UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA
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Facultad de Ciencias del Mar

Doctoral Thesis

Growth and life history traits of an exploited seabream *Boops boops* (Linnaeus, 1758) off Gran Canaria (Canary Islands)

Andrea Massaro

Las Palmas de Gran Canaria

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UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

Programa de Doctorado Gestión Sostenible de Recursos Pesqueros

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Tesis Doctoral

Growth and life history traits of an exploited seabream *Boops boops* (Linnaeus, 1758) off Gran Canaria (Canary Islands)

Tesis Doctoral presentada por D. Andrea Massaro

Dirigida por el Dr. D. José Mario González Pajuelo

Las Palmas de Gran Canaria, a 2 de mayo de 2017

El Director

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RESUMEN

La boga, *Boops boops* (Linnaeus, 1758), es una especie que se distribuye por todo el Mediterráneo, incluyendo el Mar Negro, el Océano Atlántico oriental, desde Noruega hasta Angola y en el Golfo de México y en el Caribe. Es una especie bento-pelágica, característica típica de la familia Sparidae, que generalmente se puede encontrar hasta 100 m de profundiad (Mar Mediterráneo) o 300 m (Océano Atlántico), e infrecuentemente hasta 350 m, sobre diferentes fondos (arena, barro, rocas y *Posidonia*). Por lo general, los adultos viven en aguas profundas donde se localizan durante todo el invierno. A principios de la primavera se acercan a la costa para su reproducción y, en primavera-verano, los juveniles se localizan en las aguas poco profundas, donde permanecen hasta finales del verano-principio del otoño, cuando se desplazan hacia aguas más profundas (reclutamiento).

La reproducción presenta un aspecto aún no totalmente clarificado para esta esepcie; el tipo de hermafroditismo que exhibe (proterandrico o proteroginico). Los estudios consultados mostraron una mayor incidencia de proteroginia, definiendo la boga como una especie hermafrodita que presenta poblaciones diándricas con proteroginia parcial. La boga es un reproductor parcial o heterocrono, ya que las hembras maduras ponen huevos en pulsos durante un período prolongado de tiempo. El período reproductivo es bastante amplio, con algunas variaciones estacionales según el área geográfica. La freza tiene lugar principalmente entre febrero y junio en el Mediterráneo occidental, y entre enero y mayo en el Mediterráneo oriental. La reproducción en el Océano Atlántico ocurre entre febrero y mayo.

Estudios sobre edad y el crecimiento han sido realizada previamente por varios autores en diversas áreas del Mar Mediterráneo utilizando diferentes métodos (directos e indirectos). Los resultados presentan una alta variabilidad y en algunos casos son conflictivos. Esta especie no alcanza una gran talla (~ 40 cm longitud total) y la mayoría de los individuos están entre 10 y 25 cm de longitud total. Por lo general, el reclutamiento es discreto y el crecimiento es más lento en climas fríos, aunque las capturas comerciales parecen mostrar una amplia distribución unimodal sin picos notorios.

La boga es una especie secundaria en las capturas de la pesca comercial, especialmente la que se lleva a cabo con el arrastre de fondo. La especie también es

capturada con redes de cerco, redes de trasmallo, redes de enmalle, palangres y con nasas o trampas hechas a mano.

En Gran Canaria la boga tiene un valor comercial limitado y carece de atractivo para el sector de la pesca recreativa. Esto se debe a que, a pesar de sus características morfológicas y nutricionales aceptables, que la hacen apta para la comercialización, se considera erróneamente indeseable y desagradable para la mayoría de los consumidores y, por consiguiente, desde el punto de vista de los pescadores, su comercialización no es económicamente viable a pesar de ser relativamente abundante. Generalmente, esta especie se descarta después de haber sido capturada por la pesca con redes de cerco, que tiene como especies objetivo otros peces pelágicos de tamaño mediano (sardina, caballa, chicarro) y representa la principal especie descartada de la pesca artesanal desarrollada en la Isla. Su captura también se lleva a cabo como pescas incidentales en redes de enmalle, palangre y líneas de mano. Por otra parte, la pesca de cebo vivo en las Islas Canarias requiere una cantidad sustancial de cebo para atraer a las diferentes especies de túnidos. Por esta razón representa una de las especies más comunes usadas como cebo.

El objetivo de esta Tesis Doctoral es investigar diferentes aspectos biológicos de *Boops boops* en aguas de Gran Canaria, principalmente la edad y el crecimiento, abordando el patrón de crecimiento, a través de la lectura directa de otolitos y del análisis de las distribuciones de frecuencias de tallas. Otros parámetros biológicos importante para la correcta evaluación y gestión de los recursos pesqueros como la relación talla-peso, la proporción de sexos, la talla de madurez sexual y la determinación de las etapas de maduración del ciclo reproductor también han sido estudiadas.

Un total de 2355 ejemplares de *Boops boops* fueron recolectados y seleccionados aleatoriamente, entre enero y diciembre de 2012, con una frecuencia mensual. Las muestras, en su mayoría, proceden de la captura incidental de la flota artesanal en el puerto de Arguineguín. Para cada individuo se tomó la longitud total, el peso total, el peso eviscerado y el peso de las gónadas y se registró el sexo y el estado de madurez, ambos macroscópicamente.

El análisis de la proporción de sexos se expresó como el grado de feminidad y como la relación entre ambos sexos y mostró que los machos son más frecuentes en las clases de mayor tamaño, mientras que las hembras son más frecuentes en las clases de menor tamaño. Esto se debe al carácter hermafrodita de la especie que muestra una población diándrica con proteroginia parcial, donde las hembras se desarrollan de una fase juvenil (hembras primarias), mientras que los machos se desarrollan, por una parte, como consecuencia de un proceso de inversión sexual, denominándose machos secundarios y, por otra parte, directamente de la fase juvenil (machos primarios). El porcentaje de individuos hermafroditas fue muy bajo (1,4%) con tamaño entre 14 y 21 cm de longitud total.

La talla de primera madurez (L_{50}) se estimó como la longitud a la cual el 50% de los individuos eran sexualmente maduros. Los resultados mostraron que los machos alcanzan la madurez sexual a una talla ligeramente supeior ($L_{50} = 18,6 \pm 0,7$ cm) a la estimada para las hembras ($L_{50} = 17,8 \pm 0,7$ cm).

El período de freza se determinó siguiendo la evolución mensual de los estadios de madurez sexual a lo largo del año y, además, a través de la evolución media mensual del índice gonadosomático. Los machos y las hembras presentaron un patrón de desove similar, desde enero a mayo con un pico en febrero.

Con respecto a la relación talla-peso, los resultados mostraron un crecimiento alométrico positivo para la población en general y para las hembras y machos, con un acrecentamiento en peso proporcionalmente mayor que la longitud.

El crecimiento fue estimado directamente a través de lecturas de los otolitos, e indirectamente a través de las distribuciones de frecuencia de talla. Se seleccionaron 656 otolitos sagittas para el estudio de crecimiento. Antes del examen y de la descripción, los otolitos se quemaron para incrementar el contraste de los anillos de crecimiento, facilitando así su lectura. Para cada estructura se tomó varios datos morfométricos cuantitativo (longitud total del otolito (TOL), longitud del radio de otolito (OR) y distancia de cada anillo translúcido al núcleo) y se registó un dato cualitativo sobre tipo de margen (translúcido u opaco).

La edad se estimó asumiendo que un anillo anual se constituye por la deposición alternante de una banda translúcida y una banda opaca. Sólo se consideraron bandas translúcidas las correspondientes a anillos anuales. La fecha de nacimiento teórica para asignar las clases de edad fue el 1 de enero, considerada como la fecha estándar para el hemisferio norte.

La primera marca translúcida corresponde con un anillo falso (anillo demersal). En algunos individuos es posible identificar un segundo anillo falso, localizado antes dell primer anillo translúcido, que no es continuo, es delgado y está muy cerca del primer *annulus*.

Para verificar la interpretación de la edad, los análisis se realizaron mediante una lectura doble, separadas en el tiempo, y sin tener ninguna información sobre la lectura anterior ni sobre la longitud de los individuos. A través de una hoja de cálculo de Excel desarrollada por la National Oceaographic and Atmospheric Agency (NOAA) se han evaluado los errores que influyen en la precisión. Los índices utilizados fueron el Porcentaje de Acuerdo (PA), el Porcentaje Error Promedio (APE) y el Coeficiente de Variación (CV).

La edad fué validada mediante el análisis de la evolución del tipo de borde (translúcido u opaco) y mediante la evolución del incremento marginal promedio mensual.

Los parametros de crecimiento fueron estimados con la función de crecimiento estándar de von Bertalanffy (VBGF). El paquete FSA en R-studio se utilizó para estimar los parámetros de la VBGF. Las lecturas de los otolitos se corroboraron atraves a través retrocálculo. Los métodos indirectos utilizados en este trabajo fueron Bhattacharya y ELEFAN I, ambos implementados en el paquete de software FISAT. El método de Bhattacharya se usó para separar los componentes normales de las distribuciones de frecuencia de longitud. A cada moda se asignó una edad putativa. En respuesta, el método proporciona longitud media, desviación estándar y número de individuos para cada componente modal de la distribución de frecuencia de talla. Se utilizó, también, ELEFAN I para estudiar las clases modales.

Las lecturas e interpretación de los otolitos fue particularmente difícil. Las marcas de los otolitos eran frecuentemente poco claras y difusas y esto era particularmente evidente en los peces más viejos. Esto es probablemente debido al engrosamiento del borde del otolito y la proximidad de las marcas de crecimiento. No obstante, la determinación de la edad fue alta (91,6% para las hembras y 90,0% para los machos). Una de la principales dificultades fue la correcta identificación del primer anillo anual, debido a la presencia de anillos falsos antes de la deposición del primer *annulus*. Fueron reconocidas dos marcas falsas. La primera, llamada anillo demersal se deposita cuando los reclutas llegan al fondo (asentamiento larvario) y la segunda aparece cuando los especímenes se alejan de la costa (zona de cría), para incorporarse a la población adulta. Los resultados del análisis del Incremento Marginal (MIA) mostraron la deposición anual de una zona translúcida y una opaca. Entre junio y enero se deposita el anillo translúcido, mientras que el anillo opaco se deposita entre febrero y mayo. La edad máxima obsevada fue 4 años para las hembras y 5 años para los machos. La longitud máxima registrada fue 30,5 cm de longitud total para las hembras y 33,5 cm de longitud total para los machos. Los datos de edad analizadas permitieron estimar los parámetros de crecimiento según el modelo de von Bertalanffy. Para los machos se estimaron los siguientes valores: L_∞ = 35,3 cm de longitud total, k = 0,38 años^{-1} y t_0 = -0,8 años. Para las hembras, los parámetros de la ecuación de von Bertalanffy resultaron: L_∞ = 32.3 cm de longitud total, k = 0.44 años^{-1} y t_0 = -0.8 años. Considerando la correlación lineal entre la talla de los peces y el tamaño de los otolitos, fue posible estimar los mismos parámetros también por retrocálculo. Los resultados fueron L_∞ = 30,0 cm de longitud total, k = 0,43 años^{-1} y t_0 = -0,5 años para las hembras, y L_∞ = 34,0 cm de longitud total, k = 0,40 años^{-1} y t0 = -0,5 años para los machos. La comparación de las curvas de crecimiento, mostró diferencias significativas en el crecimiento entre ambos sexos. Por esta razón, se optó por realizar el análisis sólo para sexos separados. El paquete FSA reveló que el parámetro L_∞ es que presenta una mayor influencia sobre la curva de crecimiento. Los parámetros estimados con la técnica ELEFAN fueron: L_∞ = 32,8 cm de longitud total, k = 0,38 años^{-1} y t_0 = -1.0 para las hembras y L_∞ = 35,1 cm de longitud total, k = 0,35 años^{-1} y t_0 = -1.0 año para los machos. También, se utilizó el análisis de progresión modal para validar las longitudes a la edad calculadas por el retrocalculo, y también las longitudes a la edad estimadas a partir de las clave talla-edad.

Los resultados revelaron que no había diferencias significativas. Todas las curvas de crecimiento obtenidas por métodos directos, retrocálculo y métodos indirectos se analizaron para identificar posibles diferencias. En todos los casos se detectaron diferencias significativas entre los sexos, mostrando un crecimiento más rápido los machos que las hembras. Los resultados obtenidos en este estudio descrepan en algunos casos con los resultados publicados por otros autores en diferentes áreas. Estas diferencisa puede atribuirse no sólo a factores técnicos, como la metodología utilizada y el método de interpretación (diferentes claves de interpretación en la lectura de estructuras duras), incluso a factores ambientales como la disponibilidad de alimentos y las condiciones ambientales (temperatura y salinidad) o a factores genéticos. No menos importante, la diferente tasa de crecimiento encontrada en diversas áreas podría ser la consecuencia de los diferentes niveles de explotación de la pesca comercial. Las características oceanográficas, las condiciones ambientales de esta área y la distancia geográfica relacionada con otras áreas estudiadas, jugaron un papel fundamental en la diferencia de los resultados obtenidos en este trabajo.

CONCLUSIONES

1. – *Boops boops* muestra una segregación entre juveniles y adulto en su distribución espacial en base a las capturas. Los juveniles (6-9 cm longitud total), se localizan cerca de la costa. A los 13-14 cm de longitud total los juveniles se desplazan hacia la zona de los adultos, permaneciendo durante todo el año principalmente sobre la plataforma continental (50-90 m).

2. – La relación talla peso para *B. boops* muestra un crecimiento alométrico positivo para los machos y las hembras, incrementándose en mayor proporción el peso que la talla durante el crecimiento.

3. – La proporción de sexos (1:0.852) de *B. boops*, estimada como hembras/machos, fue significativamente distinta de la relación 1:1. La proporción de sexos por clases de tallas mostró un predominio de los machos en las clases de tallas mayores. Los ejemplares intersexuales fueron observados entre 14 y 21 cm de longitud total.

4. – *B. boops* es una especie hermafrodita, con proteroginia parcial en una población diándrica.

5. – *B. boops* muestra un periodo reproductor amplio, desde principio de invierno hasta finales de primavera (desde enero hasta mayo, con un pico en febrero) con patrón similar para machos y hembras.

6. – Los machos de *B. boops* alcanzan la madurez sexual (L_{50}= 18.6 cm de longitud total) a tallas superiores que la de las hembras (L_{50}= 17.8 cm de longitud total) debido a su tipología sexual y al crecimiento diferencial entre sexos.

7. – Los parámetros de crecimiento estimados para *B. boops* utilizando diferentes metodologías no difieren significativamente entre ellos. Los parámetros de crecimiento oscilan para las hembras entre 30.0 y 32.8 cm de longitud total para L_∞; desde 0.36 hasta 0.45 años^{-1} para k, y entre -0.3 y -1.0 años para t_0, y para los machos desde 34 hasta 35.6 cm de longitud total para L_∞; desde 0.34 to 0.40 años^{-1} para k, y desde -0.03 hasta -1.0 años para t_0.

8. – *B. boops* muestra un dimorfismo sexual en crecimiento en relación con la longitud asintótica.

9. – En los otolitos de *B. boops* se identificaron dos anillos falsos de crecimiento. El anillo demersal que se deposita a los 5.6 cm de longitud total en las hembras y a los 5.5 cm de longitud total para los machos. El anillo de emigración no fue siempre visible, depositándose a los 9.4 cm de longitud total en las hembras y a los 9.5 cm de longitud total para los machos.

10. – La lectura e interpretación de los otolitos para *B. boops* fue particularmente difícil debido a la presencia de anillos falson antes de la formación del primer anillo anual o *annulus*.

11. – El análisis del incremento marginal en los otolitos de *B. boops* permitió verificar que cada año se deposita un solo anillo de crecimiento anual o *annulus*, formado por la deposición de una banda opaca y una translúcida.

12. – Los valores de Φ’ obtenidos para *B. boops* y los recogidos en la literatura muestran discrepancias que pueden ser atribuidas a las diferentes metodologías utilizadas, la correcta identificación de los anillos anuales y del patrón de crecimiento.

1. INTRODUCTION

Fisheries science is the discipline which deals with the study and assessment of the state of marine biological resources. This scientific discipline has developed since the 70's of the last century and is mainly devoted to the study of fish populations and the development of appropriate management measures for rational and sustainable exploitation of resources to achieve an exploitation level (Fig.1.0) which in the long term gives the maximum yield in weight for fishery (Sparre *et al.*, 1989).

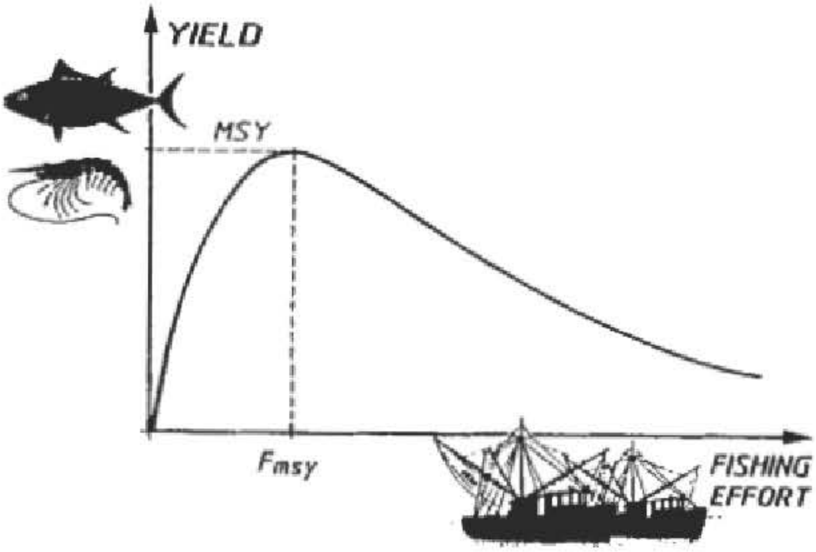


Figure 1.0 - The basic object of fish stock assessment (from Sparre *et al.*, 1989)

The fundamental unit of study for fisheries biology is *stock*, defined as a group of organisms of the same species, characterized by defined biological and ecological parameters (feeding, growth, reproduction, mortality, etc.), distributed in a particular geographical area, and subject to anthropogenic exploitation (Booke, 1981; Ihssen *et al.*, 1981; MacLean and Evans, 1981; Sparre *et al.*, 1989). An already increasing pressure on fish stocks has determined often an impoverishment, leading in severe cases to a situation of overexploitation (*overfishing*), a situation where the profitability of resource has been dramatically reduced, no longer sustainable for professional fishing activities (Sparre *et al.*, 1989). Such a situation is revealed when, with increasing fishing effort, catches do not show proportional increase, or even remain stable or decrease, in relation to fishing effort (Petersen, 1903; Russell, 1931; Murawski, 2000; Jackson, 2001). Many examples of overfishing exist in different areas of the world, as the case of Atlantic cod *Gadus morhua* (Linnaeus, 1758) or halibut *Hippoglossus hippoglossus* (Linnaeus, 1758) (Stevens *et al.*, 2000; Field *et al.*, 2009; Srinivasan *et al.*, 2010). In many cases risks was the collapse of the resource, while in others it has come to a situation of local extinction (Punt, 2000). For extinction of the resource it does not refer to the extinction of the species. Species is still present, but no longer able to produce a biomass such as to allow an economically profitable operation. In order to avoid similar situation was evident the need to develop and implement correct policies for managing marine resources allowing the resource to regenerate. Stock increases its biomass both for individual accretion and recruitment of new individuals, while decreases due to natural mortality (predation, competition) and fishing mortality (Fig. 1.1).

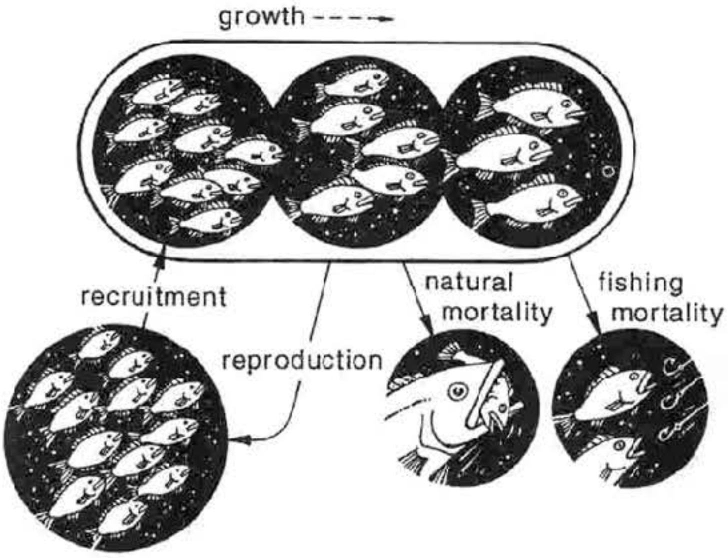


Figure 1.1 - Main factors of the dynamics of exploited fish population (from King, 1995)

Unexploited stock produces a quantity of biomass in excess, defined as Maximum Sustainable Yield (MSY) (Ricker, 1975), given by the difference between the biomass produced from growth and the recruitment and biomass lost due to natural mortality: this amount could be taken without damaging the resource. However, it is not easy to determine this amount of biomass in excess. For this reason, studies to support stock assessments are necessary to identify which factors determine changes in population. An important role is played by a branch of quantitative ecology: population dynamics. This discipline, seeking to understand and predict changes in the demographic structure and size of a natural population through the application of mathematical models in order to develop measures for the management of the resource.

The main models used for the stock assessment can be divided into global models and analytical, or structural models (Lleonart, 1993). The first does not require knowledge on the biology of the species, while the analytical models, which are the most used, need information on demographics and biology. Two examples of analytical methods are Cohort Analysis or Virtual Population (VPA) and Yield per Recruit Analysis (Beverton and Holt, 1956, 1957). Both types of analyzes require very accurate information about growth rate and age of exploited populations (Pauly, 1986; Alemany and Oliver, 1995).

In this context fits sclerochronology activity, a discipline that aims to reconstruct the history of a living organism through the study of calcified structures that accrue during the life cycle recording information on age and growth. Hederstrom (1759) was the first to consider the issue of fish aging: "*My proposal is that the age of the fish is imprinted in their vertebrae, just like the age of the trees is indicated by the growth rings*". Otoliths study is one of the most important methods used in fisheries biology to determine the age and estimate the growth of a species through the interpretation of periodic rings on these structures. Aging also allows to know the demographic structure of a population and to obtain important information on the biology of a species, such as longevity, age of first maturity and reproduction periods (Wothington *et al*., 1995; Morales-Nin *et al*., 1998a).

1.1. AIMS

The aims of this thesis were to determine age and growth of bogue, *Boops boops* (Linnaeus, 1758) off the Gran Canaria (Canary Islands), through the reading of the annual rings laid down on otoliths.

In Canary Islands, bogue does not have a great economic importance but it covers an important ecological role as it represents an intermediate link between large predators and components of zooplankton.

From an economic viewpoint, estimates of landings of this species are insufficient and, where present, they reach few tons/year (Castro *et al.*, 2015).

In Canary Islands knowledge on the biology of this species are lacking (Caldentey, 1987), and completely absent in some respects. In this sense, this work will be a contribution to biological knowledge of bogue population in Canary Islands, with particular attention to growth studies.

In this work, therefore, other aspects such as the composition in sizes, individuals size and weight, reproductive characteristics, will be examined building a solid foundation for the knowledge of this species.

1.2. GROWTH STUDIES

Growth is the body size variation designed in terms of length or somatic weight (Elliot and Hurley, 1995), while the weight increase or decrease depending on the energy reserves availability or on the development of the gonads, length is usually irreversible (Roff, 1983, 1992; Kozlowski, 1992).

Food intake from the external environment provides the energy necessary for the growth process. However, only a small part of the food consumed, often less than one-third, is available for the growth in size, being the most used for metabolism, movement and reproduction (Enberg *et al.*, 2012). A complex series of factors determines the amount of energy available for growth, at the expense of other important needs such as movement and reproduction (Fig. 1.2).

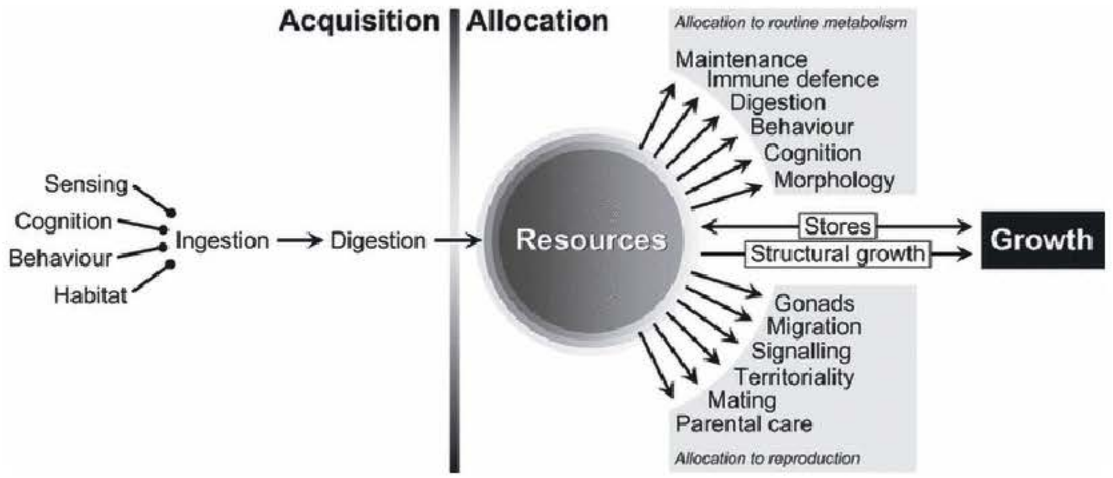


Figure 1.2 - Resource acquisition (left) and allocation (right) are both adaptive processes. The amount of acquired resources is affected by many processes influencing foraging and ingestion, which after digestion translates into available resources. Resources allocated to routine metabolism, reproduction and structural growth are generally not available for later use, whereas resources deposited in stores can be utilized later. Changes in any of the components affecting resource acquisition or in how the acquired resources are allocated may lead to altered growth (from Enberg *et al.*, 2012)

In fish, as in other organisms, high growth rate has benefits. Larger individuals usually have a higher chance of survival, a greater success in the search for a partner, increased fertility, increased ability to endure hunger and are better in the competition for resources (Enberg *et al.*, 2012). Furthermore, great body can promote the production of a large number of eggs or produce large eggs, with the result to ensure a high probability of survival of the larvae (King, 1995). In general, juveniles grow faster than adults to reach quickly large size, then growth rate decrease because reproduction season subtracts energy for growth (Jennings *et al.*, 2001). However, the energy demand is greater for larger animals. Furthermore, there are different components in a cost-benefit balance that together determine the evolutionary advantages or disadvantages to reach a certain size (Warner, 1988).

Fast growth can be expensive in terms of food intake and risky, but once individuals reach a certain size, benefits in terms of survival or reproduction can be positive (Enberg *et al.*, 2012). In fact, to be able to grow to a certain size, an individual need to acquire resources through research of food, usually at a cost of exposure predators, parasites or infections.

The growth therefore is not constant during the life cycle of the species (Rutter, 1902; Miller, 1957; Favro *et al.*, 1979; Kristiansen and Svåsand, 1998). The type and abundance of food (Jobling, 2002) are important factors in the growth process. In this regard, fishing affects growth by acting directly on many of these trophic relationships by changing the predator / prey relationship (Enberg *et al.*, 2012). Another important factor influencing the growth is temperature: species that inhabit the temperate environments have a higher growth in the summer and less in winter (Taylor, 1958).

1.3. METHODS USED FOR ESTIMATION OF GROWTH

Given the great importance of growth in the dynamic population studies, many methods have been devised to determine the age and growth study. In general, fish population growth study can be summarized in two stages. The first one, most commonly used for bony fish, is the estimation of individual age through analysis of calcified structure using standardized criterion and validation methods (Morales-Nin, 1992). Second stage is estimation of the growth parameters using a model that describe body dimension of individuals in according to their age. The von Bertalanffy growth function (von Bertalanffy, 1938) is the most widely used and it assumes the existence of an asymptotic maximum dimension towards which individuals would tend in infinite time (Beverton and Holt, 1957; Janoschek, 1957). Although this model is widely used, some authors (Beverton and Holt, 1957; Ricker, 1958, 1975) highlights the difficulties in representing the different life phases of growth with a single equation.

1.3.1. Sclerochronology

Etymologically, word *"sclerochronology"* comes from the Greek *sklêros* "lasts", *kronos* "time" e *logos* "to speak". This science aims to recreate the vital development of an organism based on the analysis of the calcified structures (de Pontual *et al.*, 2002). These structures grow together with the individual, recording continuously and creating a biological archive; codifying this archive it is possible extract significant and usable information.

There are three main structures that record this information (Fig. 1.3), scales, bones and otoliths (Leeuwenhoeck, 1696; Réaumur, 1716; Hederstrom, 1759; Dahl, 1907, 1911; Stevenson and Campana, 1992). The choice of the structure to use will depend on its ease of extraction, as well as preservation, preparation and observation.

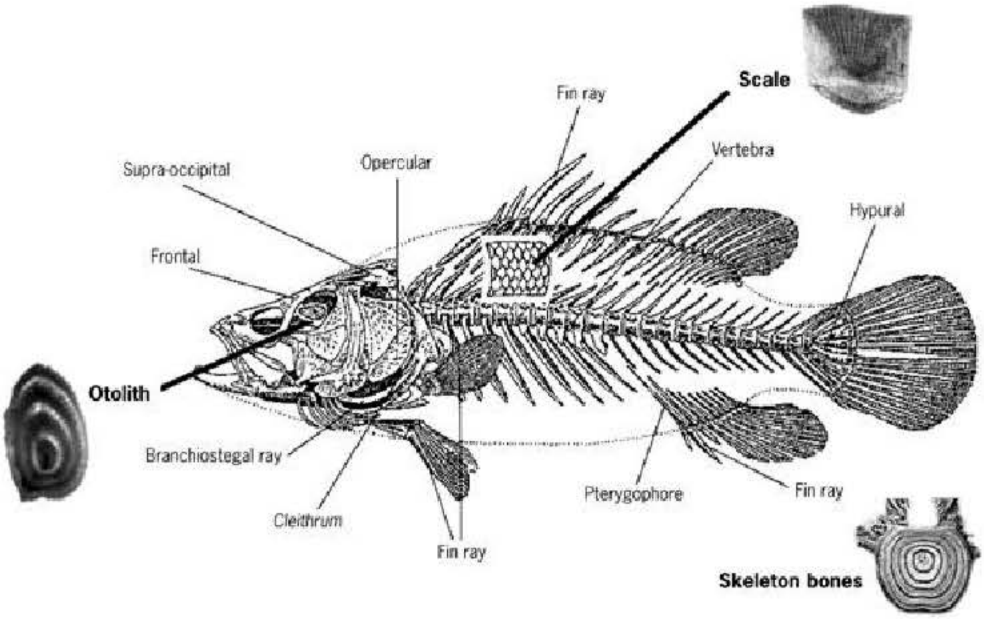


Figure 1.3 - Various calcified structures that can be used for sclerochronological studies, and the three main types of structure (otolith, scale, skeleton) (from Panfili *et al.*, 2002)

The scales (Fig. 1.4) are mineralized elements present in the upper part of the dermis (Panfili *et al.*, 2002). Its surface show a series of radial grooves (*radii*) which are distributed regularly from the center to the periphery of the structure. Age determination through the analysis of this calcified structure is advantageous because its ease of extraction and it does not imply the specimen's death. Fish have the ability to regenerate scales (McCart, 1967; Fouda, 1979; Shackleton, 1988). When a scale is lost, it is replaced by a newly regenerated scale, which, however, can not be used for age estimation (Panfili *et al.*, 2002).

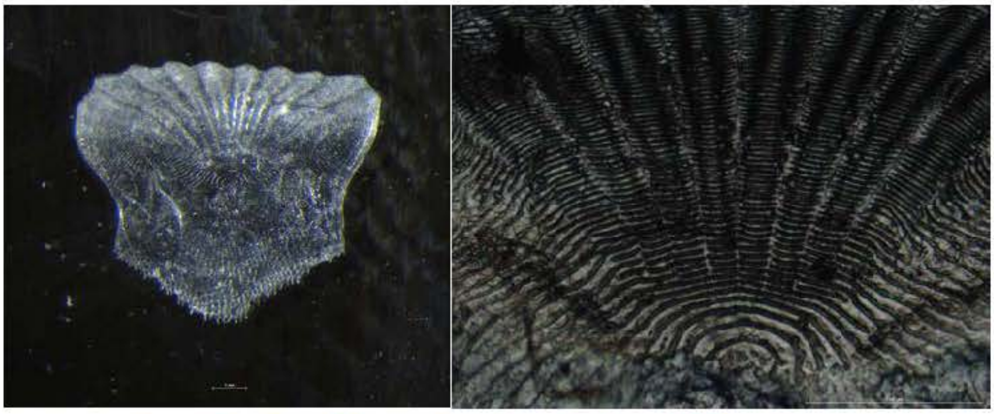


Figure 1.4 - Scale of bogue (*Boops boops*) (photo A. Massaro)

The bone structures and vertebrae are easy to extract and preserve (Fig. 1.5), but require complicated and lengthy preparation procedures (Panfili *et al*., 2002). Moreover, these structures undergo resorption processes during stress periods, losing part of the information (Panfili *et al*., 2002).

Figure 1.5 - Vertebrae of European hake (*M. merluccius*) (photo A. Massaro)

The most used structure in the individual age determination routine of bony fish is the otolith (Stevenson and Campana, 1992). As reported by Ricker (1975), this calcified structure was used for the first time by Reibisch (1899), who observed the formation of annual rings structures on otoliths of *Pleuronectes platessa* (Linnaeus, 1758).

Otoliths are three-dimensional structures present in the inner ear membranous labyrinth of bony fish and play an important role in the perception of balance. Only in bony fish otoliths are compact structures, while in other vertebrates form a mass rather amorphous calcium crystals (Romer and Parsons, 1986). Membranous labyrinth presents three saccular structures (Fig.1.6) called respectively *sacculus, utriculus* and *lagena* (Panfili *et al*., 2002). Each of these three sack contains one otolith, therefore, being the inner ear an equal organ, teleosts present three pairs of otoliths: *sagitta, lapillu*s and *asteriscus.*

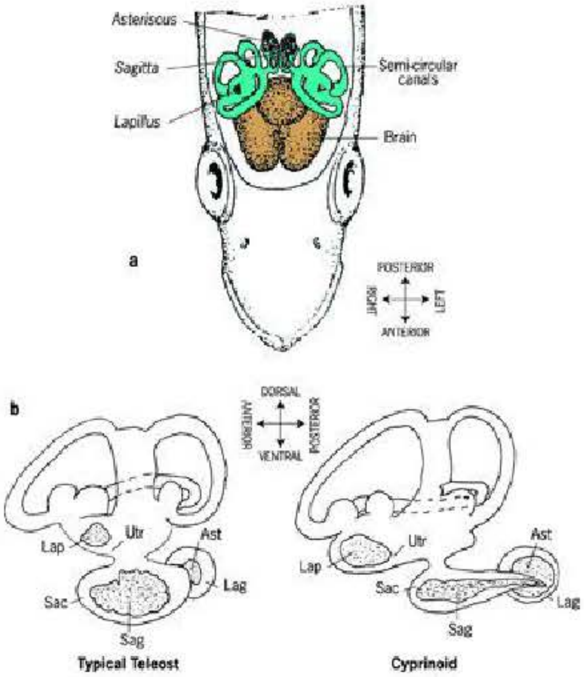


Figure 1.6 - Position of the otoliths within the inner ear of Teleost fish (modified from Secor *et al*., 1992). a) Dorsal view of the vestibular apparatus in a typical Teleost species. The top of the cranium is cut away (frontal section). b) Otoliths within the labyrinth systems of typical Teleost and Ostariophysean fishes. Ast = *asteriscus*; lag = *lagena* (vestibule); Lap = *lapillus*; Sac = *sacculus* (vestibule); Sag = *sagitta*; Utr = utriculus (vestibule)

These three otoliths differ from each other in size and shape (Fig. 1.7) usually *sagitta* have larger dimensions. For this reason, it is frequently used in studies of age determination, being easier to extract and analyze (Morales-Nin, 1992). However, in some cases *lapillus* are used (Campana and Moksness, 1991; Hare and Cowen, 1995).

Otoliths do not show re-absorption phenomena, even under conditions of stress, because of the important role in the perception of balance, for which it is necessary to maintain a precise conformation compared to the rest of the auditory apparatus (Lombarte and Popper, 1994).

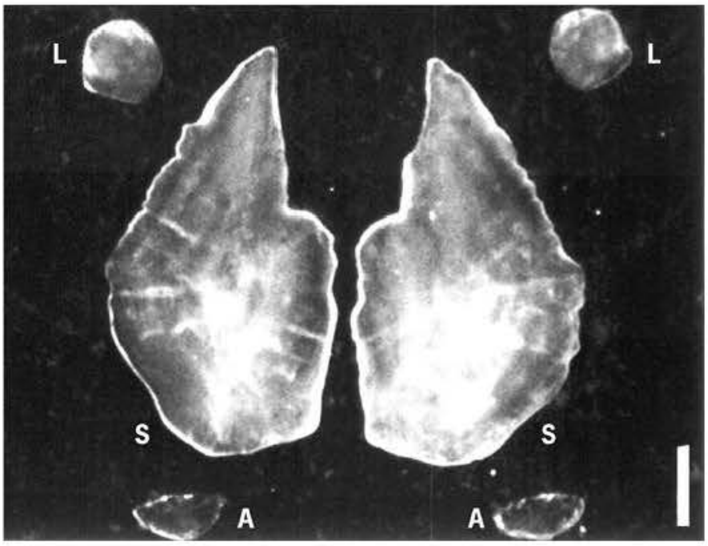


Figure 1.7 - Three otoliths of *Vinciguerria nimbaria* (Jordan & Williams, 1895). L, *lapillus*; S, *sagitta*; A, *asteriscus*, bar 300 (from Panfili *et al*., 2002)

Interspecific difference in form (Fig. 1.8) seems to be due to genetic and environmental influences (Lombarte and Lleonart, 1993; Torres *et al*., 2000). These differences made otoliths useful elements even in taxonomy (Hecht, 1979).

Figure 1.8 - Examples of various otolith shape from different species (photo A. Massaro)

Otoliths have other applications. For example, its chemical composition is a source of information about life of individuals in relation to environmental changes, temperature changes and migrations (Kalish, 1989, 1991; Arai *et al.*, 1999; Campana, 1999; Gao and Beamish, 1999) and can also be used as an indicator of pollution (Sawhney and Johal, 1999). Furthermore, studies on otoliths chemical composition allow to identify different populations of a species (Waldman, 1999).

For this last purpose otoliths shape analysis are carried out. In fact it is possible to observe significant differences between otoliths shape in the various populations of the same species and stock (Campana and Casselman, 1993; Lombarte and Lleonart, 1993).

Otoliths present a bilateral symmetry and are laterally compressed. In Fig. 1.9 morphology is shown in detail.

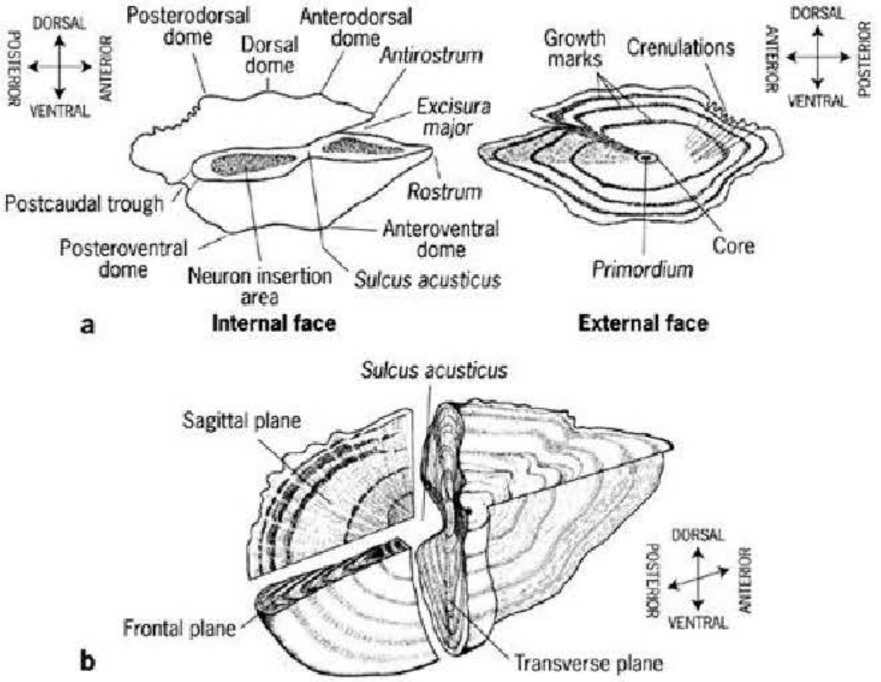


Figure 1.9 - A cross section through a typical *sagitta* illustrating the component parts (modified from Pannella, 1980; in Panfili *et al.*, 2002). a) Internal and external faces of a typical *sagitta*. b) The three planes of orientation of a typical *sagitta*

Each otolith has three orientation plans that follow those of fish: sagittal, coronal and transverse plan (Fig. 1.9). The proximal side of *sagitta* has a groove named *sulcus acusticus,* with sensorial function. A typical *sagitta* has an elliptical shape on its sagittal plan and presents a convex (proximal) and concave (distal) face (Fig. 1.10) and a growth main axis oriented in anteroposterior direction (Secor *et al.*, 1995).

Figure 1.10 - Otoliths of *Boops boops*. Distal (right) and proximal (left) side (photo A. Massaro, 2015)

Otoliths consists of both an inorganic matrix and an organic matrix. Inorganic matrix consisted of *calcium carbonate* ($CaCo_3$) placed on the organic matrix (Degens *et al*., 1969). Organic matter instead consists mainly of collagen protein fibers, generally in the form of *otolina.* Most calcium comes from the surrounding aquatic environment and it is absorbed by the gills (Simkiss, 1974; Mugiya *et al*., 1981; Campana, 1983), otherwise it partially comes from nutrition (Ichii and Mugiya,1983). Several studies have shown how organic component and $CaCO_3$ deposit depends on the seasons and, especially, on the temperature (Simkiss,1974; Casselman, 1990). $CaCO_3$ is usually laid during the quick growing period, when calcium metabolism is characterized by a superior level of activity. So, chemical deposition levels of organic and inorganic component reveal periods of slow or fast growth during one year and both environmental and physiological changes (Kalish, 1989, 1991). More substantial material layers with a superior $CaCo_3$ deposit are formed during rapidly growing periods (summer-autumn), characterized by high temperature, food availability, and are named *opaque areas*, whereas less substantial layers with an inferior mineral deposition are formed during slow-growning periods (winter-spring), with low temperature and trophic shortage, and are named *transparent areas* or hyaline (Williams and Bedford, 1974). These concentric structures forms a series of rings that appear dark or light depending on the lamp type used for the microscope, whether reflected or transmitted (Fig. 1.11).

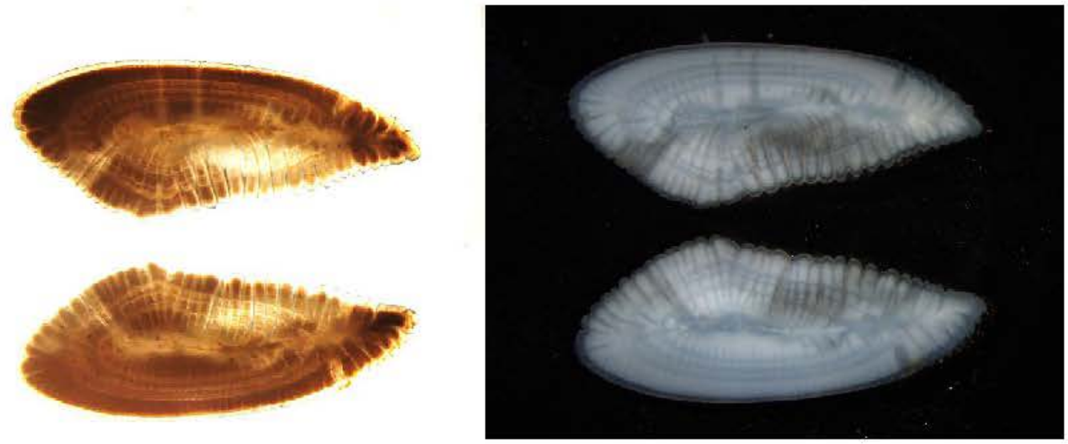


Figure 1.11 - Otoliths of *Merluccius merluccius* observed with transmitted light (left) and transmitted light (right) (photo A. Massaro, 2015)

Alternating deposit of translucent and opaque rings represents the base for the "annual rings" (*annuli)* identification (Blacker, 1974; Williams and Bedford,1974, Casselman, 1974, 1983, 1987; Morales-Nin,1987; Mugiya, 1987). Metabolic changes can take place after external processes such as changes in aquatic medium, or endogenous processes, as reproduction, and ontogenetic processes; these processes can determine alteration in the correlation between organic and inorganic matter that are settled on given calcified structures (Mosegaard *et al.*, 1988). Some variations are caused by regular fluctuations presenting specified intervals (day/night or lunar cycles, seasons) that determine the formation of gaps (*rings)* on calcified structures (Wright *et al.*, 2002). Reproductive periods, together with abrupt and sudden environmental changes such as temperature variations, migration, presence of pollutants, diseases or drastic food reductions, play a fundamental role in the rings formation mechanism resulting in the appearance of “false rings” (Pannella,1980; Campana, 1983; Campana and Neilson, 1985). These "false rings" can be very numerous and difficult to recognize, making inaccurate the reading of the annual growth rings.

1.4. AGE ESTIMATION

Age determination through direct reading of calcified structures is a complicated procedure (Morales-Nin and Panfili, 2002). Over the years, specific techniques of preparation and observation of these structures have been developed (Morales-Nin and Panfili, 2002).

Once chosen the most suitable calcified structure, estimating ages on the basis of seasonal increments requires increments and growth pattern identification (Morales-Nin and Panfili, 2002).

In addition, other information as capture date, birthday date (according to standardized registers or to reproductive biology knowledge of the test species), periodicity of increases deposition and edge quality of the observed structure (Fig. 1.12) will be considered (Morales-Nin and Panfili, 2002).

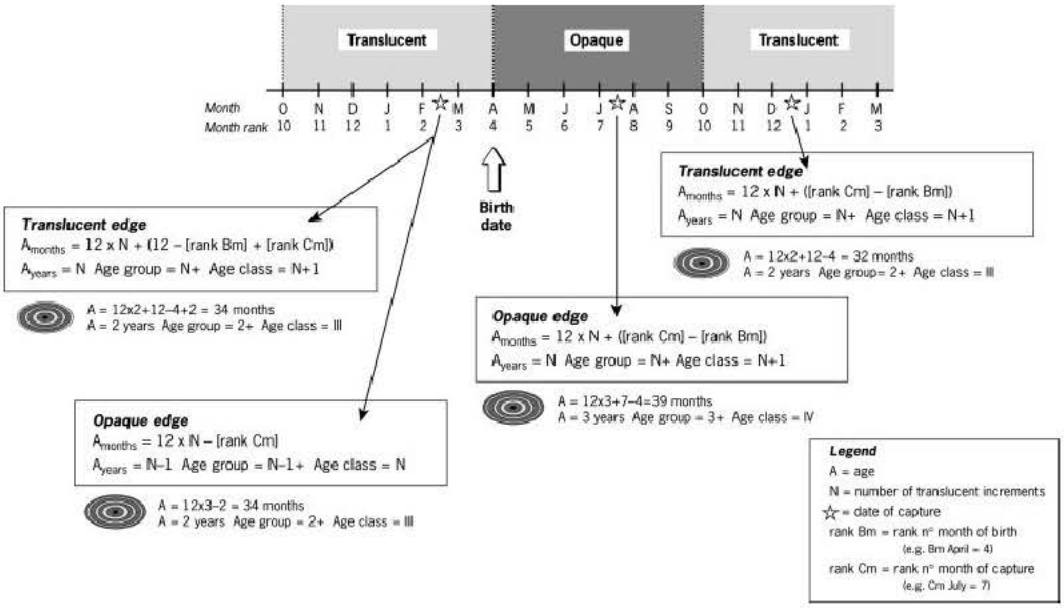


Figure 1.12 - Theoretical calculation of age (months, years) and assignation of age group and age class from a calcified structure (from Panfili *et al*., 2002)

Date of birth is not always known: in such case for standardizing age data, 1st January is considered as date of birth (Morales-Nin and Panfili, 2002).

In age estimation procedure is essential distinguish accurately annual rings (translucent ring + opaque ring) from discontinuity (checks). Annual rings differ from false rings ones because have more marked and regular development of the whole calcified structure, and present a fairly regular growth pattern in which the distance between one ring and other gradually decreases (Panfili *et al.*, 2002). Therefore, false rings usually are formed after environmental and physiological changes (spawning, food availability, disease, etc). For these reasons, validated interpretive criteria (Campana, 2001) and knowledge about the biology of the species and its life cycle knowledge, assume a crucial role in the correct structure interpretation (Williams and Bedford, 1974; Wright, 1991; Geffen, 1992).

1.4.1. Validation methods

Age determination is based on the "interpretation" of growth rings present on otoliths (Morales-Nin, 1992). Even though remarkable progress in the standardization of reading methods and the interpretive keys, otoliths reading presents many subjectivity elements, mainly correlated to the knowledge and experience of the reader (Panfili *et al.*, 2002). In order to avoid errors in stock management (Chilton and Beamish, 1982; Archibald *et al.*, 1983; Beamish and McFarlane, 1983; Leaman and Nagtegaal, 1987) is necessary to validate age determination methods to prove that the techniques used are exact, demonstrable and quantifiable (Panfili *et al.*, 2002). For this reason, validation is a required step in studies that involve direct age determination (Campana, 2001).

Validate means confirm the temporal significance of the considered increments in age determination process, in order to prove that an age determination method is accurate (Geffen, 1987; Francis, 1995). In the specific case of otolith readings, validation means to prove that the identified rings are effectively annual rings, and not false rings (Beamish and McFarlane, 1983, 1987).

Validation is important in fisheries biology as the calibration of analytical instruments and standardization of techniques are in the other sciences; nevertheless validation of estimate age continues to be forgotten (Beamish and McFarlane, 1983).

Many reviews in literature supply a broad demonstration of the importance of using such methods (Blacker, 1974; Bagenal and Tesch, 1978; Casselman, 1983, 1987; Cailliet *et al*., 1986; Beamish and McFarlane, 1987; Baillon, 1992; Campana, 1999).

There are various methods to validate age estimate. These, in turn, stand out in procedures that can validate the actual age or the periodicity of increase development, or confirm, without validate, an age estimate (Campana, 2001).

- **Direct validation**

This method is based on the insertion of a "sign" representing a temporal reference. Mark-recapture experiments are the most widely used methods. They consists in the release and recapture of previously captured organisms, measured and marked. In this way, it is possible to observe the growth occurred between mark and recapture dates (Parker *et al*., 1990). In tagging methods (Fig. 1.13), marks are usually applied directly on fish externally or internally (McFarlane and Beamish, 1990), while marks on calcified structure are chemically introduced (injections with fluorescent substances like oxytetracycline) (Fig. 1.14) or induced by different factors, such as light or food (Weber and Rigway, 1967).

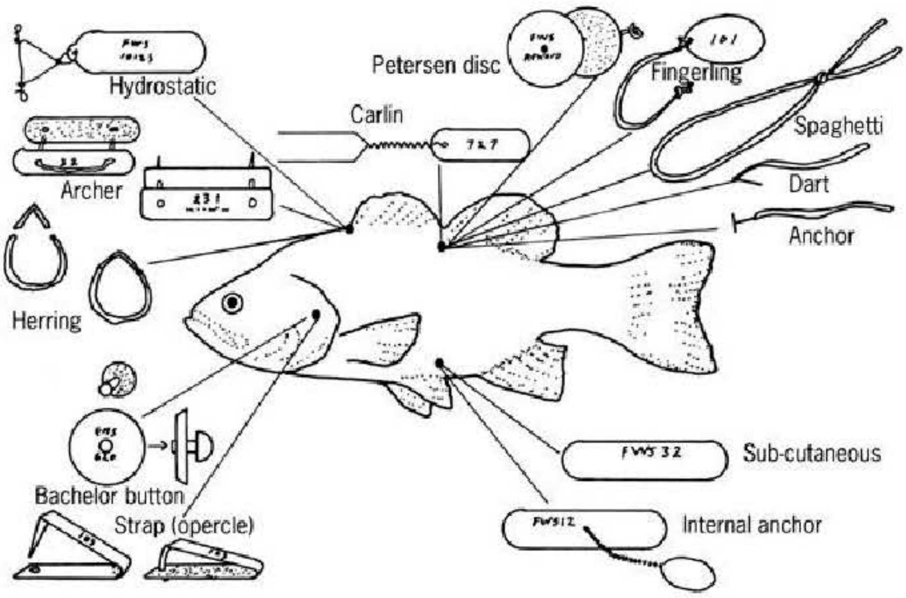


Figure 1.13 - Principal types of external tags and anatomical sites for attachment on fish (from McFarlane and Beamish, 1990)

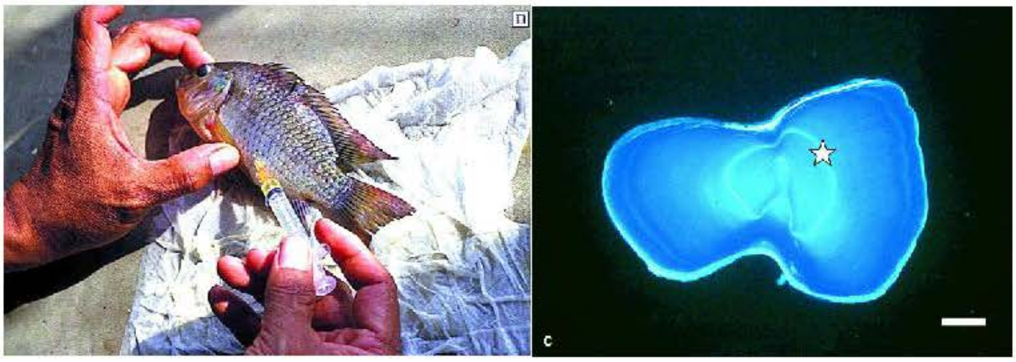


Figure 1.14 - (LEFT) Internal marking with tetracycline injection for an African tilapia (*Sarotherodon melanotheron*). (RIGHT) Tetracycline marks on slice of the dorsal ray of pike-perch (*Stizostedion lucioperca*) under epifluorescent UV light microscopy (from Panfili *et al*., 2002)

- **Semi-direct validation**

Edge analysis and Marginal Increments analysis are the most common validation techniques in growth studies. Both are based on the direct observation of the analyzed structures but provide different output data. Edge analysis (Fig. 1.15) determine *annulus* formation (qualitative data) studying the evolution of edge type of the otolith over time (Morales-Nin and Panfili, 2002). Marginal Increments analysis permits to quantify growth, distinguishing a higher growth period (spring/summer) from a lower one (autumn/winter). Often edge type identification is difficult due to optical distortion produced by the angle of refraction between the edge and the medium, which makes it difficult to count marginal increments (Morales-Nin and Panfili, 2002).

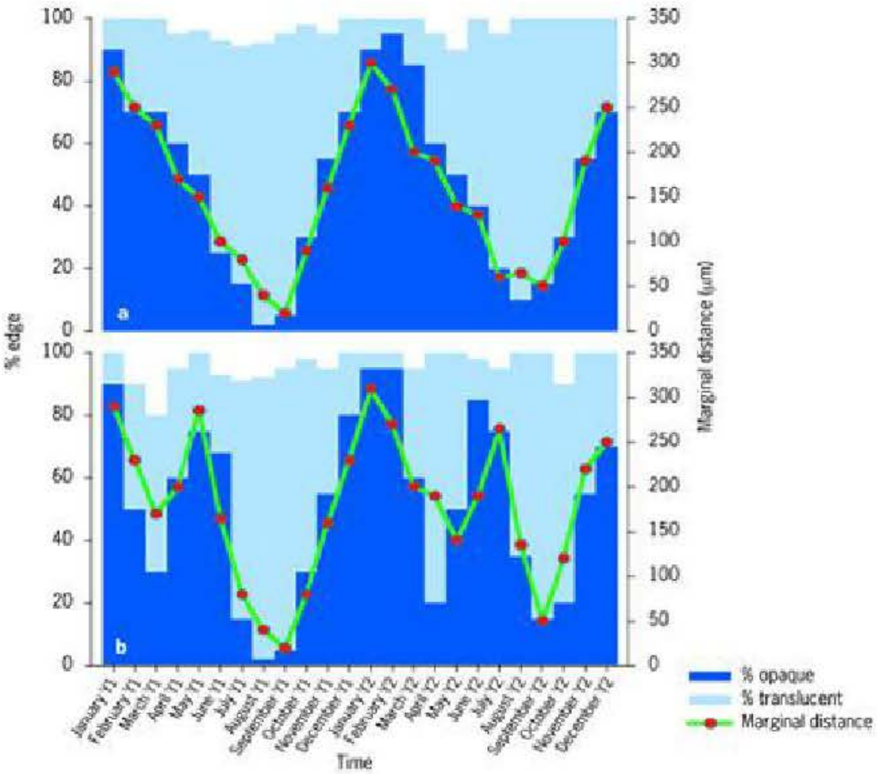


Figure 1.15 - Theoretical graph of the evolution over time of the percentage of opaque edges, the percentage of translucent edges and the margin width on a CS (from Panfili *et al.*, 2002)

- **Indirect validation**

Indirect validation is based on entire population (Morales-Nin and Panfili, 2002) and give an age interpretation without analysis of calcified structure (Holden and Raitt, 1974). In general, it consists in estimating of von Bertalanffy parameters analyzing size structure of population (Pauly and David, 1981; Casselman, 1987).

This indirect method was originally used in the 19th Century and developed through technology and software. The analysis in question (Bhattacharya, 1967) provides for the measurement and division into size classes of the catch in order to identify the various age groups, based on the assumption that each age group has a normal distribution of sizes.

Length-Frequency analysis is a technique based on the assumption that each age group has a normal distribution of sizes (Morales-Nin and Panfili, 2002) and the average sizes of individuals of different ages can be determined by the mode of a polymodal curve representing the structure of the population (Pauly, 1979, 1983, 1984, 1986). In other words, reporting on a graphic size frequencies divided for length classes, it will be obtained overlapping distribution in which each modal class corresponds to a cohort, and represents an age class.

Fig. 1.16, shows a hypothetical length distribution with three peak, each one corresponding to three age groups concerning three consecutive time intervals (t, t+1, e t+2). At time *t*, there are three classes, each of these having ages A_t, $A1_t$ and $A2_t$. That analysis hypothesizes that, in the following time interval (t+1), classes will have ages A_{t+1}, $A1_{t+1}$ and $A2_{t+1}$ and, at time *t+2*, ages A_{t+2}, $A1_{t+2}$ and $A2_{t+2}$. At time *t+2*, there is a new peak that reproduces a new age class consisting of the new recruit (King, 1995).

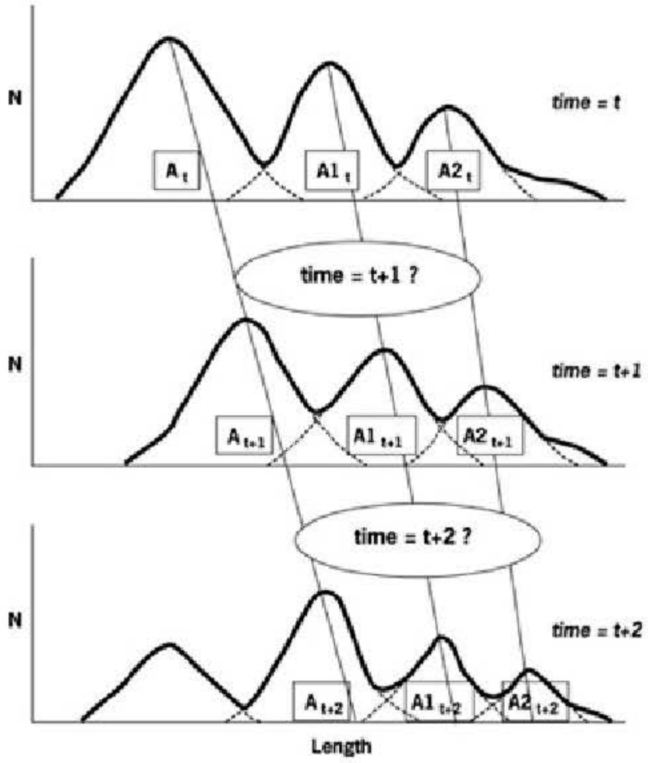


Figure 1.16 - Basic principles involved in methods for length-frequency analysis (from Panfili *et al*, 2002)

1.5. PRECISION OF AGE ESTIMATES

Growth study allows to obtain important information about the behavior of a species under fishing effort and allows to apply the analytical models for stock assessment in order to understand and predict the evolution of the resource (Oliver *et* *al.*, 1992; Alemany and Oliver, 1995). Because age determination is not an exact science, verification methods are indispensable to verify the consistency of age interpretation (Eltink *et al.*, 2000).

Over the years, exchanges and workshops (ICES) were organized in order to produce standardizing protocols able to limit errors due to subjectivity in the age estimation and wrong interpretation of calcified structures (Eltink *et al.*, 2000). Ages estimated by different readers on one or more calcified structures inevitably show differences: the purpose of verification is to identify and estimate these differences (Wilson *et al.*, 1983).

Age reading errors affect precision and accuracy (Campana, 2001). The *precision* indicates the degree of convergence, or dispersion, of collected data (sample) compared to the average value of the series to which they belong, that is their variance (or standard anomaly) compared to the sample average; whereas the *accuracy* is the degree of conformity of theoretical data, that is inferable from a measured value series (data sample), with real or reference data.

Errors that affect precision are easy to estimate because they are not related to the exact age value (Eltink *et al.*, 2000). Average Percent Error (APE) (Beamish and Fourier, 1981) and Coefficient of Variation or CV (Chang, 1982) are the most common statistical indexes which describe quantitatively the precision of estimates (Campana *et al.*, 1995, Campana, 2001).

APE replaced another index, Percentage Agreement due to the high dependence on the lifespan of species (Morales-Nin, 1992). Average Percent Error is expressed by

$$\mathrm{APE}=100^{*}\ \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{R}\sum_{i=1}^{R}\frac{\left|X_{ij}-\overline{X}_{J}\right|}{\overline{X}_{J}}\right),$$

where: N is the number of fishes which their age has been identified, R is the number of taken readings for each individual, X_{ij} is the i-th age estimated of the j-th individual, X_j is the average age of the j-th individual.

Coefficient of Variation or CV, is more robust than APE and it is more flexible (Kimura and Lyons, 1991). In that case, technically CV is an imprecision index: low values, indicating a high degree of accuracy between readings.

$$CV=100^{*}\ \frac{1}{N}\sum_{j=1}^{N}\frac{\sqrt{\sum_{i=1}^{R}\left(X_{ji}-\overline{X}_{j}\right)^{2}}}{X_{j}}$$

These indices should always be used as a quality control to estimate accuracy of the readings carried out by one reader or between multiple readers (Campana, 2001).

1.6. GROWTH MODELS

Growth models relate size with age assuming growth as function of body size of the individual (Enberg *et al.*, 2012). Many models have been proposed with the aim of finding a correlation between body size and age (Sparre *et al.*, 1989). Pütter (1920) was the first to develop a growth model on which are based all subsequent models (Beverton and Holt, 1957; Ursin, 1968; Ricker, 1975; Gulland, 1983; Pauly, 1984; Pauly and Morgan, 1987).

The most common growth model uses to describe growth in fisheries studies is the von Bertalanffy growth function (VBGF) (von Bertalanffy, 1938).

According to model, individual grows over time until reaching a maximum asymptotic length. VBGF is expressed, in terms of length, by the following function:

$$L_t= L_\infty{}^{*}\left(1-e^{[-k(t-t_0)]}\right),$$

where: L_t is the average total length of the animal at time t (at age t), L_∞ is the maximum (theoretical) asymptotic length, k is growth coefficient and represents the slope of the curve and expresses a speed measure to which maximum length is reached, t_0 is the curve intersection with X axis and represents theoretical age at length 0. t_0 parameter assumes negative values since at birth an individual has a length greater than zero (Fig. 1.17) (Sparre *et al.*, 1989).

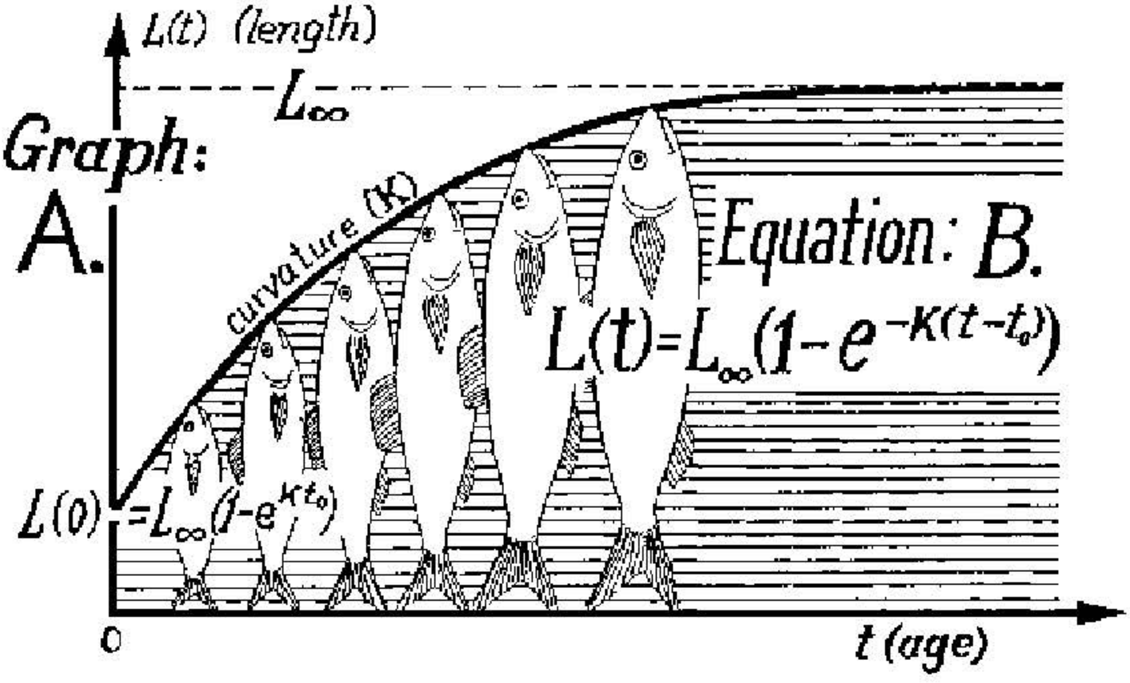


Figure 1.17 - Graphic representation of von Bertalanffy growth function (from Sparre *et al.*, 1989)

In addition, the VBGF can also be expressed in terms of weight:

$$W_t = W_\infty * \left(1 - e^{[-k(t-t_0)]}\right)^3.$$

where: W_t is the average total weight of the animal at time t (at age t), W_∞ is the maximum (theoretical) asymptotic weight.

The model assumes that the growth is related with anabolism and catabolism, which are functions of the body mass (Enberg *et al.*, 2008).

VBGF parameters are often used to describe fish life history. In general, elevated k levels are linked to rapid growth, small size of sexual maturity, high reproductive power, reduced longevity and inferior L_∞ values (Beverton and Holt, 1957).

Conversely, species characterized by inferior k values present a higher age and bigger maturity size, low reproductive power, higher longevity and high values of L_∞ (Jennings *et al.*, 2001).

Although it represents the most widely used model of growth in the growth studies, it presents some problems: it does not take into account the changes in the distribution of energy, as occurs during the breeding season and in addition, it does not consider the differences in growth rate among adults and juveniles (Enberg *et al.*, 2008).

1.6.1. Back-calculation

Back-calculation (BCF or reversed calculation) allows to estimate the size of an individual before its capture by analysis on increments present on calcified structures (Panfili *et al.*, 2002). This calculation permits to estimate length that individual should have at a certain age (Fig. 1.18), corresponding to the deposition moment of a certain ring on the calcified structure (Francis, 1990).

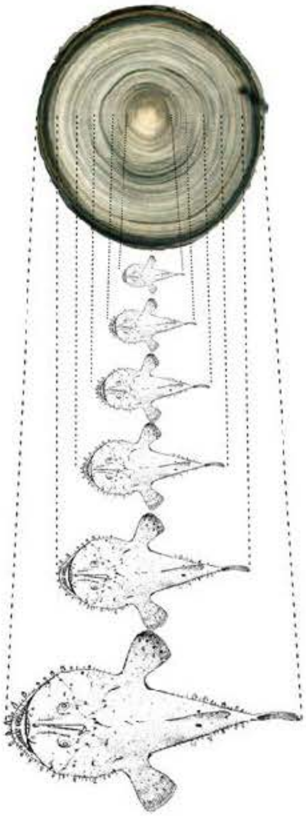


Figure 1.18. A simple example using a calcified structure (*illicum*) back-calculations to estimate retrospective growth histories of fish (photo A. Massaro, 2014)

Originally, this technique has been applied to scales (Lea, 1910; Lee, 1920) but BCF was used also for otolith, opercular bones, vertebrae and fin rays (Hickling, 1933;

Le Cren, 1947; Tweddle, 1975; Lauzanne, 1978; MacCrimmon, 1979; Clay, 1982; Antoine *et al*., 1983; Berkeley and Houde, 1983; Graynoth, 1987). The principle on which BCF is based is the significant correlation between fish and calcified structure dimensions (Francis, 1990; Panfili *et al*., 2002).

Furthermore, it can be carried out only in the case of whole otolith and exact age assignment (Panfili *et al*., 2002). With these conditions, it will be possible transform otolith dimension in somatic length and subsequently estimate growth parameters through growth models.

Back-calculation represents the best alternative to mark-recapture techniques (Davies and Sloane, 1986; Rijnsdorp and Visser, 1987). Indeed, it presents the advantage that it can also be potentially used on a higher number of samples (individuals belonging to a population or to a stock) compared with mark-recapture, in which recaptured individuals are inferior.

To carry out BCF, data as total length at capture, otolith *radius* at capture (measured from the *nucleus* to the edge) and otolith ring distance at a certain age (*radius* of given annual rings) are necessary.

Back-calculation can be realized in different methods depends on the kind of relation that exists between somatic fish length and calcified structure dimension used in back-calculation method.

The most known are (Panfili *et al*., 2002):

- Dahl-Lea direct proportionality method, when a linear relationship exists between size and *radius* of the otolith.
- Fraser-Lee method, when the intercept of the relation between somatic length and otolith radius is not at the origin.
- Campana (1990) biological intercept method, when both calcified structure size and somatic size are larger than 0.

2. SYSTEMATIC

The taxonomic position for *Boops boops* according to Nelson *et al.* (2016) is:

PHYLUM: Chordata
SUBPHYLUM: Verterbrata
CLASS: Actinopterygii
ORDER: Perciformes
FAMILY: Sparidae
GENUS: *Boops* Cuvier, 1814
SPECIE: *Boops boops* (Linnaeus, 1758)

Bogue, *Boops boops* (Linnaeus, 1758), belongs to the order of Perciformes which includes about 160 families for a total of over 10,000 species found in almost all aquatic environments.

The species belongs to the family Sparidae, the genus *Boops* is represented by 2 species: *B. boops* (bogue) and striped bogue *Boops lineatus* (Boulenger, 1892) (Fig. 2.0).

Figure 2.0 - Representation of *Boops boops* (from Sartor *et al.*, 2015)

2.1. MORPHOLOGY

The bogue (Fig. 2.1), whose name derives from its very large eyes (*boos* = ox and *ops* = eye), has a spindle-shaped body, slightly compressed laterally, covered with relatively large and robust scales. Head is conical. Mouth, small and oblique, has thin lips. Teeth are small and arranged in a single row on both jaws, the upper teeth have four sharp tips with serrated edges, while in the lower jaw, teeth have five tips with the central one larger than the other (Relini *et al.*, 1999). Long rays support all fins, except for the caudal and pectoral ones. Dorsal fin (15-16 rays) is long and wide and its posterior part is lower with a pointed posterior lobe (12-16 soft rays). Anal fin (3 rays), opposed to the soft part of the dorsal fin, is short and not reach anus. Pectoral fins are triangular, with a pointed upper lobe, and are elongated rearwards but do not reach the anal orifice (Bini, 1968; Costa, 1991). Forked caudal fin.

It is yellow-green in color with silver sides, the back is darker with a gray-green coloration and metallic reflections; the belly is white. At the top of the pectoral fin base there is a small brown blotch. 3-5 golden-yellow longitudinal stripes depart from the head and reach caudal fin. Fins are greenish, except for pectoral fins and tail, which appear dark brown (Costa, 1991; Relini *et al.*, 1999).

Figure 2.1 - Specimen of *Boops boops*

2.2. HABITAT AND DISTRIBUTION

B. boops is common throughout the Mediterranean including the Black Sea (Fig. 2.2), Eastern Atlantic Ocean, from Norway to Angola (Froese and Pauly, 2016), and western Gulf of Mexico and the Caribbean (Fischer *et al.*, 1987). In the Mediterranean Sea, the presence of this Sparidae is detected up to 350 m depth (Campillo, 1992; Cannizzaro *et al.*, 2001; El-Haweet *et al.*, 2005), but usually is found on the inner edge of the continental shelf, between the surface and 100 m (Relini *et al.*, 1999; El-Haweet *et al.*, 2005). The presence of the bogue in the Atlantic Ocean is determined up to 500 m depth (Abecasis *et al.*, 2008).

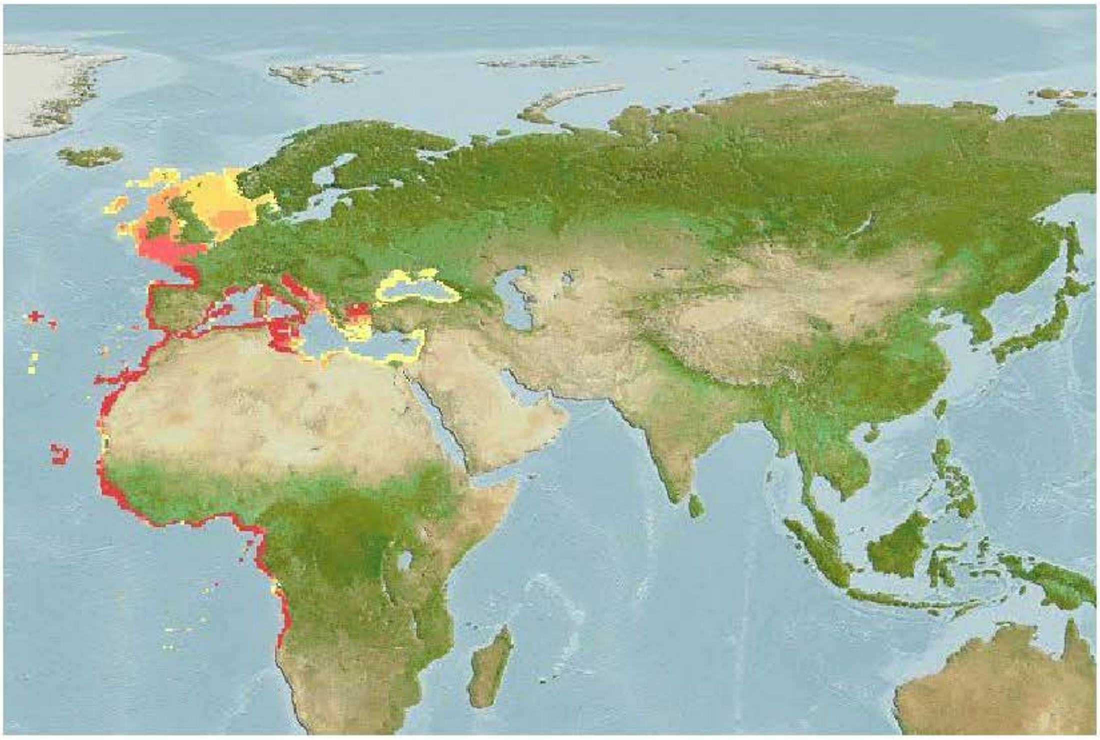


Figure 2.2 - Spatial distribution of *Boops boops*. In red areas of greatest abundance, in yellow areas of lower abundance (from www.fishbase.org)

It is a benthopelagic specie and it can generally be found down to 100 m (Mediterranean Sea) or 300 m (Atlantic Ocean), and infrequently down to 350 m, above different bottoms (sand, mud, rocks and *Posidonia* beds) (Tortonese, 1975) and it moving up to the surface during the night.

It has shoaling behavior, according to typical habit of sparids. Usually adults live in off-shore water where stationed during winter season; in early spring, they approach the coast for reproduction and in spring-summer juveniles are present in the shallow waters where remains until late summer-autumn when they reach deeper water (recruitment time) (Zúñiga, 1967).

2.3. DIET

Studies about diet composition and changes were carried out only for the Mediterranean populations (Bini, 1968; Jukić, 1972; Anato and Ktari, 1983b; Bell and Harmelin-Vivien, 1983; Sánchez-Velasco and Norbis, 1997; Derbal and Kara, 2008). In general, adults feed in the water column during the day and stay near the bottom during the night (Bini, 1968).

Bogue is mainly omnivorous species, although larvae, juveniles and adults have different diet: larvae feed mainly on copepod *nauplii* (Sánchez-Velasco and Norbis, 1997); juveniles feed on large quantities of algae (*Clorofita*) (Bini, 1968; Anato and Ktari, 1983b; Derbal and Kara, 2008). Adults feed both on pelagic preys (siphonophores, jellyfishes, copepods, eggs) (Bombace and Li Greci, 1970) and larvae of marine organisms (especially fish) and benthic preys (crustaceans, molluscs, annelids, sipunculoidei) (Milisenda *et al.*, 2014).

In Mediterranean sea, bogue's predators reported in literature relate to bony fishes belong to Carangidae, Scombridae, Serranidae, Scorpenidae, Sinodontidae, Gadidae, and Xiphiidae families, whilst in the Atlantic Ocean they belong to Zeidae, Carangidae and Sphyraenidae families (Jardas, 1976; MacPherson, 1978; Yoshida, 1980; Bradai and Bouain, 1990; Golani, 1993; Matallanas *et al.*, 1995; Labropoulou and Eleftheriou, 1997; Silva, 1999; Barreiros *et al.*, 2002, 2003; Santic *et al.*, 2003).

2.4. GROWTH

The maximum length reported in the Atlantic Ocean is 41 cm total length (Quigley and Flannery, 1995), while in the Mediterranean Sea is 40 cm total length (Costa, 1991; Cannizzaro *et al*., 2001). In general most of the specimens ranging between 10 and 25 cm total length (Fischer *et al*., 1987; Campillo, 1992). Recruitment is discrete and growth is slower in cold weather, even if commercial catches seem to show a wide unimodal distribution without noticeable peaks (Campillo, 1992). Although the bogue is generally considered as a secondary species compared to other Sparidae family members, several studies on its life cycle were carried out. Growth studies were carried out by several authors using, almost exclusively, von Bertalanffy function (Pauly, 1984). The lower asymptotic length for the Mediterranean Sea is 26 cm total length for the Ligurian and northern Tyrrhenian seas (Massaro *et al*., 2014), the highest is 45 cm total length for the Sicilian Channel (Cannizzaro *et al*., 2001). In the eastern Atlantic Ocean the asymptotic length ranging between 26.8 cm total length (Abecasis *et al*., 2008) and 43.5 total length (Serrano-Gordo, 1996) (Table 2.0).

Massaro *et al.* (2014), in the Ligurian and central-northern Tyrrhenian Sea (FAO Geographic Sub-Area 9, GSA 9) do not report any significant difference in growth between males and females and report faster growth rates, *k*, with higher values with respect to those calculated in other areas. However, values of asymptotic length estimated in GSA 9 are lower than those observed in other areas.

Table 2.0 – von Bertalanffy growth parameters of *Boops boops*. M: males; F: females; C: combined sex; L_∞ = asymptotic length (cm); k = growth coefficient ($years^{-1}$); t_0 = hypothetical age at zero length (years)

Author	**Area**	**Method**	**Sex**	**L_∞**	**k**	**t_0**
Alegria-Hernandez, 1986	Norther Adriatic Sea	Otolith	C	32.22	0.19	-2.00
		LFD	C	33.9	0.17	-1.30
Allam, 2013	South Levant	Scales	C	37.1	0.15	-1.78
Anato and Ktari, 1986a	Tunisia	Otolith	C	39.6	0.11	-1.69
Abecasis *et al.*, 2008	Portugal	Otolith	C	28.14	0.20	-1.90
Abecasis *et al.*, 2008	Portugal	Scales	C	26.76	0.34	-1.27
Caldentey, 1987	Canary Islands (Tenerife)	Otolith	C	35.2	0.17	-2.06
Campillo, 1992	France	LFD	C	30.2	0.18	
Cannizzaro *et al.*, 2001	South of Sicily	Otolith	C	45	0.13	-1.90
Djabali *et al.*, 1990	Algeria	LFD	M	26.6	0.21	-2.60
			F	27.3	0.22	-1.94
Djabali et al., 1993	Algeria	LFD	C	25.4	0.29	
El-Haweet *el al.*, 2005	South Levant	Scales	F	31.9	0.15	-1.53
			M	28.1	0.18	-1.13
		LFD	F	30.5	0.19	-0.99
			M	29.7	0.25	-0.70
El-Okda, 2008	South Levant	Otolith	C	30.1	0.15	-1.51
Giardin and Quignard, 1986	Gulf of Lyon	Scales	C	33.7	0.19	-0.75
Giardin, 1978	Gulf of Lyon	Scales	C	46.8	0.15	-0.87
Giardin, 1978	Gulf of Lyon	Otolith	C	46.5	0.08	-3.54
Serrano-Gordo, 1996	South European Atlantic Shelf	Otolith	F	43.5	0.14	-2.40
			M	42.4	0.15	-2.29
		BCF	F	41.8	0.15	-2.16
			M	41.7	0.15	-2.12
Abecasis *et al.*, 2008		Otolith	C	28.1	0.20	-1.90
		Scales	C	26.8	0.34	-1.27
Monteiro *et al.*, 2006		Otolith	C	28.1	0.22	-1.42
Hassan, 1990	Egypt	Scales	C	29.8	0.18	-1.33
Kara and Bayhan, 2008	Turkey	LFD	F	30.8	0.24	-0.90
			M	29.9	0.24	-0.98
Khemiri *et al.*, 2005	Gulf of Tunis	Otolith Slide	C	24.3	0.23	-1.65
Khemiri *et al.*, 2006	Gulf of Hammamet	Otolith Slide	C	26.8	0.22	-1.43
Layachi *et al.*, 2015	Morocco	LFD	C	30	0.41	-0.30
Lividas, 1989	Cyprus	Scales	C	24	0.53	0.45
Manasirli *et al.*, 2006	North Levant	Otolith	C	33.6	0.11	-1.90
Massaro *et al.*, 2014	Ligurian - North Thyrrenian Sea	LFD	F	25.4	0.37	-1.10
		LFD	C	26.5	0.37	-1.00
		LFD	M	26	0.39	-0.90
		Otolith	C	26	0.40	-1.20
		Otolith	M	25	0.43	-1.00
		Otolith	F	25.5	0.43	-1.20
Mehanna, 2014	Egypt	Otolith	C	27.2	0.54	-0.33
Mennes, 1985	Sahaara	LFD	C	32	0.29	
Rachid, 2014	Algeria	LFD	C	29.7	0.33	
Soykan *et al.*, 2015	Turkey	Otolith	C	29.58	0.26	-1.42
Tsangridis and Filippousis, 1991	Greece	LFD	C	36	0.40	
Zoubi, 2001	Alboran Sea	Scales	C	31.5	0.28	-0.96
Zúniga, 1967	Spain (Castellon)	Scales	C	35.6	0.17	-2.14

2.5. SEXUAL MATURITY AND REPRODUCTION

On the reproduction, one of the critical aspects still not fully explained, concerns the incidence and type of hermaphroditism (proterandric or proteroginic). D'Ancona (1949) and Reinboth (1962) defined *B. boops* as a "rudimentary" hermaphrodite species in which only one gender is developed from an initially bisexual gonad. Lissia-Frau (1966a, b), Lissia-Frau *et al*. (1977) and Serrano-Gordo (1995) defined the bogue as a sequential hermaphrodite proteroginic species with diandric population. In contrast, according to some authors, proteroginic hermaphroditism concerns only a small percentage of specimens (Campillo, 1992; Lamrini, 1998; Zoubi, 2001; Monteiro *et al*., 2006; Bottari *et al*., 2014).

Bogue is a partial spawner species, as mature females lay eggs in groups, during an extended period of time (Serrano-Gordo, 1996; El-Agamy *et. al*., 2004). The reproductive period is quite wide with some seasonal variations according to the geographical area (Girardin *et al.,* 1986; Alegría-Hernández, 1990; Lamrini, 1998; Relini *et al*., 1999; El-Agamy *et al*., 2004; Monteiro *et al*., 2006; Layachi, 2015). Spawning takes place mainly between February and June in the western Mediterranean (Zuñiga, 1967; Ávila Parga, 1970; Girardin *et al.,* 1986; Lamrini, 1998), and between January and May in the eastern Mediterranean (Vidalis, 1950; El-Agamy *et al*., 2004). Reproduction in the Atlantic Ocean occurs between February and May (Monteiro, 1989; Serrano-Gordo, 1995) (Table 2.1). As reported by Bottari *et al*. (2014), mean monthly values of gonadosomatic index and sea surface temperature are significantly and inversely correlated, suggesting that this may be an important factor for sexual maturity. Sexual maturity size (Table 2.2) is reached in the Mediterranean between 11.7 and 15.2 cm TL (sexes combined) (Vidalis, 1950; Matta, 1958; Anato and Ktari, 1983a; Livadas, 1989; Alegría-Hernández, 1990; Bensahala-Talet *et al.,* 1990; Campillo, 1992; Zoubi, 2001; El-Agamy *et al.,* 2004; Bottari *et al*., 2014), corresponding to an age of 1-2 years. In the Atlantic Ocean the length at first maturity was similar for males and females and the value for sexes combined was estimated to be 15.2 cm TL, corresponding to an age of 1-3 years (Monteiro *et al.,* 2006).

Table 2.1 - Spawning periods of *Boops boops* in different areas of Mediterranean Sea and Atlantic Ocean. (modified from Massaro; in Relini *et.al.*, 2015)

Geographic Area	Sex	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	References
Mediterranean Sea														
Italy (Gulf of Naples)	C			🟦	🟦	🟦	🟦							Lo Bianco (1909)
Greece	C			🟦	🟦	🟦	🟦							Vidalis (1950)*
Algerian coast	C			🟦	🟦	🟦	🟦	🟦						Dieuzede *et al.* (1955)
Tuscan archipelago (Italy)	C			🟦	🟦	🟦	🟦							Matta (1958)*
Spain	C				■	■	🟦							Zúñiga (1967)
Italy	C				🟦	🟦	🟦							Bini (1968)
European coasts	C			🟦	■	■								Ávila Parga (1970)
Lebanon coasts	C		🟦	🟦	🟦									Mouneimne (1978)
Gulf of Lion (France)	C			🟦	🟦	🟦	🟦							Girardin *et al.* (1986)*
E. Mediterranean	C		🟦	🟦	🟦									Whitehead *et al.* (1986)
W. Mediterranean	C				🟦	🟦								Whitehead *et al.* (1986)
Algerian coasts	C			🟦	🟦	🟦	🟦							Chali-Chabane (1988)
Tunisian coasts	C			🟦	🟦	🟦	🟦							Anato (1986)
Cyprus	C				🟦	🟦								Livadas (1989)*
Oran Coast (Algeria)	C		🟦	🟦	🟦	🟦	🟦							Bensahala Talet *et al.* (1990)
Adriatic Sea (Croatia)	C			🟦	🟦	🟦								Alegría-Hernández (1990)*
Gulf of Lion (France	C			🟦	🟦	🟦	🟦							Campillo (1992)*
Spain (Murcia)	C			🟦	🟦	🟦								Cano-Fortuna Sanchez-Lizasu (1996)
Strait of Gibraltar (Morocco)	C			🟦	🟦	🟦	🟦	🟦						Lamrini (1998)*
Egypt(Alexandria)	C	🟦	🟦	🟦	🟦	🟦								El-Agamy *et al.* (2004)*
Algeria	F		🟦	🟦	🟦	🟦							🟦	Kherraz (2011)
S. Tyrrhenian Sea	C		🟦	■	🟦									Bottari *et al.* (2014)
Black Sea														
Black Sea	C						🟦	🟦	🟦					Whitehead *et al.* (1986)
Black Sea	C				🟦	🟦								Bauchot (1987)*
Atlantic Ocean														
E. Atlantic	C				■	■								Lloris *et al.* (1977)
C. E. Atlantic	C			🟦	🟦	🟦								Bauchot *et al.* (1981)
Canary Islands	C	🟦	🟦										🟦	Ojeda (1983)•
E. Atlantic	C		🟦	🟦	🟦									Whitehead *et al.* (1986)
W. Atlantic	C				🟦	🟦								Whitehead *et al.* (1986)
Atlantic	C			🟦	🟦	🟦								Whitehead *et al.* (1986)
Canary Islands	C			🟦	■	■	■	■						Caldentey (1987)•
Algarve (Portugal)	C		🟦	🟦	🟦	🟦								Serrano-Gordo (1995)*
Peniche (Portugal)	C			🟦	🟦	🟦	🟦							Serrano-Gordo(1995)*
Algarve (Portugal)	C		🟦	🟦	🟦	🟦								Monteiro *et al.* (2006)*

■ Peak of spawning period

* in Bottari *et al.* (2014); + in Tsikliras and Stergiou (2013); • in Cano-Fortuna and Sanchez-Lizaso (1996).

Table 2.2 - Size at first maturity of *Boops boops* in different areas of Mediterranean Sea and Atlantic Ocean. (modified from Massaro; in Relini *et.al.*, 2015)

Geographic Area	**Sex**	**Length range (TL, cm)**	**Minimum Length Mature (TL, cm)**	**50% Mature (L50) (TL, cm)**	**References**
Mediterranean Sea					
Algeria	F			13.0	Bouhniol and Pron (1916)*
Greece	F			15.0	Vidalis (1950)*
	M			13.0	
Tuscan archipelago (Italy)	F			13.5	Matta (1958)
Lebanon coasts	F			12.0	Mouneimne(1978)*
Gulf of Lion (France)	C		11.0	13.0-15.0	Girardin (1978)
Gulf of Lion (France)	F			13.0	Girardin (1981)
Bou Ismail (Algerian)	F	9.5-23.5		13.5	Chali-Chabane (1988)+
Cyprus	F			15.0	Livadas (1989)*
	M			13.0	
Adriatic Sea (Croatia)	F	10.0-23.0		14.5	Alegría-Hernández (1990)+
	M	9.0-20.0		13.2	
Oran Coast (Algeria)	F	13.3-27.0		14.1	Bensahla Talet *et al.* (1990)+
Gulf of Lion (France)	C			13.0	Campillo (1992)*
Cretan Sea (Greece)	F	11.0-18.0		13.8	Kallianiotis (1992)+
	M	9.5-18.0		13.3	
	F	10.0-18.0		12.0	
	M	9.0-18.0		11.9	
Spain (Murcia)			10.0	10.2	Cano-Fortuna and Sanchez-Lizaso (1996)
Strait of Gilbraltar (Morocco)	C			15.3	Lamrini (1998)*
Morocco	C	12.2-25.6		17.1	Zoubi (2001)+
Egypt(Alexandria)	F			12.0	El-Agamy *et al.* (2004)*
	M			13.0	
Algeria	F		11.6	17.1	Kherraz (2010) *
S. Tyrrhenian Sea	F	7.9-33		13.1	Bottari *et al.* (2014)
	M	8.1-30.9		14.2	
	C	7.9-33		13.8	
Atlantic Ocean					
Algarve (Portugal)	F			~14.0	Serrano-Gordo (1995)*
	M			~13.0	
Peniche (Portugal)	F			~15.0	Serrano-Gordo (1995)*
	M			~14.0	
Algarve (Portugal)	F			~15.8	Monteiro *et al.* (2006)*
	M			~15.5	
Canary Islands	C			~13.4	Lozano *et al.* (1990)
Canary Islands	C			15.1	Caldentey (1987)

* in Bottari *et al.* (2014); + in Tsikliras and Stergiou (2015)

2.6. EVALUATION

In 1984 acoustic survey, "Canarias AI 484", was carried out to estimate the abundance by year class for Atlantic chub mackerel *Scomber colias* (Gmelin, 1789), European pilchard *Sardina pilchardus* (Walbaum, 1792) and abundance by length class for bogue (*B. boops*) (Pastor and Delgado de Molina, 1985). The total biomass estimated for bogue was 29200 ton; the total abundance in number of individuals per length class is shown in Fig. 2.3, whilst length distribution corresponding to each one of the fishing stations, and length distributions in the whole surveyed area are shown in Fig. 2.4 and in Fig. 2.5, respectively.

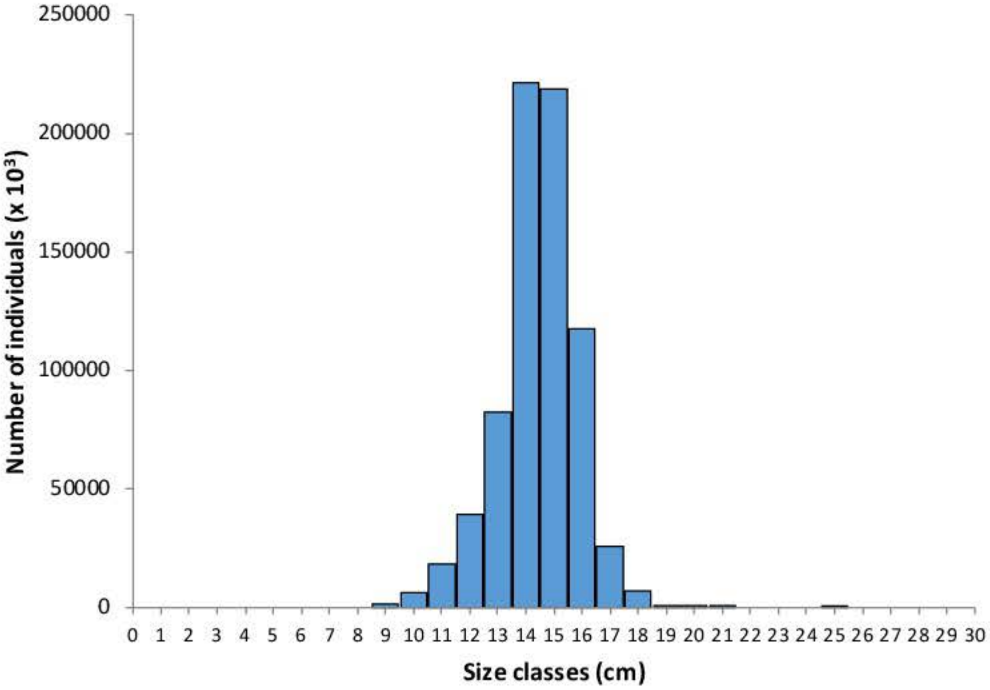


Figure 2.3 - Abundance in number of individuals per size classes for *Boops boops* of the Canary Islands

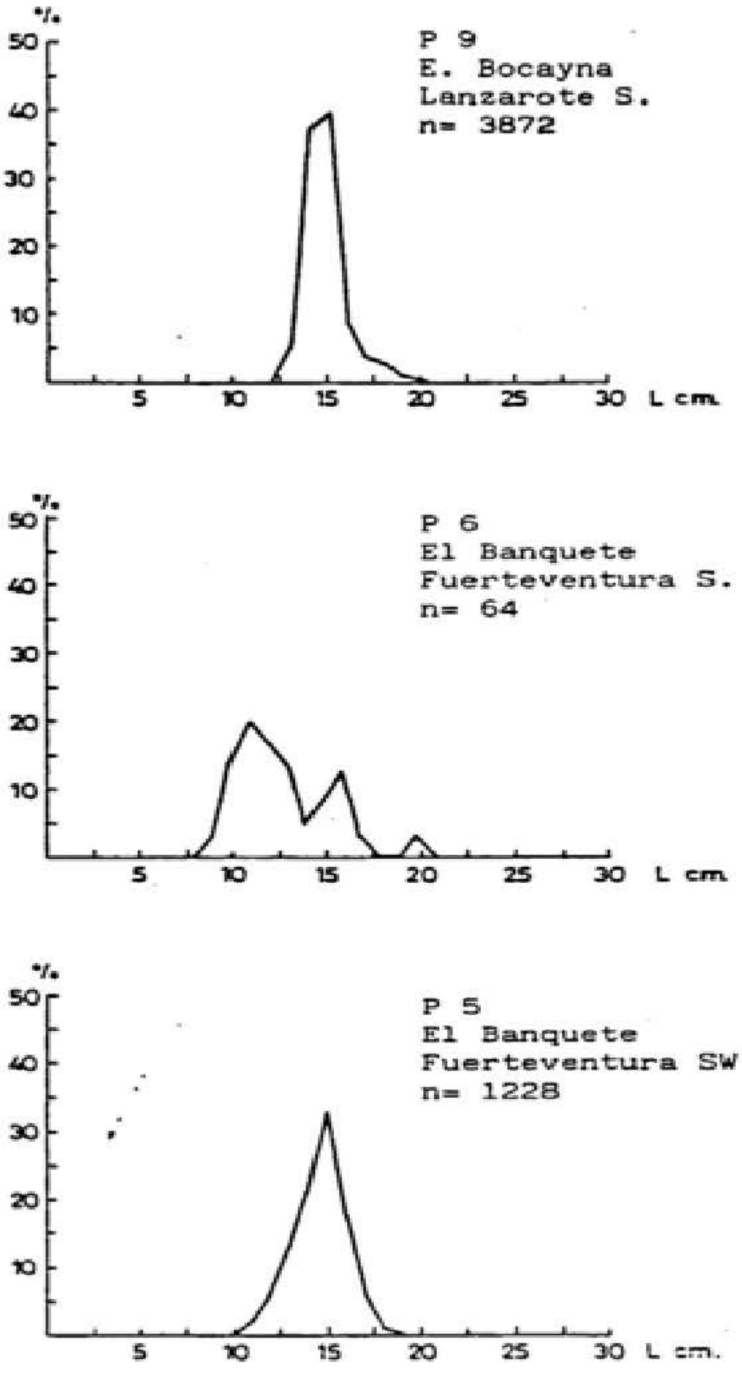


Figure 2.4 - Length distribution for bogue in the fishing stations during the acoustic survey, "Canarias AI 484" (from Pastor and Delgado de Molina, 1985)

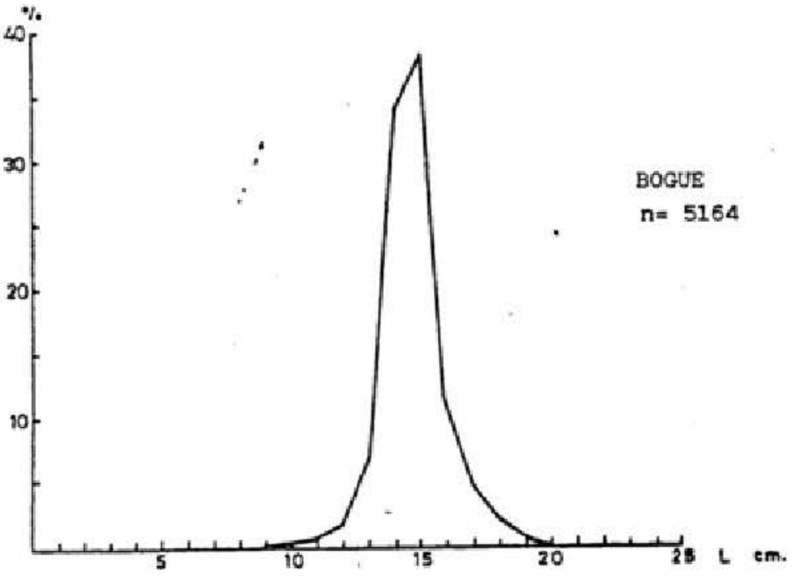


Figure 2.5 - Length distribution for bogue in the surveyed area during the acoustic survey, "Canarias AI 484" (from Pastor and Delgado de Molina, 1985)

More than 60 % of the biomass estimated was found in the waters around the islands of Fuerteventura and Lanzarote, including the shoals of El Banquete and Bajo de Amanay, situated south of Fuerteventura. It was observed a tendency of the fish concentrations to be located mainly in coastal regions of the north and north-east of each of the islands (Pastor and Delgado de Molina, 1985).

2.7. EXPLOITATION

2.7.1. Fishery and fishing pattern

Bogue is a by-catch species of the commercial fishing, especially that carried out with bottom and midwater trawling. The species is also captured by purse seines, trammel nets, gill nets (Cannizzaro *et al.*, 2001), longlines (Bini, 1968; Fischer *et al.*, 1987) and also with large traps of handmade rush baskets (Cannizzaro *et al.*, 2001).

In Gran Canaria it has limited commercial value and it lack of attractiveness for the recreational fishing sector. This is due to the fact that, despite its acceptable morphological and nutritional characteristics that make it suitable for commercialization, is erroneously considered undesirable and unpalatable for most consumers and, consequently, from the point of view of fishermen, their marketing is not economically viable despite it is relatively abundant.

Generally, it is discarded at sea after being captured by purse-seine fishery which target species are other middle-size pelagic fish (pilchard, chub mackerel, horse mackerel), and it represents the main discarded species of the artisanal fishery (>90%) (Castro *et al.*, 2015) developed off the island together with some benthic sharks and rays and species of low commercial value (box-fishes, damselfishes, etc.). Its capture also takes place as by-catch in gillnet, longline, and handline operations. On the other hand, line fishing such as that of the Canary Islands requires a substantial amount of bait to lure tuna and tuna like species. According to various sources, it appears that the most common species used for bait are the Atlantic chub mackerel (*S. colias*), followed by the European pilchard (*S. pilchardus*) and bogue (*B. boops*) (Castro *et al.*, 2015).

A system of regular fishing data collection in the Canary Islands reporting by the Canarian Government was only established in 2006 (Castro *et al.*, 2015), for this reason does not exist a historical catch statistic and estimates fishing effort. Catches data are available in the registers of markets and co-operative (cofradías) as first-sale data (Table 2.3).

Table 2.3 - Bogue catches (kg) in Canary Islands by first-sale data. By catch data no included

	YEAR				
ISLAND	**2007**	**2008**	**2009**	**2010**	**2011**
El Hierro	686.0	394.0	213.0	8.0	24.0
Fuerteventura	157.0	2078.3	550.7	941.0	91.2
Gran Canaria	73.0	88.5	171.0	206.0	116.8
La Gomera	20.0				
La Palma	1011.5	5546.0	4588.0	4474.0	1426.0
Lanzarote		29.0	442.4	549.0	773.1
Tenerife	511.0	7941.4	24485.8	19645.9	5947.9

3. STUDY AREA

3.1. LOCALIZATION

Canary Islands archipelago is a grouping of seven islands and several islets that form a zonal chain situated off northwest Africa (Fig 3.1). The islands are located between latitude 27º 37' and 29º 25' N and longitude 13º 20' y 18º 10' W of Greenwich, level with the southern portion of the large embayment that separates Cape Juby and Cape Ghir (Morocco), and have an east-west extent of ~ 500 km. The islands form part of a 3000 km long belt of islands and seamounts volcanically active, and extend from Madeira-Tore Rise to Cape Verde Islands. (Roest *et al.*, 1992), The eastern island (Fuerteventura) is separated from the African continent by 100 km of sea reaching depth greater than 1000 m. With the exception of Lanzarote and Fuerteventura, the islands have volcanic mountain ranges that exceed 1000m. The volcanic origin of the Canary is also observable by the absence of the insular platform or poorly developed (Lorenzo 1992; Roest *et al.*, 1992). In the case of Gran Canaria, the largest platform area is located on south, which is meager and reaches 200 m depth closer the coast (Lorenzo, 1992).

The island of Gran Canaria is located in the central part of the archipelago, presenting numerous sub-marine canyons that formed as a result of lateral collapse (Pajuelo *et al.*, 2015). Four main water masses characterize hydrologically these islands: the Eastern North Atlantic Central Water (ENACW), the Antarctic Intermediate Water (AIW), the Mediterranean Water (MW), and the North Atlantic Deep Water (NADW), which shows different characteristic in terms of depths and thermohaline properties (Ríos *et al.*, 1992; Hernández-Guerra *et al.*, 2002, 2003).

Canary Islands is located in the Canary Current System, one of the primary eastern boundary coastal upwelling systems of the world (Hagen, 2001; Carr, 2002; Eberwein and Mackensen, 2006; Chávez and Messié, 2009; Wilke *et al.*, 2009). This system has particular characteristics due to hydrological and productive characteristics capable of supporting large biomass of marine organisms population (Pajuelo *et al.*, 2015).

Figure 3.1 – Location of the Canary Islands

Canary Current System shows a nutrient gradient along the east west axis, and the western part is characterized by oligotrophic waters (De León and Braun, 1973; Braun, 1980) while moving towards the African continent, nutrient concentration increase due to the presence of African costal upwelling (Barton *et al.*, 1998).

The presence of these water masses with high productivity have also been identified in the south of the Canaries, where there is a high oceanographic activity due to the interaction between Canary Current System and the islands (Aristegui *et* *al.*, 1994, Barton *et al.*, 2004; Barton and Arístegui, 2004). In fact, perpendicular arrangement of islands with respect to the Canary Current System determines the formation of “calm areas” in the south of the islands (Lorenzo, 1992). These areas are characterized by a higher accumulation of plankton (Lorenzo, 1992). In general, nutrients concentration, primary production and biomass mesozooplankton measured in southwest of Gran Canaria, are higher than those provided by other authors for oceanic waters of the archipelago (Arístegui *et al.*, 1989). Furthermore, the collision of these water masses with different characteristics (Barton *et al.*, 1998) gives rise to phenomena of upwelling throughout the year, with greater intensity during the late summer (Mittelstaedt, 1991; Van Camp *et al.*, 1991; Arístegui *et al.*, 2009).

These phenomena determine changes in cell composition of the superficial coastal primary production (Arístegui *et al.*, 2004) leading to the formation of large plankton cells (Basterretxea and Arístegui, 2000; Aristegui *et al.*, 2004; Aristegui, and Montero, 2005) during periods of intense upwelling and small cell plankton communities when the intensity decreases (García-Muñoz *et al.*, 2004). This hydrographical circulation pattern around the island has relevant consequences for enrichment, retention and transport of fish eggs and larvae in the region (Rodríguez *et al.*, 2001).

From ecological point of view, the main property of Canary Current System is the presence of a thermocline between 50 and 130 m deep (Fernández de Puelles, 1987). The thermocline is present from spring until winter, reaching its peak during the summer. The constant stratification during most of the year, precludes the possibility of the nutrients reaching the surface (de León and Braun, 1973; Braun, 1980; Barton *et al.*, 1998). In the period between January and March, this semi-permanent thermocline is eroded by cooling of surface water, allowing nutrients to reach the surface levels. This phenomenon is known as “late winter bloom "and is considered the most productive phenomenon in these waters (de León and Braun, 1973; Braun, 1980; Arístegui *et al.*, 2004).

During this period an increase in concentration of chlorophyll a and primary production occurs (from 200 mg C m^2 d^{-1} reaching values of 800-1000 mg C m^2 d^{-1}) (de León and Braun, 1973; Braun, 1980; Arístegui *et al.*, 2004; Hernández-León *et al.*, 2007). This phase is followed by an increase of mesozooplankton biomass (Hernández-León *et al.*, 2004, 2007; Arístegui *et al.*, 2009).

3.2. FISHING

Fishing activities in Canary Islands are limited due the geomorphological structure and the relatively low productivity (Bas *et al.*, 1995). The small-scale fisheries are constituted by artisanal fleet consisting of medium and small size vessels, made mostly by wood, operating in neritic waters (Bas *et al.*, 1995).

In the last half-century fishing methods have not changed (García-Cabrera, 1970; Hernández-García *et al.*, 1998); however significant increase in fishing effort occurred due to the development of advanced technologies both in terms of onboard instruments both in terms of the materials used (Sistiaga-Mintegui, 2011). The result is an over-exploitation of most of the archipelago's fishing resources (González, 2008).

Comparing landed data from El Hierro and Gran Canaria is clear this over-exploitation situation; in fact although El Hierro is the smallest island of the archipelago, its landed exceed 30 times those of Gran Canaria, which has the largest platform of archipelago (García-Cabrera, 1970; Bas *et al.*, 1995).

Regarding Gran Canaria island, coastal fishing is mainly focused on demersal and benthopelagic species, as Mediterranean parrotfish, *Sparisoma cretense* (Linnaeus, 1758), red-striped mullet, *Mullus surmuletus* (Linnaeus, 1758), octopus and crustaceans (García-Cabrera, 1970; Bas *et al*, 1995; Melnychuk *et al.*, 2001). Small fleet of purse developed in last years, dedicating to the capture of pelagic coastal species, especially chub mackerel, *Scomber colias,* and sardines as *Sardinella aurita* (Valenciennes, 1847) and *Sardina pilchardus* (Bas *et al.*, 1995).

Both fisheries have a seasonal pattern, determined by fishing tuna time (Ramos, 1996; Ganzedo-López, 2005) and by biological cycles of the species (Hernández-García *et al.*, 1998).

Another important factor to take into account is the high number of recreational fishermen who exploits the resource (Bas *et al.*, 1995). Market analysis conduct by MAPya (2006) established that recreational fishing may involve between 40 and 50% of the total landed catch.

Additional strain on this situation is the absence of a catch registration system until 2006 (Bas *et al.*, 1995). This lack of control leads to underestimation of the catch (Bas *et al.*, 1995). We need only consider the example that, very often, daily catches were sold directly on the beach (Bas, *et al*., 1995). Although the current situation involves recording catches, the system is not entirely adequate; in fact, for example, there is not any control regarding catches obtained in external fisheries or on species, as bait for live-bait, for which fishing is not registered. In addition, there is not fishing effort estimation made by artisanal fleet, least of all recreational sector (MAPyA, 2006).

4. MATERIALS AND METHODS

4.1. SAMPLING

All specimens of *Boops boops* were collected monthly from January to December 2012, as by-catch from artisanal fleet landed in Arguineguín harbor (Fig. 4.0). It represents the most important harbor for Gran Canaria's artisanal fleet dedicated to pelagic fishing (Lorenzo, 1992).

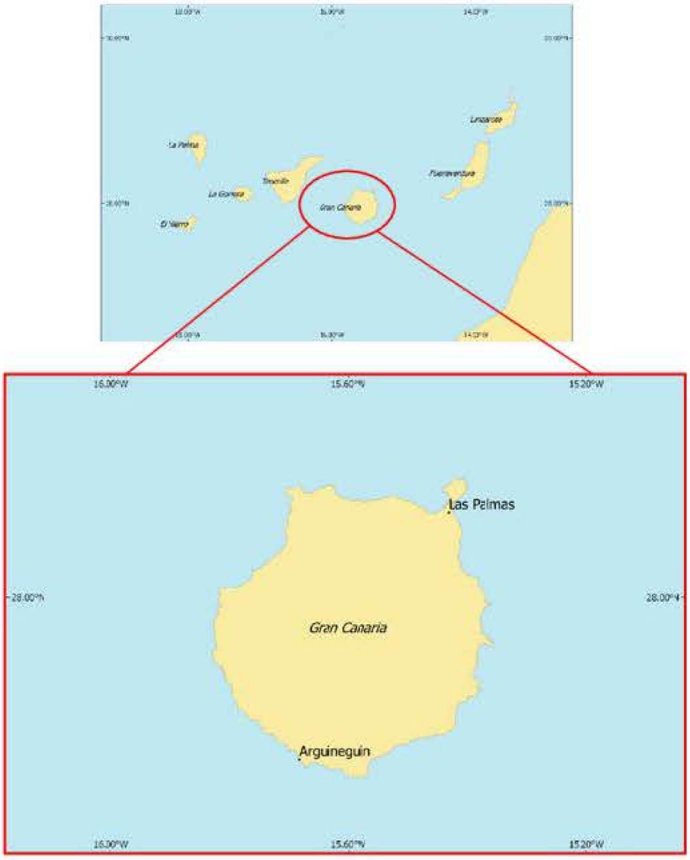


Figure 4.0 – Location of the Arguineguín harbor in the Gran Canaria Island.

Specimens were captured by F/V *Juan Carlos Primero*, (Fig. 4.1) with purse seiners, in the shelf waters (Castro, 1991) located on S/SW of the island with depth between 30 and 100 m. The vessels that use this type of fishing, also called traiñas, can be operated by one or two vessels. Most usual is a purse seine operated by a single vessel, “purse seiner”, with or without an auxiliary skiff (Castro *et al.*, 2015). Hydro-acoustic instruments, like sonar, are important tools to locate fish aggregations. Also common is the use of "natural" signs of fish aggregations (often observed with binoculars) to start with the fishing operation, like concentration of sea birds, ruffling of the water surface and presence of groups of dolphins. Artificial "Fish Aggregating Devices" (FAD's) and light attractions are used in this fishery to concentrate the fish (Castro *et al.*, 2015). After landing, the samples were immediately analyzed in the laboratory of Department of Biology.

Figure 4.1- F/V Juan Carlos Primero. Net hauling operation off Arguineguín (Photo: Massaro)

4.2. BIOLOGICAL DATA COLLECTED

All samples from commercial catches were taken to the laboratory for testing of biometrics, individual weights and age determination. For each specimen of *B. boops* were taken the following data:

- Total length (TL): measured as the length from the apex of the head to the end of the longest radius of the caudal fin, using with a ichthyometer and with an appreciation to the nearest lower 0.5 centimeter.
- Total weight (TW): taken with a technical balance with 0.01 g precision and an appreciation of 0.01 g.
- Eviscerated weight (EW) taken with a technical balance with 0.01 g precision and an appreciation of 0.01 g.
- Gonad weight (GW) taken with a technical balance with 0.001 g precision and an appreciation of 0.001 g.

On sub-sample also, both otoliths (*sagittae*) were removed, dry and preserved in envelope for latter growth studies (Fig. 4.2). Pairs of *sagitta* otoliths were removed by median sagittal cut from the mouth up to the back of the head area (Fig. 4.3). After extraction (Fig. 4.4), each otolith was cleaned in distilled water in order to remove any residual organic material (tissue, blood, etc.) and stored dry in small plastic containers (Eppendorf type). Each phial was marked by a code indicating all the information necessary to trace sample.

Figure 4.2 - Specimens of *Boops boops* with its otoliths (Photo: Massaro)

Figure 4.3 - Median sagittal cut (Photo: Massaro)

Figure 4.4 - Otoliths position (Photo: Massaro)

As most of the majority of the teleost species, bogue is not characterized by sexual dimorphism, and sex determination and gonadal development stage is carried out with macroscopical gonads examination. Sex of the individuals were classified as female (F), male (M), intersexuals (T) or indeterminable (I). For all specimens sampled this analysis was carried out by a longitudinal cut from anal cavity to gills (Fig. 4.5).

Figure 4.5 - Dissection of a specimen for macroscopic observation of gonads (Photo: Massaro)

With advancing of the maturation process, in both sexes is observed an increase in size of the gonads, which occupy more space within the abdominal cavity (Table 4.0). For the different degrees of development of the gonad is associated a specific stage of maturity, described and coded in a macroscopic scale (Table 4.1). In this work, for the evaluation of different maturity stages, was adopted the MEDITS Protocol (Relini *et al.*, 2008). This maturity scale distinguishes the following stages:

- **Stage 0: undetermined**. Sex is not distinguishable to naked eye. Gonads are very small and translucent.
- **Stage 1: virgin**. Gonads, although still small, allows the distinction between the sexes. In females, ovaries are small, translucent or color tends to pink, shorter than 1/3 of the abdominal cavity. In males, testicles are thin, thread-like translucent.
- **Stage 2a: developing**. Gonads begins for the first time the maturation process. In females, the ovaries are still small, with color between pink and red and length

less than half of the abdominal cavity. In males, testicles are thin, whitish and shorter than half of the abdominal cavity.

- **Stage 2b: recovery**. Gonads are larger compared to the earlier stage, take up the vitellogenesis process having already completed one or more reproductive cycles. In females, ovaries take a color ranging from pink to red and orange and they are long for about a half of the abdominal cavity. Blood vessels are visible, but the oocytes are not visible by naked eye yet. In males, testicles have a whitish coloration and they are more or less symmetrical and long about half of the abdominal cavity.
- **Stage 2c: maturing**. In this stage, the size of the gonads increases. In females, the ovaries are pinkish-yellow with grainy, long about 2/3 of the abdominal cavity. Oocytes are visible by naked eye through the ovarian tunica, which is not yet completely translucent. Under light pressure oocytes are not expelled outside the urogenital orifice. In males, testicles have color between white and cream and they are long about 2/3 of the abdominal cavity. Under light pressure seminal fluid not ejected.
- **Stage 3: mature/spawning**. Gonads reaches more or less the maximum size. In females, the ovaries are pink-orange colored. They are very long from 2/3 up to the whole extension of the abdominal cavity. Oocytes are distinguishable by naked eye, hydrated (transparent) or in the hydration process. Under light pressure they are ejected and, in more advanced cases, they flow out freely. In males, testicles with white-cream color are soft and long from 2/3 up to the whole extension of the abdominal cavity. Under light pressure the seminal liquid is expelled and in more advanced cases flows freely.
- **Stage 4a: spent**. Gonads appear flushed and dilated due to gametes deposition. In females, ovaries are reddish and considerably reduced in size to about more than half of the cavity. The ovarian walls are flaccid and ovaries contains residues of oocytes disintegrated with dull and / or translucent aspect. In males, testicles are flabby and dilated blood vessels take on a white color with red edges, also fallen to about half the abdominal cavity.
- **Stage 4b: resting**. Gonads take on a completely flaccid and emptied aspect. In females, ovaries show red-rose coloration. They cover about 1/3 of the abdominal

cavity. Oocytes are no longer visible by naked eye. In males, testicles with pink-red color are more or less symmetrical and long about 1/3 of the cavity abdominal.

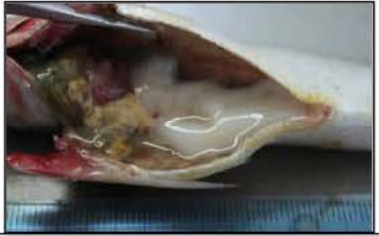
Table 4.0 - Codes of sexual maturity for bony fish (from Relini *et al.*, 2008 - MEDITS-Handbook. Version n. 8, 2016)

SEX	**GONAD ASPECT**	**MATURATION STATE**	**STAGE**
I	**Sex not distinguished by naked eye. Gonads very small and translucid, almost transparent. Sex undetermined.**	**UNDETERMINED**	**0**
F	**Small pinkish and translucent ovary shorter than 1/3 of the body cavity. Eggs not visible by naked eye.**	**IMMATURE=VIRGIN**	**1**
M	**Thin and withish testis shorter than 1/3 of the body cavity.**		
F	**Small pinkish/reddish ovary shorter than ½ of e body cavity. Eggs not visible by naked eye.**	**VIRGIN-DEVELOPING***	**2a**
M	**Thin withish testis shorter than 1/2 of the body cavity.**		
F	**Pinkish-reddish/ reddish-orange and translucent ovary long about ½ of the body cavity. Blood vessels visible. Eggs not visible by naked eye.**	**RECOVERING***	**2b**
M	**Withish/pinkish testis, more or less symmetrical, long about ½ of the body cavity**		
F	**Ovary pinkish-yellow in colour with granular appearance, long about 2/3 of the body cavity. Eggs are visible by naked eye trough the ovaric tunica, which is not yet translucent. Under light pressure eggs are not expelled.**	**MATURING**	**2c**
M	**Withish to creamy testis long about 2/3 of the body cavity. Under light pressure sperm is not expelled.**		
F	**Ovary orange-pink in colour, with conspicious superficial blood vessels, long from 2/3 to full length of the body cavity. Large transparent, ripe eggs are cleary visible and could be expelled under light pressure. In more advanced conditions, eggs escape freely.**	**MATURE/SPAWNER**	**3**
M	**Whitish-creamy soft testis long from 2/3 to full length of the body cavity. Under light pressure, sperm could be expelled. In more advanced conditions, sperm escapes freely.**		
F	**Reddish ovary shrunked to about 1/2 length of the body cavity. Flaccid ovaric walls; ovary may contain remanants of disintegrating opaque and/or translucent eggs.**	**SPENT**	**4a**
M	**Bloodshot and flabby testis shrunken to about 1/2 length of the body cavity**		
F	**Pinkish and translucent ovary long about 1/3 of the body cavity. Eggs not visible by naked eye.**	**RESTING***	**4b**
M	**Whitish/pinkish testis, more or less simmetrical, long about 1/3 of the body cavity.**		

Table 4.1 - Macroscopic images for all maturity stages in *Boops boops* (modifed from Massaro; in Relini *et. al.*, 2015)

FEMALES			
Stage	Maturation state	Photos	
1	Immature virgin		
2a	Virgin developing		
2b	Recovering		
2c	Maturing		
3	Mature spawner		
4a	Spent		
4b	Resting		

Table 4.1 (continue) - Macroscopic images for all maturity stages in *Boops boops* (modifed from Massaro; in Relini *et. al.*, 2015)

MALES			
Stage	Maturation state	Photos	
1	Immature virgin		
2a	Virgin developing		
2b	Recovering		
2c	Maturing		
3	Mature spawner		
4a	Spent		
4b	Resting*		

4.3. CATCHES COMPOSITION

The measurements of the sizes of specimens of bogue have been used for construct size-frequency histograms. The size structure was calculated for both the total population and separately for males and females.

4.4. LENGTH-WEIGHT RELATIONSHIP

Length-weight relationship describes body growth in marine organisms (Schreck and Moyle, 1990). In fact, it makes possible to evaluate the relative growth of the animal throughout his life, highlighting any morphological changes (Binohlan and Pauly, 1998).

Length-weight relationship, also, is a useful tool to convert the equation size-age by weight-age, in order to estimate the biomass of a population starting from size distributions (Wootton, 1990; Pauly, 1993; Petrakis and Stergiou, 1995; Gonçalves *et al.*, 1996; Binohlan and Pauly, 1998). The model that best expresses this relationship is exponential model

$$P = a\, L^{b}$$

where: a and b represent two curve parameters. For teleosts fishes with isometric growth the value of b does not differ significantly from 3; for values greater than 3, growth is allometric positive that explains the greater increase in weight with respect to size, otherwise the growth is allometric negative. To test allometric growth (b=3) was applied t-Student test (Pauly, 1984) with n-2 degrees of freedom and null hypothesis b=3. The same test was used to check for any significant differences between the value of b within males and females.

4.5. ESTIMATION OF REPRODUCTIVE PARAMETERS

In-depth knowledge of the reproductive potential of exploited populations, starting from the evaluation of the structure of the population in terms of sex ratio, maturation pattern, reproduction cycle, spawning season and size at the first maturity, are fundamental to assess the dynamics (King, 1995). These parameters can contribute at the evaluation of the relationship between parental stock and recruitment stock, representing one of the most delicate and complex dynamics of a stock (Ricker, 1954; Beverton and Holt, 1957).

4.5.1. Sex ratio

The proportion of the sexes, as the size at first maturity too, is an intrinsic biological species parameter, whose variations are often due to effects environment, not least catch due to fishing effort. These two parameters contribute to maintaining, within certain limits, the reproductive capability of the species and its continuity through the diversity of adaptation mechanisms and of the responses to the variability of environmental conditions (Baroiller *et. al*., 2009).

Sex ratio was expressed as the femininity rate: ratio between total number of females and total number of females and males.

$$SR_F = \frac{F*100}{(M+F)}$$

Sex ratio was also calculated as number females *vs* number males/number females. Sex ratios were tested statistically for significant deviations from the expected 1:1 ratio with a χ^2 test (α=0.05). Relation between sex-ratio and the total length (LT) was also carried out.

4.5.2. Maturation pattern

The spawning season was estimated by monitoring the monthly changes in the frequency of the maturity stages. For each month, the percentages of the different maturity stages were estimated separately for males and females. The monthly evolution of the frequency of the maturity stages was followed to determine the spawning period. The spawning season was also established from the monthly evolution of the Gonadosomatic Index (GSI). GSI was calculated by expressing gonad weight as a percentage of eviscerate weight (Anderson and Gutreuter, 1983).

$$GSI=\frac{GW}{EW}*100$$

Eviscerated weight, compared to total body weight, ensures greater standardization of data, not being affected by the viscera weight especially from the presence or absence of food in the digestive system (Anderson and Gutreuter, 1983).

4.5.3. Length at first maturity

Length at first maturity (L_{50}) is defined as the length at which 50% of individuals in the population reaches sexual maturity for the first time (Fontana, 1969), and was estimated considering immature specimens belonging to stage 0 (undetermined), 1 (immature/virgin) and 2A (virgin/developing) and the mature specimens stage 2B (recovering), 2C (maturing), 3 (mature/spawner), 4A (spent), 4B (resting). Length at first maturity was determined by fitting the following logistic function to the proportion of reproductively active fish in each size class (stages 2B to 4B):

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

where: *P* is the percentage of fish mature at total length *TL*; and *r* the model parameter (Saila *et al.*, 1988). The function was fitted to data by means of the Levenberg-Marquardt algorithm for non-linear least squares parameter estimation (Draper and

Smith, 1966). Maturity ogives obtained for separate sexes were compared by Chen test based on the sum of squared residuals (SSR Sum Squared Residuals) (Chen *et al.*, 1992).

4.6. AGEING

Age determination of *B. boops* was carried out directly by otolith readings, counting annuli present on these structures and, indirectly, by analyzing the distributions of size-frequency.

4.6.1. Otoliths, examination and interpretation

Otoliths were burned in order to achieve a greater growth rings alternation, and thus, facilitating their reading (Christensen, 1964). Translucent growth rings contain more protein and they acquire a darker caramelized tone when burned. In this study otoliths were burned in an oven at 200°C. Burning time depends on otolith size, and process must be carefully, monitored to avoid burning the otolith without damage it (Fig. 4.5).

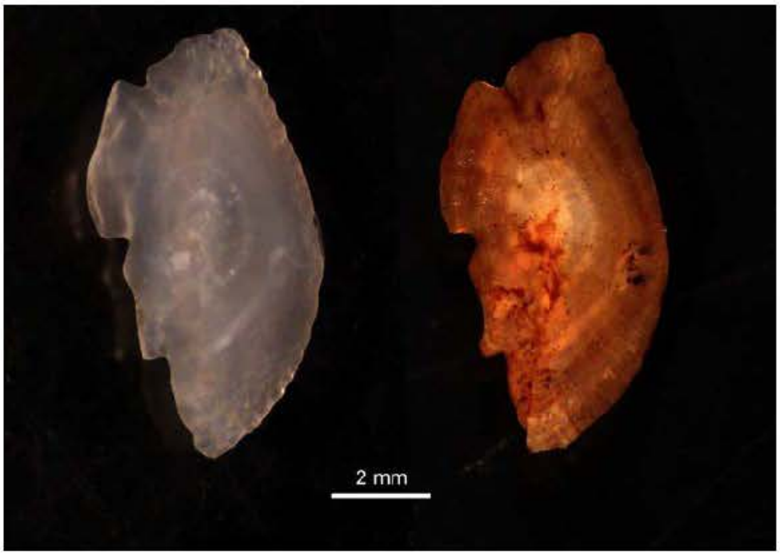


Figure 4.5 - Comparison between same otolith of *Boops boops* before (left) and after (right) burn. (Photo: Massaro, 2014)

After cooled otolith was directly immersed in a petri dish containing sea water as clarifying liquid and observed at stereoscope. After reading, otoliths were properly washed and stored dry again for any future readings. Otoliths, usually the left, were read at stereoscope with distal face up and immersed in sea water on dark background with reflected light (Fig. 4.6) to increase the contrast (Morales-Nin, 1992).

Figure 4.6 - Otoliths at stereoscope on dark background with reflected light (Photo: Massaro, 2014)

In accordance with the standardized procedures at the international level, it was decided to identify and count only translucent bands of annual rings (Morales-Nin and Panfili, 2002). Under reflected light translucent bands appear dark, so they were easily identifiable and distinguishable. Starting from central region (core) of otolith, were counted translucent bands of each ring up to the outer margin.

The area selected for counting rings was the posterior region on the distal face of the otoliths, along the antero-posterior axis (Morales-Nin and Panfili, 2002; Wright *et al.*, 2002) with the rostrum region used as the confirmation area (Fig. 4.7).

The first translucent band, well evident, around the core was interpreted as demersal ring (Fig. 4.8-4.10). This check would be formed in corresponding to the passage from the phase of larval life (pelagic) to the nekton-benthonic phase (recruitment to the bottom) (Fischer, 1999).

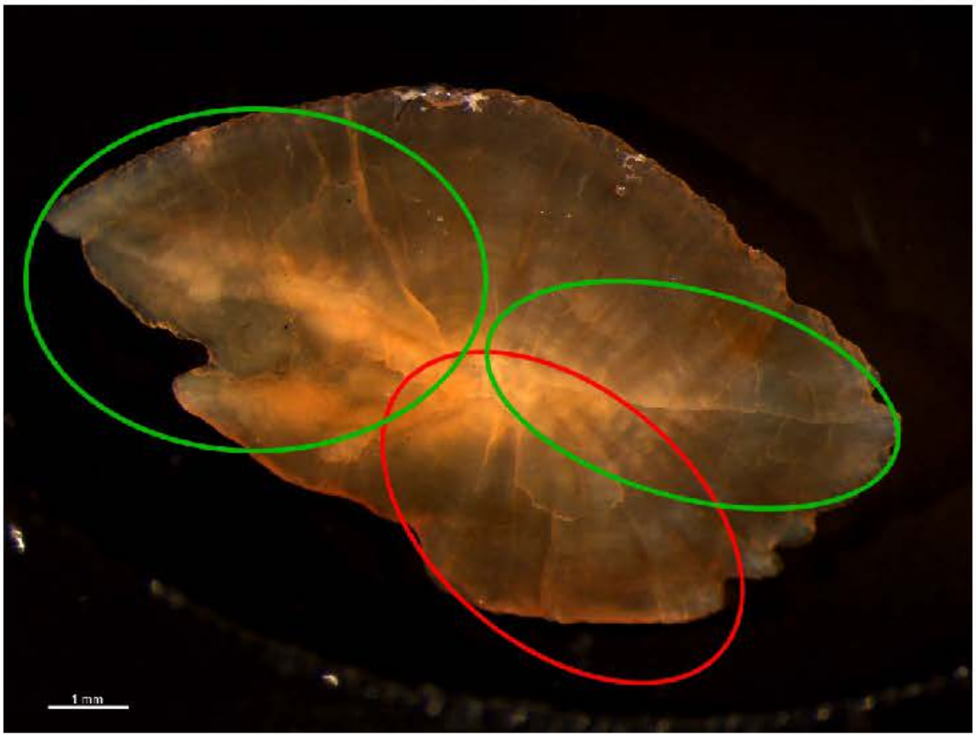


Figure 4.7 - Otolith of *Boops boops* immersed in sea water in which preferred areas for counting rings are showed (red circle: Rings counting area, green circles: Rings checking areas) (Photo: Massaro, 2014)

Figure 4.8 - Otolith of *Boops boops* (Age 3 years, TL 23 cm, Male, month of capture: March; Red dots: translucent rings, black dot: demersal ring) (Photo: Massaro, 2014)

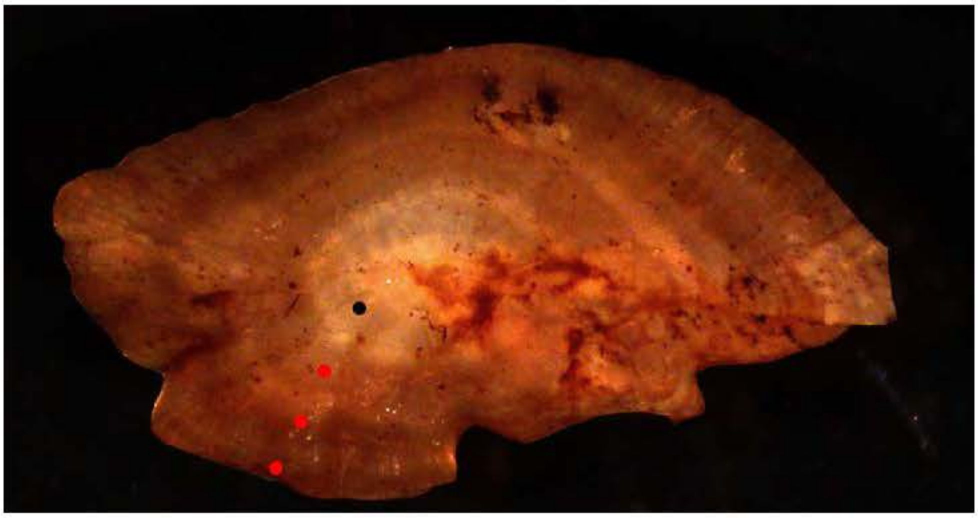


Figure 4.9 - Otolith of *Boops boops* (Age 3 years, TL 24.5 cm, Female, month of capture: March; Red dots: translucent rings, black dot: demersal ring) (Photo: Massaro, 2014)

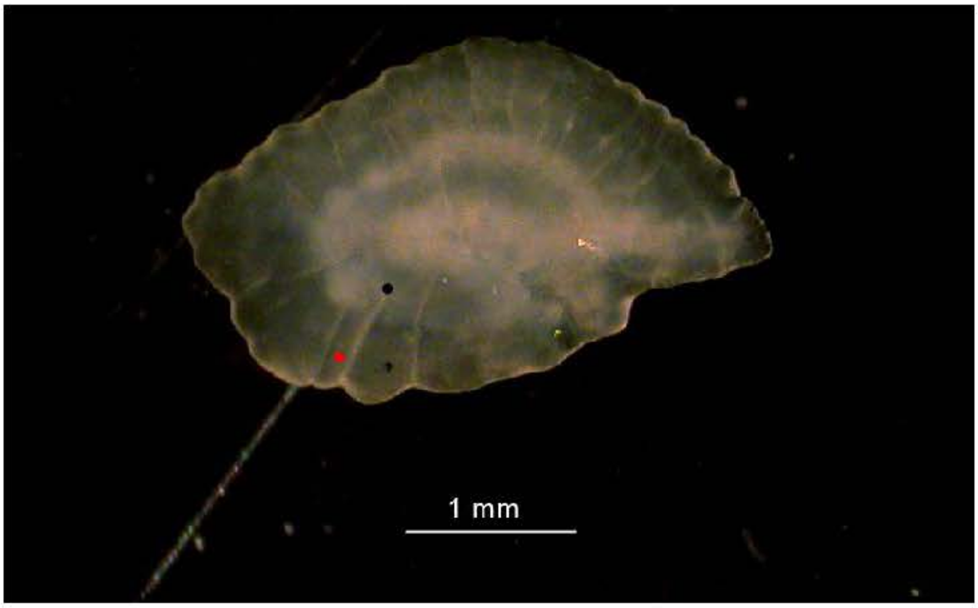


Figure 4.10 - Otolith of *Boops boops* (Age 0 years, TL 9 cm, Female, month of capture: October; Red dots: translucent rings, black dot: demersal ring) (Photo: Massaro, 2014)

Sometimes, it is possible identify a second check, before the first translucent ring, which is not continuous, appears thin and close to first annual ring (Fig. 4.11-4.17).

Figure 4.11 - Otoliths of *Boops boops* (Age 3 years, TL 22.5 cm, Female, month capture March; Red dots translucent rings, black dot: false rings) (Photo: Massaro, 2014)

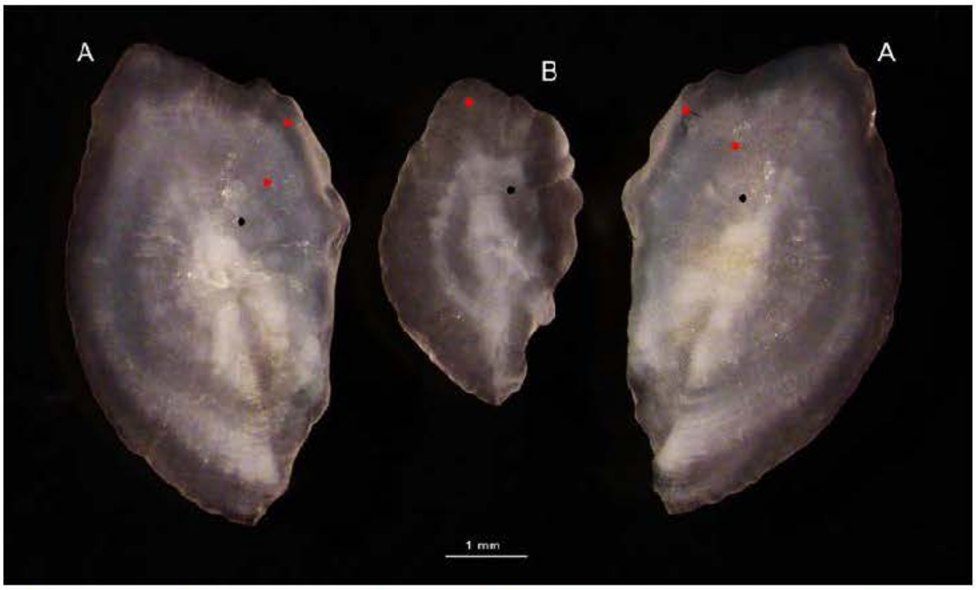


Figure 4.12 - False ring in *Boops boops*. (a) Age 1 year, TL 17.5 cm, Male, month capture: November. (b) Age 0 years, TL 9 cm, Male, month capture October. Red dots are translucent rings and black dots are false rings (Photo: Massaro, 2014)

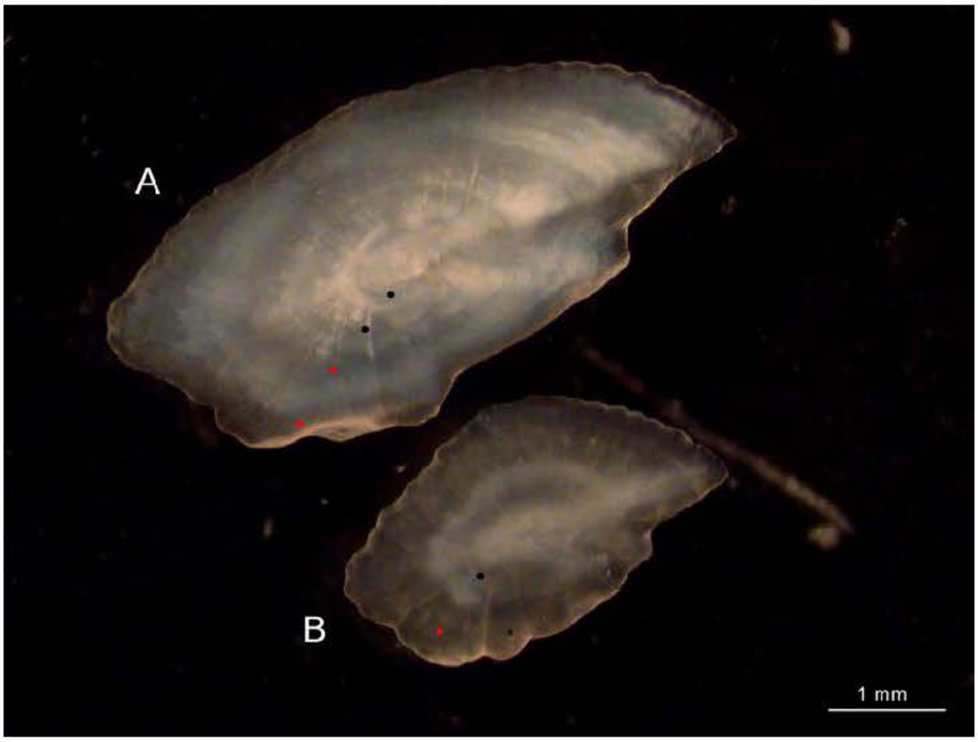


Figure 4.13 - False rings in *Boops boops*. Age 2 year, TL 20.5 cm, Male, month capture November. (b) Age 0 years, TL 9.0 cm, Male, month capture October. Red dots are translucent rings and black dots are false rings (Photo: Massaro, 2014)

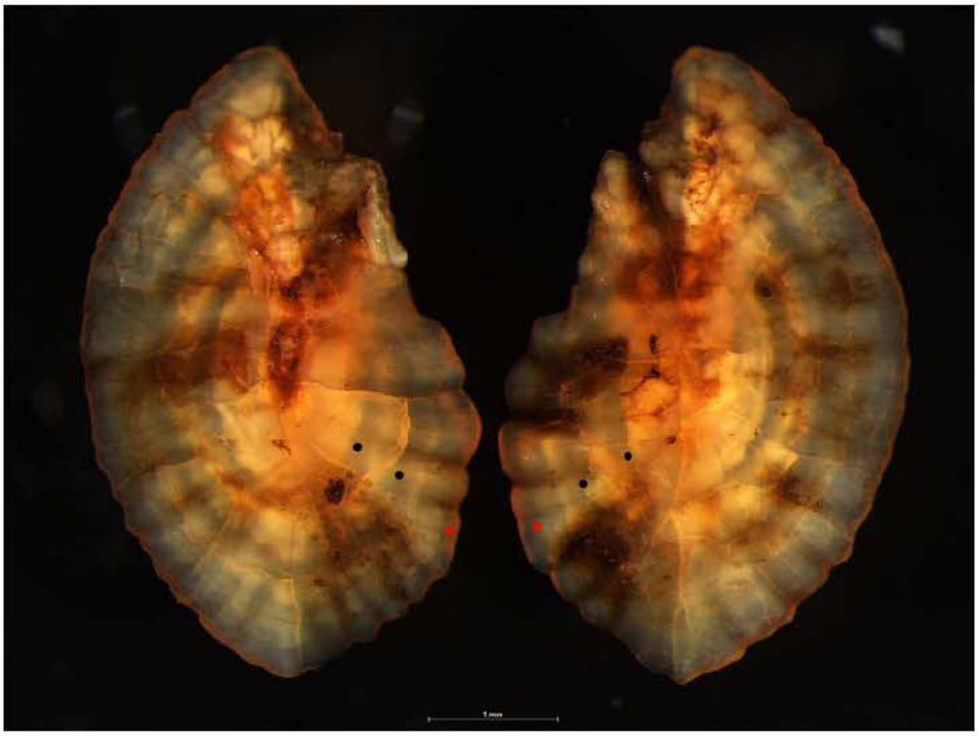


Figure 4.14 - Otoliths of *Boops boops* (Age 0 years, TL 14.5 cm, Female, month capture November; Red dots are translucent rings and black dots are false rings) (Photo: Massaro, 2014)

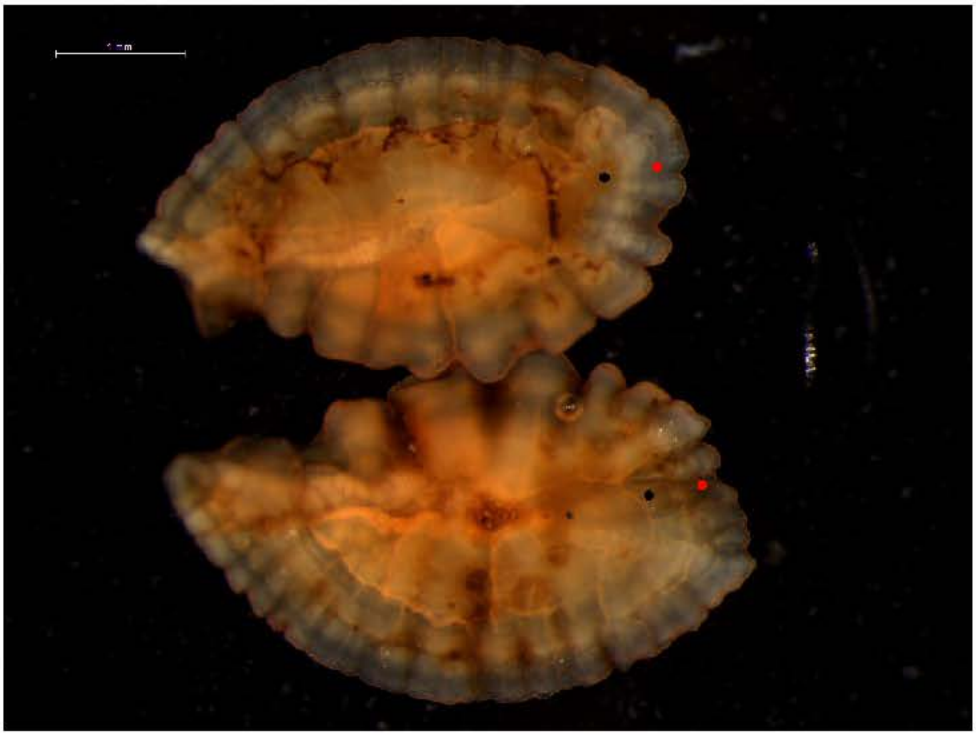


Figure 4.15 - Otoliths of *Boops boops* (Age 0, TL 13 cm, Female, month capture July; Red dots are translucent rings and black dots are false ring) (Photo: Massaro, 2014)

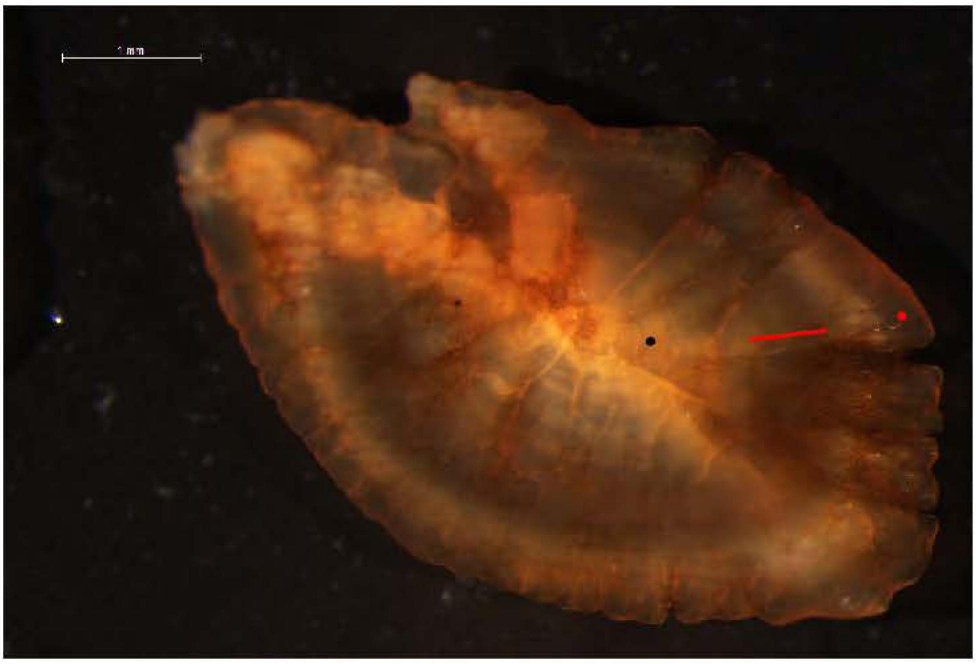


Figure 4.16 - Otoliths of *Boops boops* with first winter ring as a translucent zone because second false ring is jointed with the first true ring. (Age 1 year, TL 20.5 cm, Female, month capture September; Red dots are translucent rings and black dost are false ring) (Photo: Massaro, 2014)

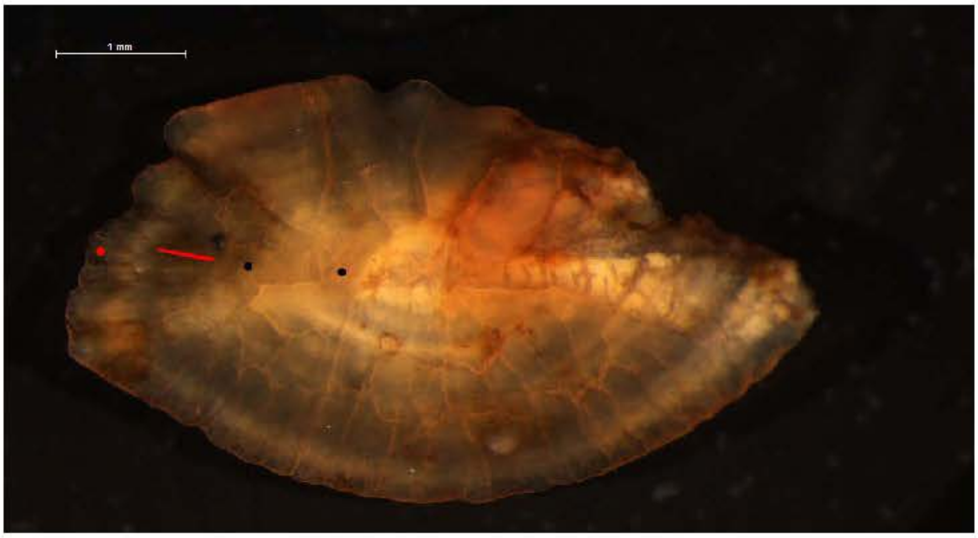


Figure 4.17 - Otoliths of *Boops boops* with first winter ring as a translucent zone and second false ring laid down close to first true ring (Age 1 year, TL 19.5 cm, Female, month capture July; Red dots are translucent rings and black dots are false ring) (Photo: Massaro, 2014)

For each structure, several morphometric measurements such as, total otolith length (TOL), *otoliths radius* (OR), edge type (translucent or opaque), and the distance from the center (core) of each translucent ring identified (radius length for ring i, RL_i) were obtained with a precision of 0.01 mm acquiring and elaborating otolith images using Leica Application System program. All measures were taken in the posterior part of otolith (antirostral) (Fig. 4.18).

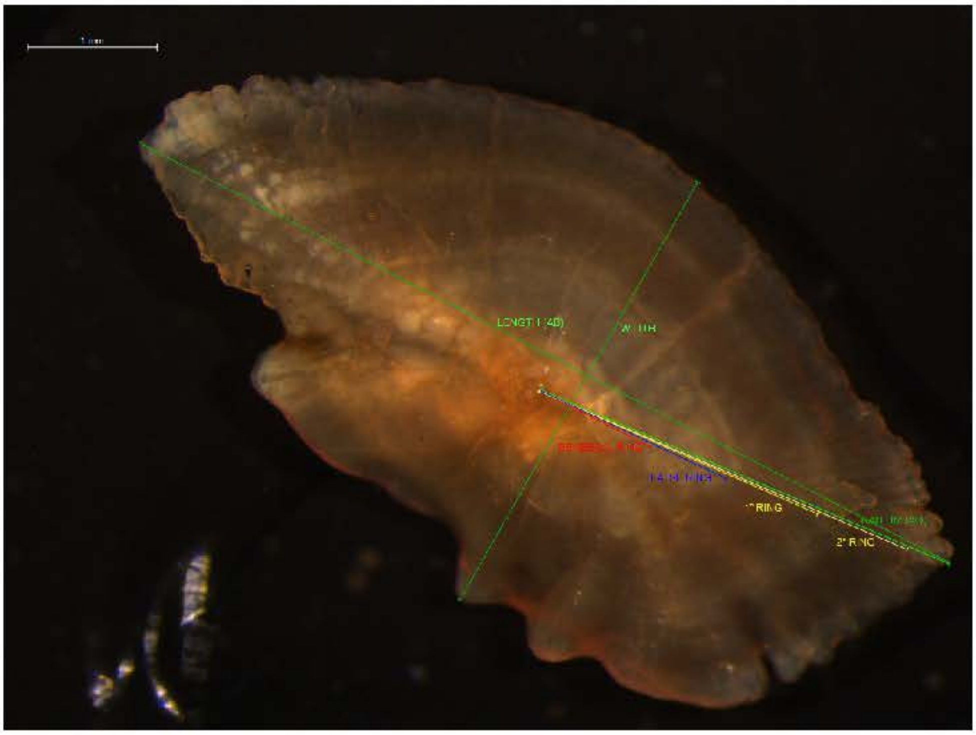


Figure 4.18 - Digital photo of *Boops boops* otolith showing measurements analysed in this study. (Photo: Massaro, 2014)

Reading was carried out without having any information about the otolith and the animal to which it belongs, except the date of capture. Furthermore, annulus was characterized by the brightest contrast between the preceding translucent and the subsequent opaque zone. In general, a criterion for the discrimination of the false rings was represented by the decrease of the distance between the various rings from the first to the last recognized.

All otoliths were read twice. When counts did not agree, a third reading was performed, and the two concurring readings were accepted as the age of the fish. When the three counts differed, the otolith was rejected from further analysis. In this comparison, readings were conducted in a random order (Dwyer *et al.*, 2003).

4.6.2. Semi-direct validation of age determination

Semi-direct validation of the deposition of rings and growth pattern was carried out by Edge Analysis and Marginal Increment analysis (MIA).

Edge analysis consists of studying otolith edge evolution over time (Morales-Nin and Panfili, 2002) and permits to show the annual periodicity of the formation of each *annulus* (translucent ring plus opaque ring), providing qualitative data. That analysis has been carried out on all samples, from individuals having one year or more. Unlike Edge analysis, Marginal Increments analysis provides quantitative data on the periodicity of otolith growth; in fact, it allows to quantify growth, distinguishing a period of faster growth from a lower growth one. The formula used for this work was proposed by Panfili *et al.* (2002):

$$\text{M.I.} = \frac{(\text{OR-RL}_i)}{(\text{R}_i\text{-RL}_{i-1})}$$

where: OR is the otolith *radius* and RL_i and RL_{i-1} are distances from core to the last and penultimate rings.

That analysis cannot be made on individuals having age 0 since, not having yet the first annual ring, it is not possible to quantify their increase. Consequently, only individuals having one year or more were considered.

To assign the age class (number of calendar years after the birth date) to which a fish belonged the number of annual rings was counted, and information on the date of capture, the nature of the margin of the otolith, the main period of a seasonal increment formation and the birth date were taken into account (Morales-Nin and Panfili, 2002). The 1st of January was considered as the theoretical birth date, then for specimens captured in the first half of the year, age is equal to the number of translucent rings (N); while for the specimens caught in the second half of the year, age is equal to the number of translucent rings less 1 (N-1) (Table 4.2).

Table 4.2 - Age interpretation criteria for *Boops boops*. Age equal to the number of the translucent rings (N) or age equal to the number of translucent edge less one (N-1)

Capture data	Edge type	Age
1st Jan - 30th Jun	Translucent	N
	Opaque	N
1st Jul - 31th Dec	Translucent	N-1
	Opaque	N

4.6.3. Estimation of growth parameters

Among the different equations describing growth, the most frequently chosen in the study of fish populations is the von Bertalanffy growth function (von Bertalanffy, 1938). Growth parameters have been estimated to separate sexes, using the following equation:

$$L_t = L_\infty * \left(1 - e^{[-k(t-t_0)]}\right),$$

where: L_t is the average total length of the animal at time t (at age t), L_∞ is the maximum (theoretical) asymptotic length, k is growth coefficient and represents the slope of the curve and expresses a speed measure to which maximum length is reached, t_0 is the curve intersection with X axis and represents theoretical age at length 0. The growth parameters of von Bertalanffy (L_∞, k and t_0) were estimated through non-linear regression using FSA package (Ogle, 2016), available for the statistical software R. Extra sums-of-squares test (Ritz and Streibig, 2008) was used to identify significant different between sexes.

L_∞ and k values have been used to estimate the *phi-prime* (Φ') (Pauly and Munro, 1984). Φ' is an index calculated with the following formula:

$$\Phi' = \log k + 2 \log L_\infty$$

It provides a synthetic index of growth parameters of von Bertalanffy curve and it could be used to compare the results obtained from different authors for different curves. Age length keys (ALK) have been calculated for separated sexes. For each age group, total number of individuals, mean length (cm) and standard deviation (sd) were calculated. Indeterminate individuals greater than 10 cm LTL were divided according with sex ratio vector, while indeterminate individuals smaller than 10 cm were divided equally in males and females. VBGF parameters was also calculated in terms of weight as:

$$W_t = W_\infty * \left(1 - e^{[-k(t-t_0)]}\right),$$

where: W_t is the average total weight of the animal at time t (at age t), W_∞ is the maximum (theoretical) asymptotic weight.

4.6.4. Validation test

The bias and precision of *annuli* counts were compared between readers, using paired *t*-tests and age bias plots (Campana *et al.*, 1995; Campana, 2001). For each paired comparison, a coefficient of variation (CV) was also used to measure precision, together with a paired *t*-test to compare differences statistically (Chang, 1982; Dwyer *et al.*, 2003) the APE (Average Percent Error) and the CV (Coefficient of Variation).

4.6.5. Indirect validation of age determination

Indirect validation of the growth was studied using seasonal length-frequency distributions according to the Petersen method (Sparre *et al.*, 1989). The frequency distributions of each sex were separated using model progression analysis (Bhattacharya's method) with FiSAT II software (Gayanilo *et al.*, 2005). Bhattacharya's method identifies normal distributions of the polymodal length-frequency distributions. Separation indices between different cohorts with values of less than 2 indicate a large overlap between cohorts and were considered statistically unacceptable (Sparre *et al.*, 1989). The normal distribution of each component was assumed to represent an age group in the population.

Growth was modeled using the von Bertalanffy growth function (VBGF). A preliminary estimation of L_∞ was obtained separately for males and females using the Gulland and Holt (1959). That method is based on the attribution to single modes having a putative age estimated on the basis of the sampling date, and takes into consideration the knowledge of the spawning season and of the recruitment time.

Another method of length frequency distribution analysis was carried out to estimate growth parameters: Electronic Length-Frequency analysis (ELEFAN I). ELEFAN I routine analysis of length-at-age data were used for the non-linear estimation of the growth parameters. Most of *non-parametric* methods works through the research of a series of value pairs L_∞ - k and the elaboration, for each combination, of the curve adaptation goodness to interpolate remarkable peacks of different distributions (GOF–goodness of fit) (Magnifico, 2007). The best solution, that is the curve passing through the highest number of peacks, will provide the growth estimate (MacDonald and Pitcher, 1979). These methods require in input samples collected over time and fit a series of growth curves (von Bertalanffy, 1938), with the different value pairs L_∞ - k; t_0 is estimated through the Pauly equation (Pauly, 1983):

$$\log(-t_0) = -03922 - 0.2752 \log L_\infty - 1.038 \log k$$

In ELEFAN there are different steps:

- frequency distribution is interpolated with five points moving average obtaining a restructured length-frequency distribution;
- "peaks" and "valleys" result clear compared to the moving average curve (moving average frequency);
- on the data transformed, a family of von Bertalanffy curves is designed for k and L_∞ values or just k;
- for each curve, the goodness-of-fit R_n = ESP/ASP is calculated, where ESP (Explained Sum of Peaks) is the sum of intercepted peaks, while ASP (Available Sum of Peaks) is the sum of available peaks;
- the curve that maximizes R_n is the one with values k and L that constitute the final result.

4.6.6. Back-calculation

Ages was estimated also indirectly through back-calculation, using FRASER-LEE equation (Fraser, 1916; Lee, 1920). The back-calculation method is used to corroborate direct readings, giving an additional support to indirect validation through Length Frequency Data (LFD) analysis by means of the comparison of estimated age through direct reading and back-calculation. These results were compared, using Student's *t* test (significance $p<0.05$). Fraser-Lee method is applied in back-calculation when the intercept of the relationship between total length and otolith radius is not from the origin (Morales-Nin and Panfili, 2002). In these circumstances, length at age t (L_t) is back-calculated with the following formula:

$$L_i=c+(TL-c)*(RL_i / OR)$$

where: TL and OR are respectively total length and otolith radius at captured age, L_i and RL_i are respectively total length and otolith radius at i-th age and c is the linear regression intercept between total length and otolith radius and represents a correction factor due to the fact that, at age zero, somatic length in not equal to zero (Bagenal and Tesch, 1978). The different morphometric relationships identified between somatic length and biometrics of otolith were statistically tested by linear regression.

The three parameters von Bertalanffy growth curve was fitted to the back-calculated mean length at age using nonlinear regression. von Bertalanffy growth parameters obtained from otolith readings, back-calculation and Bhattacharya, were compared with each other by Chen test based on analysis of the sum of squared residuals (Chen *et al.*, 1992).

Subsequently, von Bertalanffy growth curves obtained from Length-at-Age estimated directly (otoliths), back calculating and obtained indirectly from Bhattacharya, were compared with each other by Chen test based on analysis of the sum of squared residuals (Chen *et al.*, 1992). Finally, the Φ 'obtained values were compared with those in the literature for different areas.

5. RESULTS

5.1. MONTHLY DISTRIBUTION OF CATCHES

During 2012 were sampled 2892 specimens of *B. boops*, 902 (31.2%) males, 1069 (36.9%) females, 33 (1.1%) intersexual and 888 (30.8%) indeterminate (Table 5.0).

Table 5.0 - Number of males (M), females (F), intersexual (T) and indeterminate (I) of *Boops boops* sampled

Month	F	M	I	T	Total
January	121	74	60		255
February	56	58	3		117
March	194	84	7		285
April	26	145	3		174
May	41	82	1		124
June	4	7	754		765
July	116	76	26	2	220
August	142	91	7		240
September	35	34	6	6	81
October	119	51	7	2	179
November	62	59	11	23	155
December	153	141	3		297
Total	1069	902	888	33	2892

The high number of indeterminate individuals is due to the fact that for the smaller individuals (TL<11 cm) macroscopic sex detection is very difficult because gonads are very small and not well developed; medium-large indeterminate individuals instead are due only to degradation of the gonads.

The minimum size observed was of 4.0 cm TL. The minimum sizes observed for males and females were respectively 8.5 cm TL and 10 cm TL, the maximum size was 34.5 cm TL for males and 30.5 cm TL for females. For intersexual individuals minimum and maximum size was 14.0 and 21.0 cm TL, respectively.

Monthly length frequency distributions relating to the capture of *B. boops* are represented in Fig. 5.1. Demographic structure shows a normal distribution in all months sampled.

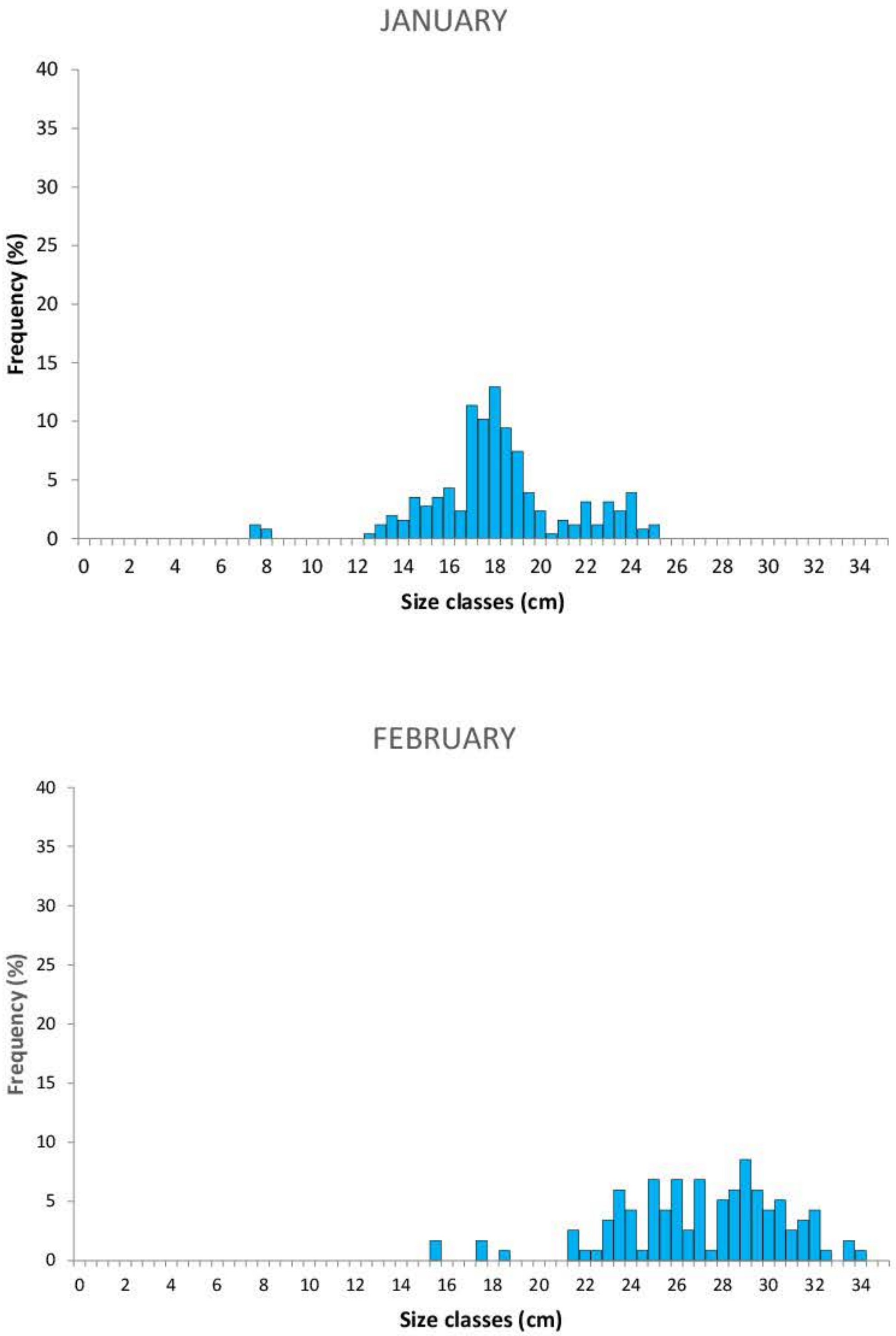
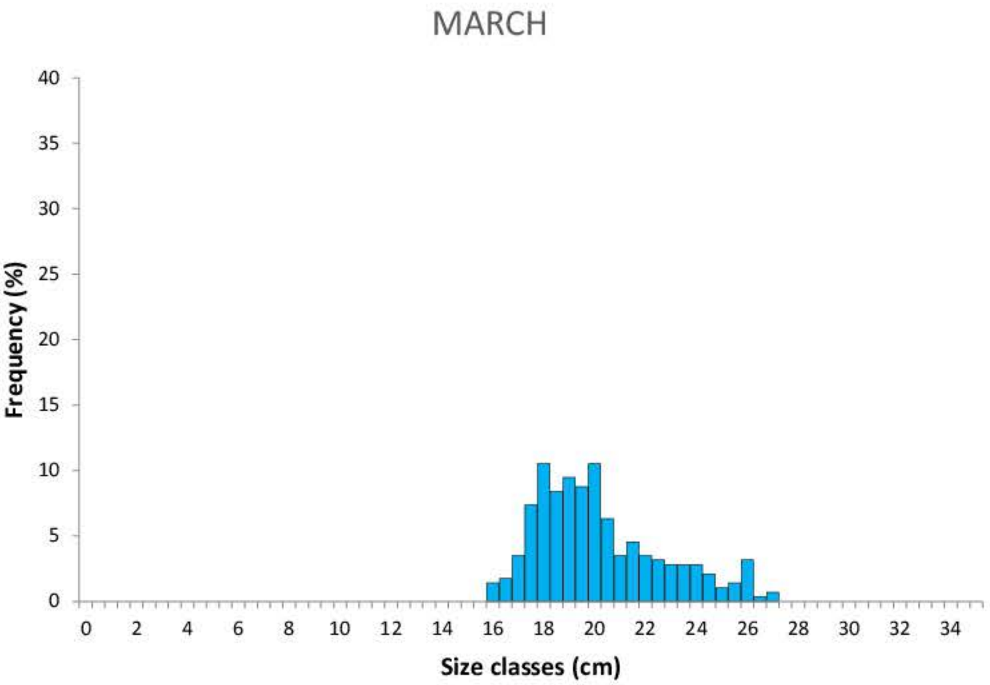


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands



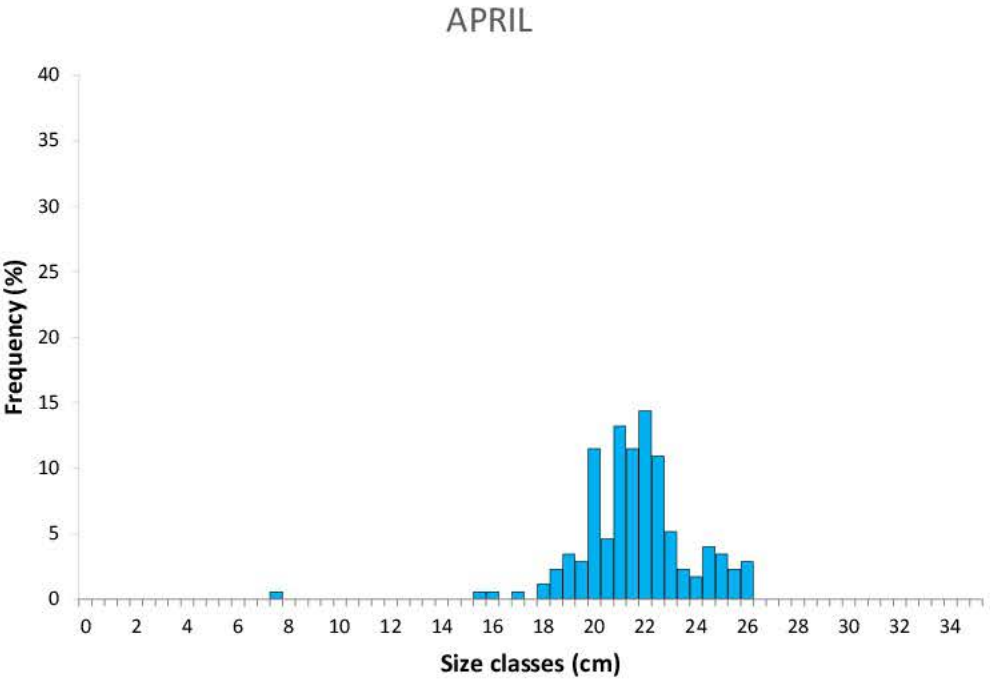
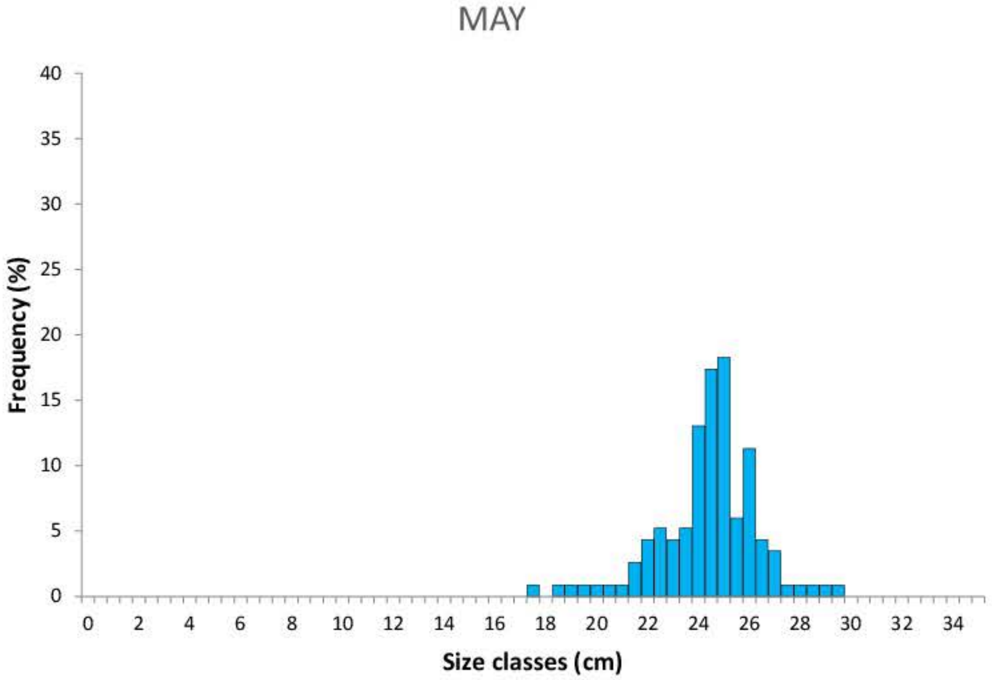


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands (continue)



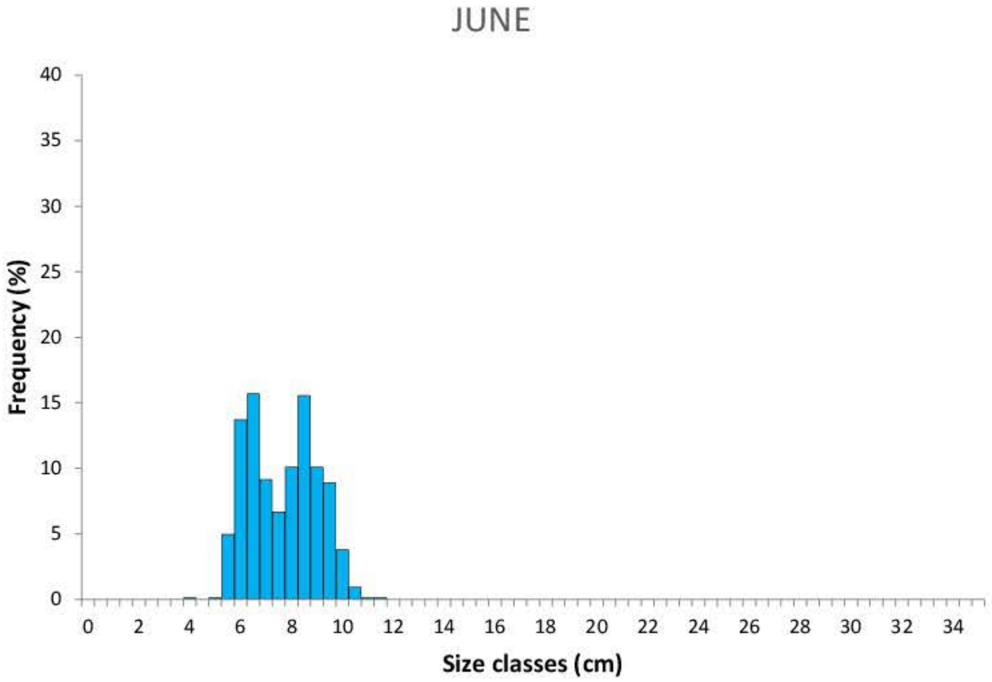
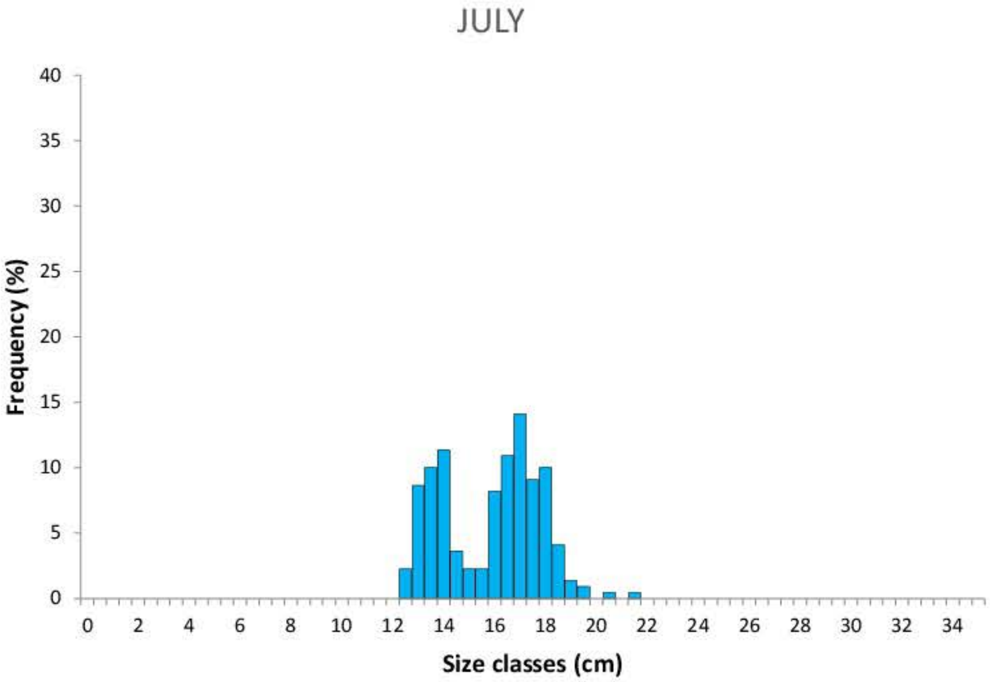


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands (continue)



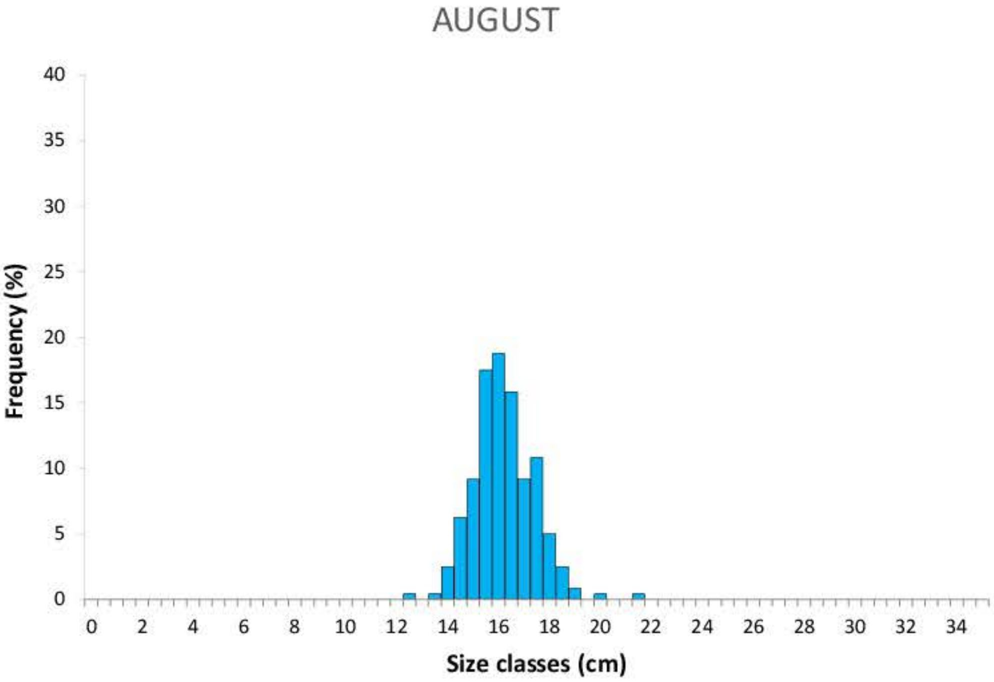


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands (continue)

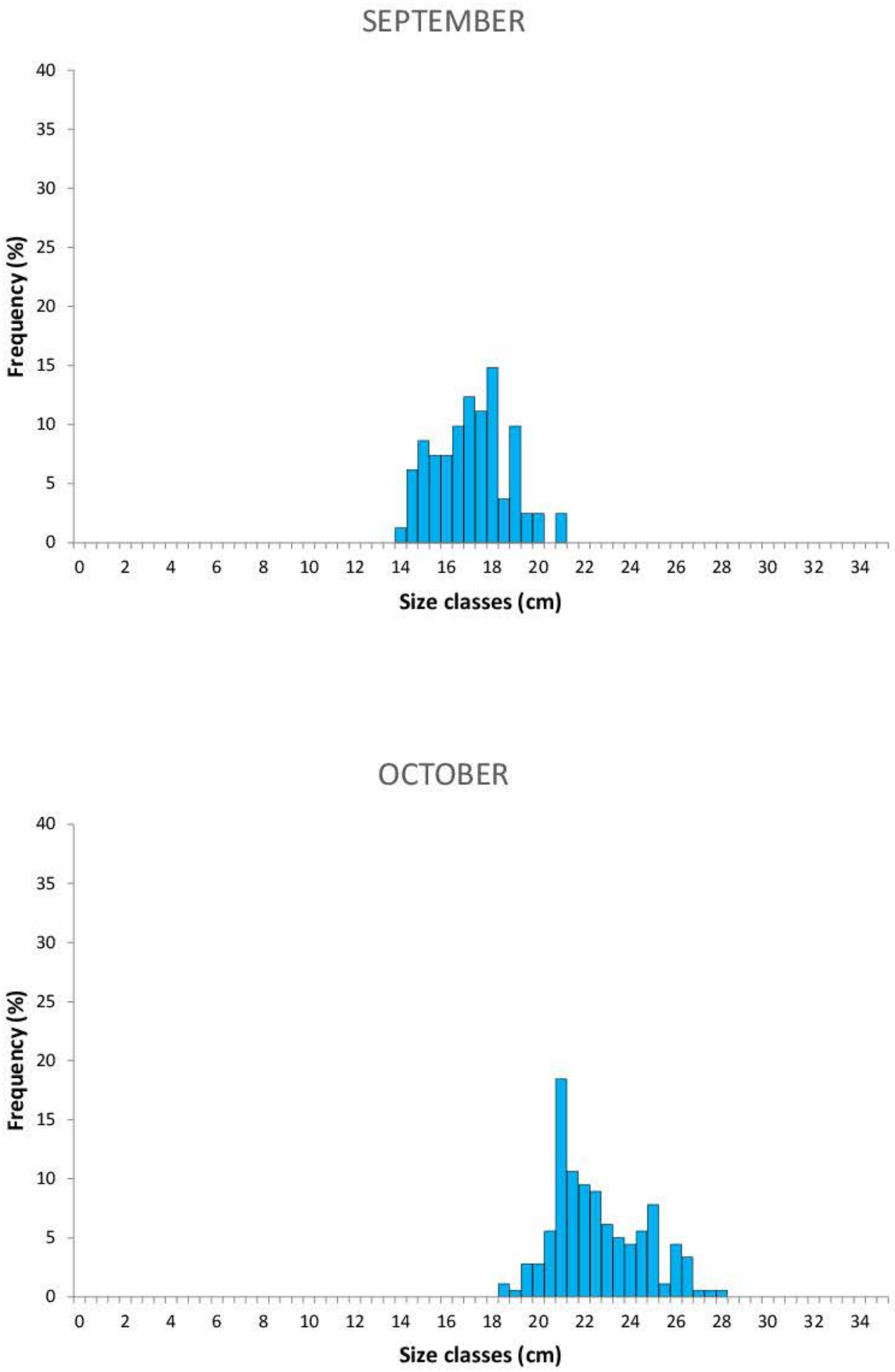
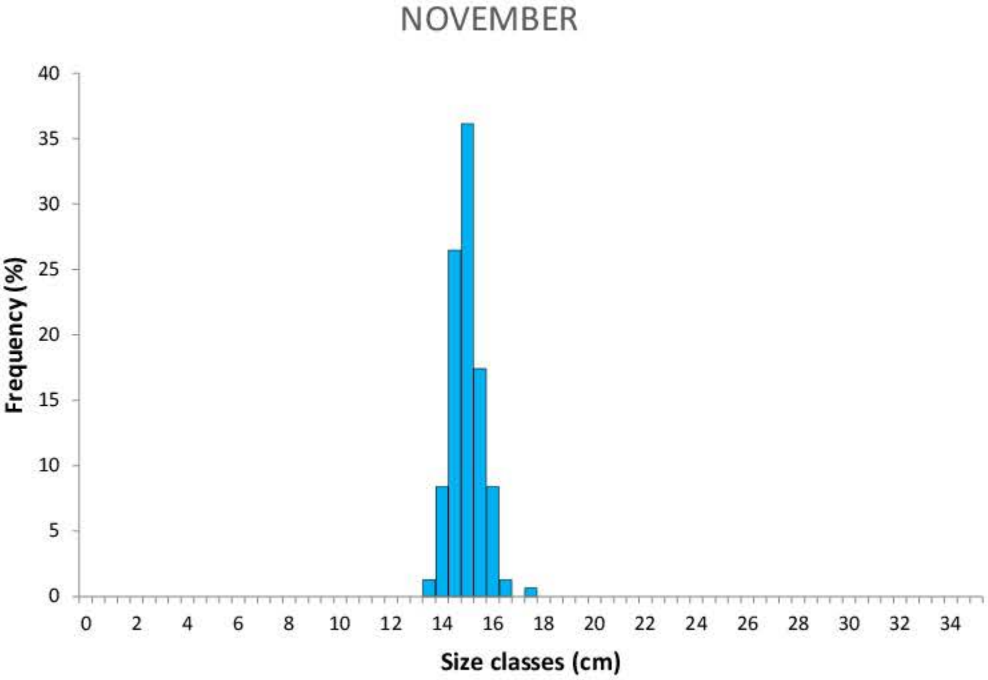


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands (continue)



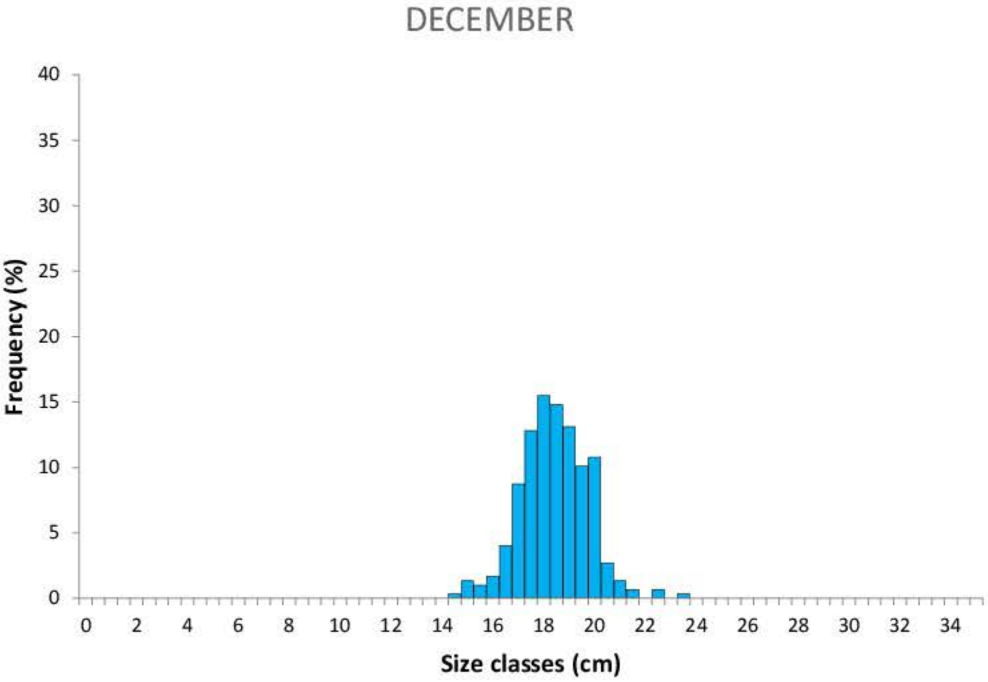


Figure 5.1 - Monthly frequency distribution of *Boops boops* of the Canary Islands (continue)

Length distributions show the presence of a predominant group each month, with relatively high frequency values. The highest modal value was found during the month of May (24.5 cm TL), while the lowest value in June (6.5 cm TL).

Wide range of sizes was observed during the studied period (4-34 cm TL) (Fig. 5.2). Catches size composition shows a polymodal trend, in which can be recognize two main groups. The first one consists of specimens ranging between 4-10.5 and the second one composed of specimens with size from 12 to 34 cm TL.

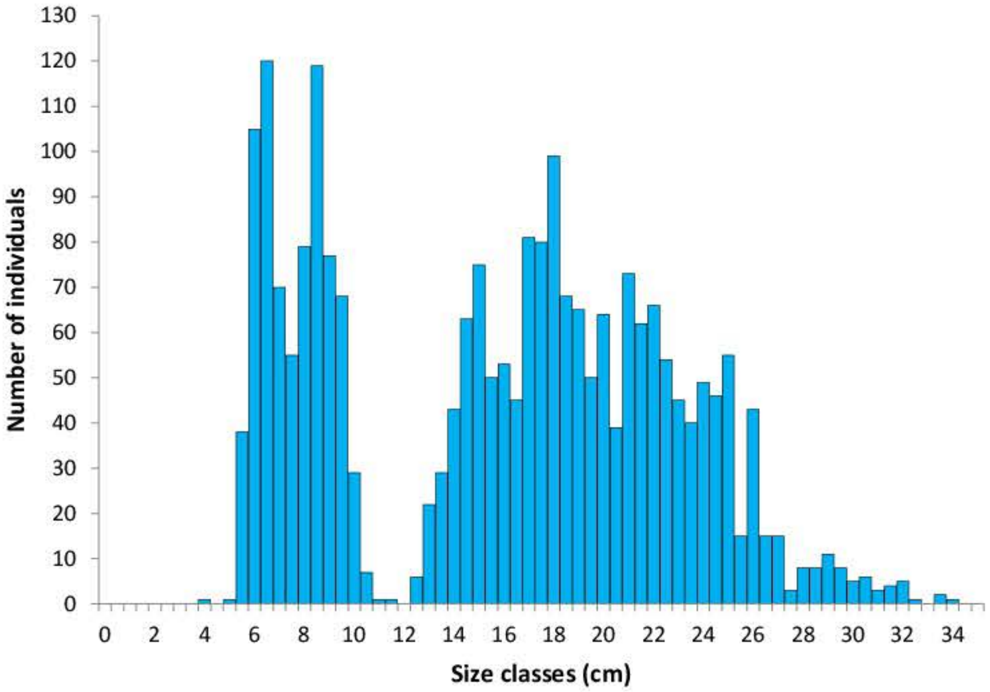


Figure 5.2 – Total size composition of catches of *Boops boops* of the Canary Islands

5.2. LENGTH-WEIGHT RELATIONSHIP

Length-weight relationship was calculated for total population and for separate sex (Fig. 5.3). For the entire population and for both sexes, *b* parameter was significantly different from 3 ($p<0.01$), expressing positive allometric growth with an accretion by weight proportionally greater than animal length. Curve parameters and r^2 value is showed in Table 5.1. r^2 value is highly significant. *t*-test showed that there were not statistically significant differences in the value of *b* between males and females ($t=0.09$; $p>0.05$), demonstrating that at the same size there were not differences in weight between individuals of different sex.

Table 5.1 - Length-Weight relationship parameters for total population, males and females of *Boops boops*. *a* and *b* are the parameters of the power function; Sd(b), the standard deviation of *b*; r^2, the coefficient of determination and *t*-test, the value of the *t*-test

	a	**b**	**Sd (b)**	**r^2**	**t-test**
Total	0.0066	3.1525	0.2033	0.9959	32.178
Females	0.0091	3.0471	0.3402	0.9876	3.846
Males	0.0083	3.0790	0.2763	0.9939	7.4002

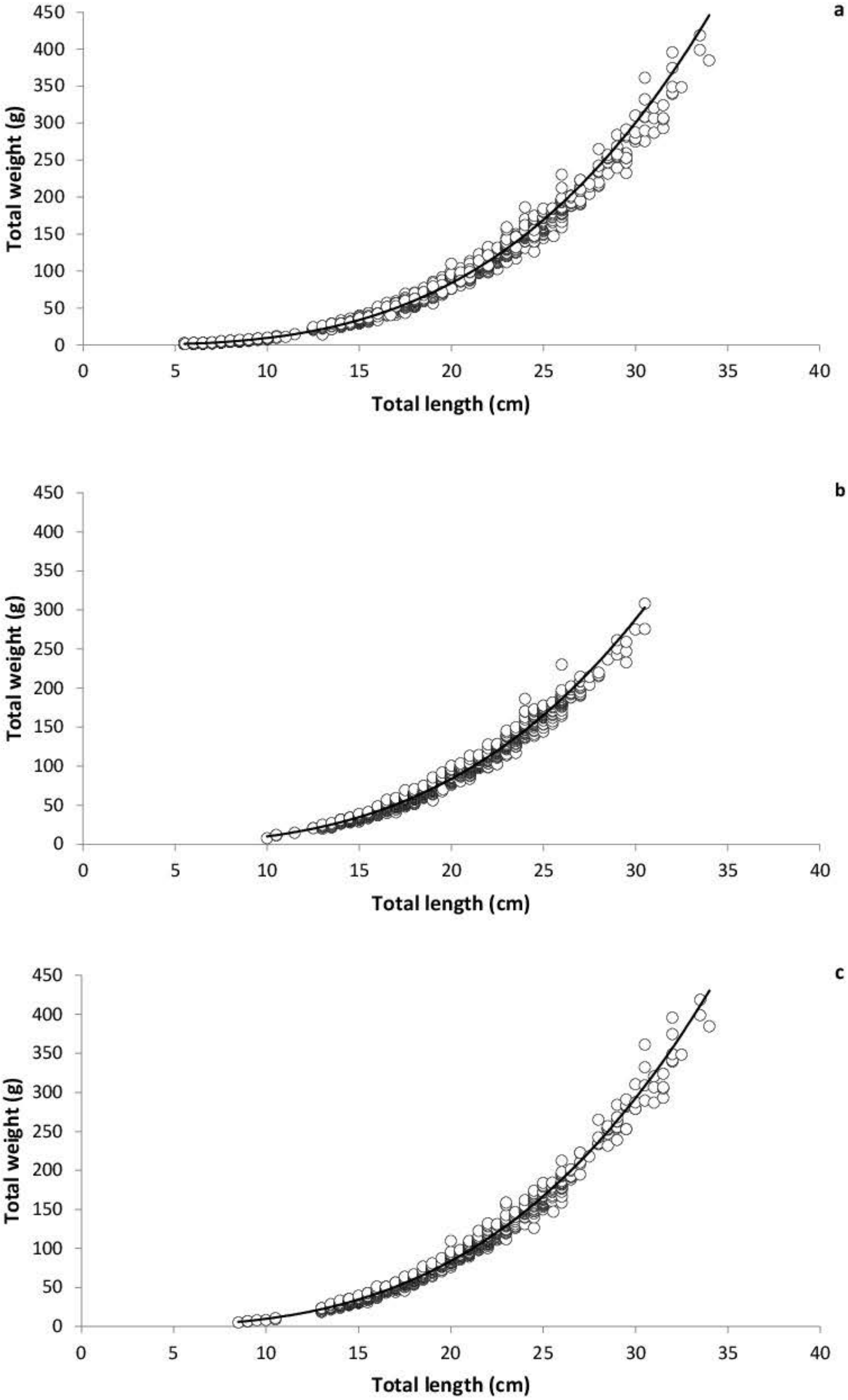


Figure 5.3. Length-weight relationship for (a) all individuals, (b) males and (c) females of *Boops boops* of the Canary Islands

5.3. SEX RATIO AND SEXUAL TIPOLOGY

The sex ratio estimated was 1:0.852 (F:M) and the estimated as the rate of femininity was 0.542. Sex-ratio value was significantly deviated from the ratio 1:1 (chi-square test χ^2=14.14; p=0.0062) (Table 5.2).

Table 5.2 - Total number of males and females, sex ratio and chi-square test value for *Boops boops* of the Canary Islands

Sex	**value**
Male	902
Female	1069
Sex ratio	1:0.852
Rate Femininity	0.542
Chi-square	14.14*

*Chi-square$_{0.05}$ >3.84

Fig. 5.4 shows sex ratio trend over the year. Sex ratio values as rate of femininity ranging from 0.70 (March and October) to 0.15 (April). Mean sex ratio on January, October, from March to May and from July to August was significantly different from 0.5, while on the remaining months sex ratio value was 0.5 (Table 5.3).

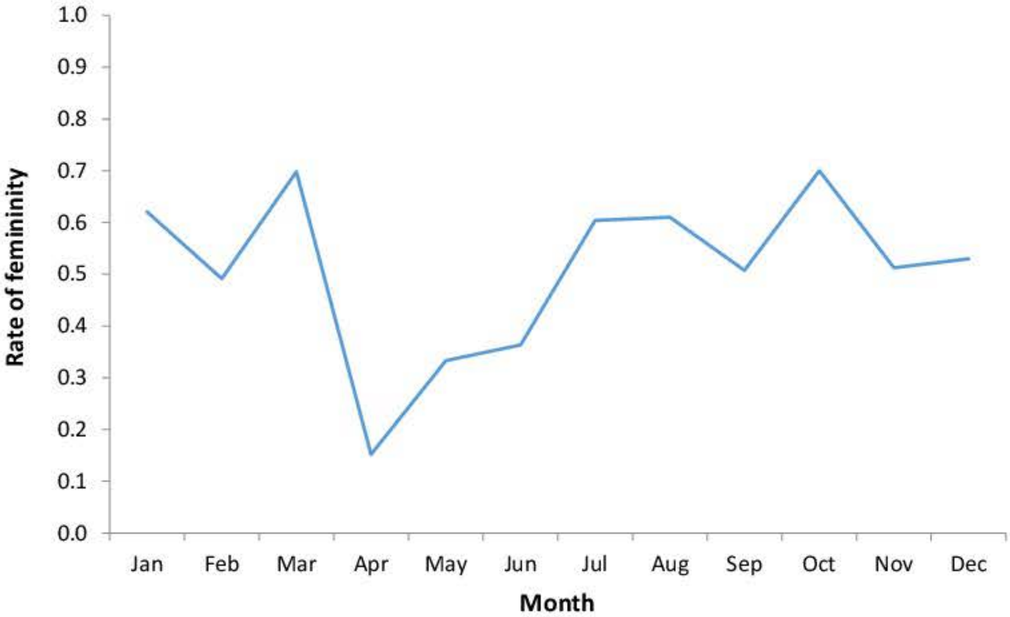


Figure 5.4 - Sex ratio trend, as feminity rate, of *Boops boops* of the Canary Islands over the year

Table 5.3 - Number of males (m) and females (f) and the sex ratio as relation 1:1 and as femininity rate, and chi square test values for *Boops boops* of the Canary Islands

Month	F	M	Sex Ratio	Sex Ratio Fem. rate	Chi-square
January	121	74	1:0.61	0.62	11.32*
February	56	58	1:1.04	0.49	0.035
March	194	84	1:0.43	0.70	43.52*
April	26	145	1:5.58	0.15	82.81*
May	41	82	1:2.00	0.33	13.66*
June	4	7	1:1.75	0.36	0.81
July	116	76	1:0.66	0.60	8.33*
August	142	91	1:0.64	0.61	11.16*
September	35	34	1:0.97	0.51	0.01
October	119	51	1:0.43	0.70	27.2*
November	62	59	1:0.95	0.51	0.07
December	153	141	1:0.92	0.52	0.48

*Chi-square$_{0.05}$ > 3.84

In addition, variation in sex ratio average related to the total length was evaluated (Table 5.4, Fig. 5.5).

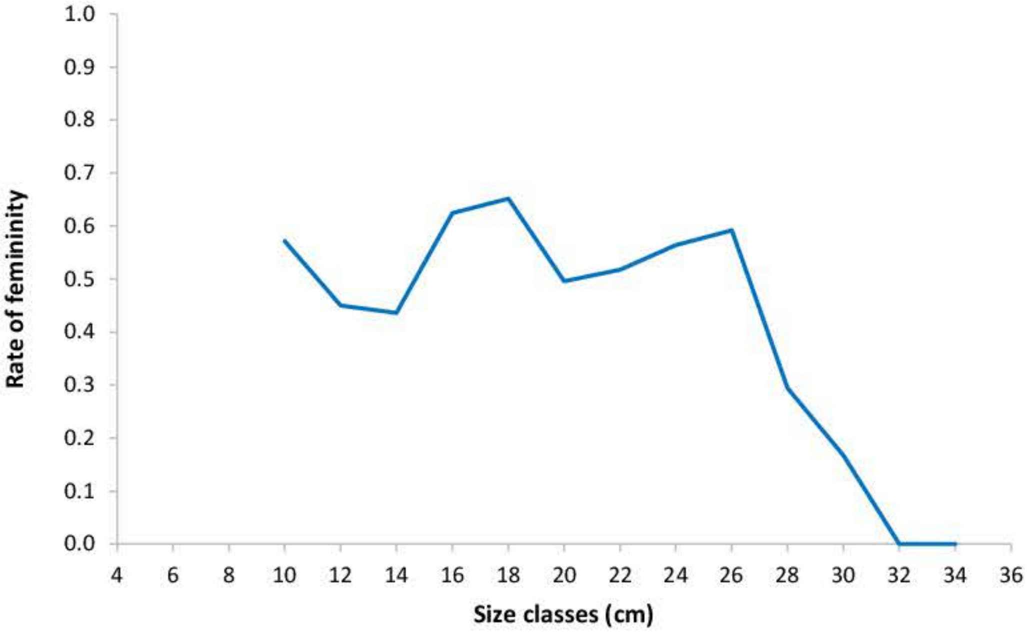


Figure 5.5 – Rate of femininity of *Boops boops* of the Canary Islands by size classes

Table 5.4 - Sex ratio and chi square values by size classes for *Boops boops* of the Canary Islands

Size (cm)	F	M	Fem. Rate	Sex Ratio	Chi-square
8		7			
10	8	5	0.62	0.63	0.69
12	35	48	0.42	1.37	2.03
14	123	164	0.43	1.33	5.85*
16	211	129	0.62	0.61	19.77*
18	229	126	0.65	0.55	29.88*
20	154	143	0.52	0.93	0.40
22	128	111	0.54	0.87	1.20
24	115	79	0.59	0.69	6.68*
26	53	35	0.60	0.66	3.68
28	10	28	0.26	2.80	8.52*
30	3	17	0.15	5.67	9.80*
32		9			
34		1			

*Chi-square$_{0.05}$ > 3.84

Considering sex-ratio by size classes (Fig. 5.6), significant differences were observed. Females predominated between 16 and 18 cm TL (sex-ratio:0.61-0.55, $\chi^2>3.84$; $p<0.05$), and at 24 cm TL (sex-ratio:0.69; $\chi^2=6.68$; $p<0.05$) whereas males predominated at 14 cm TL (sex-ratio:1.33; $\chi^2=5.85$; $p<0.05$) and over 28 cm TL (sex-ratio: 2.80-5.97, $\chi^2=8.52-9.80$; $p<0.05$). However, it is important to note the relatively small sample size in the largest length class. Few intersexual were found (N=33, i.e. 1.4%), mainly in November, with a total length varying from 14 to 21 cm total length.

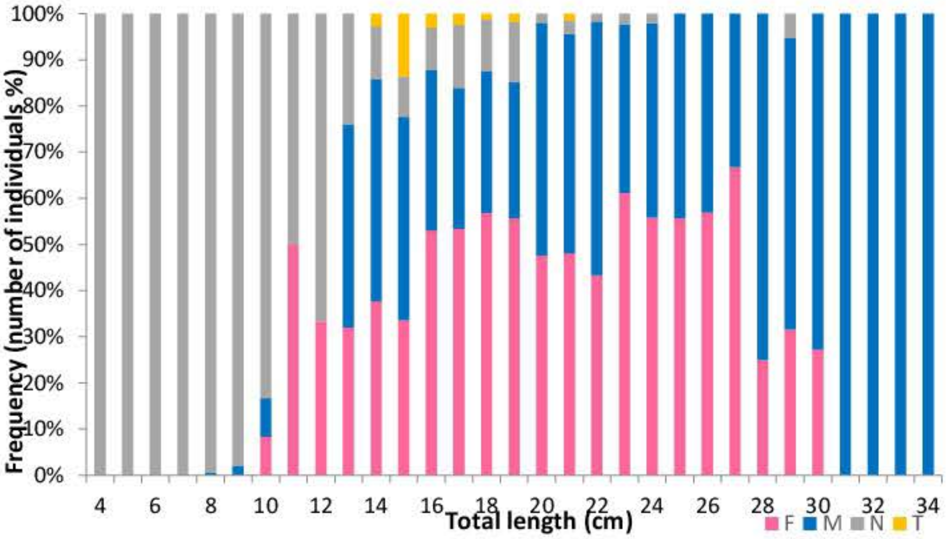


Figure 5.6 - Demographic structure of *Boops boops* of the Canary Islands. F, females; M, males; N, indeterminate; T, intersexual.

5.4 - SEXUAL MATURITY AND DEPOSITION CYCLE

Monthly distribution of different sexual maturity stages for *Boops boops* are showed Table 5.5 and Fig. 5.7. Individuals on stage 2b was always present throughout the year with higher values on September (82.9%) and October (95.8%), which indicate resumption of the new cycle maturational in the totality of the population at the end of the spawning season. Females in maturation stage (2c), appeared on November (1.6%), and they were present until April (7.7%). Maximum value was observed on February (73.2%), on January mature females in deposition stage (3) began to be present with a low percentage (0.8%). In this stage, gonads are characterized by the presence of oocytes in all maturational stages. Deposition rate in females was maximum on February (21.4%) Females in spent stage (4a) was visible at the end of reproductive season (from March to May). Maximum value was observed on May (68.3%). Females in resting stage (4b) were observed from April to end May.

Males shows relatively short reproduction period, with individuals in maturation stage (2c) from December to March with higher value in February (70.7%). Males in recovery stage (2b), show an increasing trend from July to October (from 2.7% to 90.2%). Stage 4a and 4b show same trend for both sex. For both sex, maturational peak was recorded on February with values 21.4% for females and 24.1% for females.

Table 5.5 - Total number of individuals (n) and monthly percentages of maturity stages for females (a) and males (b) of *Boops boops* of the Canary Islands. 1, immature/virgin; 2A, virgin/developing; 2B, recovering; 2C, maturing; 3, mature and / or spawner; 4A, spent; 4B, resting. n is the number of individuals

a	**Maturity stage (%)**							
Month	**1**	**2A**	**2B**	**2C**	**3**	**4A**	**4B**	**n**
January	5.0	39.7	26.4	28.1	0.8			121
February			5.4	73.2	21.4			56
March	0.5	32.5	34.0	26.8	5.2	1.0		194
April		15.4	26.9	7.7	11.5	34.6	3.8	26
May			14.6		14.6	68.3	2.4	41
June	100.0							4
July	29.3	45.7	25.0					116
August	19.7	42.3	38.0					142
September		17.1	82.9					35
October		4.2	95.8					119
November	8.1	61.3	29.0	1.6				62
December	14.4	32.7	37.9	15.0				153
Total	100	327	416	153	32	39	2	1069

b	**Maturity stage (%)**							
Month	**1**	**2A**	**2B**	**2C**	**3**	**4A**	**4B**	**n**
January	21.6	50.0	13.5	14.9	0.0			74
February		3.4		70.7	24.1	1.7		58
March	11.9	45.2	36.9	2.4	3.6			84
April		2.8	13.1		2.8	71.0	10.3	145
May			6.1		4.9	80.5	8.5	82
June	100.0							7
July	51.3	44.7	3.9					76
August	38.5	52.7	8.8					91
September	11.8	38.2	50.0					34
October		9.8	90.2					51
November	11.9	69.5	18.6					59
December	14.9	45.4	33.3	6.4				141
Total	139	286	197	63	25	170	22	902

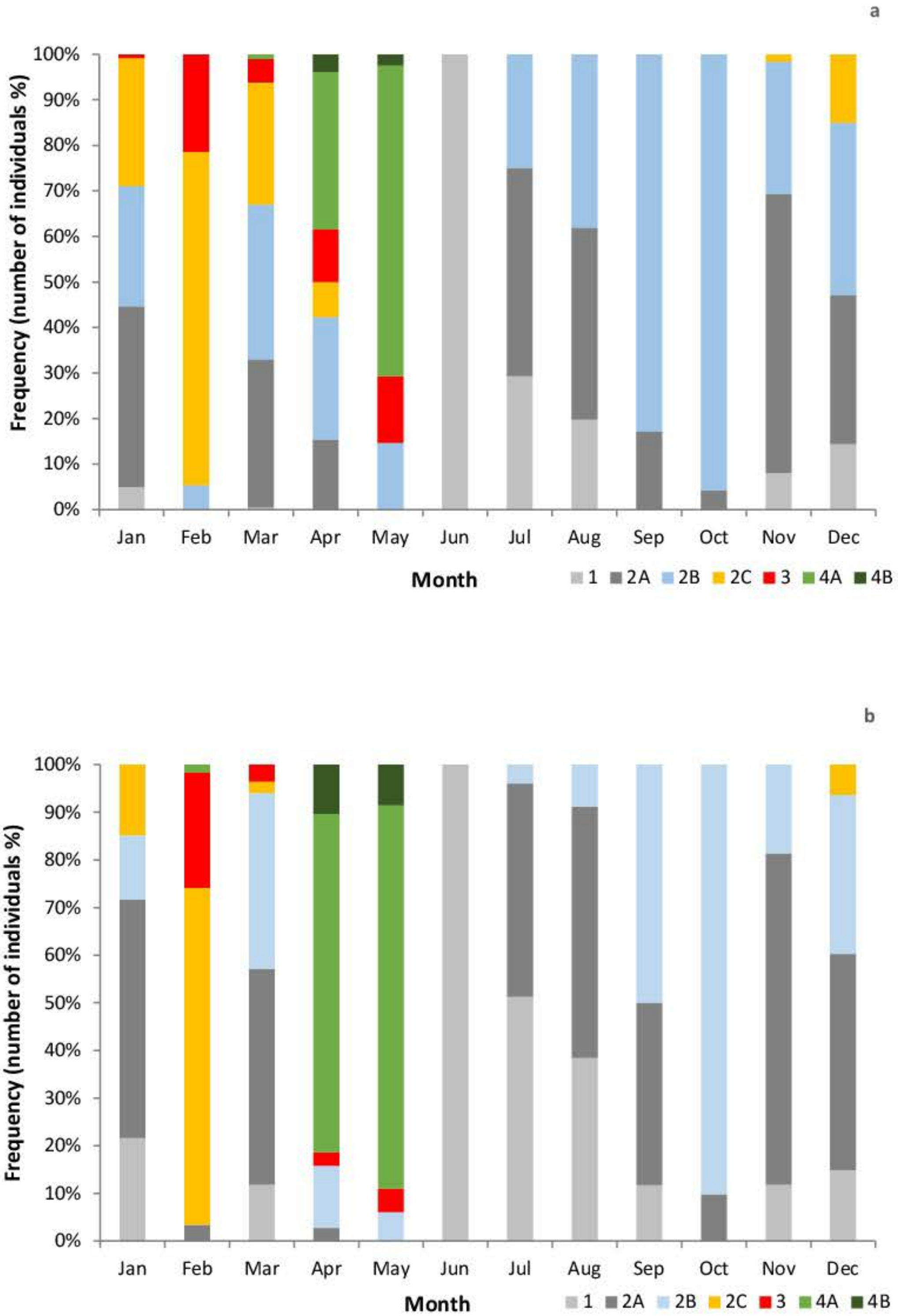


Figure 5.7. Monthly percentages of maturity stages for (a) females and (b) males of *Boops boops* of the Canary Islands. 1, immature/virgin; 2A, virgin/developing; 2B, recovering; 2C, maturing; 3, mature and / or spawner; 4A, spent; 4B, resting.

5.5. GONADOSOMATIC INDEX

Gonads of this species presents a well-marked difference between sexes in individuals larger than 10 cm TL. Testes mean weight increase from 0.005 g in stage 1 to 19.180 g in stage 2C whilst in females, the ovary reaches a large size with maturity, with mean ovarian weight increasing from 0.012 g in stage 1 to 9.940 g in stage 3.

Monthly evolution of the gonadosomatic index (IGS) for both sexes is presented in Table 5.6. The GSI trend follows the same pattern described on the performance of the monthly percentages of maturity stages. In fact, in females IGS shows a peak on February (3.2 ±0.67), month in which presence of females in deposition stage (stage 3) was maximum. In males, the GSI shows same pattern with a peak on February (3.28 ± 076) (Fig. 5.8).

Table 5.6 - Gonadosomatic index and standard deviation (sd) in females (F) and males (M) of *Boops boops* of the Canary Islands

Month	F	sd	M	sd
January	1.90	0.50	0.75	0.36
February	3.20	0.68	3.29	0.77
March	0.70	0.39	0.16	0.09
April	0.83	0.40	0.70	0.48
May	1.20	0.70	0.93	0.39
June	0.89	0.30	0.65	0.20
July	0.30	0.16	0.29	0.15
August	0.32	0.13	0.26	0.18
September	0.35	0.14	0.21	0.19
October	0.41	0.14	0.09	0.03
November	0.28	0.11	0.09	0.12
December	0.80	0.11	0.36	0.20

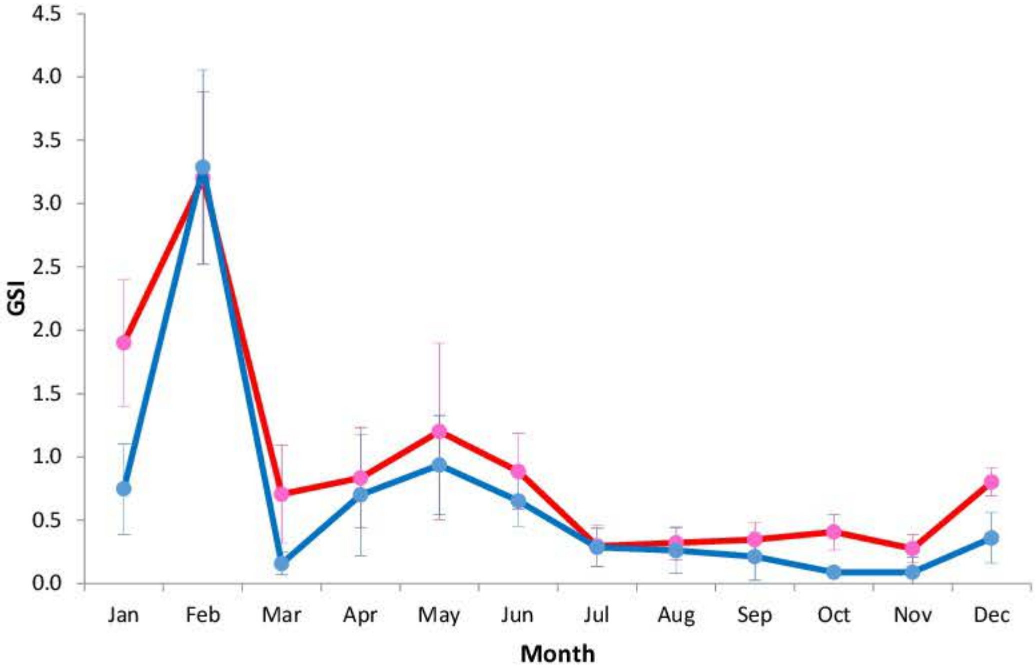


Figure 5.8. Monthly evolution of the gonadosomatic index (GSI) in for females (red) and males (blue) of *Boops boops* of the Canary Islands. Vertical bars represent the standard deviation

5.6. SIZE AT FIRST SEXUAL MATURITY

Tables 5.7-5.8 shows female and male divided into maturity stage by size classes during the spawning period. The smallest mature male and female analyzed were 13.0 and 14.0 cm TL, respectively. The average length at first maturity for females and males were 17.8 ±0.7 and 18.6 ±0.7 cm total length, respectively (Figs. 5.9-5.10). Size at which all individuals were mature was 22 cm for females and 23 cm for males. No significant difference in length at first maturity was found between sexes (*t*-value=0.8561, *p*=0.395). r^2 values were 0.991 for females and 0.996 for males confirming that model was good for experimental data.

Table 5.7 - Number of mature females by maturity condition for *Boops boops* of the Canary Islands.. 1, immature/virgin; 2A, virgin/developing; 2B, recovering; 2C, maturing; 3, mature/spawner; 4A, spent; 4B, resting.

Size (cm)	**1**	**2A**	**2B**	**2C**	**3**	**4A**	**4B**	**Total**
8								
9								
10	6							6
11	2							2
12	4							4
13	28	3						31
14	22	36	7					65
15	4	38	16					58
16	16	41	18	4		1		80
17	8	79	44					131
18	6	80	49	2		1		139
19	4	36	49	2				91
20		8	54	5		1		68
21		6	62	12		6		86
22			43	16	1	5	1	66
23			18	31	9	3	1	62
24			16	33	3	10		62
25			23	20	6	4		53
26			14	15	5	5		39
27			3	8	2	1		14
28					3	1		4
29				2	3	1		6
30				2	1			3
Total	100	327	416	152	32	39	2	1069

Table 5.8 - Number of mature males by maturity condition for *Boops boops* of the Canary Islands. 1, immature/virgin; 2A, virgin/developing; 2B, recovering; 2C, maturing; 3, mature/ spawner; 4A, spent; 4B, resting.

Size (cm)	**1**	**2A**	**2B**	**2C**	**3**	**4A**	**4B**	**Total**
8	2							2
9	5							5
10	5							5
11								
12	12	2						14
13	26	7	1					34
14	32	42	4					78
15	11	63	11			1		86
16	14	31	8					53
17	15	47	14					76
18	14	46	14	1		2		77
19	3	23	19			3	1	49
20		18	33	1		16		68
21		5	33	2		28	7	75
22		2	30	5		33	6	76
23			11	6		15	3	35
24			11	1	3	26	2	43
25				1	5	28	2	36
26			7	4	2	15	1	29
27				2	1	3		6
28			1	13				14
29				9	5			14
30				7	2			9
31				6	2			8
32				4	3			7
33				1	1			2
34					1			1
Total	139	286	197	63	25	170	22	902

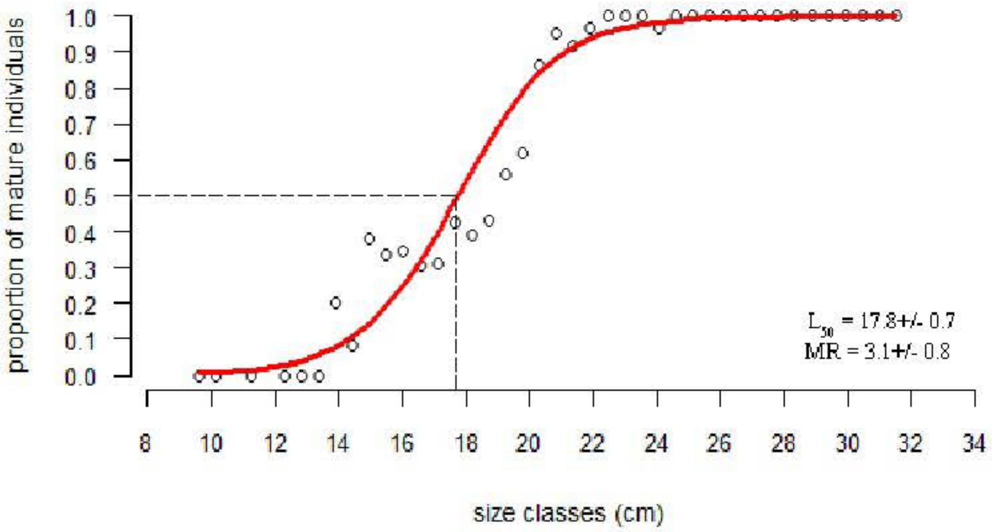


Figure 5.9 -Maturity ogive with length at first maturity (L_{50}) and maturity range (MR) value with relative standard deviation for females of *Boops boops* of the Canary Islands

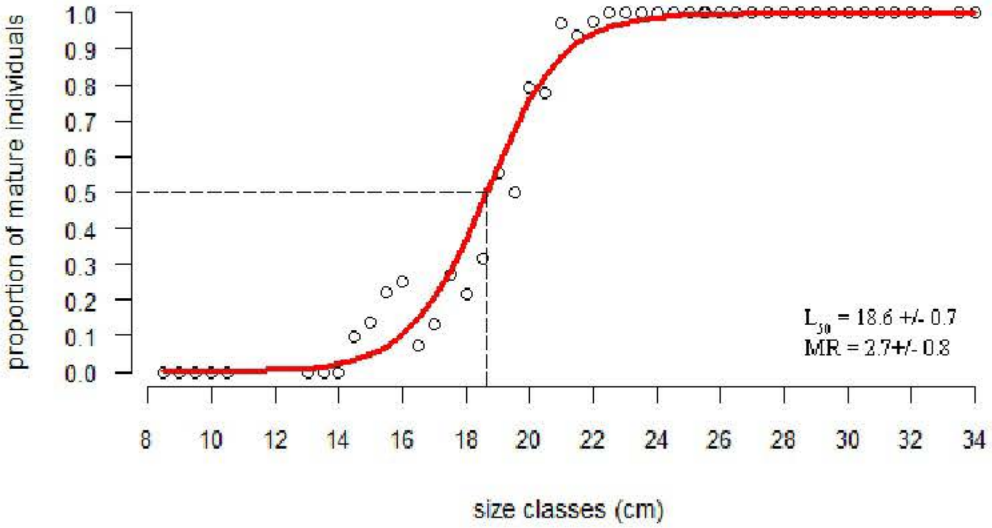


Figure 5.10 – Maturity ogive with length at first maturity (L_{50}) and maturity range (MR) value with relative standard deviations for males of *Boops boops* of the Canary Islands

5.7. GROWTH

5.7.1. Anatomical method: direct otoliths reading

In total were collected and analyzed 656 otoliths (Table 5.9). 17 otoliths were not readable (crystallized or damaged). Age of 639 specimens was determined, 246 females, with sizes ranging from 10 to 30.5 cm TL, 260 males, with sizes comprised between 8.5 and 34.0 cm TL; 75 otoliths were collected from indeterminate individuals (ranging from 5.5 to 24.5cm TL) and 8 from individual with intersexual gonads (from 14.5 to 21 cm TL) (Table 5.10).

Tables 5.11-5.12 shows age groups composition for females and males. From ALK, average sizes corresponding to different age groups were estimated. Regarding females, age classes ranging between 0 and 4 years, while for males ranging between 0 and 5. The maximum recorded age for female (4 year) correspond to a specimens of 30.5 cm TL; for males, the maximum recorded age (5 years), correspond to a specimen of 33.0 cm TL; and for both sex, the most represented age group was 1 year.

Table 5.9 - Number of reading otoliths for females (F), males (M), indeterminate (I) and intersexual (T) for *Boops boops* of the Canary Islands

Sex	Total	Range (TL, cm)
F	273	10.0-30.5
M	280	8.5-34.0
I	77	5.5-24.5
T	9	14.5–21.0

Table 5.10 - Number of otoliths sampled of *Boops boops* of the Canary Islands by size class. Females (F), males (M), indeterminate (I) and intersexual (T)

Size (cm)	F	M	I	T	Total
5			2		2
6			13		13
7			16		16
8		1	15		16
9		3	12		15
10	1	3	8		12
11		3	3		6
12	2	4			6
13	9	12	2		23
14	15	17	1	1	34
15	18	13	1		32
16	23	11		2	36
17	22	20	1	3	46
18	31	17	1	2	51
19	22	9	1	1	33
20	13	16			29
21	16	14		1	31
22	14	26	2		42
23	15	16			31
24	15	26	2		43
25	22	22			44
26	19	16			35
27	8	4			12
28	4	6			10
29	4	11			15
30	3	8			11
31		5			5
32		4			4
33		2			2
34		1			1
Total	276	290	80	10	656

Table 5.11 - Age-length key for females of *Boops boops* of the Canary Islands. Sd, is the standard deviation of the size

	Age class (years)				
Size (cm)	**0**	**I**	**II**	**III**	**IV**
5	1				
6	5				
7	7				
8	8				
9	6				
10	6				
11	1				
12	4				
13	9	1			
14	9	7			
15	7	9			
16		22	1		
17		23	1		
18		30	2		
19		20	3		
20		13	0		
21		13	4		
22		11	2	3	
23		3	10	1	1
24		1	7	7	2
25		1	6	10	4
26		1	1	12	5
27			1	6	1
28				1	3
29			1	1	2
30				1	2
Number	63	155	39	42	20
Mean size (cm)	10.8	18.4	22.9	25.6	26.7
Sd	2.9	2.4	2.7	1.7	2.0

Table 5.12 - Age-length key for males of *Boops boops* of the Canary Islands. Sd, is the standard deviation of the size

	Age class (years)					
Size (cm)	**0**	**I**	**II**	**III**	**IV**	**V**
5	5					
6	5					
7	8					
8	10					
9	7					
10	2					
11	2					
12	4					
13	11	3				
14	11	10				
15	2	11	1			
16		15				
17		21	1			
18		12	1			
19		9	4			
20		9	3			
21		19	2	2		
22		12	8	2		
23		2	6	7		
24		2	6	15	5	
25			6	13	2	
26				5	1	
27			1	1	1	
28			2	3	3	2
29				4	5	
30				1	2	4
31				1	2	2
32					1	
33					1	1
34					1	
Number	67	125	41	54	24	9
Mean size (cm)	10.7	18.8	23.1	25.8	28.8	30.9
Sd	3.0	2.8	2.8	2.1	2.8	1.4

Growth parameters (L_∞, k and t_0), with the respective confidence interval (Figs. 5.11-5.13) and residuals analysis (Figs. 5.12-5.14), were estimated for both sexes, by direct approach using the von Bertalanffy model (VBGF) available in FSA package (R program). A summary of parameters estimates, with standard deviations for each parameters and *t*-test and corresponding *p*-values, are shown in Table 5.13.

Table 5.13 - Growth parameters of *B. boops*. Sd standard deviation, t value and significance. L_∞= asymptotic length; k = growth coefficient; t_0 = hypothetical age at zero length. *t*-value, *t*-test value. *p*, is the p-value

Sex	**Parameters**	**value**	**Sd**	***t* value**	***p***
Females	L_∞ (cm)	32.3	0.749	43.05	$p<0.0001$
	k (years^{-}1)	0.44	0.028	16.07	$p<0.0001$
	t_0 (years)	-0.8	0.040	-19.93	$p<0.0001$
Males	L_∞ (cm)	35.3	1.022	34.51	$p<0.0001$
	k (years $^{-1}$)	0.38	0.026	14.62	$p<0.0001$
	t_0 (years)	-0.8	0.041	-19.35	$p<0.0001$

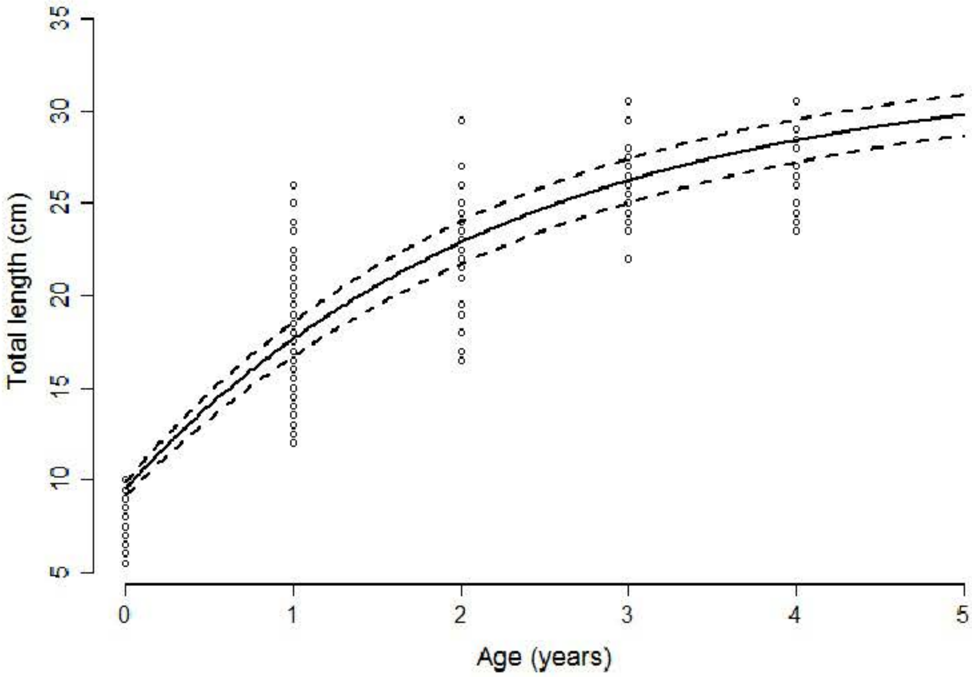


Figure 5.11 - von Bertalanffy growth curves and confidence interval (ES) for females of *Boops boops* of the Canary Islands

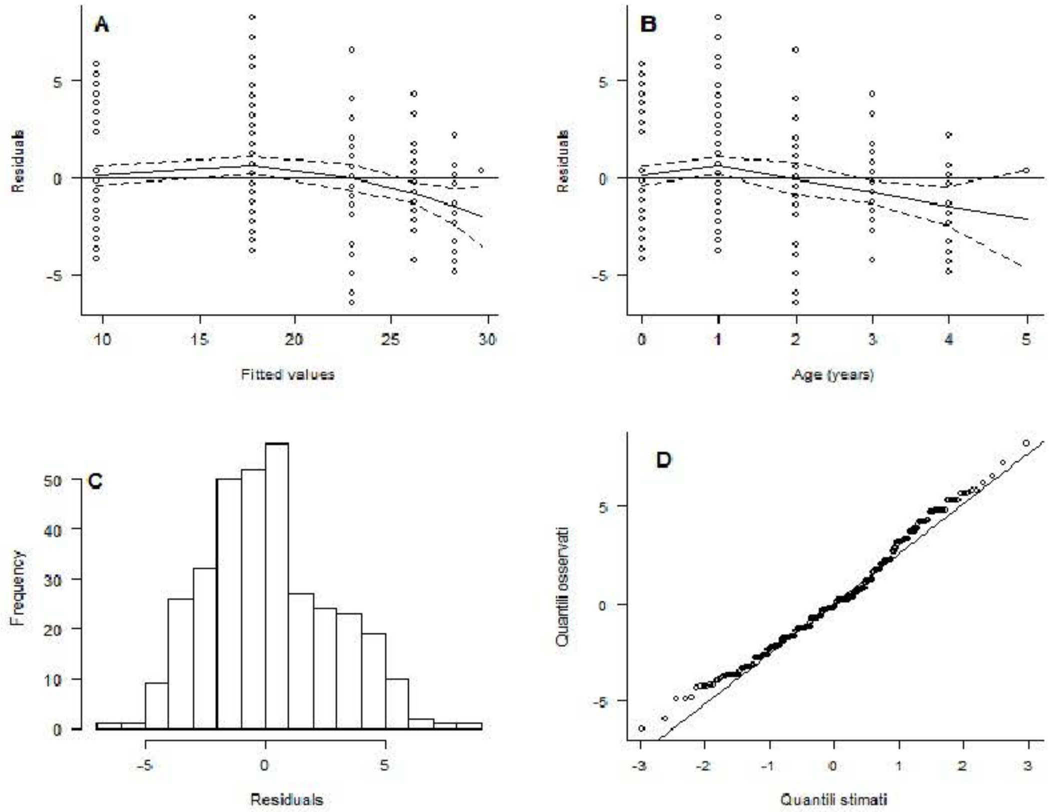


Figure 5.12 – Residual plot (A-B), histogram of residual (C) and quantile (D) from fitting the VBGF to the female of *Boops boops* of the Canary Islands

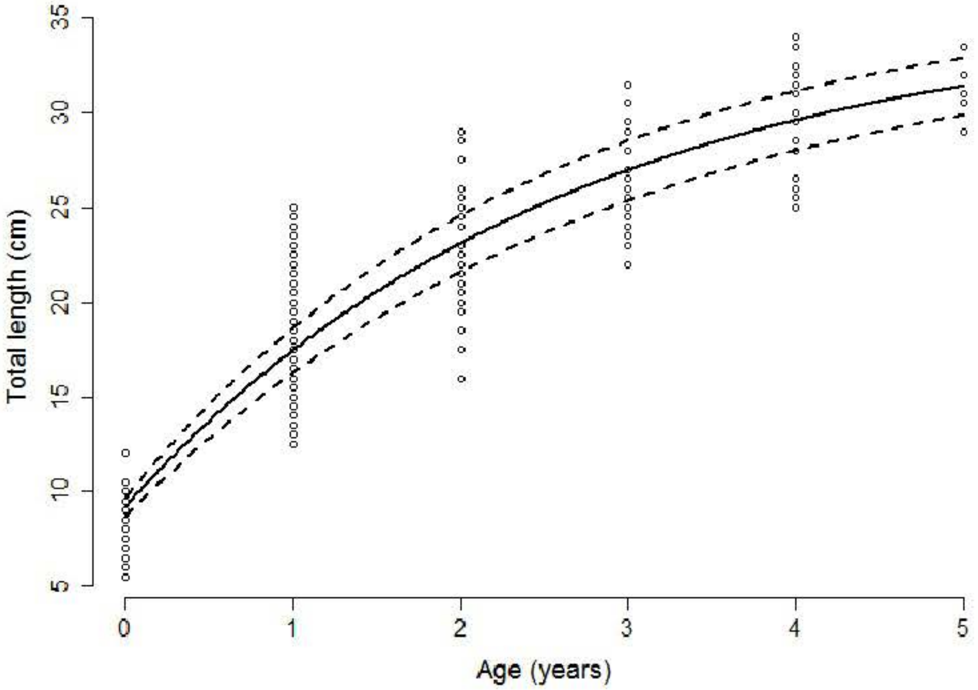


Figure 5.13 von Bertalanffy growth curves and standard deviation for males of *Boops boops* of the Canary Islands

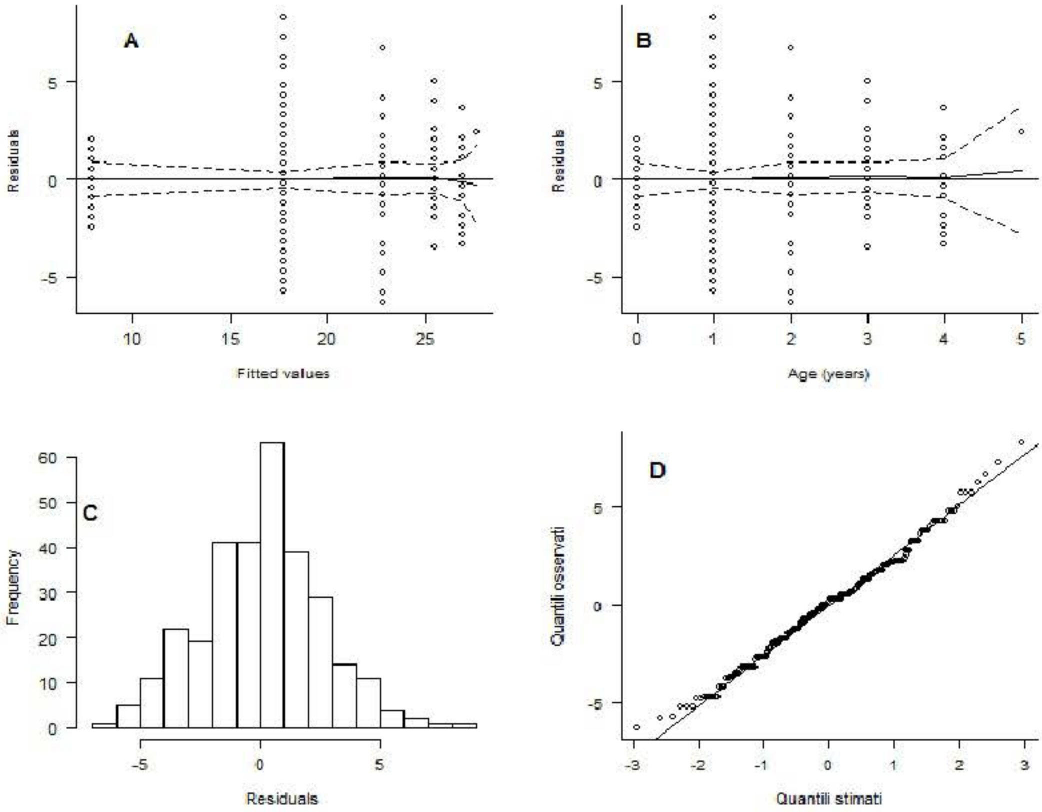


Figure 5.14 - Residual plot (A-B), histogram of residual (C) and quantile (D) from fitting the VBGF to the female of *Boops boops* of the Canary Islands

Extra sums-of-squares test identified a significant different between sexes in L∞ values (χ^2=6.5132; p=0.012). von Bertalanffy growth parameters were also estimated in terms of weight (Figs. 5.15-5.16). Growth parameters obtained are shown in Table 5.14.

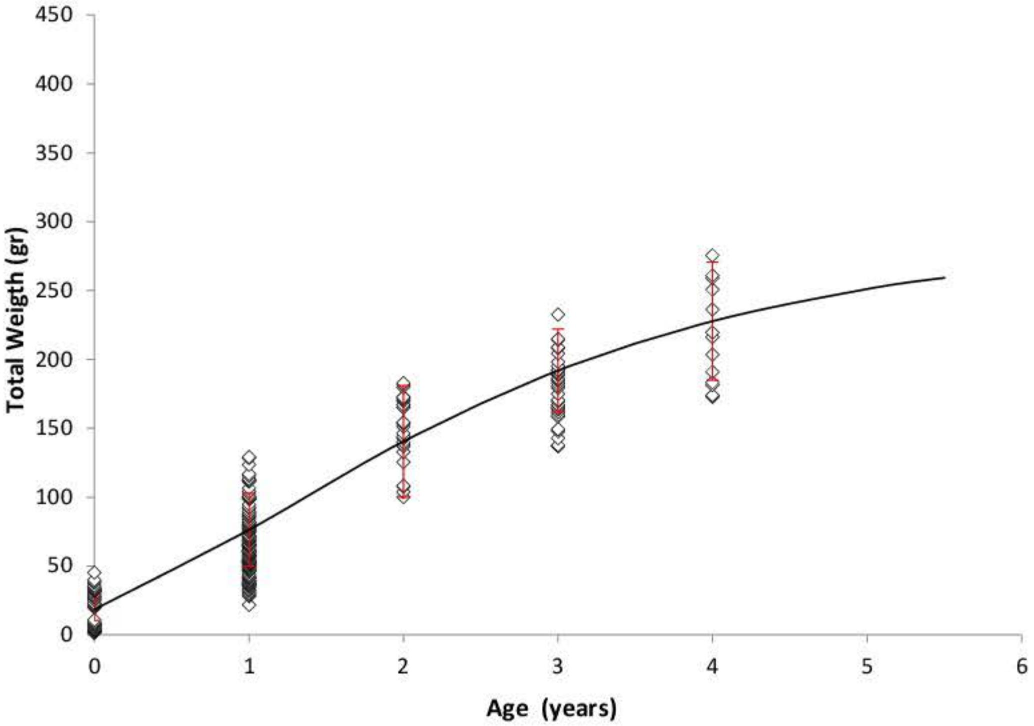


Figure 5.15 - von Bertalanffy growth curves and standard deviation for females of *Boops boops* of the Canary Islands

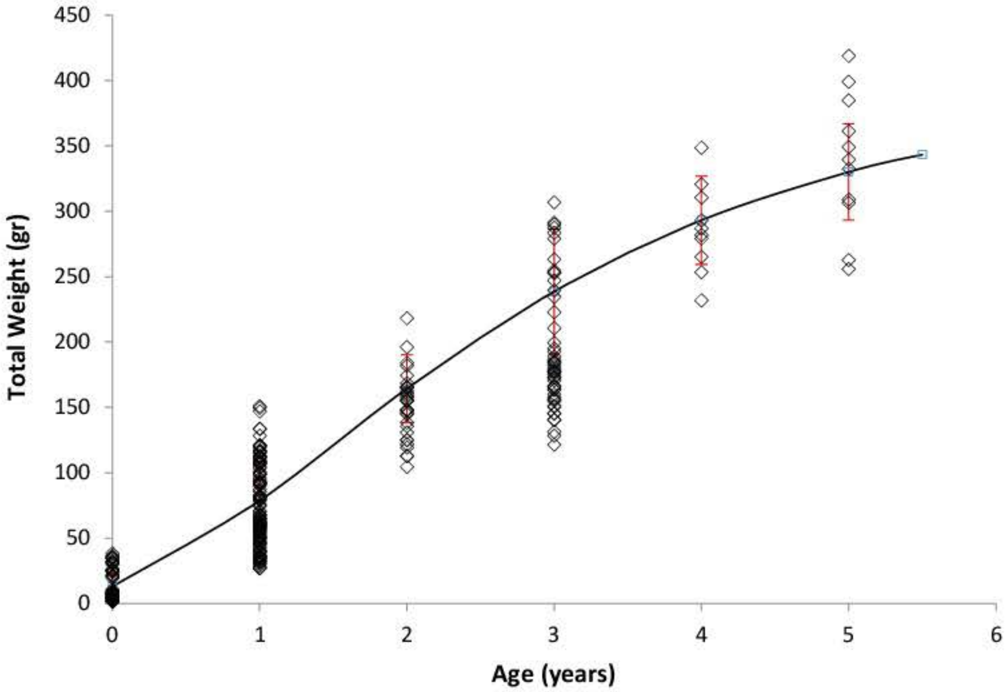


Figure 5.16 - von Bertalanffy growth curves and standard deviation for males of *Boops boops* of the Canary Islands

Table 5.14 - Growth parameters of *Boops boops* of the Canary Islands. L_∞= asymptotic length; k= growth coefficient; t_0= hypothetical age at zero length

Sex	**L_∞ (cm)**	**k (years $^{-1}$)**	**t_0 (years)**
Females	31.5	0.45	-0.8
Males	35.5	0.4	-0.9

Chen's test used to compare growth curve showed significant differences in growth between sexes (Table 5.15).

Table 5.15 - Chen's test result for individual and pooled data. RSS: Residual Sum of Squared; DF: Degree of Freedom DF; Estimate F: F value; df of F: Degree of Freedom of F; P(F<x)0.01: p-value; Critical F: F value (α=0.05)

Test	Individual	Pooled
RSS	612444.509	5.1E+05
DF	605	606
Estimate *F*	96.94	32.15
df di F	3	602
P(F<x)0.01	3.4E-15	
Critical F	2.62	

5.7.2. Direct age validation

Ageing precision, including percent agreement and the total coefficient of variance, plus generating both an age-bias are presented in Tables 5.16-5.19 and in Figs. 5.17-5.18.

Table 5.16. Sample size, total coefficient of variation (CV) and percent agreement for females of *Boops boops* of the Canary Islands

Females	
N Tested	273
N Agreed	250
Disagreed	23
%Agreement	91.60%
Total CV	5.19%

Table 5.17 – Number of individuals (N), number (N Agreed) and percentage of agreement (% Agremt), Average test age (Average Age) for each production age (Prod Age) with standard deviation (Sd) for females of *Boops boops* of the Canary Islands

Prod Age	N	N Agreed	% Agremt	Average Age	Sd
0	29	25	0.86	0.14	0.35
1	145	140	0.97	1.01	0.19
2	38	32	0.84	1.95	0.40
3	41	36	0.88	2.98	0.35
4	20	17	0.85	3.95	0.39

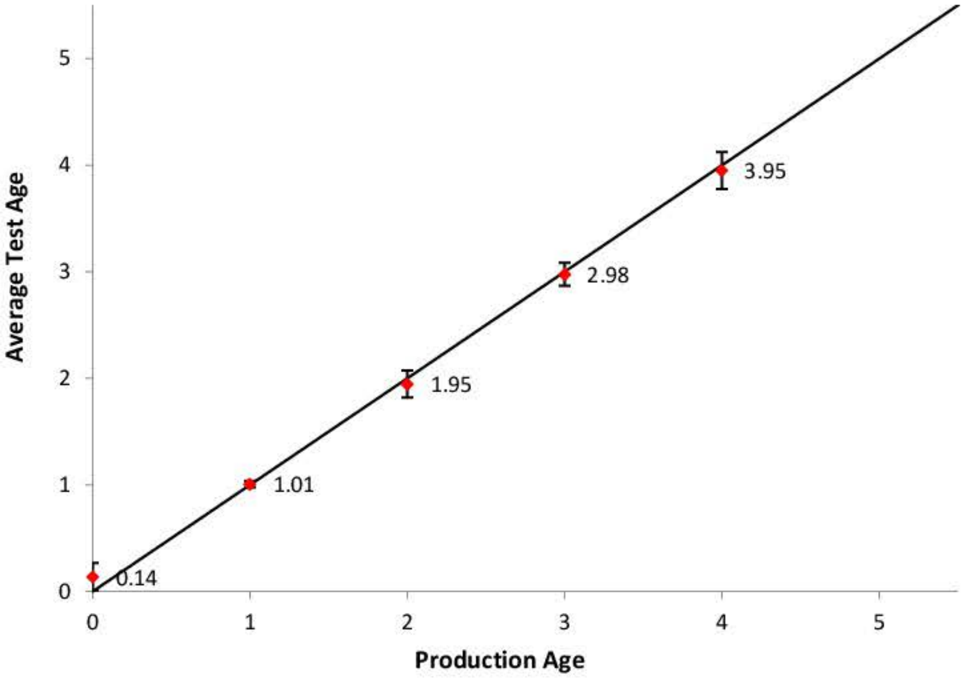


Figure 5.17 - Age bias plots with the mean age recorded +/- SD of each age for *Boops boops* of the Canary Islands

Table 5.18- Sample size, total coefficient of variation (CV) and percent agreement for males of *Boops boops* of the Canary Islands

Males	
N Tested	280
N Agreed	252
Disagreed	28
%Agreement	90.00%
Total CV	6.41%

Table 5.19 - Number of individuals (N), number (N Agreed) and percentage of agreement (% Agremt), Average test age (Average Age) for each production age (Prod Age) with standard deviation (Sd) for males of *Boops boops* of the Canary Islands

Prod Age	N	N Agreed	% Agremt	Average Age	s.d.
0	32	28	0.88	0.13	0.34
1	122	113	0.93	0.99	0.27
2	38	36	0.95	1.95	0.23
3	56	51	0.91	3.05	0.30
4	21	18	0.86	3.86	0.36
5	11	6	0.55	5.09	0.70

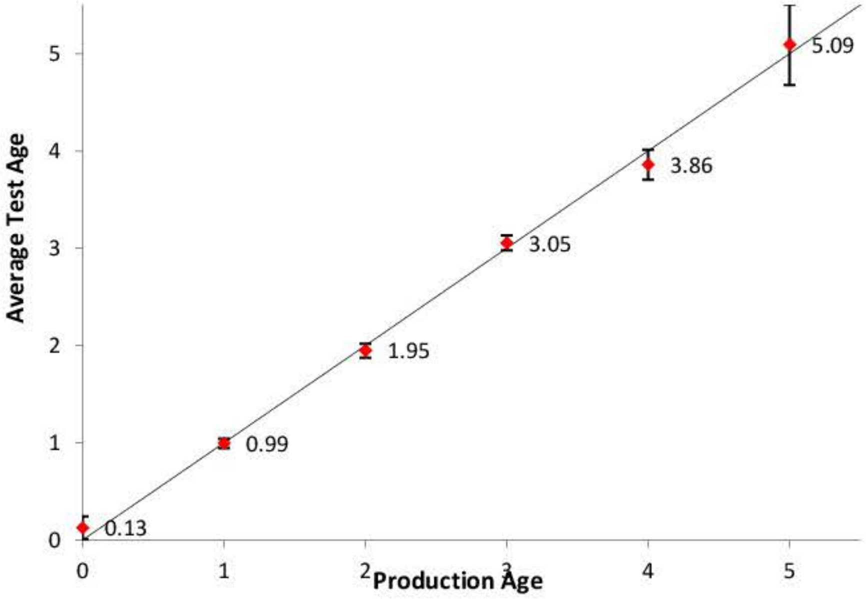


Figure 5.18 - Age bias plots with the mean age recorded +/- SD of each age for *Boops boops* of the Canary Islands

As indicated by the age bias plots for females and males (Figs. 5.17-5.18), all between-two-reading comparisons exhibit a certain degree of agreement (>84%) particularly for age 1 (97%) regarding female and age 2 for males (95%). Only age 5 for male show very low agreement (55%) due to limited sampling (11 specimens). In all predicted ages, mean ages assigned in first reading not deviate considerably from the age assignments during second reading. For both sex a slight relative underestimation of ages was revealed.

The precision estimates between two reading (Tables 5.16-5.18), and percentage of agreement show high correlation (>90.0%) for both sexes and low correlation coefficient values, 4.20% for females and 6.41% for males, indicated high precision between two reading.

5.7.3. Back calculation

Length at age were also estimated by means for the Back-calculation method using Fraser-Lee formula. The results obtained are shown in Tables 5.20-5.21.

Table 5.20 - Length at age Back-calculated for females of *Boops boops* of the Canary Islands. Sd, is the standard deviation

Annual rings	**Demersal ring**	**Age (years)**			
		1	**2**	**3**	**4**
0	7.1				
1	5.7	15.9			
2	5.3	15.3	19.5		
3	5.8	15.6	20.3	23.9	
4	6.2	15.5	20.2	23.1	25.8
Mean size (cm)	5.6	15.6	19.8	23.7	25.8
SD	1.2	2.3	2.6	2.3	1.9

Table 5.21 - Length at age Back Calculated for males of *Boops boops* of the Canary Islands. Sd, is the standard deviation

Annual rings	**Demersal ring**	**Age (years)**				
		1	**2**	**3**	**4**	**5**
0	5.2					
1	5.2	16.3				
2	5.4	14.9	19.4			
3	5.8	17.1	21.9	25.3		
4	6.2	16.6	21.5	24.9	28.2	
5	6.4	17.6	21.9	25.5	28.2	30.9
Mean size (cm)	5.5	16.2	20.8	25.2	28.2	30.9
SD	1.1	2.3	2.8	2.4	2.5	1.9

Use of this method was possible because relationship between fish size and otoliths size was testify: relationship between total length (TL), otolith radius and diameter (OR, TOL) were estimated. Figs. 5.19-5.21 shows graphically these relations with the respective statistical analysis. Also in this case, indeterminate individuals greater than 10 cm TL were divided according with sex ratio vector, while indeterminate individuals smaller than 10 cm were divided equally in males and females. In Table 5.22 shows the results of the linear regression between the measurements. Although in all cases r^2 values were high.

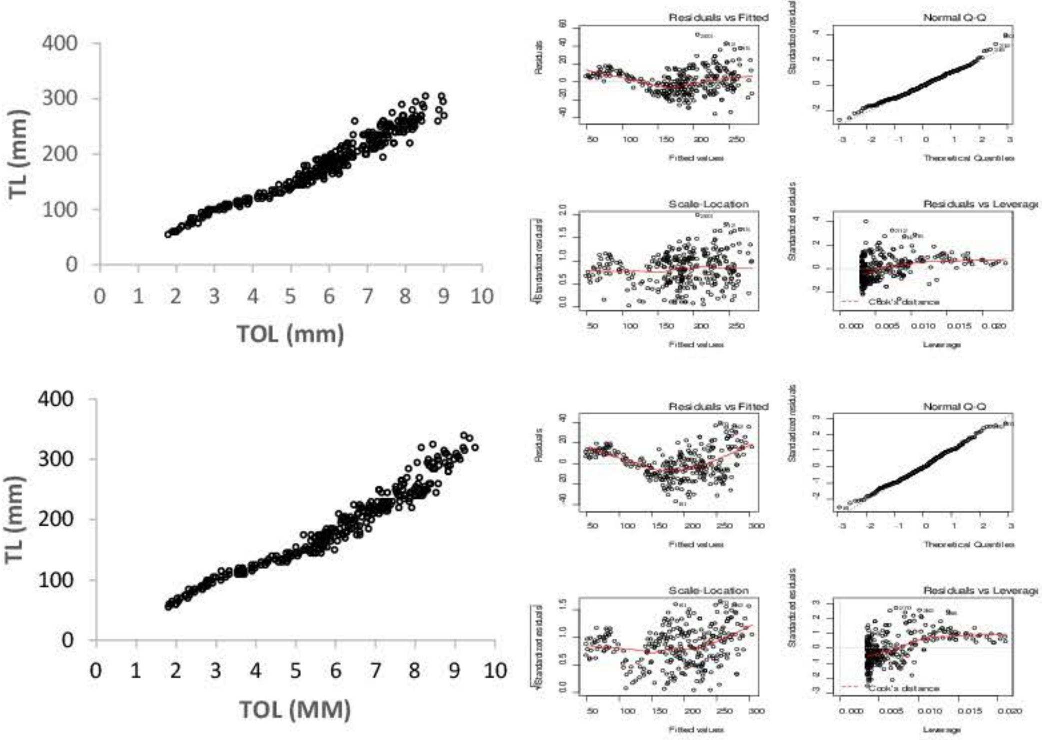


Figure 5.19 - Morphometric relationship between total length (TL) and otolith diameter (TOL) of female (up) and males (bottom) and relative residuals analysis for *Boops boops* of the Canary Islands

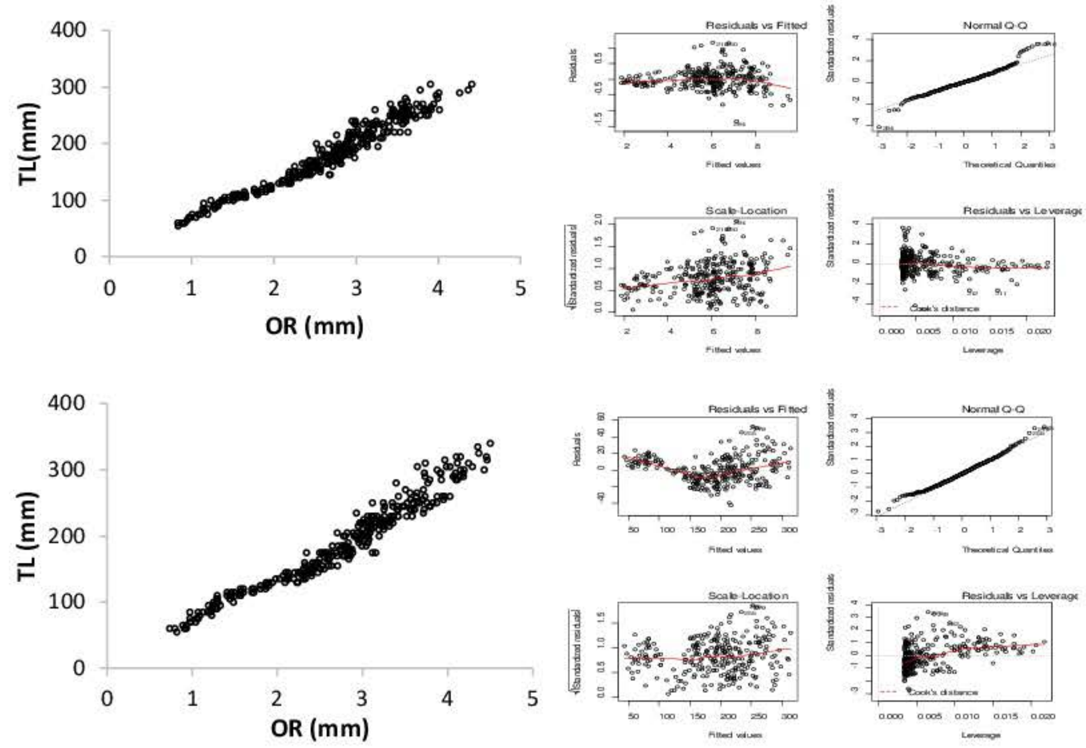


Figure 5.20 - Morphometric relationship between total length (TL) and otolith radium (OR) of female (up) and males (bottom) and relative residuals analysis for *Boops boops* of the Canary Islands

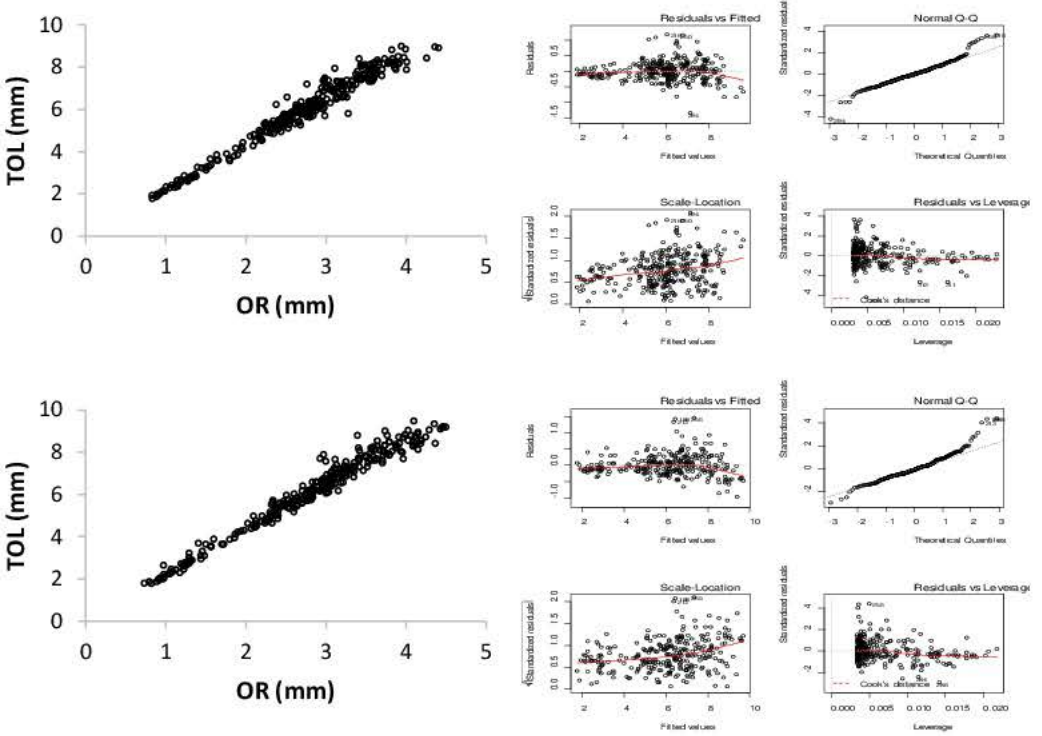


Figure 5.21 - Morphometric relationship between otolith diameter (TOL) and otolith radium (AO) of female (up) and males (bottom) and relative residuals analysis for *Boops boops* of the Canary Islands

Table 5.22 - Results of the linear regression analysis between different morphometric measurements. *a* intercept, *b* slope; TL, total length; *AO*, otolith radium; *AB*, otolith diameter; *Sd*, standard deviation; *p*-value, test value

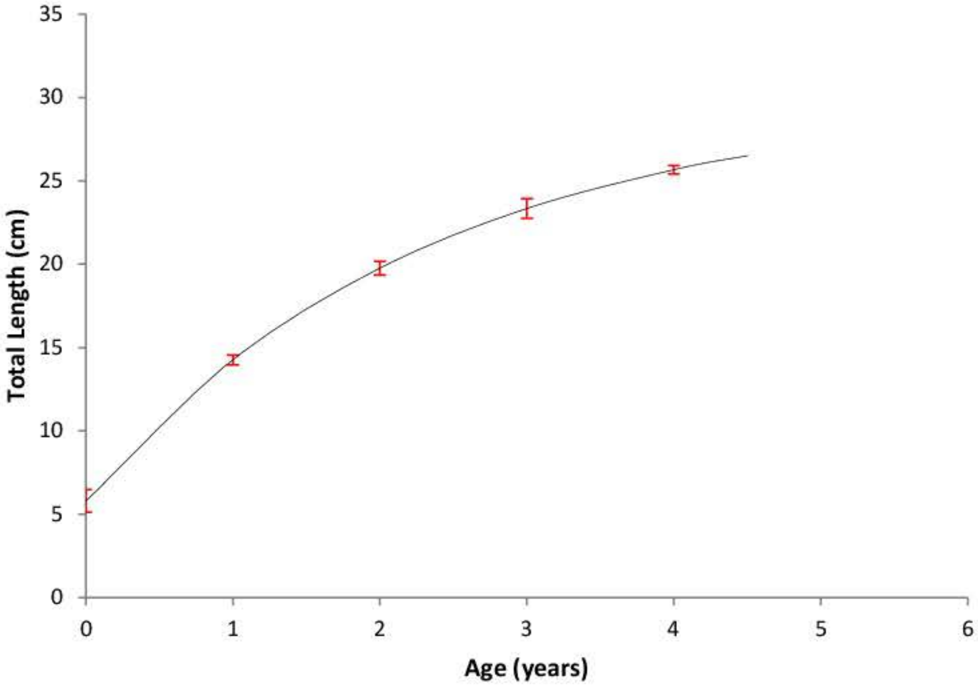
MORPHOMETRIC RELATION	SEX	a	b	R^2	Sd.	*t* value	*p*-value
TL/TOL	F	-8.493	32.42	0.913	2.7814	-3.05	$p<0.001$
	M	-11.3061	33.2167	0.9432	2.8844	-3.92	$p<0.001$
TL/OR	F	-9.582	71.148	0.9414	2.83	-3.028	$p<0.001$
	M	-8.817	71.874	0.946	2.973	-2.965	$p<0.001$
TOL/OT	F	0.0989	2.1554	0.963	0.0665	2.487	$p<0.001$
	M	0.2137	2.1089	0.9701	0.0641	3.334	$p<0.001$

Using back calculated lengths at age, growth parameters L_∞ k and t_0 were estimated (Table 5.23).

Table 5.23 - Growth parameters of *Boops boops* of the Canary Islands estimated from back-calculation analysis. L_∞=asymptotic length; k= growth coefficient; t_0= hypothetical age at zero length

SEX	L_∞ (cm)	k (years $^{-1}$)	t_0 (years)
Females	30.0	0.43	-0.50
Males	34.0	0.4.0	-0.50

Growth curves obtained (Fig. 5.22) were compared using Chen's test, which showed significant differences in growth between sexes (Table 5.24).



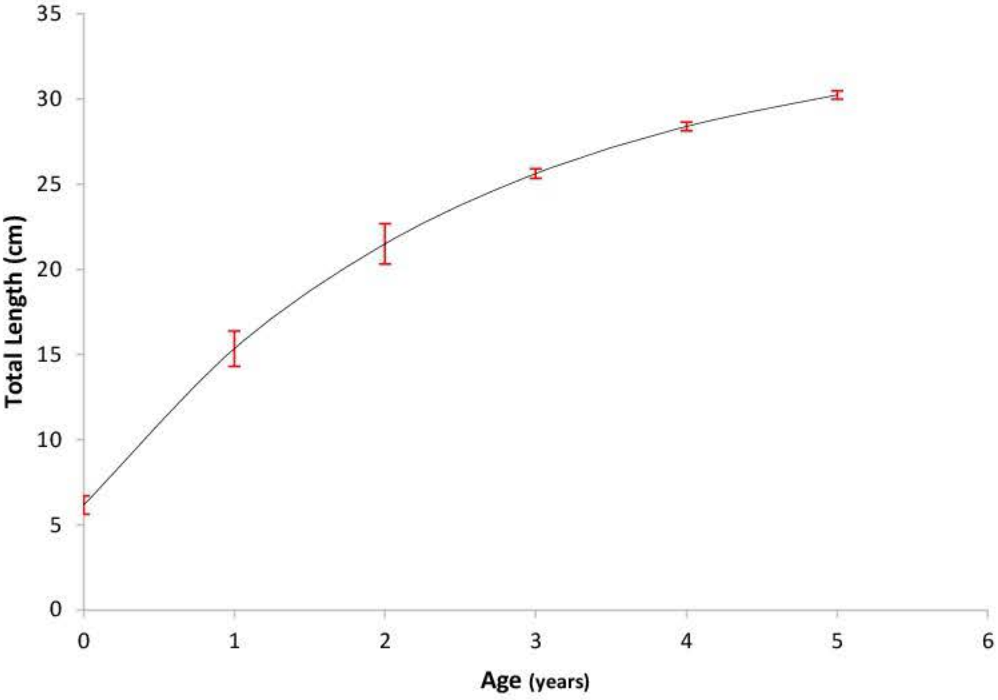


Figure 5.22 - von Bertalanffy growth curves and standard deviation of *Boops boops* of the Canary Islands (females upper; males bottom) estimated from back-calculation

Table 5.24 - Chen's test result for individual and pooled data. Rss: Residual Sum of Squared; DF: Degree of Freedom DF; Estimate F: F value; df of F: Degree of Freedom of F; P(F<x)0.01: p-value; Critical F: F value

Test	Individual	Pooled
RSS	15321144.83	1.0E+06
Df	1625.00	1626.00
Estimate *F*	1516.57	504.59
df of F	3.00	1622.00
P(F<x)0.01	4.6E-131	
Critical *F* (0.05)	2.61	

5.7.4. Semi-direct validation

Semi-direct validation of the rings deposition pattern was carried out respectively by edge analysis and marginal increment analysis (MIA). Table 5.25 shows frequency for months for observed edges and relative MIA values.

Table 5.25 - Percentage of otoliths with opaque (O), translucent (T) edge and relative MIA values in each month of *Boops boops* of the Canary Islands. Standard deviation (Sd) is also indicated

Month	**T (%)**	**O (%)**	**MIA**	**Sd**
Jan	66.7	33.3	0.19	± 0.08
Feb	49.3	50.7	0.21	± 0.07
Mar	16.4	83.6	0.28	± 0.09
Apr	14.3	85.7	0.29	± 0.14
May	53.0	47.0	0.2	± 0.13
Jun	62.9	37.1	0.18	± 0.08
Jul	93.8	6.3	0.16	± 0.09
Aug	89.9	10.1	0.13	± 0.08
Sep	87.8	12.2	0.12	± 0.09
Oct	96.1	3.9	0.09	± 0.04
Nov	94.2	5.8	0.13	± 0.10
Dec	79.6	20.4	0.15	± 0.11

Edge analysis (Fig. 5.23) shows the deposition of a translucent ring and opaque ring through year: the first one is laid down from June to January and the second one between February and May.

A further validation of accretion pattern was provided by marginal increment analysis (Fig. 5.24). Results shows a periodicity in growth otolith, with an increase of marginal increment between February and May during opaque ring deposition.

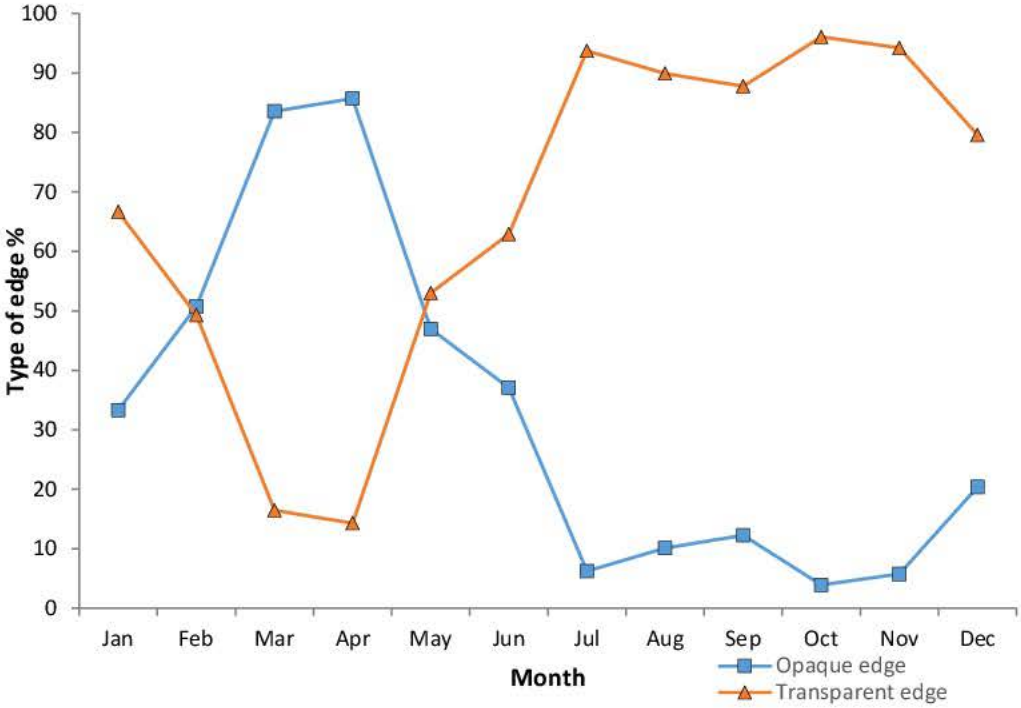


Figure 5.23 - Monthly percentage of type of edge for *Boops boops* of the Canary Islands

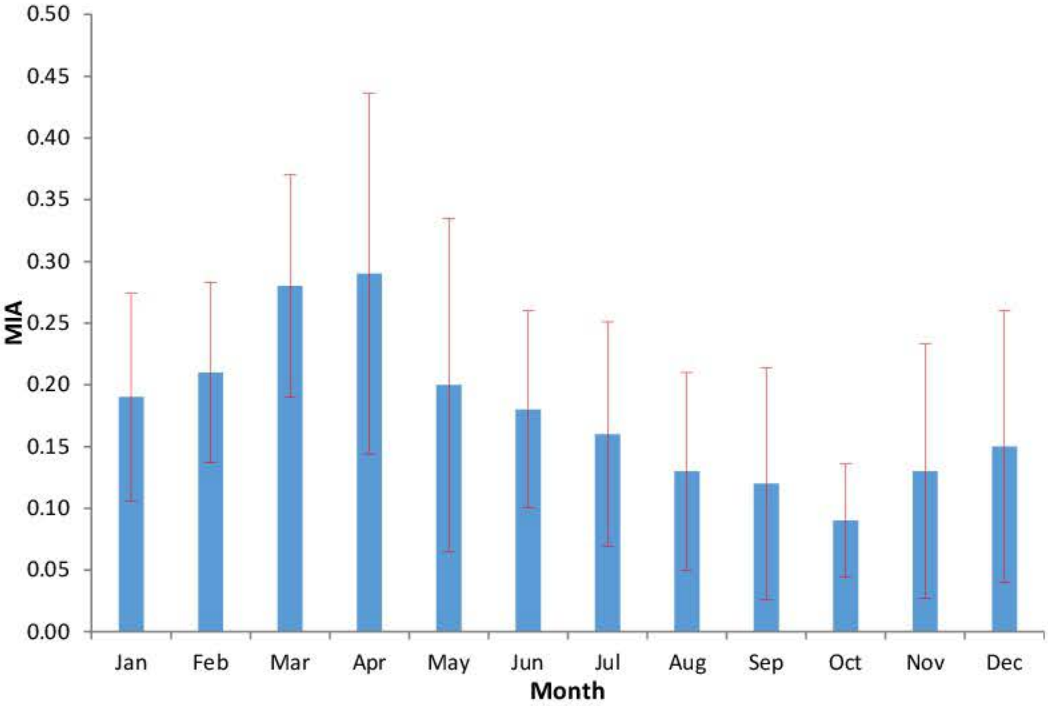


Figure 5.24 - Monthly trend of marginal increment (average) ± standard deviation for *Boops boops* of the Canary Islands

MIA values trend relate with mean water column temperature (10-60 m depth) (Fig. 5.25) highlight inverse correlation. MIA maximum values occurs in March and April, when temperature reaches minimum values, in opposition when water temperature reaches its maximum (September - October), MIA values are lower

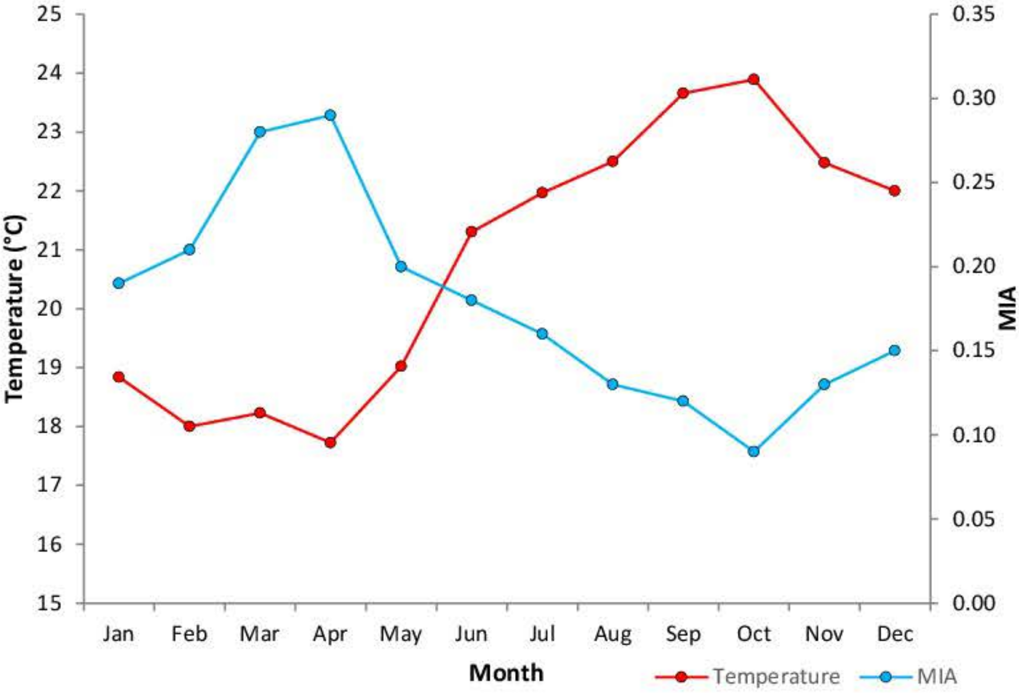


Figure 5.25 - Monthly trend of marginal increment (average) in the otoliths of *Boops boops* of the Canary Islands and water temperature

5.7.5. Indirect validation: ELEFAN I and Bhattacharya methods

Frequency distributions was considered for recognize age classes of each month (Fig. 5.26); MPA program (Gayanilo *et al.*, 1989), proved a separation index, whose value must be greater than 2.0 (critical value) for considering significant difference between groups. Monthly modal lengths obtained (Tables 5.26-5.27) by Bhattacharya were assigned to different age groups, taking into account the average lengths by age class found by otoliths reading.

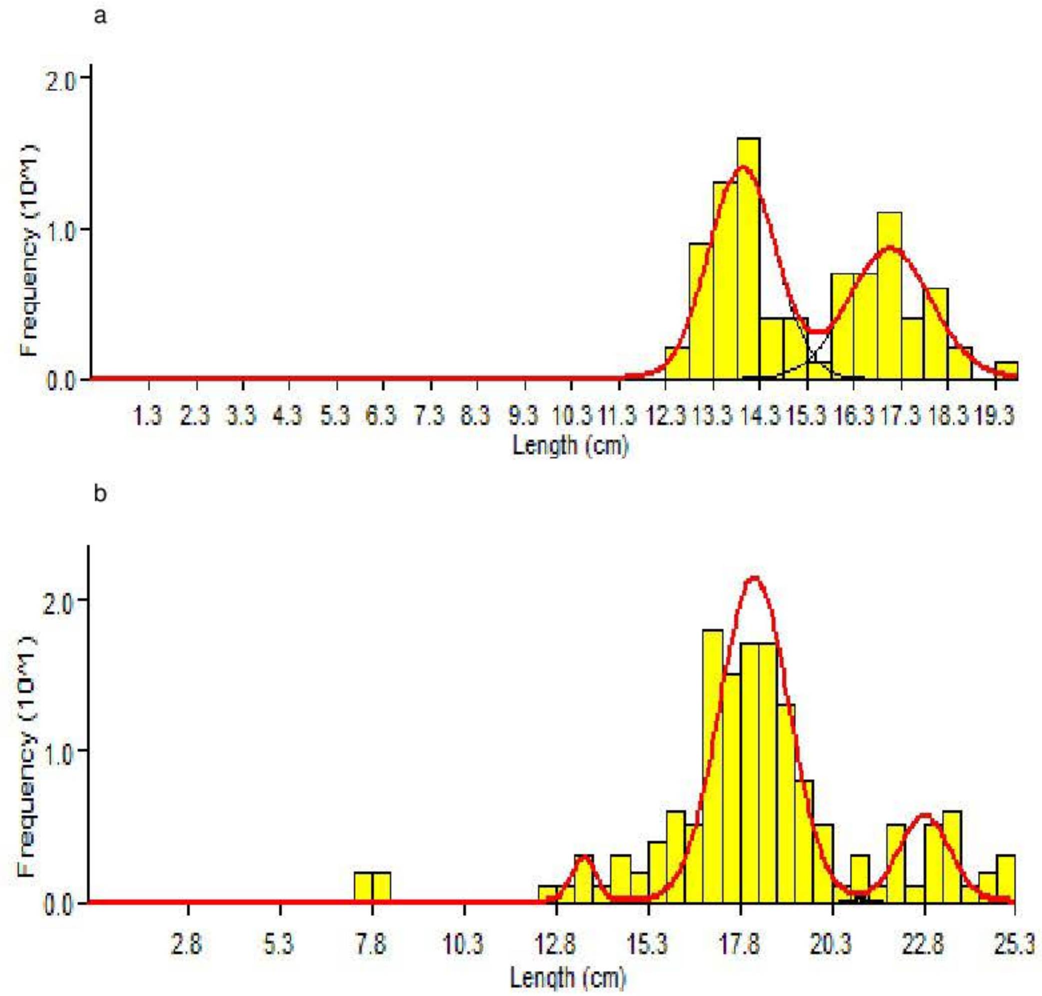


Figure 5.26 - Example of Bhattacharya's method: composition, identification and separation of composite distribution. Males/July (a); Females/January (b)

Table 5.26 - Average lengths corresponding to modal classes obtained for each month by Bhattacharya with standard (sd.) and separation index values (red) for females of *Boops boops* of the Canary Islands

Month			**Modal class(cm)**		
	0	**1**	**2**	**3**	**4**
January	13.5 (0.3)	18.1 (0.9)	22.8 (0.7)		
		7.25	5.63		
February			23.5 (0.5)	25.8 (0.9)	28.7 (0.8)
			3.26	3.28	
March		19.1 (1.2)	23.4 (1.3)		
			3.08		
April		18.7 (0.6)	22.1 (1.3)		
			2.81		
May		19.2 (0.8)	23.7 (1.4)		
			3.41		
June	8.35 (1.12)				
July	10.6 (0.6)	15.8 (0.8)			
		5.4			
August		15.3 (1.1)			
September		17.8 (1.2)	20.2 (0.9)		
			2.82		
October		18.4 (0.8)	23.8 (0.9)	25.0 (0.6)	
			3.45	2.98	
November		16.2 (0.6)			
December		16.3 (1.2)			

Table 5.27 - Average lengths corresponding to modal classes obtained for each month by Bhattacharya with standard (sd.) and separation index values (red) for males of *Boops boops* of the Canary Islands

Month	**MODAL CLASS (cm)**					
	0	**1**	**2**	**3**	**4**	**5**
January	15.1 (0.9)	17.9 (0.8) 3.37	22.0 (0.6) 5.43			
February					27.2 (0.6)	29.7 (1.2) 4.5
March		18.8 (1.1)	22.1 (0.5) 4.3			
April			21.6 (1.0)	24.8 (0.5) 4.23	26.8 (0.8) 3.2	
May			22.9 (1.0)	25.0 (0.9) 4.3		
June	7.6 (1.2)					
July	13.9 (0.7)	17.1 (0.8) 3.95				
August		16.2 (1.2)				
September	15.2 (1.1)	18.7 (0.4) 2.4				
October			21.4 (1.1)	23.9 (1.3) 3.25		
November	12.3 (0.8)					
December		17.1 (1.2)	20.3 (0.9) 3.2			

This method allowed to discriminate modal classes in every month. Maximum number of modal classes were 4 on April for combined sexes, 3 on February and October for females and 3 on January and March for males; however, in the majority of months only two modes were identified and just one only in four months (June, August, November and December). Age group 0 were discriminated mainly from the month of June corresponding to recruitment.

Recognition of the cohorts was not problematic. In fact, in all cases, separation index was greater than critical value (2.0). Using average lengths obtained for each cohort and assigned age to each of them, growth parameters (L_∞, k and t_0) were estimated (Table 5.28).

Table. 5.28 - Growths parameters of *Boops boops* of the Canary Islands estimated by Bhattacharya. L_∞= asymptotic length; k= growth coefficient; t_0= hypothetical age at zero length

Sex	**L_∞ (cm)**	**k (years^{-1})**	**t_0 (years)**
Females	32.8	0.38	-1.0
Males	35.1	0.35	-1.7

Results were tested by Chen's test which identified significance difference between sexes (Table 5.29).

Table 5.29 - Chen's test result for Bhattacharya for individual and pooled data. RSS: Residual Sum of Squared; DF: Degree of Freedom DF; Estimate F: F value; df of F: Degree of Freedom of F; P(F<x)0.01: p-value; Critical F: F value (α=0.05)

Test	**Individual**	**Pooled**
RSS	80.51	9.2E+01
DF	39.00	40.00
Estimate *F*	5.75	1.77
df of F	3.00	36.99
P(F<x) 0.01	2.5E-03	
Critical F	2.87	

A second indirect method of age estimating is represented by ELEFAN I (Figs. 5.27-5.28). Table 5.30 shows growth parameters estimated.

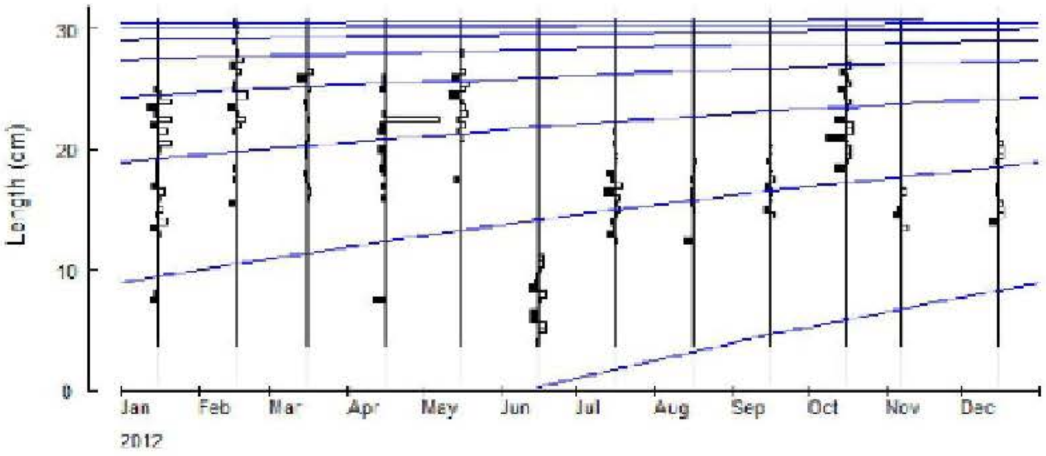


Figure 5.27 - Growth curve for females of *Boops boops* of the Canary Islands adjusted by ELEFAN I method

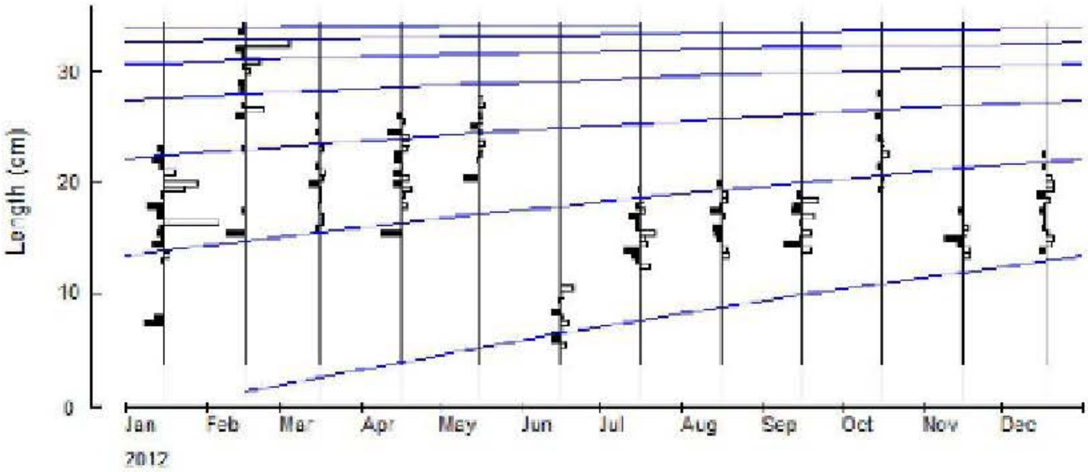


Figure 5.28 - Growth curve for males of *Boops boops* of the Canary Islands adjusted by ELEFAN I method

Table. 5.30 - Growth parameters of *Boops boops* of the Canary Islands estimated by ELEFAN I. L_∞= asymptotic length; k= growth coefficient; t_0= hypothetical age at zero length

SEX	**L_∞ (cm)**	**k (years $^{-1}$)**	**t_0 (years)**
Females	31.10	0.36	-0.30
Males	35.60	0.34	-0.30

5.7.6. Indirect validation

Direct readings, represented by translucent rings identified and measured, were indirectly validated by comparison of the mean lengths at age estimated by back-calculation with those estimated using modal progression analysis calculated in the period from June to December, when translucent ring is laid down; only sampled classes in that period was evaluated for the analysis.

The results obtained were tested by t-test; differences between means were not observed in both sexes (Tables 5.31-5.32).

Table. 5.31 - Mean length at age estimated by back-calculation (BCF) and by modal progression analysis (LFD) and t-test results for females of *Boops boops* of the Canary Islands

	Females			
	Method		**t - test**	
Age	**BCF**	**LFD**	***t*-value**	***p*-value**
1	15.6	16.7	1.894	0.090
2	19.8	22.2	1.448	0.243

Table. 5.32 - Mean length at age estimated by back-calculation (BCF) and by modal progression analysis (LFD) and *t*-test results for males of *Boops boops* of the Canary Islands

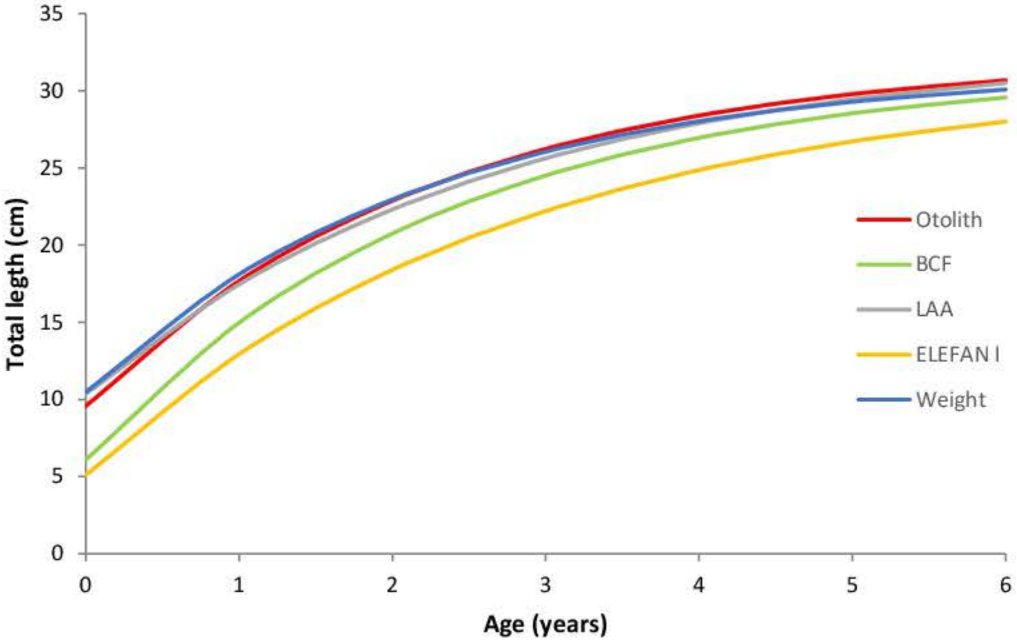
	Males			
	Method		***t* - test**	
Age	**BCF**	**LFD**	***t*-value**	***p*-value**
1	16.5	17.2	1.121	0.299
2	21.1	20.9	0.338	0.752

5.7.7. Growth parameters

All results relating to the growth parameter obtained by different methods are summarized in Table 5.33 and curves obtained are shown in Fig. 5.29.

Table. 5.33 - Growth parameters of *Boops boops*,with *phi prime* (Φ') values, estimating by different methods L_∞= asymptotic length; k= growth coefficient; t_0= hypothetical age at zero length

Methodology	Sex	L_∞ (cm)	k (years^{-1})	t_0 (years)	Φ'
Otoliths	F	32.3	0.44	-0.8	2.66
	M	35.3	0.38	-0.8	2.68
Weight	F	31.5	0.45	-0.8	2.65
	M	35.5	0.40	-0.9	2.70
Back-calculation	F	30.0	0.43	-0.5	2.59
	M	34.0	0.40	-0.5	2.67
Length-at-age	F	32.8	0.38	-1.0	2.61
	M	35.1	0.35	-1.0	2.63
ELEFAN I	F	31.1	0.36	-0.3	2.54
	M	35.6	0.34	-0.3	2.63



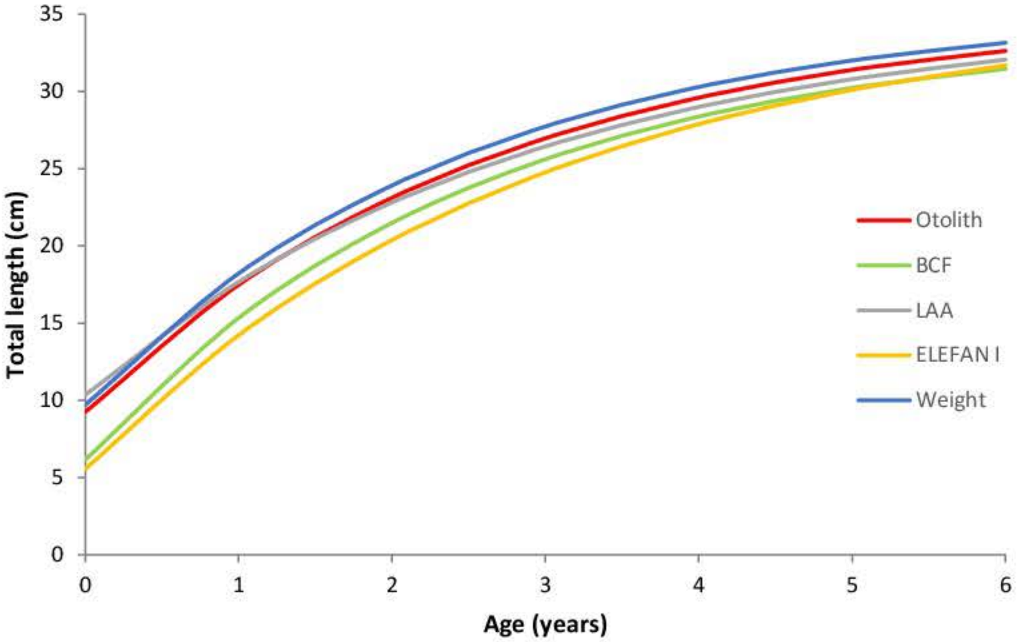


Figure.5.29 - von Bertalanffy growth functions of *Boops boops* of the Canary Islands estimated starting from the growth parameters obtained by the different methods (upper females, bottom males)

Curves obtained by direct reading, weight, back-calculation and Bhattacharya were compared by Chen's test to evaluate different in growth curve for separated sex: any significant difference were observed (Table 5.34).

Parameters obtained by ELEFAN I were not considered in this analysis because Chen's test requires pairs of age-length data.

Table 5.34 - Chen's test result for growth curves estimated by different methods for separated sexes (a female; b males) of *Boops boops* of the Canary Islands. RSS, Residual Sum of Squared; DF, Degree of Freedom DF; Estimate F, F value; df of F, Degree of Freedom of F; P(F<x) 0.01, p-value; Critical F, F value (**α=0.05**)

a	**Test**	**Individual**	**Pooled**
	RSS	13478.856	1.3E+04
	DF	1421.00	1450.00
	Estimate *F*	0.11	0.36
	df of F	9.00	1440,00
	P(F<x) 0.01	1.0E+00	
	Critical F	1.89	

b	**Test**	**Individual**	**Pooled**
	RSS	12480.64	1.3E+04
	DF	1434.00	1462,00
	Estimate *F*	1.47	4.62
	df of F	9.00	1452.00
	P(F<x) 0.01	1.5E-01	
	Critical F	1.89	

6. DISCUSSION

This work has provided important knowledge about some biological aspects of bogue, *Boops boops*, in Gran Canaria. The main objective was to estimate the growth parameters through direct and indirect methods.

The demographic structure obtained for the bogue characterized the population as consisting mainly of medium-sized individuals as reported by Khemiri *et al.* (2005) for Tunisian coasts and Lamrini (1998) for Strait of Gibraltar. Similar results were demonstrated by Serrano-Gordo (1995) in Portugal waters and El-Agamy *et al.* (2004) in Egypt coast. In Gran Canaria the structure sizes of *B. boops* is mostly represented by medium-sized individuals ranging from 15 - 19 cm TL. Analyzing the monthly size distributions, it is noted that the bogue has a space-time distribution as well described by Zúñiga (1967) for eastern Spanish water. Very similar distribution was described by many authors (Castro, 1991; Lorenzo, 1992) for mackerel (*Scomber colias*) in Gran Canaria and horse mackerel (*Trachurus picturatus*) in Tenerife (Jurado, personal note). Studying frequency distributions joined with sampling area, can be recognize a segregation between adults and juveniles. Juvenile phase, which extends until individuals reach a size close to 6-9 cm in length, correspond to coastal life (15 - 20 m). These individuals represent the recruits born in the months before, and they remain in coastal areas for few time. In this area individuals lives in schools along with other species such as *Sardina pilchardus*, *Scomber colias*, *Trachurus spp*. (Pastor and Delgado de Molina, 1985; Castro, 1991) where are captured by fishermen and sell as bait. Subsequently, individuals reaching a size close to 13-14 cm TL, begin to be caught in another area located on the island-shelf (50-90 m depth) which are caught by fishermen with purse seine when mackerel and sardines are target fish. Individuals of this size begin to be caught in this zone from July until November. Adult individuals remain throughout the year on the continental shelf, as shown by the demographic composition of the catches; this means that during the breeding season does not perform any migration as described for other species in the area (Castro, 1991; Lorenzo, 1992).

It should be taken into account that a sampling distortion occurred because samples comes from commercial landed and not from survey.

These results were corroborated also by the results of the survey carried out to determine larval fish assemblage off Gran Canaria (Moyano and Hernández-León, 2009; Moyano *et al*., 2009, 2014) in terms of the larval fish community, *B. boops* was the key species during winter assemblage characterizing sampling from December to June, in agreement with the adults spawning period in the area (Franquet and Brito, 1995).

In part, sampling strategy has to be taken in account to explain the simultaneous absence of two life phases in the distribution. In fact, of the different habitats that bogue occupies throughout its life, just the main fishing area was regularly sampled, since commercial catches were the only way for obtaining samples.

Length-weight relationship play an important role in the study of biology of a species because it allows the conversion of growth-in-length equations to growth-in-weight, for use in stock assessment models and allows the estimation of biomass from length observations; furthermore, it allows an estimate of fish condition and is useful for comparisons between region of a certain species (Wootton, 1990; Pauly, 1993; Petrakis and Stergiou, 1995; Goncalves *et al*., 1996; Binohlan and Pauly, 1998).

With respect to length-weight relationship for bogue in Gran Canaria, results showed a positive allometric growth for whole population and for females and males, with a accretion by weight proportionally greater than length. Adbedeloumab (2000) in Gran Canaria reported same results. Contrariwise results were in contrast to that obtained by Caldentey (1987) in Tenerife for which declared a positive allometric growth for juveniles and a negative allometric growth for adults. However, the results obtained in this work were very similar to those estimated by other authors in other areas (Allam, 2003; Valle *et al*., 2003; Mendes *et al*., 2004; Monteiro *et al*., 2006; Carbonara *et al*., 2012; Cau *et al*., 2013; de Ranieri, 2013; Spedicato *et al*.,2014).

Length-weight parameters depends on several factors such as the composition in size of catches and sampling period, but certainly influence of environmental characteristics can be not ignored. In this regard, it should be noted that the oceanographic dynamics of the Canary Islands is linked to the North African continent (Molina and Laatzen, 1986, 1989; Fernández de Puelles, 1987; Barton *et al*., 1998; Barton and Arístegui, 2004; Pelegrí *et al*., 2005a, b; Hernández-León *et al*., 2007; Wilke *et al*., 2009) and, therefore, this must be reflected in these relationships. This could explain differences between far areas; clearly oceanographic differences that characterize Tenerife and Gran Canaria islands are not so great as to be able to determine such substantial differences. In this way, conflicting results may be attributable to differences in sampling without precluding possible genetic differences between stocks.

Regarding analysis of sex-ratio values, expressed as femininity rate, was not significantly deviated from ratio 1:1. In summary, it was evident how males were more concentrated in the larger size classes on the contrary of females which were concentrated more frequently in smaller size classes in according with results reported in the literature by other authors in different areas (Alegría-Hernández, 1990; Lamrini, 1998; El-Agamy *et al.*, 2004; Layachi *et al.*, 2015). Studies carried out by Girardin and Quignard (1986) and Monteiro *et al.* (2006), found a predominance of females in the larger size classes as well for Adbedeloumab (2000) in Gran Canaria. In the southern Tyrrhenian Sea Bottari *et al.* (2014) described an equal sex distributions among size classes. The percentage of intersexual individuals was very low (1.4 %) conforming to Bottari *et al.* (2014). In comparison to the 23% value reported by Lamrini (1998), results were in accordance with Zoubi (2001) and Monteiro *et al.* (2006), who reported percentages of 5.1 and 5 %, respectively. Intersexual specimens, ranging between 14 to 21 cm total length, were found mainly in November in full agreement with Adbedeloumab (2000) who reported rare hermaphrodite individuals (2%) ranging between 17 and 22 cm total length. Lamrini (1998), on studied carried out in Gibraltar strait, determined inversion length at 16 cm total length. Monteiro *et al.* (2006) found intersexual individuals distributed over the size range 16-24 cm total length in January, July and August. In light of the considerations shown up to this point, the predominance of females at smaller sizes, the high number of males at largest sizes and presence of individuals with well-formed testes and residues of degenerated ovaries, indicate that this species is a hermaphrodite, characterized by a diandric population with a partial proteroginic sexual inversion. These results are supported for the conclusion of D'Ancona (1949), Girardin (1981) and Serrano-Gordo (1995), who considered this species, with an old terminology, as a rudimentary hermaphrodite or late gonochorism (actually considered as non-funtional hermaphroditism), and in particular with the conclusion of Reinboth (1962) who described *B. boops* as a protogynous species with diandric population.

By definition, protogynous hermaphrodites function first as females after which they change sex and function as males, being all males (secondary males) necessarily derived from females. This may be demonstrated by a separation in the size of the sexes, histological evidence of testicular development after a functional female phase through histological analysis (Sadovy and Shapiro, 1987).

The presence of males already from smaller sizes is characteristic that distinguishes a diandric species (Monteiro *et al*., 2006), where males are not exclusively derived from females (Serrano-Gordo, 1995). Diandric species undergo two male developmental pathways; some males differentiate directly from juveniles through sexual differentiation (primary male), while others (secondary male) derived from functional females through sex change.

In non-functional hermaphrodites, young fishes possess an immature intersexual gonad but mature as either male or female fish with no evidence of sex reversal. According to Buxton (1990) and Sadovy and Shapiro (1987), analyzing demographic structure of population can be useful to recognized reproductive styles. In protogynous species the females are smaller than the males and all sex reversing individuals have an intermediate size between two sexes; in non-functional hermaphrodites, males and females have a similar size range and intersexual states are all small and non-functional. Due to large proportion of primary males occupying all size rangers (Sadovy and Shapiro, 1987), size-frequency distribution not showed a clear bimodal distinction between males and females; however, intersexual individuals had intermediate size between sexes.

Gonadosomatic index is another distinctive character (Buxton, 1990). In protogynous species it is much greater in the females than in the males, while in rudimentary hermaphrodites, ovary and testis size is more equitable (Buxton, 1990).

Based on all previous observations it is possible consider bogue as a protogynous hermaphrodite, in a diandric population where only a low number of individuals have a direct development toward males (primary males) from bisexual initial phase (Lissia-Frau, 1966a, 1968, 1977). In contrast, some authors who considered the bogue as a gonocoric species (Campillo, 1992; Lamrini, 1998; Zoubi, 2001; Monteiro *et al*., 2006; Bottari *et al*., 2014) where protogynous hermaphroditism concerns only a small percentage of specimens. The results of this study are according with the first case.

Monthly percentage of maturity stage and gonadosomatic variations were useful descriptors of the reproductive cycle of bogue in Gran Canaria. Males and females presented a similar pattern, from late-winter to early-spring spawner, already reported for Atlantic population (Serrano-Gordo, 1995; Monteiro *et al*., 2006) and for Gulf of

Lyon (Girardin, 1981). This species may be considered an intermediate spawner (Tsikliras *et al.*, 2010) with slight differences in the spawning season in different areas. In Canary Islands, bogue showed an extending period from January to May with a peak in February. IGS and mature individuals percentages increased from January and reached its peak in February, another slight increase was recorded in May, then IGS decreases throughout the year. Results were in accordance with other studies carried out in the same area. Adbedeloumab (2000) and Ojeda (1983) observed individuals in mature stage between December and February, whereas Caldentey (1987) determined that breeding occurs from December to July, with a spawning peak between the April and July; González *et al.* (1990) located spawning period between December and July, observing peak during March-April. Breeding season coincides approximately with previous observations for the same species in the Western Mediterranan. In this sense, Zúñiga (1967) for Mediterranean Spanish coast, and Ávila Parga (1970), indicated that the spawning season occurs in April-May. Lloris *et al.* (1977) also indicated April-May as a spawning period in the eastern Atlantic. Bauchot *et al.* (1981) in the Central Eastern Atlantic, indicated breeding season between March and May; while Whithead *et al.* (1986) asserted that reproduction occurs during the summer in the Black Sea.GSI values were in accordance with those reported for bogue in Atlantic waters (Serrano-Gordo, 1995). In southern Tyrrhenian Sea (Bottari *et al.*, 2014) and in east-central Aegean Sea (Soykan *et al.*, 2015) GSI values were lower than those reported in southern Portugal by Monteiro *et al.* (2006) and in the Southern Adriatic Sea by Kasalica *et al.* (2011). This different seem to suggest that bogue invests different energy in gonadal development due factors such as environment condition, predation, competition and food availability (Kashiwagi *et al.*, 1987; Sheaves, 2006). In this study, spawning took place when the water temperature was low (from 18.8 to 20°C). Mean monthly GSI values were significantly correlated with SST, suggesting that this factor may be important for sexual maturity. Studies focused exclusively on the biological response of different species to different temperatures, demonstrating reproductive parameters, as spawning season and GSI, exhibited significant variations depending on water temperature (Mann *et al.*, 1984; Encina and Granado-Lorencia, 1997; Nicolas, 1999; Coward and Bromage, 2000; Pusey *et al.*, 2001). The opposite of what one would expect, in the Canary archipelago the reproduction occurs when the sea temperature reaches the minimum values; this could be explained by the high food availability in the archipelago due to "late winter bloom". Compared to other species of

Sparidae in Canary Islands, *Diplodus puntazzo* (Walbaum, 1792) (Pajuelo *et al.*, 2008), *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) (Pajuelo *et al.*, 2006a), *Pagrus auriga* (Valenciennes 1843) (Pajuelo *et al.*, 2006b), *Sarpa sarpa* (Linnaeus, 1758) (Méndez-Villamil *et al.*, 2001), *Pagrus pagrus* (Linnaeus, 1758) (Pajuelo and Lorenzo, 1996), *Pagellus erythrinus* (Linnaeus, 1758) (Pajuelo and Lorenzo, 1998) and *Lithognathus mormyrus* (Linnaeus, 1758) (Lorenzo *et al.*, 2002), spawning period resulted relatively extend.

The estimate of the length at first maturity showed that males reach sexual maturity at larger sizes (L_{50}=18.6 cm total length) than females (L_{50}=17.8 cm total length). The difference observed in sexual maturity between sexes may be explained adequately by protogynic behavior and by different growth patterns as reported by Girardin (1978), Livadas (1989), Alegría-Hernández (1990) and Serrano-Gordo (1995). Estimated values were higher than those estimated in other areas. Lamrini (1998), reported 15.4 cm total length (both sexes) in Gibraltar strait, Khemiri *et al.* (2005), between 14 cm and 16 cm total length (both sexes) in Tunisian water, El-Agamy *et al.* (2004), 12 cm for males and 13 cm total length for females, Serrano-Gordo (1995) 15 cm for females and 14 cm total length for males in Portuguese coasts; Gaamour *et al.* (2004) 13 cm total length (both sexes) in Tunisian Mediterranean waters). In Canary Islands, Caldentey (1987) reported a length at sexual maturity of 15.1 cm total length for combined sexes, while Lozano (1990) observed 13.2 cm total length for combined sexes. These discrepancies may be the result of multiple factors, as technical errors relating to the method estimation or related to ecological and environmental characteristics, such as temperature, salinity and food availability (Champagnat, 1983; Jabeur *et al.*, 2000; Mahe *et al.*, 2005; Basilone *et al.*, 2006). These factors affect metabolic reactions and consequently growth and reproduction. The macroscopic assignment of maturation stages leads to the subjective errors; in this sense, some authors (Saborido-Rey and Junkeira, 1998; Domínguez-Petit, 2007; Relini *et al.*, 2008) highlighted a possible bias between developing-virgin stage (2a) and recovering stages (2b), as well as between the immature (1) and resting stages (4b), because of their similar macroscopic appearance. In both sexes, developing-virgin and recovering stages can be distinguished solely based on gonads proportion into abdominal cavity. Presence of visible blood vessels on the surface of the ovary can be an indicator, but these differences fade in smaller specimens. Although histological studies (Bottari *et al.*, 2014) confirmed such similarity in males, merging the two stages is not advisable because it would not allow discrimination between the mature and immature proportion of the stock. Histologically, there is a clear distinction between phase 2a and 2b ovaries, even in smaller specimens this was not the case in ovaries of the immature (1) and virgin development stages (2a), which are very similar both at the macroscopic and microscopic level. In this case, merging the two stages, may be advisable (Bottari *et al.*, 2014). Another clear distinction is appreciable histologically between immature and resting testes, but also by macroscopically observing size and thickness differences (Bottari *et al.*, 2014).

Fishing pressure also has showed influence on the sexual maturity in the different areas (Trippel, 1995; Murawski *et al.*, 2001). In this regard, according with Enberg *et al.* (2012), a possible evolutionary response from fishes to the fishing pressure would be to anticipate sexual maturity, reducing size of first maturity in order to ensure the survival of species (Beacham, 1983a, b, c; Morgan *et al.*, 1993; O'Brien *et al.*, 1993). On the other side the anticipation of maturity size would lead to a reduction in fertility (Trippel, 1995; Modugno, 2009).

The evaluation of age determination in the bogue had previously been carried out by several authors. Girardin (1981) and Girardin and Quignard (1986) used scales, while Serrano-Gordo (1996) stated that for the Portuguese coast otoliths gave better results. Abecasis *et al.* (2008) in southern Portugal carried out a comparative study between scales and otoliths concluding that otoliths seem to be more appropriate for ageing bogue, while Girardin (1978, 1981) reported ages determined by reading whole otoliths that were similar to those based on scales. Khemiri *et al.* (2005) in Tunisian water used sliced otolith. Whole otoliths were used by Cannizzaro *et al.* (2001) in South of Sicily, by Manasirli *et al.* (2006) in North Levant, in Northern Adriatic Sea by Alegría-Hernández (1986) and by Massaro *et al.* (2014) in Ligurian and North Thyrrenian Sea. In the Canary Islands Caldentey (1987) conducted the only study about growth of bogue using otoliths.

As shown in Fig. 6.0, growth parameters in the literature (Table 6.0) are very heterogeneous. It was evident that these differences were due to high variability both L_∞ and k (Fig. 6.2).

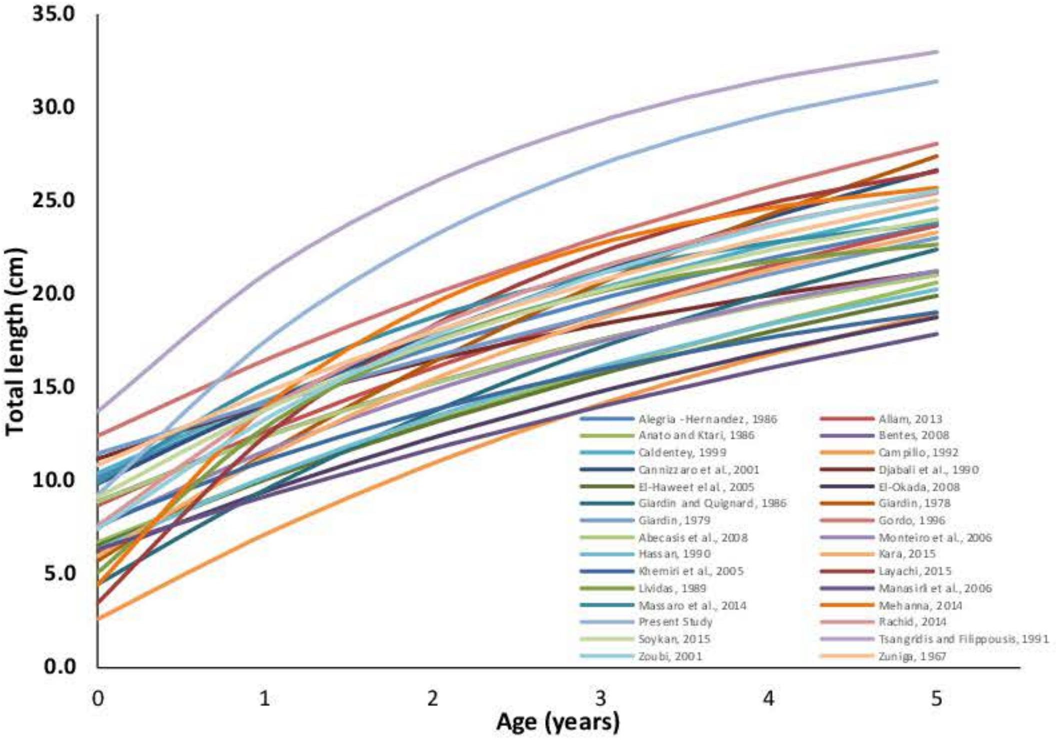


Figure 6.0 - von Bertalanffy growth curve of *Boops boops* estimated starting from growth parameters L_∞, k and t_0 provided by different authors reported in Table 6.0

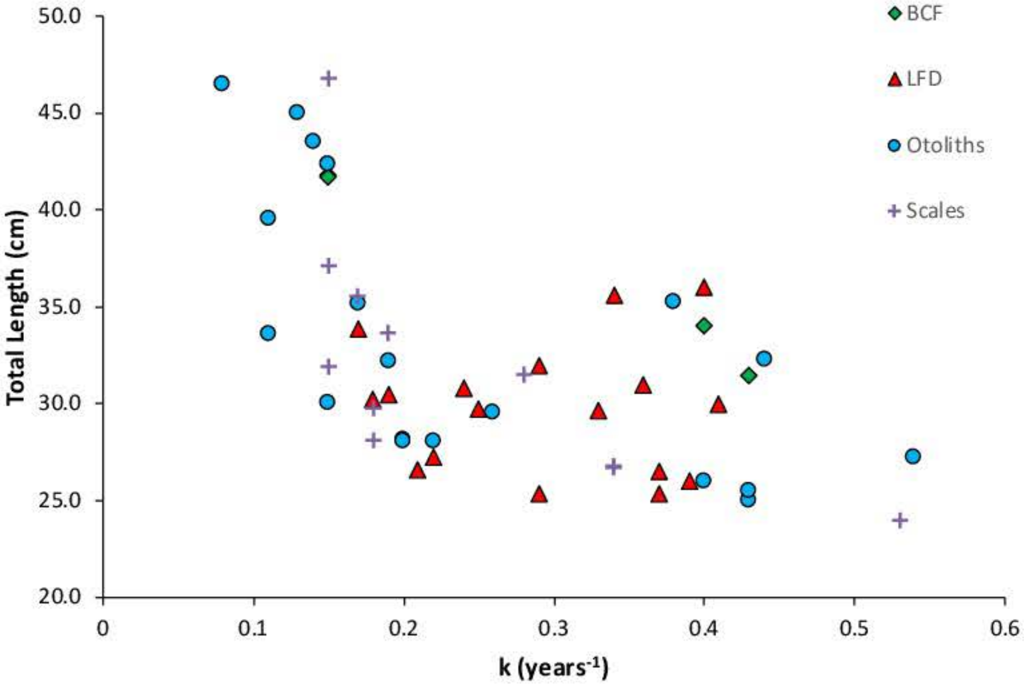


Figure 6.1 - L_∞ vs k scatter plot for *Boops boops*. L_∞ and k provided by different authors reported in Table 5.0

L_∞ varies between 24 cm and 46.8 cm total length, while k ranging between 0.08 and 0,54 years^{-1}. Results obtained in this work were not entirely congruent with the values estimated by other authors in different areas. This difference in growth parameters could be due to used method, difference in fish maximum size in the used samples, or due to the difference in environments factors as ecological parameters, trophic resources, salinity and temperature. It cannot affirm that the differences were attributable solely at the methodology. In fact, k values obtained by same method, for example length-frequency distributions, showed heterogeneous values (0.17-0.41 years^{-1}). Since bogue is characterized by longer spawning period, individuals with similar lengths, born in the same year, can be found throughout the year, making it difficult to correct discrimination of the individual modal components, with the consequence of k over-underestimation. As regards the different values of k obtained by direct otoliths reading, these differences were attributable to different interpretation and recognition of the annual growth rings.

Reading and interpretation of bogue otoliths was particularly difficult. Age estimation was problematic as seen elsewhere by Girardin (1978, 1981), Alegría-Hernández (1989), Serrano-Gordo (1995), and Abecasis *et al*. (2008). The otolith marks were frequently unclear and diffuse and this was particularly evident in older fish. This is probably due to thickening of the otolith edge and the nearness of the growth marks. Furthermore, age determination was successful for otoliths (91.6% for females and 90.0% for males). One of the main difficulties in ageing of bogue was represented by the correct identification of the first annual ring, due to presence of false rings before the deposition of the 1st *annulus*. As explained earlier, fish ageing have to interpret as annual rings those are marked generally at a certain time of year, because many species have their first spawn after the first year of life and migratory rings usually have a higher periodicity through year. As reported by Zúñiga (1967) in his studies on scales, bogue shows two migration rings before first annual ring. These two types of rings shows difficulties in their reading being the most of the times very tenuous, making it very difficult to appreciate immediately. On otoliths this rings appeared subtle and not always well marked, much more notorious in the individuals of a year or less than those of greater age. Since these rings were laid down before the first ring, they were no considered as annual rings. Moreover, these rings cannot be laid down due to spawning phenomena since the first reproductive event occurs after the first year. These rings were seen as a migratory character rings, since they coincide with the migrations made by bogue in its first months of life (Zúñiga, 1967). The first check, called *demersal ring*, appears when recruits on the bottom occurs (Morales-Nin, 1986; Morales-Nin *et al.*, 1998a, b). This ring is present in all those demersal species that have a pelagic larval stage. Second ring was not appear in all samples and often appear as a transparent zone because it was jointed with the first true ring. This check is laid down when specimens move away from the coast. This hypothesis seems plausible, as corroborated by the analysis of catches. As mentioned earlier, larvae are pelagic and during the first state post-larvae were caught in shallow waters near the coast, which indicates a change of habitat and feeding, aspect that influences the growth rate; later larger individuals reach the deepest funds, change that would be represented by the second pre-winter ring. Results of the biometric analysis showed that mean distance of second check was significantly different from the distance of the first annual ring (*t*-value=54.22, $p=2.2\times10^{-6}$) (Fig. 6.3).

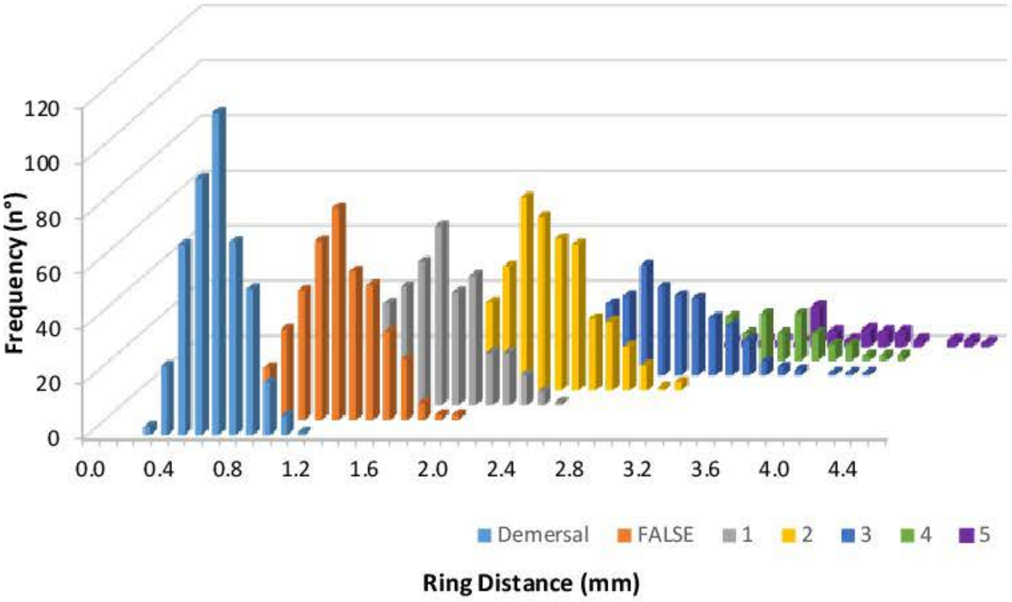


Figure 6.3 - Frequency distributions of the distances from the center of each annual ring identified

The frequency distribution of *annuli radii* was in agreement with the seasonal regularity of the growth pattern presented and mean of each *annulus* was well separated and statistically different from successive rings. Back calculating demersal ring and false ring were 5.6 cm and 9.4 cm total length for females, and 5.5 and 9.5 cm total length for males. These values were in full agreement with Zúñiga (1967) who identified, with scales at 7.3 cm and 9.3 cm total length, the length at which two false rings are deposited. Slight differences in length to which demersal ring is laid down, can be explained by differences in growth due to different geographic area. This would explain the different values of k depending on the false rings considered. Identification of two checks define higher values of k, while if only demersal ring is considered as false ring, values of k result lower These different values, when used in analytical models for stock assessment, can lead to very different conclusion. For example, incorrect estimates of k, would lead to erroneous estimates of natural mortality (Beverton and Holt, 1956) with consequences on management measures. Therefore it is clear the great importance of being able to provide correct estimates of growth and age parameters. This difficulty can be overcome through age validation methods This aspect was a strength of this work, since in the literature there are few works on growth by reading hard structures supported by validation methods (Campana, 2001), in particular for bogue few studies relating age validation has been carried out in Mediterranean, completely absent in Canary Islands.

A linear correlation between somatic size and biometrics otolith was detected, making possible to estimate growth parameters also by means of the results in length at age provided by the Back-calculation using the formulas proposed by Freser-Lee. Comparison of growth curves, showed significant differences in growth between sexes. For this reason, it was chosen to perform the analysis only on separate sexes. FSA package allowed to determine which parameter between L_∞, k and t_0, was more involved in these differences; results revealed that L_∞ was the parameter that most influenced the growth. Males in fact reach faster, larger sizes than females.

The semi-direct validation methods, as Edge analysis and Marginal Increment analysis (MIA), allowed to validate annual periodicity of rings deposition and a seasonality in such deposition. The results identify a period from February to May where opaque ring was laid down and one from June to January where transparent ring deposition occur. These results showed a completely opposite pattern compared to that reported in other areas. Abecasis *et al.* (2008) described opaque ring deposition from May to October in South Portugal, Khemiri *et al.* (2005) reported from May to October in Tunisian coast and Monteiro *et al.* (2006), from April to September in Portugal coasts. This growth pattern is characteristic of the small pelagic fish inhabiting these waters (Jurado, personal note; Lorenzo, 1992). This oceanic area, unaffected by the African upwelling and the eddy influence, is characterized by a strong stratification of the water column during most of the year that precludes the input of new nutrients into the photic layer (Franchy Gil, 2014). Because winter convection, in January-March the seasonal thermocline is eroded allowing at the nutrient to surface until the photic layer, generating the so-called “late winter bloom”. During the winter bloom, maximum values of chlorophyll *a* concentration and primary production are reached in surface waters, coinciding with the maximum mixed layer depth and nutrient availability (Franchy Gil, 2014). During this productive period, the enhanced phytoplankton growth is followed by an increase of mesozooplankton biomass (Franchy Gil, 2014). Thus, maximum food availability occurs for fish off the Canary Islands, resulting in the period of faster growth, and opaque ring deposition (Lorenzo, 1992). Bento-pelagic behavior of bogue allows it to take advantage of this food availability, explaining the concurrence of the reproductive period with the maximum growth period.

Simulations carried out with ELEFAN I can give clear and correct results just in situations where peaks are well separated (Rosenberg and Beddington, 1987). In this way, ELEFAN method presents two problems. First, it seems susceptible to the appearance of discrete modes in data; secondly, being an ad hoc method, it needs a statistical structure explicit of error, so it does not provide estimate standard errors and neither a guideline to performances in different situations. ELEFAN I seem to be the most suitable method for small fish species, as bogue, with a faster growing and a shorter life-span. However, parameter k is always underestimated, while L_∞ is always overestimated. The trend of ELEFAN I method to underestimate k can be partially due to the fact that the modes identification is rather complicated when cohorts are overlapped, particularly in older groups. Furthermore, the presence in data of individuals longer than L_∞ causes a L_∞ overestimate and a k underestimate, as both parameters are strongly correlated (Isaac, 1990). Factors such as seasonal changes in growth rate, variable recruitment period, size-dependent selection, or data grouped in greater length class intervals did not essentially change the tendency of the bias of L_∞ and k (Isaac, 1990). The combination of factors as growth variability and effect produced by size-depending selection reduces the accuracy of growth parameters estimates (particularly k) (Peacor *et al.*, 2007). L_∞ estimate is not strongly influenced by these factors. Size-dependent selection effects and recruitment processes eliminate slow-growing fishes (i.e., the smallest ones) from the first cohort in the samples (Isaac, 1990). Therefore, the difference between the modal lengths of the first and second cohorts is smaller in the samples than the true size difference in the natural population (Isaac, 1990). This leads to the computation of a smaller annual growth rate and therefore an underestimation of k (Isaac, 1990).

Indirect validation methods were used in order to validate the age assigned for direct way, starting from the length frequency distributions. Since the direct interpretation involves recognition and counting of transparent rings laid down in the second part of year, validation focused on the comparison between the mean lengths at age estimated by Back-calculation with those estimated by modal analysis of individuals sampled from July to December. Results obtained were statistically tested and they showed no significant differences between mean lengths for each modal age with corresponding length at the age of direct readings (Back-calculation). These estimates obtained from two independent methods confirmed the correct identification of transparent rings as annual rings.

All growth curves obtained by direct methods, back calculation and indirect methods, were tested for identifying possible differences. In all cases, significant differences were detected between sexes, showing a faster growth of males compared to females. Results obtained separately by different methods to separate sexes were also tested. In this case, no differences were detected.

As previously mentioned, results were not entirely congruent with the values estimated by other authors in different areas (Table 6.0). These differences are certainly attributable to used methodology and interpretation method, environmental factors, genetic factors, Oceanographic characteristics, environmental conditions of this area and geographical distance related to other studied areas, played a fundamental role in the difference of the results obtained in this work.

To compare growth parameters obtained in this study, growth performance index Φ' (Pauly, 1979; Munro and Pauly, 1983) was estimated and compared with those provided by the literature (Table 6.0). Results were comparable with those obtained in other areas.

Table 6.0 - von Bertalanffy growth parameters (L∞, k and t0) and growth performance index of *Boops boops* estimated by different authors and in this work

Author	Area	Method	Sex	L_∞	k	t_0	Φ'
Alegría-Hernández, 1986	Norther Adriatic Sea	Otolith	C	32.22	0.19	-2.00	2.30
		LFD	C	33.9	0.17	-1.30	2.29
Allam, 2013	South Levant	Scales	C	37.1	0.15	-1.78	2.31
Anato and Ktari, 1986	Tunisia	Otolith	C	39.6	0.11	-1.69	2.24
Abecasis *et al.*, 2008	Portugal	Otolith	C	28.14	0.2	-1.90	2.20
Abecasis *et al.*, 2008	Portugal	Scales	C	26.76	0.34	-1.27	2.39
Caldentey, 1987	Canary Islands	Otolith	C	35.2	0.17	-2.06	2.32
Campillo, 1992	France	LFD	C	30.2	0.18		2.22
Cannizzaro *et al.*, 2001	South of Sicily	Otolith	C	45	0.13	-1.90	2.42
Djabali *et al.*, 1990	Algeria	LFD	M	26.6	0.21	-2.60	2.17
			F	27.3	0.22	-1.94	2.21
Djabali *et al.*, 1993	Algeria	LFD	C	25.4	0.29		2.27
El-Haweet *el al.*, 2005	South Levant	Scales	F	31.9	0.15	-1.53	2.18
			M	28.1	0.18	-1.13	2.15
		LFD	F	30.5	0.19	-0.99	2.25
			M	29.7	0.25	-0.70	2.34
El-Okda, 2008	South Levant	Otolith	C	30.1	0.15	-1.51	2.13
Girardin and Quignard, 1986	Gulf of Lyon	Scales	C	33.7	0.19	-0.75	2.33
Girardin, 1978	Gulf of Lyon	Scales	C	46.8	0.15	-0.87	2.52
Girardin, 1978	Gulf of Lyon	Otolith	C	46.5	0.08	-3.54	2.24
Serrano-Gordo, 1996	South European Atlantic Shelf	Otolith	F	43.5	0.14	-2.40	2.42
			M	42.4	0.15	-2.29	2.43
		BCF	F	41.8	0.15	-2.16	2.42
			M	41.7	0.15	-2.12	2.42
Abecasis *et al.*, 2008		Otolith	C	28.1	0.2	-1.90	2.20
		Scales	C	26.8	0.34	-1.27	2.39
Monteiro *et al.*, 2006		Otolith	C	28.1	0.22	-1.42	2.24
Hassan, 1990	Egypt	Scales	C	29.8	0.18	-1.33	2.20
Kara and Bayhan, 2008	Turkey	LFD	F	30.8	0.24	-0.90	2.36
			M	29.9	0.24	-0.98	2.34
Khemiri *et al.*, 2005	Gulf of Tunis	Otolith Slide	C	24.3	0.23	-1.65	2.13
Khemiri, 2006	Gulf of Hammamet	Otolith Slide	C	26.8	0.22	-1.43	2.20
Layachi et al., 2015	Morocco	LFD	C	30	0.41	-0.30	2.57
Livadas, 1989	Cyprus	Scales	C	24	0.53	0.45	2.48
Manasirli *et al.*, 2006	North Levant	Otolith	C	33.6	0.11	-1.90	2.09
Massaro *et al.*, 2014	Ligurian - North Thyrrenian Sea	LFD	F	25.4	0.37	-1.10	2.38
		LFD	C	26.5	0.37	-1.00	2.41
		LFD	M	26	0.39	-0.90	2.42
		Otolith	C	26	0.4	-1.20	2.43
		Otolith	M	25	0.43	-1.00	2.43
		Otolith	F	25.5	0.43	-1.20	2.45
Mehanna, 2014	Egypt	Otolith	C	27.2	0.54	-0.33	2.60
Mennes, 1985	Sahaara	LFD	C	32	0.29		2.47
Rachid, 2014	Algeria	LFD	C	29.7	0.33		2.46
Soykan *et al.*, 2015	Turkey	Otolith	C	29.58	0.26	-1.42	2.36
Tsangridis and Filippousis, 1991	Greece	LFD	C	36	0.4		2.71
Zoubi, 2001	Alboran Sea	Scales	C	31.5	0.28	-0.96	2.44
Zuniga, 1967	Spain (Castellon)	Scales	C	35.6	0.17	-2.14	2.33
Present Study	Canary Islands (Gran Canaria)	BCF	M	34.0	0.40	-0.50	2.67
		BCF	F	31.5	0.43	-0.50	2.63
		Laa	M	35.1	0.35	-1.00	2.63
		Laa	F	32.8	0.38	-1.00	2.61
		LFD	M	35.6	0.34	-0.50	2.63
		LFD	F	31.0	0.36	-0.50	2.54
		Otolith	M	35.3	0.38	-0.80	2.68
		Otolith	F	32.3	0.44	-0.80	2.66
		Weight	M	35.5	0.40	-0.90	2.70
		Weight	F	31.5	0.45	-0.80	2.65

7. CONCLUSIONS

1. - *Boops boops* showed a segregation between adults and juveniles in their spatial distribution. Juvenile phase (6-9 cm total length), correspond to coastal life. From 13-14 cm total length, juveniles starting to move towards adult area where the individuals remain throughout the year on the continental shelf (50-90 m).

2. - Length-weight relationship for *B. boops* showed a positive allometric growth for females and males, with an accretion by weight proportionally greater than length.

3. - Sex-ratio of *B. boops* as females:males (1:0.852) was significantly deviated from ratio 1:1. Sex-ratio by size classes showed a male's predominance in the larger size classes. Intersexual specimens, ranging between 14 to 21 cm total length.

4. - *B. boops* is a hermaphrodite species, with a partial protogynous in a diandric population.

5. - *B. boops* showed a wide reproductive period, from early-winter to late-spring (from January to May, with a peak in February) with similar pattern for males and females.

6. - Males of *B. boops* reach sexual maturity at larger sizes (L_{50}=18.6 cm) than females (L_{50}=17.8 cm) due to sexual typology and to different growth patterns.

7. - The growth parameters obtained for *B. boops* using different methods do not differ significantly. The growth parameters range for females between 30.0 and 32.8 cm total length for L_∞; from 0.36 to 0.45 year^{-1} for k, and between -0.3 to -1.0 years for t_0, and for males from 34 to 35.6 cm total length for L_∞; from 0.34 to 0.40 year^{-1} for k, and from -0.03 to -1.0 years for t_0.

8. - *B. boops* shows a sexual dimorphism in growth pattern in term of asymptotic length.

9. - In *B. boops* otoliths were identified two false rings. The demersal ring laid down at 5.6 cm total length for females and at 5.5 cm total males for males. The migratory ring was not always visible, laid down at 9.4 cm total length for females, and 9.5 cm total length for males.

10. - Otoliths reading and interpretation for *B. boops* were particularly difficult because of the presence of false rings before the deposition of the 1st *annulus*.

11. - Marginal Increments analysis for *B. boops* otoliths verified that an annual ring or *annulus* deposition is formed for the deposition of one opaque and one translucent band.

12. - Φ' values obtained for *B. boops* and those obtained from literature show discrepancies that can be attributable to the different methodologies used, the correct identification of annual rings and the growth pattern.

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