PERIODICUM BIOLOGORUM
VOL. 112, No 2, 133–138, 2010

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Reproduction, length-weight relationship and condition of sardine, *Sardina pilchardus* (Walbaum, 1792), in the eastern Middle Adriatic Sea (Croatia)

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Key words: Sardine, Adriatic, reproduction, length-weight relationship, condition

Abstract

Background and Purpose: *The reproductive cycle of sardine,* Sardina pilchardus *(Walb.), from offshore (Dugi otok) and inshore waters (Virsko more) of Mid Adriatic Sea was studied to gain information on spawning period, sex ratio, length-weight relationship and condition of this most commercially important fish species in the Adriatic Sea.*

Materials and Methods: *A total of 1,219 sardine specimens were collected from monthly random samples of purse seine catches realized in the Mid Adriatic Sea during the March 2004 – February 2005 period. Fish were measured and weighed. Sex was determined and gonad maturity stage was assessed. Gonadosomatic index (*GSI*) was calculated by expressing the monthly gonad weight as a proportion of the total body weight. The length (*LT*)–weight (*W*) relationship was determined (log* W = *log* a + b *log* LT) as well as the monthly fish condition, using Fulton's equation (K = *100* W/ LT ^{3}*).*

Results and Conclusions: *The total length of sardine ranged from 13.0 to 19.0 cm and the mass ranged from 16.72 to 51.45 g. Sex ratio was different from 1:1; males predominated (♂/♀ = 1.2). The reproductive activity period was from October to May, coinciding with the most developed stages of gonads as well as with the highest gonad weights and gonadosomatic indices. The length-weight relationship of sardine was described by the expression:* $W = 0.026\ LT^{2.5538}$ *($r^2 = 0.697$). Fulton's condition factor showed greater values in sardine samples from the inshore waters (Virsko more, K = 0.8205) than those from the offshore waters (Dugi Otok, K = 0.7317).*

Received February 5, 2008

INTRODUCTION

The sardine, *Sardina pilchardus* (Walbaum, 1792), is the most numerous and the most economically important fish species in the Adriatic Sea *(1, 2)*. It belongs to the Clupeidae family and lives in the eastern Atlantic from 15° to 66°N and from 23° to 42°E, including the entire Mediterranean basin. As a typical representative of shoaling small pelagic fish species, sardine migrates in shoals 14 cm/sec (3). Hydrographic (temperature) and biological factors (feeding and spawning) are the major reasons for sardine migrations *(4, 5, 6, 3, 7)*. During autumn and especially winter months sardine migrates toward spawning grounds which are located in the open waters of the Adriatic Sea. In spring, its shoals return to shallower, coastal waters *(8, 6, 9)*.

Sardine is a multiple spawner with continuous gametogenesis, external fertilization, no parental care and very high fecundity *(10)*. Fecundity depends on the spawning season duration and previously stored reserves and food availability to ensure the continuous development of gametes *(11)*. First maturity occurs at very low size and age *(12, 13, 14)*. It probably varies in length from year to year because ecological conditions have an immense influence on the sexual maturity of fish, in particular the amount of available food and the temperature *(15, 16)*.

The length-weight relationship is widely used in fishery studies as it allows conversion of growth-in-length equations to growth-in-weight for use in stock assessment models, estimation of biomasses from length observation, estimate of the condition of the fish and comparison between regions of certain species life histories (*17,18,19*). These relationships are also frequently used to follow seasonal variations in fish growth and to estimate condition indexes *(20, 21, 22)*.

Considering the economic importance of sardine and its position in the feeding chain of the ecosystem sardine along with plankton, constitutes the base of the sea ecological pyramid – it is necessary to survey all changes in sardine population so that it would be possible to react in time to all possible negative changes or suggest measures for protecting this most commercially important fish species in the Adriatic Sea *(2)*.

It is an interesting fact that the first records on the fisheries, catches and distribution of small pelagic fish in the eastern part of the Adriatic Sea date from the tenth century and originated from the southeast area of Dugi Otok which is the area of our investigation.

Thus, the objective of this study was to gather precise information of the spawning period, sex ratio, length-weight relationship and sardine condition in the eastern Mid Adriatic Sea.

MATERIAL AND METHODS

Sardine specimens (N=1,219) were obtained by sampling 12 purse seine catches of small pelagic fish species from the catches of inshore (Virsko more) and offshore waters (Dugi Otok) of the eastern Mid Adriatic Sea (Figure 1).

Sardines were caught by purse seine using 8 mm mesh under artificial light, during the night, but not during a full moon. Samples were collected monthly from March 2004 to February 2005. Virsko more (inshore waters), situated northwest of Zadar, has an average depth of 45 m. The sea bottom is mainly covered with sand *(23)*. Average surface temperature in inshore waters was between 11°C (March) and 26.5°C (August). During summer months, the average oxygen saturation is 105.4%. Hydrographic parameters of offshore waters (Dugi Otok) showed slight oscillation; average surface temperature was between 11°C (March) and 24.2°C (July). The mean value of salinity was from 37.01 p.s.u. (April) to 38.67 p.s.u. (March) *(24)*. Winds were very strong, especially the southern wind which usually dominates in this area.

Figure 1. *A map showing the sampling area of the sardine,* Sardina pilchardus *(Walb., 1792), in inshore waters (■) and offshore waters (●) during March 2004 – February 2005.*

In the laboratory, fish were measured (nearest mm in total length /*LT*/), weighed (nearest cg in wet mass) and dissected for sex determination immediately after landing.

The analysis of the reproductive cycle was based on the monthly gonad weight (W_g) and gonadosomatic index (*GSI*). Gonadosomatic index (*GSI*) was calculated by expressing the monthly gonad weight as a proportion of the total body weight ($GSI = 100Wg/W$, where W is somatic fish weight and Wg is gonad weight). This index was calculated for each of the analyzed individuals and, finally, a mean monthly index was estimated.

Sex ratio (male:female) was calculated and significant differences from the expected ratio (1:1) were tested by means of χ^2 test *(25)*.

The length (*LT*)–weight (*W*) relationship was determined according to the equation: $\log W = \log a + b \log LT$.

The Fulton's equation ($K = 100W/LT^3$) *(26)* was used to estimate monthly fish condition, where a and b are the coefficient and exponent of the annual $LT - W$ relationship, respectively. To avoid the length influence on fish condition, only data on fish from 14.0 to 18.0 cm were used to describe seasonal condition changes.

RESULTS

Population structure

During the time of investigation, 1, 219 sardine specimens were analyzed. The total length of the sardines ranged from 13.0 to 19.0 cm (Figure 2) with the mean length = 16.03 ± 0.88 cm. The total body weight ranged between 16.72 g and 51.45 g. The mean body weight of all specimens was 31.49 ± 5.32 g.

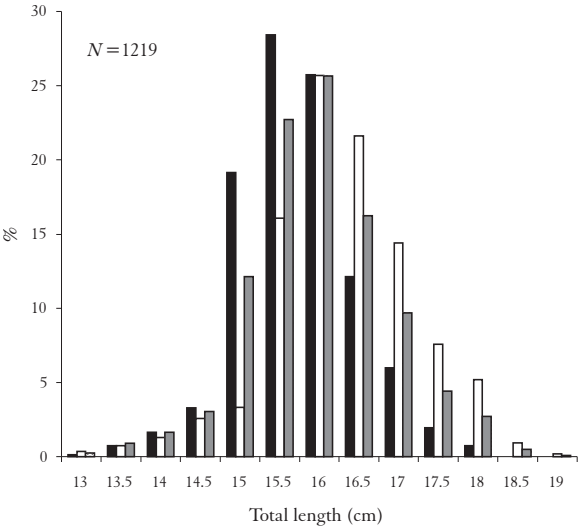

Figure 2. *Length- frequency distribution of sardine,* Sardina pilchardus *(males ■; females □; total ▩) from catch samples realized in the Mid Adriatic Sea, March 2004-February 2005.*

The male length – range was 13.0 to 18.0 cm with the mean length of 15.64 ± 0.86 cm in inshore waters, and in offshore waters it was between 14.0 to 18.0 cm with the mean length 15.88 ± 0.66. The female length range was slightly wider, from 13.0 to 18.2 cm in inshore waters with the mean length of 15.93 ± 0.97 cm, and from 15.0 to 19.0 in offshore waters (Figure 3) with the mean length of 16.72 ± 0.76 cm. In addition, females were more frequent at bigger size classes than males. There were statistically significant differences between male and female weights (t=27.971; p<0.01) and lengths (t=21.98; p<0.01).

Sex ratio

The monthly variation of sex ratio in relation to length classes presented in Fig. 4. Out of the total sardine specimens analyzed during the study (N=1,219), 668 (54.8%) specimens were males, 541 (44.4%) were females and 10 (0.8%) undetermined, juvenile specimens. The overall sex ratio during the investigation period was in favor of males (♂/♀=*1.2); it significantly deviates from the hypothetical distribution of 1:1* (χ^2= 13.34; *d.f.*= 1;

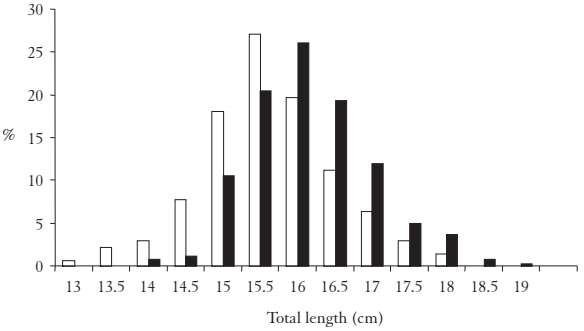

Figure 3. *Length frequency distribution of sardine from catch samples realized in inshore (□; N= 509) and offshore waters (■; N=700) Mid Adriatic Sea, March 2004-February 2005.*

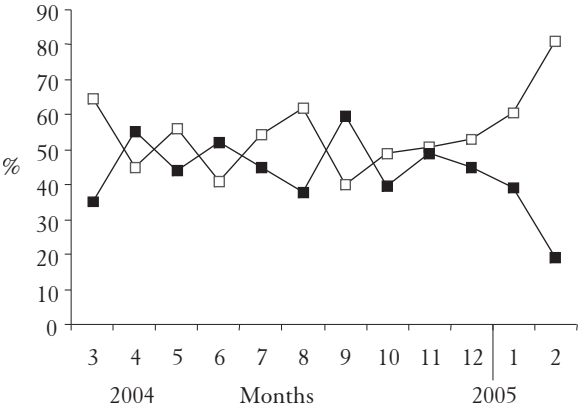

Figure 4. *Frequency distribution of male (□; N= 668) and female (■; N=541) sardines caught in the Mid Adriatic Sea, March 2004-February 2005.*

p<0.01). Males mainly predominated in all months, except in April, June and September, when predomination of females was evident (Figure 4).

Gonadosomatic index

GSI and gonad weight showed the lowest values during the May-September period; minimal *GSI* was noticed in July – 0.34% ♂ and 0.47% ♀. Higher values of *GSI* were noticed during the October-April period and the peaks were during the November-February period –

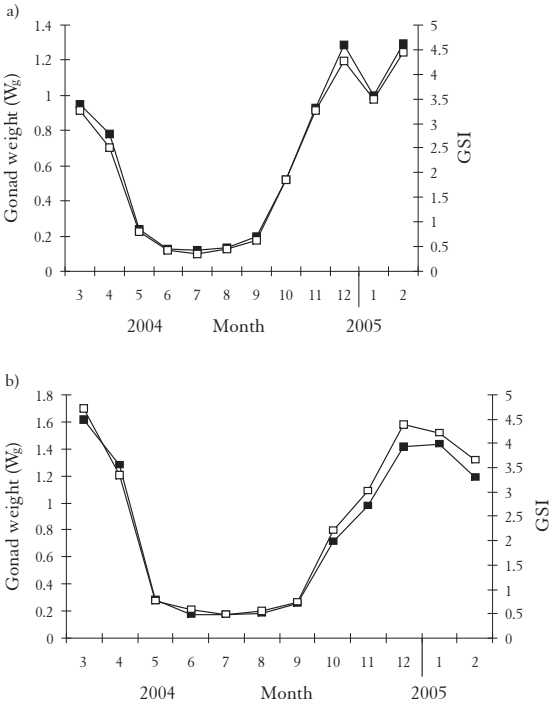

Figure 5. *Gonadosomatic index* (GSI; □) *and gonad weight* (W_g; ■) *of the sardine,* Sardina pilchardus*, male (A) and female (B) from catch samples realized in the Mid Adriatic Sea (Zadar area) during March 2004-February 2005.*

maximal *GSI* was in February (4.45%) for males, and for females it was in March (4.71%). Peaking was more pronounced for females (Figure 5). According to the results of the present investigation, spawning occurred in October and lasted until April when the inactive phase of the maturity cycle started. The most intensive spawning was during December-March.

Length-weight relationship

The length-weight for males was: $W = 0.0425\ L^{2.3707}$; $r^2 = 0.5820$ and for females it was: $W = 0.0342\ L^{2.4645}$; $r^2 = 0.7329$ (Figure 6). The relationship for sardine from inshore waters (N=517) was: $W = 0.0307\ L^{2.5132}$; $r^2 = 0.6827$ and from the offshore catch samples (N=702) was: $W = 0.0206\ L^{2.6299}$; $r^2 = 0.7482$ (Figure 7). The slope of regressions and regression coefficients indicate a negative allometric growth for both sexes and areas – a proportionally higher length increase relative to weight. Females had a significantly ($t = 16.69$; $p<0.01$) higher regression coefficient (b=2.4645; $r^2 = 0.7329$) than males (b=2.3707; $r^2 = 0.5820$).

A comparison of length-weight relationship between the two-studied areas demonstrated that sardines from Dugi Otok had greater exponent b of length-weight relationship (b=2.6299) than those from Virsko More (b=2.5132).

Condition

The Fulton's condition factor (K) was analyzed in specimens which ranged from 14.0–18.0 cm. Sardines of smaller length sizes from both areas had a greater Fulton's condition factor than those of larger lengths (Fig. 8). Fulton's condition factor showed greater values in sardine samples from inshore waters (K=0.8205) than those from offshore waters (K=0.7317) (Figure 8). It is evident that fish from the inactive phase of reproductive cycle was generally in better condition (K=0.8234) than the fish caught during spawning season (K=0.7409) (Figure 9).

Analysis of variance showed that there were statistically significant differences among K values from inshore and offshore sardine samples from the Mid Adriatic Sea ($F = 3.28$; $p<0.01$).

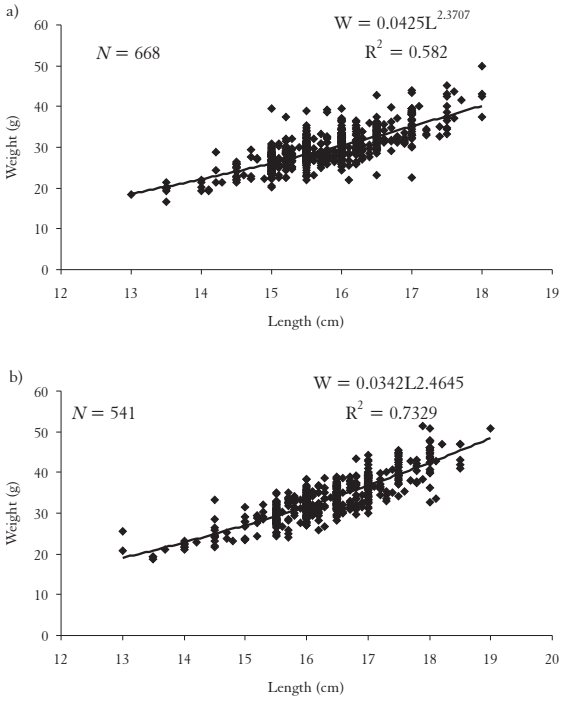

Figure 6. *Length-weight relationship of male (A) and female (B) sardine from catches in the Mid Adriatic Sea during March 2004--February 2005.*

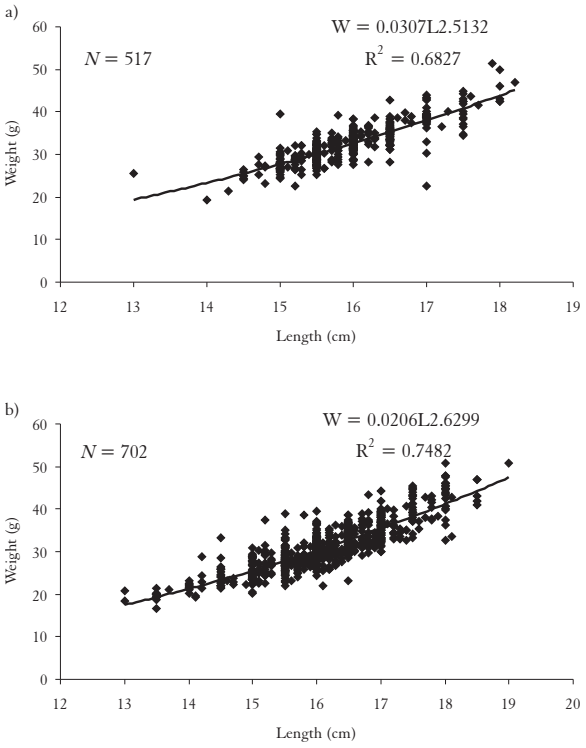

Figure 7. *Length-weight relationship of sardine from catches realized in inshore (A) (Virsko more) and offshore waters (B) (Dugi otok) of the Mid Adriatic Sea during March 2004-February 2005.*

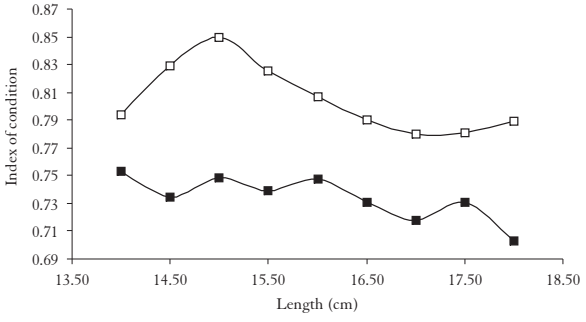

Figure 8. *Fulton's condition factor* (K) *in sardine samples from inshore waters (Virsko More; □; N= 509) and offshore waters (Dugi Otok; ■; N= 700) of the Mid Adriatic Sea during March 2004--February 2005.*

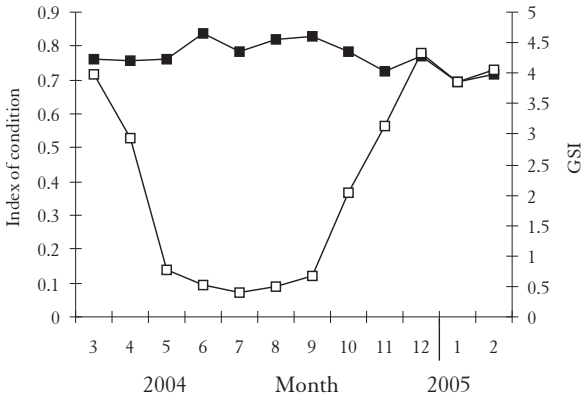

Figure 9. *Condition factor (*K*) and gonadosomatic index (*GSI*) in sardine samples of the Mid Adriatic Sea, during March 2004-February 2005.*

DISCUSSION

In population structure, sardine females showed wider length range, greater modal, mean length and weight than males, higher in offshore waters than in inshore waters (Figs. 2, 3). Sinovčić *(27)* also found that sardines from catch samples from the inshore Mid Adriatic Sea were smaller in length those that from offshore waters. Muino *et al*. *(28)* found greater length size amounts in offshore sardine catch samples compared to those from the inshore waters of the Atlantic.

The sardine, like other clupeids, is a multiple spawner producing several batches of oocytes within reproductive period *(29, 30)*. Temporal evolution of gonadosomatic index showed that spawning season in the study area took place during October-April, which included maturation, spawning and post-spawning period. Our results on the reproductive cycle of sardine are consistent with observations of most researcher who have studied sardine spawning duration and found that it extended over 8-9 months with the maximum values of *GSI* from December to March in the Adriatic and Aegean Sea *(1, 6, 10, 12, 13, 14, 31, 32, 33, 34)* when the lowest annual values of sea temperature were reported.

The length-weight relationship of sardines from the Mid Adriatic Sea showed negative allometric growth. Some earlier studies from the Adriatic Sea also reported negative allometry of sardine length-weight relationship in the North Adriatic (b=2.757) and Middle Adriatic (b=2.851) *(32, 35)*. Negative allometry was found in length-weight relationship of sardine from the Ionian Sea in 1995 *(36)* and in 2003 *(37)*. Significant differences between the slopes (b) of the length-weight relationship between seasons (spring and summer) were found for sardine on the Portuguese west coast *(38)*. These differences may be attributed to changes in water temperature, salinity and food availability, as well as to changes in maturity stage *(39)*.

It was found in the present study that the sex ratio skewed to males in almost all length classes (Figure 3). In general, variations of the sex ratio at different sizes are related to unequal rates of growth and mortality *(40)*, although a supplementary analysis of more samples of each size would be advisable in order to corroborate the obtained results. Analysis of sardine length-weight relationship showed that female sardines were significantly heavier than males for a given length. Similar results have been reported earlier *(13, 32, 41)*. In general, it is considered that a greater number of males is unadvantageous since, as pointed out by Wootton *(42)*, only populations with the sex ratio biased toward females have a greater rate of reproduction.

The Fulton's coefficient of condition trends indicates its size dependence – small fish specimens were in better condition than the bigger ones. Also, samples of sardine catches from inshore waters were generally in better condition than those from offshore waters. The Adriatic Sea is a semi-closed oligotrophic area. Besides, inshore waters abound in sardine food, mainly zooplankton, which is not the case in offshore waters *(43)* and this is likely the main reason for higher values of Fulton's condition factor in inshore rather than offshore waters. Consequently, Sinovčić *(44)* reported the same situation with another similar pelagic species, the anchovy.

In summer, when tropic conditions are at its best, specimens feed abundantly *(43)*, whereas the accumulated reserves are in agreement with previous observations *(6, 45)*. During autumn, in the gonad maturation phase, a decrease of mean K could be explained by reserves used for sexual products. At the same time, gonad growth depressed fish digestive tract and prevented food consumption. Decrease in condition factors during an inactive phase in reproductive cycle could be explained by reserves used for sexual products. The energy normally used for maintenance and growth of the individual is diverted toward gonadic maturation and spawning. These results are in agreement with previous observations *(46, 47, 48, 49)*.

REFERENCES

1. SINOVČIĆ G 2001 Small pelagic fish from the Croatian fishing ground. *In*: Mannini P, Massa F, Milone N (*eds.*), Priority Topics to Small Pelagic Fishery Resources of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. *GCP/REP//ITA/TD*-03, Termoli, AdriaMed Technical Documents, p 53–58
2. CINGOLANI N, KARIŠ T, SINOVČIĆ G, KAPEDANI E 2003 Sardine (*Sardina pilchardus*,W.) stock assessment in the Adriatic Sea: 1975–2002. *AdriaMed. Occasional Papers* (Mannini P, Massa F, Milone N, *eds.*) *1:* 1–11
3. MUŽINIĆ R 1973 Migrations of adult sardines in the central Adriatic. *Neth J Sea Res* 7: 19–30
4. MUŽINIĆ R 1950 Tagging of sardine (*Clupea pilchardus* Walb.) in the Adriatic in 1949. *Acta Adriat 4(7):* 1–30
5. MUŽINIĆ R 1952 Tagging of sardine (*Clupea pilchardus* Walb.) in the Adriatic in 1950 and 1951. *Acta Adriat 4(11):* 1–22
6. MUŽINIĆ R 1954 Contribution à l'étude de l'écologie de la sardine (*Sardina pilchardus* Walb.) dans l'Adriatique orientale. *Acta Adriat 5 (10):* 1–219
7. MUŽINIĆ R 1979 O nekim pelagičnim ribama u srednjodalmatinskom otočnom području. *Acta biol 8/1–10:* 123–176
8. GRUBIŠIĆ F 1964 Lovišta srdele uz jugoslavensku obalu, njihov raspored i karakteristike. *Acta Adriat 13 (11):* 103–110

9. MUŽINIĆ R 1956 Some observations on the habits of the sardine. Papers Internat techn conference conservation of the living resources of the sea. Rome, 1955, p 95–97
10. SINOVČIĆ G 1983–84 Fecundity of sardine, *Sardina pilchardus* (Walb.) in the Central Adriatic. *Nova Thalassia 6:* 351–363
11. HUNTER J R, GOLDBERG S R 1980 Spawning incidence and batch fecundity in northern anchovy. *Engraulis mordax. Fish Bull* U. S. *77:* 641–652
12. SINOVČIĆ G 1983 The fecundity-age relationship of sardine, *Sardina pilchardus* (Walb.) in the Central Adriatic. *Rapp Comm int Mer Méditer 28:* 31–32
13. SINOVČIĆ G, ZORICA B, FRANIČEVIĆ M, ČIKEŠ V 2003 First sexual maturity of sardine, *Sardina pilchardus* (Walb.) in the eastern Adriatic Sea. *Period biolog 105 (4):* 401–404
14. SINOVČIĆ G, ČIKEŠ KEČ V, ZORICA B 2007 Population structure, size at maturity and condition of sardine, *Sardina pilchardus* (Walb., 1792), in the nursery ground of the eastern Adriatic Sea (Krka River estuary, Croatia). *Estuar Coast Shelf Sci*., doi: 10.1016 /j.ecss.2007.07.037
15. NIKOLSKY G V 1963 The ecology of fishes. Shkola, V., London and New York, p 352
16. BLAXTER J H S 1969 Experimental rearing of pilchard larvae, *Sardina pilchardus*. *J Mar Biol Assoc U K 46:* 219–234
17. GONÇALVES J M S, BENTES L, LINO P G, RIBEIRO J, CANARIO A V M, ERZINI K 1996 Weight-length relationship for selected fish species of the small-scaled demersal fisheries of the south and south-west coast of Portugal. *Fish Res 30:* 253–256
18. FROESE R, PAULY D 1998 FishBase 1998: Concepts, design and data sources. Manila, ICLARM, p 293
19. MOUTOPOULOS D K, STERGIOU K I 2002 Length-weight and length-length relationships of fish species from the Aegean Sea (Greece). *J Appl Ichthyol 18 (3):* 200–203
20. ANDERSON R, GUTREUTER S 1983 Length, weight and associated structural indices. *In*: *Fisheries techniques,* Nielsen L, Johnson D *(eds.)* American Fisheries Society, Bethesda, MD, p 283–300
21. SAFRAN P 1992 Theoretical analysis of the weight-length relationships in fish juveniles. *Mar Biol 112*: 545–551
22. RICHTER H, LÛCKSTÄDT C, FOCKEN U, BECKER K 2000 An improved procedure to assess fish condition on the basis of length-weight relationships. *Arch Fish Mar Res 48:* 255–264
23. MAGAŠ D 1977 Vir. Prilog geografskim istraživanjima u zadarskoj regiji. Rad JAZU 24/1977, p 5–51
24. ZORE-ARMANDA M, GRBEC B, MOROVIĆ M 1999 Oceanographic properties of the Adriatic Sea. *Acta Adriat 40:* 39–54
25. SOKAL R, ROHLF F J 1981 Biometry, 2nd edition. Freeman W.H. and Company Publishers, New York, p 859
26. LE CREN E D 1951 The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J Anim Ecol 20:* 201–219
27. SINOVČIĆ G 2002 O značajkama naselja male pelagičke ribe u području makarskog akvatorija. *Ekološke monografije Biokovo 2*: 375–392
28. MUINO R, CARRERA P, IGLESIAS M 2003 The characterization of sardine (*Sardina pilchardus* Walbaum) schools off Spanish-Atlantic coast. ICES. *Mar Sci 60 (6):* 1361–1372
29. GANIAS K, SOMARAKIS S, CARAGITSOU E, KOUTSIKOPOULOS C, MACHIAS A, THEODOROU A 2001a Differential egg production of sardine off the central Hellenic coasts in December 1999. Proc 36th CIESM Congress 36, p 268
30. SOMARKIS S, GANIAS K, C, KOUTSIKOPOULOS C, MACHIAS A, PAPACONSTATINOU C 2001 Applying the daily egg production method (DEPM) to small sardine stocks in the Eastern Mediterranean (Central Greece). Working Doc ICES Study Group on the Estimation of spawning biomass for sardine and anchovy (SGSBSA) Lisabon, 22–25/10/2001, p 21
31. SINOVČIĆ G 1984 Summary of biological parameters of sardine, *Sardina pilchardus* (Walb.), from the Central Adriatic. *FAO Fish Rep 290:* 147–148
32. SINOVČIĆ G 2000 Responsible Exploitation of the sardine, *Sardina pilchardus* (Walb.), Population in the Coastal Region of the Eastern Adriatic. *Period biolog 102 (1):* 47–54
33. CINAGHIR B 1996 Reproduction of European Pilchard, *Sardina pilchardus* (Walbaum, 1792) in the Agean Sea. *Turk J Zool 20:* 33–50
34. VOULGDARIGDOU P, STERIGOU I K 2003 Trends in various biological parameters of the European sardine, *Sardina pilchardus* (Walbaum, 1792), in the Eastern Mediterranean Sea. *Sci Mar 67 (1):* 269–280
35. ALEGRIA HERNÀNDEZ V 1983 A comparision of the length--weight relationship in sardine (*Sardina pilchardus*, Walbaum, 1792) from the northern and central Adriatic fishing grounds. *Rapp Comm int Mer Médit 28 (5):* 25–26
36. SAFRAN P 1992 Theoretical analysis of the weight-length relationships in fish juveniles. *Mar Biol 112:* 545–551
37. KOUTRAKIS M, TSIKLIRAS A 2003 Length-weight relationship of fishes from three northern Aegean estuarine systems (Greece). *J Appl Ichthyol 19*: 258–260
38. MENDEZ B, FONSECA P, CAMPOS A 2004 Weight-length relationships for 46 fish species of the Portuguese west coast. *J Appl Ichthyol 20*: 355–361
39. WEATHERLAY A H, GILL H S 1987 The biology of fish growth. Academic Press, London, p 443
40. TURNER S C, GRIMES C B, ABLE K W 1983 Growth, mortality, and age/size structure of the fisheries for the tilefish, *Lopholatilus chaemaelonticeps*, in the middle Atlantic-Southern new England region. *Fish Bull 81:* 751–763
41. ALERGIA HERNANDEZ V 1985 A contribution to the study of heterogeneity of the Adriatic sardine (*Sardina pilchardus*, Walb.) population. *Acta Adriat 26 (2):* 109–122
42. WOOTTON R J 1982 Environmental factors in fish reproduction. *In:* Proceed Internat on Reproductive Physiology of fish, Richter C J J, Goos H J T *(eds.),* Pudoc, Wageningen, The Netherlands, p 210–219
43. VUČETIĆ T 1975 Synchronism of the spawning season of some pelagic fishes (sardine, anchovy) and the timing of the maximal food (zooplankton) production in the central Adriatic. *Publ Stn Zool Napoli 39 (Suppl):* 347–365
44. SINOVČIĆ G 1992 Biologija i dinamika populacije brgljuna *Engraulis encrasicolus* (Linnaeus, 1758) u Jadranu. Doktorska disertacija, Prirodoslovno-matematički fakultet, Zagreb, p 163.
45. KRVARIĆ M, MUŽINIĆ R 1950 Investigation into the fat content in the sardine tissues (*Clupea pilchardus* Walb.). *Acta Adriat 4 (8):* 1–26
46. TOMASINI J A, BOUCHEREAU J L, BEN SAHALA TALET A 1989 Reproducion et condition chez la sardine (*Sardina pilchardus* Walbaum, 1792) des côtes oranaises (Algérie). *Cybium 13 (1):* 37–50
47. PEREZ N FIGUEREDO, I LON C H 1992 Batch fecundity of *Sardina pilchardus* Walb., of the Atlantic Iberian Coast. *Bol Inst Esp Oceanogr 8(1):* 155–162
48. ABAD R, GIRALDEZ A 1993 Reproducion, factor de condicion y talla de primer madurez de la sardina *Sardina pilchardus* (Walb.), del litoral del Malaga, mar de Alboran (1989 a 1992). *Bol Inst Esp Oceanogr 9(1):* 145–155
49. ZWOLINSKI J, STRATOUDAKIS Y, SOARES E 2001 Intra-annual variation in the batch fecundity of sardine off Portugal. *J Fish Biol 58:* 1633–1645