ISSN 1330-061X
CODEN RIBAEG

UDK: 597.2/.5:591.134.018.4](267.36)
Original scientific paper

RELATIONSHIPS BETWEEN FISH LENGTH AND OTOLITH LENGTH, WIDTH AND WEIGHT OF THE INDIAN MACKEREL *Rastrelliger kanagurta* (CUVIER, 1817) COLLECTED FROM THE SEA OF OMAN

L.A Jawad[1*], A. Ambuali[2], J.M. Al-Mamry[1], H.K.Al-Busaidi

Summary

The relationships between otolith dimensions and fish size (Fish total and fork lengths) for the teleost species, *Rastrelliger kanagurta* (Cuvier, 1817) collected from the vicinity of Muscat City at Oman Sea were examined and found to be linear. Otolith morphometric observations included length, weight and width were correlated with the total and fork lengths of the fish. Regression models relating each otolith morphometric parameter to the two fish lengths are provided. The significance of each parameter for estimating fish length was examined. The length, width and weight of otolith appeared to have the best discrimination for estimating total and fork length of fish as well as the easiest parameters to measure.

Keywords: Otolith dimensions, fish length, *Rastrelliger* , Oman Sea, Sultanate of Oman

INTRODUCTION

The Indian mackerel, *Rastrelliger kanagurta (*Cuvier, 1817*),* is a small pelagic fish caught mainly with gillnets. This species is very important in the fisheries along its geographical distribution and particularly in Oman (Al-Abdessalaam, 1995). Only during the year 2009, the total landing of this species reached to around 11 000 tons (Ministry of Fisheries Wealth, 2010).

In all bony fishes (Osteichthyes) there are three pairs of otoliths, or ear stones: the sagittae, asteriscus, and lapillus. Otoliths are mineral inert components made of calcium

1 Marine Science and Fisheries Centre, Ministry of Fisheries Wealth, P.O. Box 427, Postal Code 100, Muscat, Sultanate of Oman;

2 Department of Marine Science and Fisheries, Sultan Qaboos University, P.O. Box 34, Al-Khud, Sultanate of Oman.

* Corresponding author: laith_jawad@hotmail.com

carbonate in the form of aragonite, in a protein matrix. They are located within the inner ear where they contribute to several physiological processes, such as audition, mecano-reception and equilibration (P o p p e r and C o o m b e, 1982) which allow fishes to achieve a better perception of their own environment. Except in Cypriniformes and Siluriformes, the sagittae are the largest pair of otoliths in most bony fishes (P a x t o n, 1998). Fisheries biologists have used otoliths and in particular sagittae in registering the information of age, reproduction and migration (M o r a t et al., 2008). Otoliths are also involved in the ecological studies (C a m p a n a, 2005), stocks assessment (T r a c e y et al., 2006; G o n z a l e z – S a l a s and L e n f a n t, 2007), and determination of the diet of predatory fishes (L i l l i e n d a h l and S o l m u n d s s o n, 2006).

The demonstration of the significant positive relationship between otolith size and fish size could goes back seventy years ago when T r o u r (1954) and T e m p l e m a n n and S q u i r e s (1956) who attempted to study this relationship in the cod species *Borreogadus saida* and haddock *Melanogrammus aeglefinus*.

For most species, the relationship between otolith dimensions and fish length can be described by a simple linear regression. Otolith weight also has been correlated with fish length (H u n t, 1979; L y c h a k o v e t al., 2006).

Studies regarding otolith dimensions and fish weight-length relationships have not been conducted for Omani fishes. Thus, this information is needed not only to provide baseline biological information for many important species, but to be able to carry out diverse studies, for example, to analyse the diet of piscivores in the region, to determine which fishery resources were used by early Omani and to provide information to reconstruct ancient marine environments. The objective of this work at hand is to study the relationships between fish length and otolith measurements for the Indian mackerel in the waters of the Sultanate of Oman. Moreover, this study will hopefully mark the birth of a guide to the identification of Omani fish otoliths.

MATERIALS AND METHODS

Fish specimens were collected during the period March-May 2008 from the coastal waters of Muscat City at the Sea of Oman. A single population of *R. kanagurta* was used in the analysis presented in this study. All specimens were identified, and then total length (TL; most anterior point to the posteriot tip of caudal fin) and fork length (FL; most anterior point to the inflection point between the upper and lower lobes of caudal fin) were measured to the nearest millimetre. Sagittae were (total of 46 individuals, *i.e.*, 92 otoliths) removed through a cut in the cranium to expose them and then cleaned and stored dry in glass vials and the left and right otolith were considered separately. Sagittae specimens were collected from different fish length groups and triplicate specimens from each length group were collected to ensure that the obtained sample is more representative and the estimated parameters are more robust. Specimens with obvious evidence of calcite crystallization (S t r o n g et al., 1986) or other aberrant formations were rejected. Each sagittae, systematically placed with the sulcus acusticus oriented through the observer and its length was determined using hand-held vernier callipers and defined as the longest dimension between the rostrum and postrostrum axis (nomenclature of S m a l e et al., 1995) and width as the dimensions from the dorsal to ventral edge taken at right angles to the length through the focus of the otolith. Individual otolith weight (in milligram) was determined using an electronic balance. The relationship between otolith length, width, weight and fish lengths (TL and FL) were determined using least squares regression analysis.

RESULTS

The range of the total and fork lengths of the specimens used in this study is 238-315 mm and 211-283 mm respectively with a mean of 283.5 and 257.8 mm respectively. The fish lengths available for the species in question were those observed in commercial fisheries and research surveys but the extremes of length ranges were undersampled.

Regression of the difference between left and right otolith on fish total length indicated slopes did not differ significantly from zero ($P > 0.05$) with a correlation of 0.023, 0.002 and 0.001 for length, width and weight respectively. Similarly, the correlations obtained for the regression of the difference between left and right otolith on fork length were not significantly different from zero ($P > 0.05$) The correlation values were 0.026, 0.002 and 0.003 for otolith length, width and weight respectively. Results of regression analysis are given in Table 1.

Table 1. Results of regression analysis of the difference between left and right otolith dimension of fish total and fork lengths of Rastrelliger kanagurta*. Significance level was set at 5%.*

Tablica 1. Rezultati analize regresije razlike između lijeve i desne dimenzije otolita ukupne i vilica dužine kod Rastrelliger kanagurta

Parameter	Intercept	Slope	Correlation	Significance
Total length – ukupna dužina				
Otolith Length-dužina	284.14	18.895	0.023	P>0.5
Otolith Width-širina	283.72	11.557	0.002	P>0.5
Otolith Weight-masa	283.46	140.05	0.001	P>0.5
Fork Length – vilica dužina				
Otolith Length-dužina	258.41	19.236	0.026	P>0.5
Otolith Width-širina	257.72	3.319	0.002	P>0.5
Otolith Weight-masa	257.88	208.86	0.003	P>0.5

The range in observed values for otolith length, width, and weight of the species in question are 4.41-6.01mm, 1.63-2.39nn, and 0.001-1.008g respectively.

A linear regression model was used to determine the relationship between the fish total and fork lengths and the three otolith dimensions used in the present study. Results of regression analyses are given in Table 2.

Table 2. Results of the regression analysis of fish total and fork lengths on otolith dimension of Rastrelliger kanagurta*. Significance level was set at 5%.*

Tablica 2. Rezultati analize regresije otolita ukupne i vilica dužine kod Rastrelliger kanagurta

Parameter	Intercept	Slope	Correlation	Significance
Total length-ukupna dužina				
Otolith length-dužina	108.02	32.945	0.449	P<0.5
Otolith width-širina	105.87	89.673	0.539	P<0.5
Otolith weight-masa	209.08	8383.2	0.697	P<0.5
Fork length-vilica dužina				
Otolith length-dužina	102.75	29.103	0.395	P<0.5
Otolith width-širina	90.905	84.235	0.536	P<0.5
Otolith weight-masa	192.22	7383.3	0.609	P<0.5

Plots of the relationships between otolith dimensions and fish total and fork lengths are given in Figures 1-6.

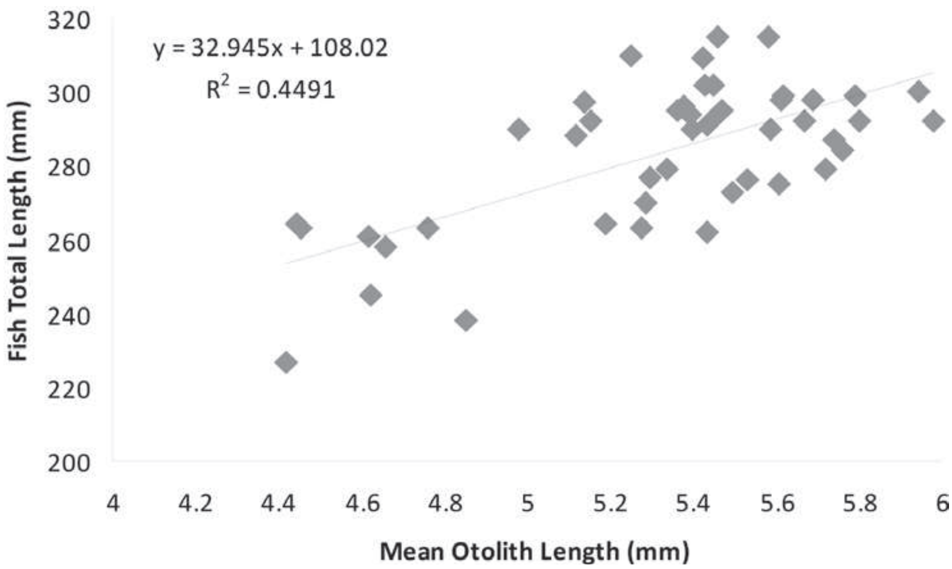

Fig.1. Total length-mean otolith length relationship in Rastrelliger kanagurta

Slika 1. Odnos između ukupne dužine i srednje vrijednosti dužine otolita kod Rastrelliger kanagurta

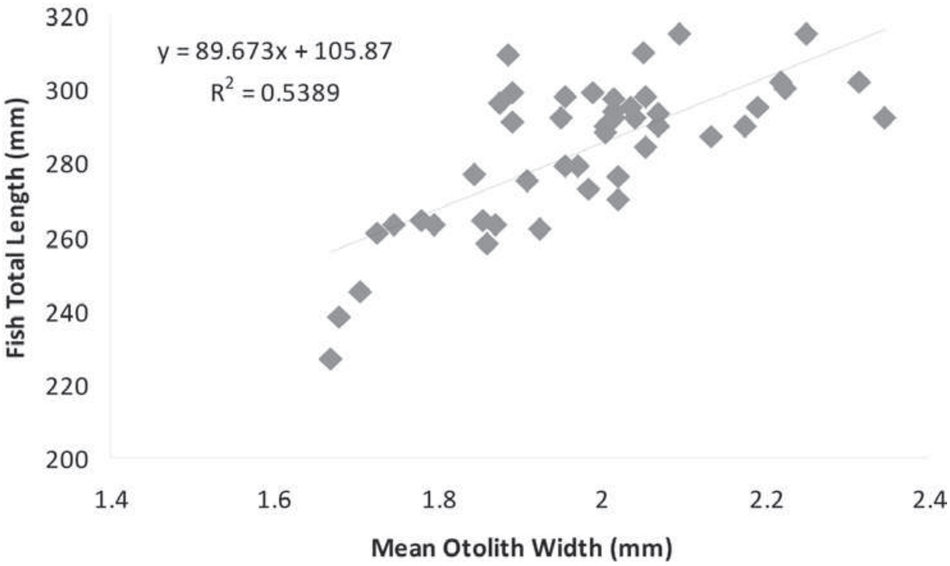

Fig. 2. Fish total length-mean otolith width relationship in Rastrelliger kanagurta

Slika 2. Odnos između ukupne dužine riba i srednje vrijednosti širine otolita kod Rastrelliger kanagurta

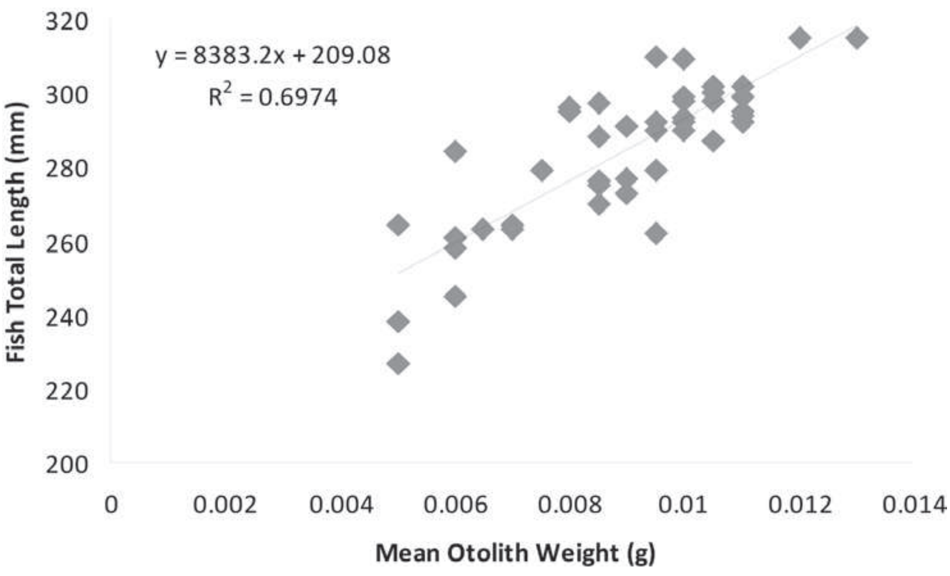

Fig. 3. Fish total length-mean otolith weight relationship in Rastrelliger kanagurta

Slika 3. Odnos između ukupne dužine riba i srednje vrijednosti težine otolita kod Rastrelliger kanagurta

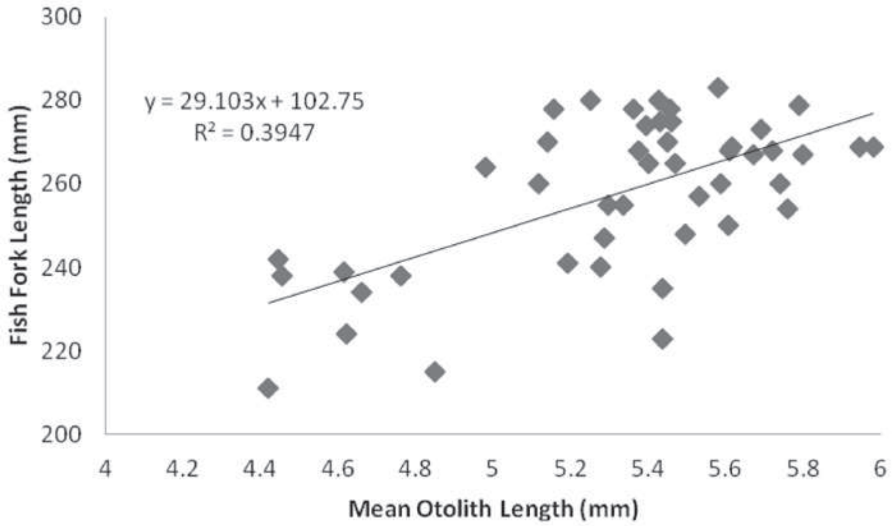

Fig. 4. Fish fork length-mean otolith length in Rastrelliger kanagurta

Slika 4. Odnos između vilica dužine riba i srednje vrijednosti dužine otolita kod Rastrelliger kanagurta

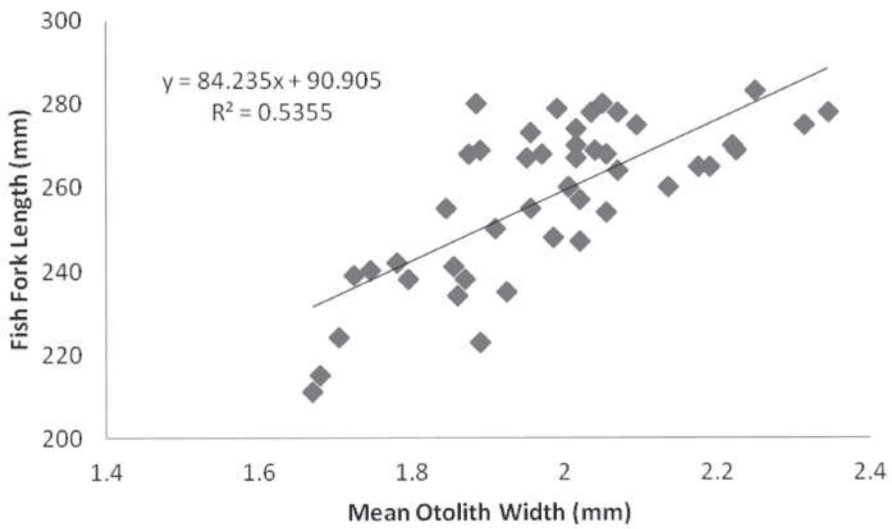

Fig. 5. Fish fork length-mean otolith length relationship in Rastrelliger kanagurta

Slika 5. Odnos između vilica dužine riba i srednje vrijednosti dužine otolita kod Rastrelliger kanagurta

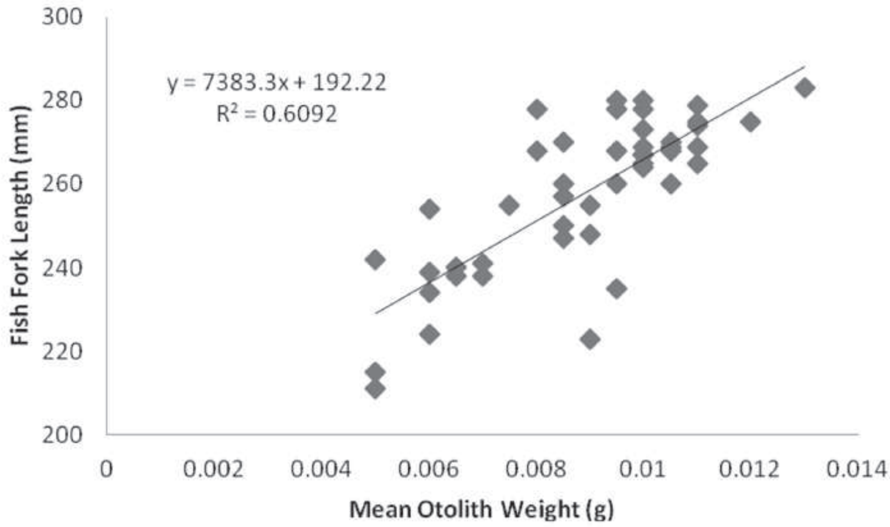

Fig. 6. Fish fork length-mean otolith weight relationship in Rastrelliger kanagurta

Slika 6. Odnos između vilica dužine riba i srednje vrijednosti težine otolita kod Rastrelliger kanagurta

DISCUSSION

P a x t o n (2000) recognised an arbitrarily otolith size range. In this range, he suggested that members of the suborder Scombroidei have generally small otolith 0.08-3.27 % SL. The result of the present study showed that the otolith of *Rastrelliger kanagurta* has a range of 1.9-2.1 % SL which falls near the bottom lower limit of the small otolith category of P a x t o n (2000). The members of the suborder Scombroidei are epipelagic fishes (F r o e s e and P a u l y, 2010). P o p p e r et al. (1988) suggested that the small to very small otolith is might be due to low signal to noise that limits signal detection and rough seas in surface waters may generate so much background noise that acute hearing is impossible. On the other hand, P a x t o n (2000) came to a conclusion that rough seas may cause heavy otoliths to move too much in the sacculus. He also concluded that acute colour vision in well-lit surface waters (many epipelagic fishes have large eyes) may be so important that the disadvantages of the ratio of the low signal to noise and the too much movement in the sacculus are more important than acute hearing in calm water.

Results indicated that otolith linear dimensions and weight were related to fish length by linear regression model and the increases in linear dimensions and weight appeared to keep pace with increases in fish length. These results agree with those of H u n t (1979) on several species collected from Northwest Atlantic Ocean and several other authors (H a r v e y et al., 2000; M o r a t et al., 2008). This linear relationship will continue until the fish reaches maximum size; thereafter the otolith increases only in thickness A y d i n et al. (2004). This linear correlation between body length and otolith dimensions is stronger in younger individuals than that of the older fish. However, the level of this correlation also depends on some other factors such as feeding and habitat conditions (B e a m i s h and M c F a r l e n, 1987; G e l d i a y and B a l i k, 1996).

The lack of significant difference between the left and right otolith is consistent with the observation that the otolith pair are mirror images of each other (H u n t, 1979).

A relationship between otolith dimension and fish length has been used in identifying prey size from stomach content samples (R o s s, 2005). H a r k o n e n (1986) discusses some of the problems associated with this technique. Unlike other authors (H u n t, 1979), results of this study suggested that otolith dimensions and weight are considered the most appropriate for this task. However, given that both otolith weight and linear dimensions were strongly correlated with the fish length, it may be more appropriate to select only one for prediction of fish length. For fish total length and fork lengths and of the two, otolith weight and width are the preferred choice because precision of the estimate is higher than that for otolith length.

R o s s (2005) has stated some sources of error in the estimation of fish size from otolith size and suggested they should be recognized. The linear otolith-length to fish-length relation may depend on the growth rate in some species (M u g i y a and T a n a k a, 1992; S e c o r and D e a n, 1989) or become curvilinear in some larval or juvenile fishes (W e s t and L a r k i n, 1987). Alternatively, the linear relation may change at intervals relative to fish size (F r o s t and L o w r y, 1981) or ontogenetic stage (H a r e and C o w e n, 1995) in some species. Thus, extrapolation may lead to significant error in the estimation of fish size, although most of these error sources were identified from larval or early juvenile fishes. Erosion of the otolith recovered from feces or regurgitated digestive pellets might add additional biases to the process of fish length estimation (R o s s and J o h o n s o n, 2000).

Fish size-otolith size relationships will be useful for researchers examining food habits of piscivores and size of fish in archaeological samples. Many more species and sizes of fish should be sampled to cover the full ranges of fishes involved in these studies.

Sažetak

ODNOSI IZMEĐU DUŽINA RIBE I DUŽINA, ŠIRINA I MASE OTOLITA INDIJSKE SKUŠE *Rastrelliger kanagurta* (CUVIER, 1817) IZ OMANSKOG MORA

L.A Jawad[1*], A. Ambuali[2], J.M. Al-Mamry[1], H.K.Al-Busaidi

U ovom radu utvrđeni su linearni odnosi između veličine otolita i veličine ribe (totalne dužine i dužine vilice) za vrstu koštunjača, *Rastrelliger kanagurta* (Cuvier, 1817) prikupljenu iz okoline grada Muscata u Omanskom moru. Morfometrijska istraživanja otolita, koja su uključivala dužinu, težinu i širinu, korelirana su s ukupnom dužinom i dužinom vilice ribe. Regresijski modeli koji se odnose na svaki morfometrijski parametar otolita napravljeni su na dvije dužine ribe. Ispitan je značaj svakog parametra za procjenu dužine ribe. Dužina, širina i masa otolita pokazali su se kao najbolje sredstvo za procjenu ukupne dužine i dužine vilice ribe, kao i najlakši parametar za mjerenje.

Ključne riječi: dimenzije otolita, dužina ribe, *Rastrelliger,* Omansko more, Sultanat Oman

ACKNOWLEDGEMENTS

Our sincere thank goes to the Ministry of Fisheries Wealth, Marine Science and Fisheries Centre and the directorate of Agriculture and Fisheries Developmental Fund for giving us the opportunity to work on the fish samples within the qualitative and quantitative distribution of marine organisms in Sultanate of Oman and to provide the appropriate financial support.

REFERENCES

Al-Abdessalaam, T. Z. S. (1995): Marine species of Sultanate of Oman. Marine Science and Fisheries Centre, Ministry of Fisheries Wealth, Oman, Sultanate of Oman, 412pp.

Aydin, R., Calta, M., Coban, M. (2004): Relationships between fish lengths and otolith length in the population of *Chondrostoma regium* (Heckel, 1843) inhabting Keban Dam Lake. Pakistan J. Boil. Sci., 7, 1550-1553.

1 Marine Science and Fisheries Centre, Ministry of Fisheries Wealth, P.O. Box 427, Postal Code 100, Muscat, Sultanate of Oman;

2 Department of Marine Science and Fisheries, Sultan Qaboos University, P.O. Box 34, Al-Khud, Sultanate of Oman.

* Corresponding author: laith_jawad@hotmail.com

Beamish, R. J., McFarlen, G. A. (1987): Current trends in age determination methodology. In: Age and growth of fish (Summerfelt, R. C. and Hall, G. E., Eds.), Iowa State University Press, 15-42.

Campana, S. (2005): Otolith science entering the 21st century. Marine and Freshwater Res., 56, 485-495.

Froese, R., D. Pauly. (Editors) (2010): World Wide Web electronic publication. www.fishbase.org, version, (07/2010).

Frost, K. J., Lowry, L. F. (1981): Trophic importance of some marine gaddids in northern Alaska and their body-otolith size relationships. Fish. Bull., 79, 187-192.

Geldiay, R., Balik, S. (1996): Freshwater fishes of Turkey (in Turkish). 2nd Edition, University of Aegean Sea, Faculty of Fisheries Press, Bornova-Izmir, Turkey, pp, 519.

Gonzales-Salas, C., Lenfant, P. (2007): Interannual variation and intraannual stability of the otolith shape in European anchovy *Engraulis encrasicholus* (L.) in the Bay of Biscay. J. Fish Biol., 70, 35-49.

Hare, J. A., Cowen, R. K. (1995): Effects of age, growth rate, and ontogeny on the otolith size-fish size relationships in bluefish, *Pomatomus saltatrix*, and the implications for the back-calculation of size in early life-history stages. Canad. J. Fish. Aquat. Sci., 52, 1909-1922.

Harkonen, T. (1986): Guide to the otoliths of the bony fishes of the Northeast Atlantic. Danbiu Aps. Biological Consultants. Henningsens Alle 58, DK-2900, Hellerup, Denmark, ISBN 87-982290-2-8.

Harvey, J. T., Loughlin, T. R., Perez, M. A., Oxman, D. S. (2000): Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean. NOAA Technical Report NMFS 150, US Department of Commerce, Seattle, WA, 38 pp.

Hunt, J. J. (1979): Back-calculation of length at age from otoliths for silver hake of the Scotia Shelf. ICNAF Sel Papers, 5, 11-17.

Lilliendahl, K., Solmundsson, J. (2006): Feeding ecology of sympatric European shags *Phalacrocorax artistotelis* and great cormorants *P. carbo* in Iceland. Mar. Biol., 149, 979-990.

Lychakov, D. V., Rebane, Y.T., Lombarte, A., Fuiman, L. A., Takabayashi, A. (2006): Fish otolith asymmetry: morphometry and modelling. Hearing Res., 219, 1-11.

Ministry of Fisheries Wealth (2010): Fishery Statistics Book 2009. Fisheries Statistics and Information Department, Ministry of Fisheries Wealth, Muscat, Oman, 209pp.

Morat, F., Banaru, D., Merigot, B., Batjakeas, I., Betoulle, S ., Vignon, M., Lecomte-Finiger, R., Letoutneur, Y. (2008): Relationships between fish length and otolith length for nine teleost species from the Mediterranean basin, Kerguelen Islands, and Pacific Ocean. Cybium , 32, 265-269.

Mugiya, Y., Tanaka, S. (1992): Otolith development, increment formation, and an uncoupling of otolith to somatic growth rates in larval and juvenile goldfish. Jap. Soc. Sci. Fish., 58, 845-851.

Paxton, J. R. (1998): Squirrelfishes and their allies. In: Encyclopedia of fishes, 2nd edition (eds. J. R. Paxton and W. N. Eschmeyer), 160-164, San Diego, CA, Academic Press.

Paxton, J. R. (2000): Fish otoliths: do sizes correlate with taxonomic group, habitat and/or luminescence? Phil. Trans. Roy. Soc. Lond., B 355, 1299-1303.

Popper, A. N., Coombe, S. (1982): The morphology and evolution of the ear in Actinopterygian fishes. Amer. Zool., 22, 311-328.

Popper, A. N., Rogers, P.H., Saidel, W.M., Sox, M. (1988): Role of the fish ear in sound processing. In: Sensory biology of aquatic animals (ed. J. Atema, R.R. Fay, A.N. Popper & W.N. Tavolga), 687-710, New York, Springer.

Ross, R. M. (2005): Use of fish-otolith-length regressions to infer size of double-crested cormorant prey fish from recovered otoliths in Lake Ontario. Northeastern Nat., 12, 133-140.

Ross, R. M., Johonson, J. H. (2000): Error and bias in otolith-based estimates of prey fish size caused by digestion in cormorants (Astract). DCCO- Fisheries Conflict in North America: a Workshop for Scientific Discourse on DCC-Fisheries Conflicts, November 1, 2000, Plymouth, MA, USA.

Secor, D. H., Dean, J. M. (1989): Somatic growth effects on the otolith-fish size relationship in young pond-reared striped bass, *Morone saxatilis*. Canadian J. Fish. Aquat. Sci., 46, 113-121.

Smale, M. J., Warson, G., Hecht, T. (1995): Otolith atlas of Southern African marine fishes. Monograph 1. Grahamstown, South Africa, Smith Institute of Ichthyology.

Strong, M. B., Neilson, J., Hunt, J. (1986): Aberrant crystallization of pollock otoliths. Canad. J. Fish. Aquat. Sci., 43, 1457-1463.

Templemann, W., Squires, H J. (1956): Relationship of otolith lengths and weights in the haddock, *Melanogrammus aeglefinus* (L.), to the growth of the fish. J. Fish Res. Bord.Cand., 13, 467-487.

Tracey, S. R., Lyle, J. M., Duhamel, G. (2006): Application of elliptical Fourier analysis of otolith form as a tool for stock identification. Fish. Res., 77, 138-147.

Trour, G. C. (1954): Otolith growth of the Barents Sea cod. P-V. Reun. Cons. Int. Explor. Mer., 150, 297-299.

West, C. J., Larkin, P. A (1987): Evidence of size-selective mortality of juvenile sockeye salmon (*Oncorhynchus nerka*) in Babine Lake, British Columbia. Canad. J. Fish. Aquat. Sci., 44, 712-721.

Received: 16. 12. 2011.
Accepted: 29. 6. 2011.