in Northwest Wales, NE Atlantic, the age estimation for *C. lucerna* was from 0 to 7 years old; while females were found up to 7 years old, males were not found older than 5 years old (McCarthy and Marriott, 2018).

In this study, during the spring-summer months, between May and September, most of the otolith's margins were classified as opaque. During autumn-winter, from November to March, otoliths margins were mainly classified as translucent. Previous studies indicate the same pattern, with the deposition of opaque bands during the period of fast growth (spring months) and deposition of the translucent bands during the period of slow growth (winter months), suggesting an increment annual deposition, as previously reported (Papaconstantinou, 1981; Boudaya *et al.*, 2008).

Regarding the identification of sex and maturation stages, it was possible to observe that no errors occurred between the macroscopic and histological sex identification of the individuals. However, this was not the case regarding the stage identification of the gonads. Therefore, it was possible to conclude that through the macroscopic identification some individuals were misidentified and, in this way, to attribute the maturation stages it is necessary to use histology, although it is a more expensive and laborious method.

Concerning reproduction, histological identification of the gonads, GSI and HSI values suggest that *C. lucerna* in northern Portugal spawn between November and March with a peak in January. This is supported by the high presence of spawning capable individuals among the months of November and March, the high GSI values between January and March, the low values of HSI between November and March and the increasing of those among July and September, and for the great percentage of immature individuals in the month of May. Although an extended spawning season has been earlier identified for *C. lucerna*, it seems to vary

regionally (Papaconstantinou, 1984; Boudaya *et al.*, 2008; El-Serafy *et al.*, 2015). For example, in Greece, the peak reproduction occurs from January to May and, in Egypt, it occurs between November and February (Papaconstantinou, 1984; El-Serafy *et al.*, 2015). The differences between the spawning seasons could be the reflection of different temperature regimes among the areas (Kashiwagi *et al.*, 1987).

The condition factor (K) represents an important measure to infer the nutritional state of the fish and is influenced by numerous physical and biological factors, for example: the age of the fish, maturation stage, type of diet, temperature of the water and others (Le Cren, 1951; Barnham and Baxter, 1998; Froese, 2006). The K value calculated along this study was low (varied between 0.803 and 0.891) compared with the İlhan and Toğulga (2007) study, in İzmir Bay, Eastern Mediterranean, that varied between 0.992 and 1.163. In northern Portugal, the maximum K value was attained before the spawning period, in September, and the minimum was found after the spawning season, in May. This seems to corroborate with Eryilmaz and Meriç (2005) who suggested that the variation of the condition factor along the year in this species indicate a variation in the state of gonads, as well as, changes in the diet.

There is another parameter to consider, which is related to the stomach fullness during the lifecycle of tub gurnard. Several studies proved that the feeding rates decrease during the spawning season (Caragitsou and Papaconstantinou, 1990), but in Morte *et al.*, (1997) the number of empty stomachs of *C. lucerna* remained constant during all the year. In this study, realized in northern Portugal, it was possible to observe an increase in the number of empty stomachs during the spawning season. In the current study the higher percentage of empty stomachs occurred in January, which corresponds to the peak of the reproduction.

The overall sex-ratio in the present study is in favour of females (1.00:0.31). This pattern was found in different studies, such as in NE (Eryilmaz and Meriç, 2005: 1.00: 0.50) and Eastern Mediterranean (El-Serafy *et al.*, 2015: 1.00:0.52).

The estimated von Bertalanffy growth parameters indicate that females ($L_{\infty} = 54.1$ cm) attain larger sizes than males ($L_{\infty} = 33.3$ cm) and that males ($k = 0.42$ year⁻¹) grow faster than females ($k = 0.14$ year⁻¹) in northern Portugal, Atlantic. Several studies have stated the same pattern. For example, in Eastern Mediterranean, the L_{∞} and k were respectively defined as 29.8 cm and 0.274 year⁻¹ for males and as 32.4 cm and 0.255 year⁻¹ for females; and in NE Atlantic, L_{∞} was defined as 43.9 cm and k as 0.360 year⁻¹ for males and L_{∞} was defined as 50.7 cm and k as 0.260 year⁻¹ for females (El-Serafy *et al.*, 2015; McCarthy and Marriott, 2018).

In most cases previously studied, *C. lucerna* males attain the maturity at younger ages and smaller sizes than females, at least in the Mediterranean specimens (Boudaya *et al.*, 2008; El-Serafy *et al.*, 2015). Eryilmaz and Meriç (2005) described that, in NE Mediterranean, *C. lucerna* males attain the maturity at around 19.0 cm, while the females attain the maturity at around 18.5 cm, both at around 3 years old. Boudaya *et al.*, (2008), in Western Mediterranean, reported that maturity in males is attained at around 19.2 cm (1.3 years) and in females is attained at around 21.6 cm (2.9 years). El-Serafy *et al.*, (2015) indicated that, in Eastern Mediterranean, *C. lucerna* males mature at about 15.0 cm (1.2 years) and females at about 15.2 cm (1.4 years). In NE Atlantic, the opposite occurred, McCarthy and Marriot (2018) stated that *C. lucerna* males mature at 29.1 cm (2.8 years) and females at 27.7 cm (2.7 years). In this study, although it was also realized with specimens from the Atlantic, the pattern founded was the same as in the Mediterranean studies, with the males maturing earlier ($L_{50}=18.3$ cm, $A_{50}=0.61$ years) than females ($L_{50}=20.3$ cm, $A_{50}=0.71$ years). The differences in the results among the areas could be related with the fact of the size of maturation being straight related to the population density, feeding regime and the differences in temperature among the locations (Nikolsky, 1963; Kashiwagi *et al.*, 1987).

The age and length of the first maturity, as well as the estimated von Bertalanffy growth parameters, proved to be follow a similar pattern to studies performed in the different areas, indicating that it is a species with a relatively fast-growth and moderately long-lived (Papaconstantinou, 1984; Boudaya *et al.*, 2008).

In conclusion, the results along this study are in line with the results obtained in other studies previously performed. The study of the biological parameters could be a useful tool to help in the management of the fisheries and the knowledge about *C. lucerna* in northern Portugal and also allow to improve the data about the species in Atlantic, due to the lack of the studies in the area.

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