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Biological characteristics of the round sardinella *Sardinella aurita* Valenciennes, (1847) off the Lebanese coast

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ABSTRACT

The present study investigates aspects of the biology of round sardinella, Sardinella aurita (Valenciennes, 1847) collected from Dora and Tripoli (Lebanon) between September 2012 and September 2013. A total of 1422 specimens were collected from catches of purse seines and gillnets. Data on fish total length (L_T), total weight (W_T), sex and maturity were obtained. The length–weight relationships showed positive allometry. An overall sex ratio was calculated to be F/M=1.4. The L50 were estimated to be 18.26 ± 0.52 cm and 19.20 ± 0.62 cm for males and females, respectively.

Keywords: round sardinella; Levantine basin, life history, Mediterranean

INTRODUCTION

Small pelagic fishes represent about 20-25 % of the total annual world fisheries catch (ICES 2012). Clupeidae are key species in the marine food chain and their presence is needed to maintain the balance of ecosystems (Smith et al. 2011). As plankton, they can exercise control over zooplankton abundance, control "top-down" or that of their own predators control "bottom-up" in different situations (Bakun 1996). For example, the collapses of populations of sardines and anchovies have been accompanied by declines in the amount of sea birds and marine mammals (Chavez et al. 2003). Therefore, major changes in the abundance of these species may be accompanied by marked changes in the ecosystem structure (Alheit et al. 2009). Natural predation (mammals, seabirds, fish) and fishing (artisanal inshore and offshore industry) are the main sources of mortality of adult individuals (Bacha et al. 2014).

The GFCM (General Fisheries Commission for the Mediterranean) Working Group analyzed the variations of several small pelagic stocks across the Mediterranean in 2011 (GFCM 2011). Stock assessments of small pelagics in seven sub-regions in the Mediterranean show that most stocks are fully exploited and about 71% are overfished (Nieto et al. 2015).

The biological characteristics of small pelagic fisheries fluctuate not only due to fishing activity but also due to natural causes. In this regard, the analysis of time series is considered crucial to understand the dynamics of small pelagics in the ecosystem, and management should take into consideration that different phases (e.g. regime shifts) which show different productivities are common for these species (GFCM 2014). Moreover, the decrease of sardine and anchovy stocks off the Mediterranean since the mid-nineties was accompanied by an increase of another clupeid, *Sardinella aurita*, which was more pronounced in the northwestern Mediterranean region than in the Alborán Sea (ICES 2012). In addition, the northward expansion of round sardinella is directly related to sea warming as observed in the northern Aegean Sea. The distributional change may have an ecological effect on ecosystems and could also affect the local fisheries (Tsikliras 2008). The round sardinella, *Sardinella aurita*, is also commercially exploited in several southern Mediterranean countries, such as, Egypt (86% of total catch) (Abd EL Hakim et al. 2012), Algeria (Bouaziz et al. 1998) and Tunisia (Gaamour et al. 2001).

The Lebanese fishing fleet is composed of small scale artisanal vessels less than 12 m in length (Pinello & Dimech 2013). Small pelagics are attracted by a floating light and traditionally captured using purse seine nets over shallow waters (0-50 m). The families mostly captured in terms of catch abundance are Clupeidae (49.28%), Engraulidae (41.69%) and Scrombridae (7.01%) (Bariche et al. 2007).

Ecosystem management for sustainable exploitation of fishery resources and improved conservation of marine biodiversity is still absent in many fishery policy layouts in Lebanon. Facing this situation, the Lebanese National Center for Marine Sciences of the National Council for Scientific Research, as part of its activities and in the framework of the CANA+ project, performed the study of pelagic fishes especially the round sardinella, *Sardinella aurita*, which is among the most heavily exploited fisheries resources in the country. The study aims to estimate for the first time the: (1) sex ratio, (2) length frequency distribution, (3) length-weight relationship and (4) length at 50% maturity.

MATERIAL AND METHODS

A total of 1422 round sardinella specimens were monthly collected from September 2012 to September 2013. Samples were collected onboard a commercial purse seine (mesh: 8 mm) fishing with artificial light at night and a gillnet (mesh: 12 mm) fishing boat facing Dora and Tripoli that are respectively located in the central and northern part of the Lebanese coast, Eastern Mediterranean (Figure 1).

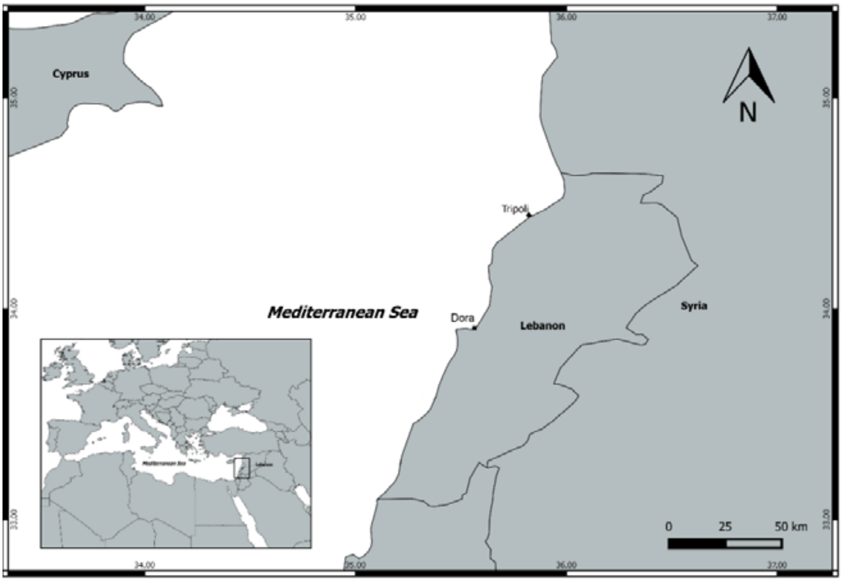

Figure 1. Location of the Dora and Tripoli ports along the Lebanese coast

The total length (L_T) to the nearest millimeter and total weight (W_T) to the nearest 0.01g of the fish were recorded for each specimen.

A nonlinear least squares function, *nls*, on the statistical software 'R project' (R Development Core Team 2014) was used to estimate of the parameters 'a' and 'b' of the nonlinear power equation between total weight and total length (LeCren 1951) as shown in equation (1):

$$W_T = aL_T^b \qquad (1)$$

Sex and maturity were determined macroscopically using the gross sexual classification system of (Fontana 1969) on the basis of the shape, appearance and structure of gonads. The following seven maturity stages were determined: (I) immature, (II) sexual rest, (III) in the process of maturation, (IV) pre-spawning (V) spawning (VI) recovery, (VII) post-spawning. All individuals classified as I–III and VII were considered as sexually immature whereas those classified as IV–VI were considered as sexually mature (Stergiou 1999). The $\chi 2$ test (RohIf F. I. & Sokal 1981) was used to compare the observed sex ratio to the theoretical 1:1 ratio using the *chisq.test* function using the statistical software R project (R Development Core Team 2014).

Size at maturity was also determined by the length at which 50% of the fish sample is mature (L_{50}). A logistic function relating the proportions of individuals and the total length of the fish was used to fit the L_{50} curve (Echeverria 1987) also using R project. The proportion of mature specimens in each length group was determined. The logistic equation (equation 2) takes the following form (Ghorbel et al. 2002):

$$P = \frac{1}{1+e^{(a+bL_T)}} \quad (2)$$

where P is the proportion of mature specimens in each determined length class, and 'a' and 'b' are parameters estimated by fitting the data to the logistic curve.

Finally, a Shapiro-Wilk normality test was used to test for the normality of the sample using the *shapiro.test* function on R project. A Kruskal-Wallis test was used to examine the differences between total length and total weight according to sex and gear using the *kruskal.test* function. A post-hoc Nemenyi test was used for pairwise multiple comparisons of the ranked data after significant results from the Kruskal-Wallis tests using the *posthoc.kruskal.nemenyi.test* function of the PMCMR package.

RESULTS

Sex ratio

Regarding sex ratio, 1422 of round sardinella were analyzed; 496 (34.9%) were females, 347 (24.4%) were males and 579 (40.7%) were undetermined specimens giving an overall sex ratio F/M=1.4. For all months examined, females predominated over males (Table 1). Significant differences were observed between the observed sex ratio and the hypothetical distribution of 1:1(χ^2=32.7, df=1, p-value$<$ 0.001). The greatest variation in relationship between females and males was detected in October 2012 (F/M=2.3), whereas during September January, February and August, the lowest variation in sex ratio was observed (Table 1).

Length frequency distribution

The total length of round sardinella (N=1257) ranged from 5.6 to 30 cm (table 2). Significant differences were observed in L_T and W_T distributions between fish captured by purse seines and gillnets (L_T: Kruskal-Wallis test, H=192.83, P<2.2e-16; W_T: Kruskal-Wallis test, H=192.57, P<2.2e-16). Fish of L_T ranging from 5.6 to 19 cm were captured by purse seine net and fish of L_T ranging from 19 to 30cm were captured by gillnets (Figure 2) and table . The largest number of specimens was shown in length class 11.5-12 cm (Figure 2). Monthly mean lengths of round sardinella are presented in Figure 3. The highest mean length value (23.13 cm) was recorded in May and the lowest (9.7 cm) in August.

Moreover, significant differences were observed in L_T and W_T distributions according to sex (L_T: Kruskal-Wallis test, H=425.48, P<2.2e-16; W_T: Kruskal-Wallis test, H=459.83, P<2.2e-16). The post hoc Nemenyi test gave significant differences of L_T and W_T according to sex between both males and females and the undetermined specimens (Nemenyi test, P<0.05).

Table 1. The monthly distribution of females (F), males (M), undetermined specimens (ND) and sex ratios for round sardinella (*Sardinella auita*). (N = Number of specimens in the sample).

Month	N	F	M	ND	%F	%M	%ND	Sex ratio F/M
Sep-12	132	44	36	52	33.3	27.3	39.4	1.2
Oct-12	393	79	34	280	20.1	8.7	71.2	2.3
Nov-12	125	39	22	64	31.2	17.6	51.2	1.8
Dec-12	101	36	20	45	35.6	19.8	44.6	1.8
Jan-13	190	67	56	67	35.3	29.5	35.3	1.2
Feb-13	95	46	37	2	48.4	38.9	2.1	1.2
Mar-13	55	26	14	15	47.3	25.5	27.3	1.9
Apr-13	85	40	34	11	47.1	40.0	12.9	1.2
May-13	40	23	17	0	57.5	42.5	0.0	1.4
Aug-13	76	36	27	13	47.4	35.5	17.1	1.3
Sep-13	130	60	50	30	46.2	38.5	23.1	1.2

Table 2: Length and weight for *sardinella aurita* according to fishing gear. N=number of fish, Min=minimum, Max=maximum.

		Total length (cm)			Total weight (g)		
	N	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Purse seine	1274	5.6	18.9	12 ± 2.6	1.5	61	15.64 ± 3.57
Gillnets	148	19	29.6	23.9 ± 3.1	7.2	219	129 ± 51.2

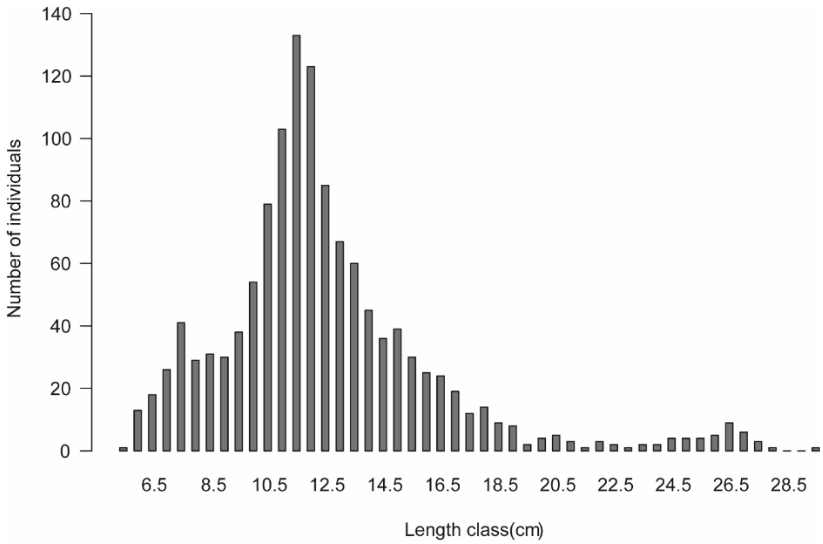

Figure 2. Length frequency distribution of the studied *Saradinella aurita* sample

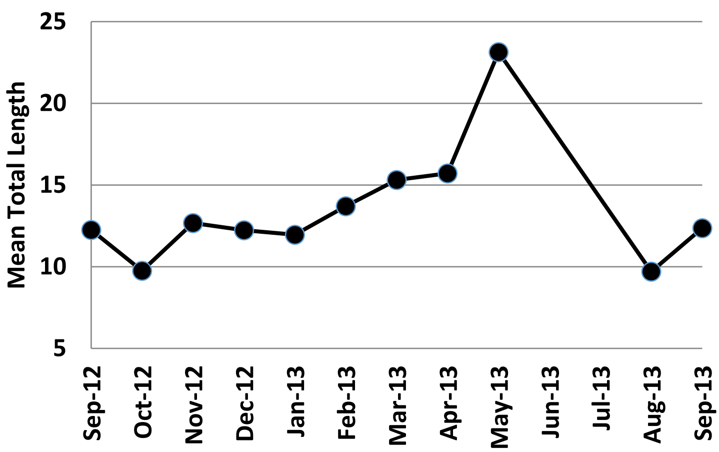

Figure 3. The monthly mean L_T of the round sardinella collected during this study

Length-weight relationship and L_{50}

The length (L_T) – weight (W_T) relationship was estimated using a nonlinear power regression analysis. Significant differences were obtained from the statistical comparison of length-weight relationships between males and females (ANCOVA, F = 30.864, $P<0.05$); therefore, the sexes were separated (Males: $W_T = 0.006\ L_T^{3.128}$, $R^2 = 0.97$; Females: $W_T = 0.004\ L_T^{3.282}$, $R^2 = 0.98$) (Figure 4).

The calculated parameters of L_T – W_T relationship for sexes separated demonstrated a scaling coefficient greater than three (males: b= 3.128; females: b=3.282) and showed the positive allometry for both sexes.

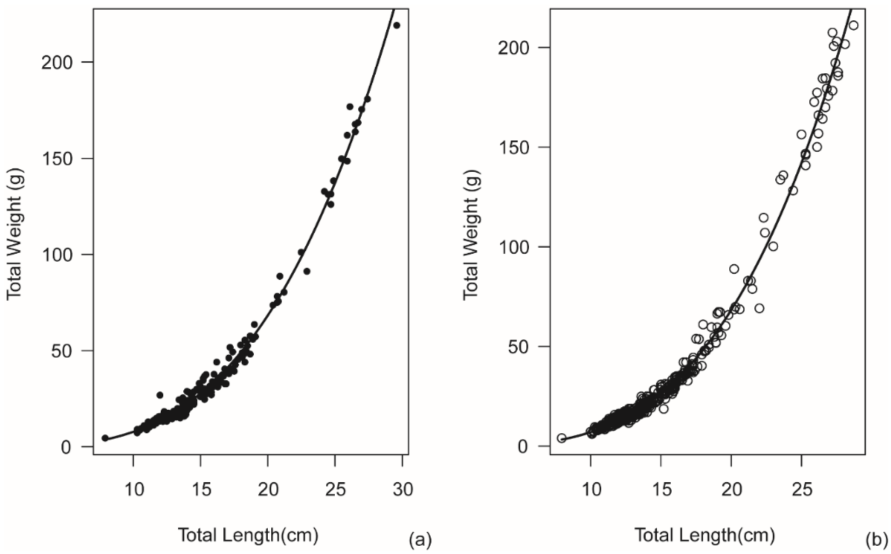

Figure 4. The length-weight relationship of the *Sardinella aurita* sample during the study period for the males (●) (a) and females (○) (b)

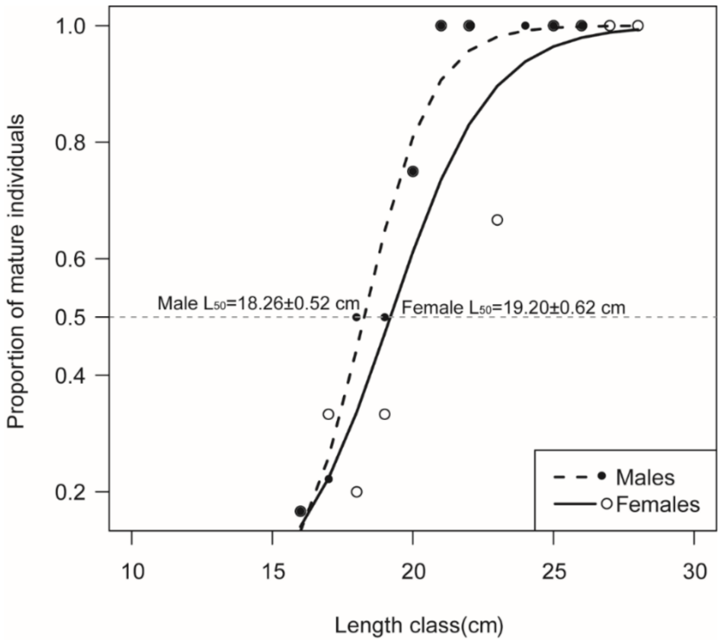

Figure 5. The proportion of mature round sardinella according to length class to estimate the length at 50 % maturity (L_{50}) in logistic regressions (Logistic curves: Males = - - - - - ; females = ———) during the study period for males (●) and females (○).

Finally, the examination of male and female maturity stages according to length classes in a logistic regression indicated that the length at 50% maturity (L50) was 18.26 ± 0.52 cm for males and 19.20 ± 0.62 cm for females (Figure 5).

DISCUSSION

An overall sex-ratio (F/M= 1.4) was found in the present study. Round sardinella females predominated over males through all the months of the year. The highest sex ratio value was observed in October 2012 (F/M=2.3), when this species was intensively spawning., Furthermore, assuming that females occur in the sea layer closer to the surface they are more vulnerable to fishing (Mustać 2010; Mustać & Sinovčić 2011).

A domination of females over males, noted during this eastern Mediterranean study, was also noted in the West Atlantic and southern Mediterranean (Boely & Champagnat 1970; Gaamour et al. 2001). Mustać & Sinovčić (2011) showed a sex ratio of F/M= 1.4 in the eastern and central Adriatic. Regarding the Atlantic, females are shown to dominate over the males (F/M=1.2, F/M=1.56) in Senegal and Mauritania respectively (Camarena 1986; Lawal &

Mylnikov 1988). The sex ratio exhibited a monthly variation and showed that the number of males and females was equal for lengths lower than 160 mm, whereas the number of males was higher for length classes of 160 mm (Tsikliras & Antonopoulou 2006).

Sex ratio could be influenced by the availability of food (Nikolsky 1963; Nikolsky 1969) and by sampling in inshore or in offshore water. In fact, Mustać and Sinovčić in 2012 found that females dominate over males in inshore water. Nikolsky (1969) reported that when food is abundant, females predominate, and the situation inverts in regions where food is limited. In this study, the domination of females during all months of the year could be explained by catching in inshore waters with higher primary and secondary production than the offshore (Lakkis 1990; Baker et al. 1994; Mustać & Sinovčić 2012).

The length-weight relationship for round sardinella indicated a positive allometric growth for males and females (b=3.128, b=3.282 respectively). This result coincides with that previously obtained by Mustać & Sinovčić (2012) and Sinovcic et al. (2004) in the Adriatic Sea, and by Tsikliras et al. (2005) northern of the Aegean Sea. Regarding the southeastern Mediterranean, *Sardinella aurita* showed a negative allometric growth (Salem et al. 2010; Mehanna S. F. & Salem 2011; Abd EL Hakim et al. 2012). The difference in allometric growth may be related to unavailable food and an unsuitable environment (Salem et al. 2010; Abd EL Hakim et al. 2012). It can also vary according to many factors, such as, season, sex, food, maturity stages and technique of sampling (Le Cren 1951). It was also observed that round sardinella females are significantly longer than males from the southern to the eastern Mediterranean (Bensahla-Talet et al. 1988; Gaamour et al. 2001; Tsikliras & Antonopoulou 2006).. In total, females were greater in number (N=496) than males (N=347), which could influence the presented length-weight results (Froese et al. 2011).

Round sardinella males were observed to be smaller and younger at maturity than females in the eastern Levantine basin. This study coincides with the results obtained by Tsikliras & Antonopoulou (2006) northern of the Aegean Sea. More recent studies in Senegal show annual average sizes at first maturity to be 23.6 cm (L_T) and 25 cm (L_T) (Diouf et al. 2010) and 26 cm (L_T) and 21 cm (L_T) (Samba 2011) for females and males respectively. Note that the size of first maturity observed in the Atlantic is slightly higher than that observed in other study areas of the Mediterranean Sea (Tsikliras & Antonopoulou 2006).

According to Boëly et al. (1982), the size at 50% maturity (L_{50}) of *Sardinella aurita* females is 18.5 cm in Senegal, 90% are mature at 21cm and all reach maturity 25 cm. However, it can vary from one year to another or within one year following the current quarter (Boëly et al. 1982). The size at first maturity of the round sardinella can vary from year to year and during different seasons (Deme et al. 2012). The size at first maturity also varies according to gender (Diouf et al. 2010; Samba 2011). Like most Clupeidae, the higher size at first sexual maturity in females is justified by slower growth of males.

Regarding Clupeidae, like *Sardina pilchardus*, the size of individuals, and thus growth, decreases both according to longitude (from west to east in the Mediterranean) and latitude (from the English Channel to northern Morocco in the Atlantic) (Alemany & Alvarez 1993).

The variation in size at first sexual maturity among different zones could be related to increased salinity conditions that can lead to the reduction in size (Panfili et al. 2004) and be explained by the higher growth rate observed in Senegalese waters (Boëly 1980). It can also be due to the different conditions in every region influencing the physiological characteristics of the population in that region, which can consequently affect its growth and development. Moreover, changes to age and size at maturity can be the product of phenotypic and genetic responses to fishing (Rochet 1998; Law 2000; Hutchings 2002). An example related to bony fish is the Atlantic cod (*Gadus morhua*) whose 30- to 40-year declines have been associated with significant reductions in age and length at maturity, changes mostly explained as genetic responses to fishing (Hutchings 2005).

Studies on life history parameters such as age and growth, along with basic information on distribution, abundance, movements, feeding, reproduction and genetics, are essential for biologists to understand and predict how populations will grow and how they will respond to fishing pressure. This study presents basic biological data for *S. aurita* needed for stock assessment. This data is essential to understand the growth rate, age structure, and other aspects of population dynamics. Therefore, this study draws attention to the *S. aurita* population in Lebanon, as rare are the studies that are performed about this species along the Lebanese coast. This species could be majorly exploited by fishermen for its commercial significance; thus, management measures should be implemented to prevent this vast exploitation. The data presented here will be useful for the ongoing assessment of such commercially significant pelagic fish populations.

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