OTOLITH SIZE—FISH SIZE RELATIONS IN THE JEWEL LANTERNFISH *LAMPANYCTUS CROCODILUS* (ACTINOPTERYGII: MYCTOPHIFORMES: MYCTOPHIDAE), FROM DEEPWATER ENVIRONMENT OF THE SOUTHERN AEGEAN SEA

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Abstract. Otoliths are widely used in stomach content analysis because they are one of the last species-specific features to be digested by piscivorous predators and they may be used as an important tool for prey classification. The linear regressions between otolith size (length and height), otolith weight versus fish length and weight of the benthopelagic species, *Lampanyctus crocodilus* (Risso, 1810), living in the Sigacik Bay were provided. The specimens were collected during the period of July–September 2007 throughout the southern Aegean Sea, using bottom trawls. There were no differences detected between the size and weight of left and right otolith. A single linear regression was applied to measurements of both the otolith and the fish (length and weight). All calculated regressions showed a high coefficient of determinations ranging between 0.842 and 0.965. Analyzing the morphometric relations, I concluded that otolith sizes and weight are good indicators of the standard length and weight of *L. crocodilus*. The aim of this study was to examine the otolith and fish size relation of the jewel lanternfish in the Aegean Sea in order to provide a reliable tool—for researchers studying food habits of top predators—to determine the size and weight of prey fish from the length or weight of the otoliths recovered.

Keywords: myctophid, fish food item, prey size estimation, sagittae, Sigacik Bay. Turkey

Otoliths are small opaque structures composed of calcium carbonate in an organic matrix and they also have vestibular and sound detection function in fishes other than lampreys, sharks, and rays (Campana 2004). Otoliths have distinctive shape, which vary widely among fish families, yet can be highly species-specific (Maisey 1987). Thus, several identification guides and keys have been published for South Africa by Smale et al. (1995), for northeast Atlantic Ocean by Härkönen (1986), for Bering Sea by Morrow (1976), for northwest Atlantic Ocean by Campana (2004), for the western Mediterranean, north and central eastern Atlantic by Tuset et al. (2008), and for fossil fishes by Nolf (1985).

During feeding studies, the identification and quantification of these preys is frequently a difficult task: in most cases specimens are already partially or totally digested and the hard remains in stomachs, intestines, faeces, and faeces are the only diagnostic features that can be considered (Battaglia et al. 2010). In particular, otoliths are quite resistant to the digestion and they may be used as an important tool for prey classification in several dietary studies (Pierce and Boyle 1991, Pierce et al. 1991, Granadeiro and Silva 2000, Battaglia et al. 2010). Furthermore, the diet analysis of marine mammals and sea birds requires non-invasive methods, so the examination of sagittae from faeces and regurgitated digestive pellets is often the only way to recognize the preys (Duffy and Laurenson 1983, Johnstone et al. 1990, Pierce and Boyle 1991, Pierce et al. 1991, Battaglia et al. 2010). Their importance is also documented in stomach analysis of cephalopods that use their beaks to chop preys (Watanabe et al. 2004), making them identifiable only by otolith determination (Battaglia et al. 2010).

The jewel lanternfish, *Lampanyctus crocodilus* (Risso, 1810), is a benthopelagic species and one of the most abundant myctophid fishes found in the Mediterranean Sea and Atlantic Ocean (Hulley 1989). Stefanescu and Cartes (1992) stated that adult specimens of this species live near to the sea bottom. According to Belluscio et al. (2000) and Fanelli et al. (2009), the jewel lanternfish were found in the diet of two demersal elasmobranchs: *Galeus melastomus* Rafinesque, 1810 and *Etmopterus spinax* (Linnaeus, 1758) in the central Tyrrhenian Sea. Valls et al. (2011) noted that *L. crocodilus* was found only from the stomach contents of *G. melastomus* captured in the slope off the Balearic Sea. Jacobsen and Hansen (2001) found *L. crocodilus*

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in the stomach contents of wild Atlantic salmon, *Salmo salar* Linnaeus, 1758, from the Northeast Atlantic. *L. crocodilus* has also been detected in diet of a bird—the critically endangered Balearic shearwater (*Puffinus mauretanicus*)—by using a two-isotope (δ^{15}N and δ^{13}C) mixing model (Navarro et al. 2009). Benthopelagic fish species, such as *L. crocodilus*, living near to the sea floor (Mauchline and Gordon 1991) play an important ecological role in the transfer of energy from the pelagic food web to benthic food webs. Thus, their high biomass is an important food resource in the marine trophic web (Al-Mamry et al. 2010). *Lampanyctus crocodilus* is a discard or by-catch species in trawl landings in Turkey. Although it is not commercially important, its ecological importance is evident by its presence in the diets of several predators. The aim of this study was to provide new data on the morphology and the relations between the otolith size and the fish size (*L. crocodilus*) for the researchers studying on the stomach contents and trophic interactions among marine animals. The fish were collected during the period of July–September 2007 throughout off the Sigacik Bay (southern Aegean Sea) using a conventional bottom trawls with a cod-end mesh size of 24 mm. Species identification was made following Hulley (1989) and Nelson (2006). Myctophids taken with bottom trawls tend to have damaged caudal fins. This meant that standard length was used as a measure of size instead of total length. Fish standard length (SL) was measured to the nearest mm. Fish weight (*W*) was determined to the nearest 0.01 g on a digital balance. Sagittae (Fig. 1) were (total of 228 individuals, i.e., 456 otoliths) removed with forceps through a cut in the cranium. Otoliths were then cleaned with 10% NaOH solution, stored dry in glass vials, and the left and right otolith were considered separately. Each sagitta was placed with the sulcus acusticus oriented upwards and otolith length (OL) was measured [mm] through an eye-piece micrometer under with a stereo zoom microscope (Olympus SZX-16). It was defined as the longest dimension between the rostrum and postrostrum axis (nomenclature of Smale et al. 1995 and Tuset et al. 2008) through the focus of the otolith (Al-Mamry et al. 2010). Otolith height (OH) was measured [mm] as the longest dimension between the ventral and dorsal surfaces of each sagitta. Individual sagittal otolith weight (OW) was determined [mg] using an electronic balance. Firstly, the paired *t*-test was used to check any differences between left and right otolith. When significant differences ($P < 0.05$) were not found, the H_0 hypothesis ($b_{\text{right}} = b_{\text{left}}$) was accepted and a single regression was used for each parameter (OL, OW, and OH). Linear regression equations

$$y = ax + b$$

were fitted to determine what equations (OW–W, OL–OW, SL–OH, OH–W, OW–OH, OL–W, OL–SL, OH–OL, and OW–SL) described various relations between otolith and fish size (Tarkan et al. 2007).

The sagittal otoliths of 228 *Lampanyctus crocodilus* specimens were examined. Table 1 shows the descriptive statistics regarding length and weight of *L. crocodilus* and sagittal otoliths (with otolith width). No significant differences (Student's *t*-test for paired comparisons, $P > 0.05$) were found between left and right otolith length, weight and width data. Therefore, the left sagittae measurements were used for the calculation of equations. Relations between fish and otolith measurements were given in Table 2. All of them yielded high coefficient of determination (r^2) between 0.842 and 0.965.

The most abundant demersal fish species in the eastern Ionian Sea were *Galeus melastomus* Rafinesque, 1810; *Mora moro* (Risso, 1810); and *Lampanyctus crocodilus* in term of density and *Hexanchus griseus* (Bonnaterre, 1788); *M. moro*; and *G. melastomus* in terms of biomass (D'Onghia et al. 2004). *L. crocodilus* were collected by Merella et al. (1997) from bottom trawls in the western Mediterranean within the size range of 9.0–21.0 cm TL. The size range of the species (8.0–14.8 cm TL) has been found in the same area by Morey et al. (2003).

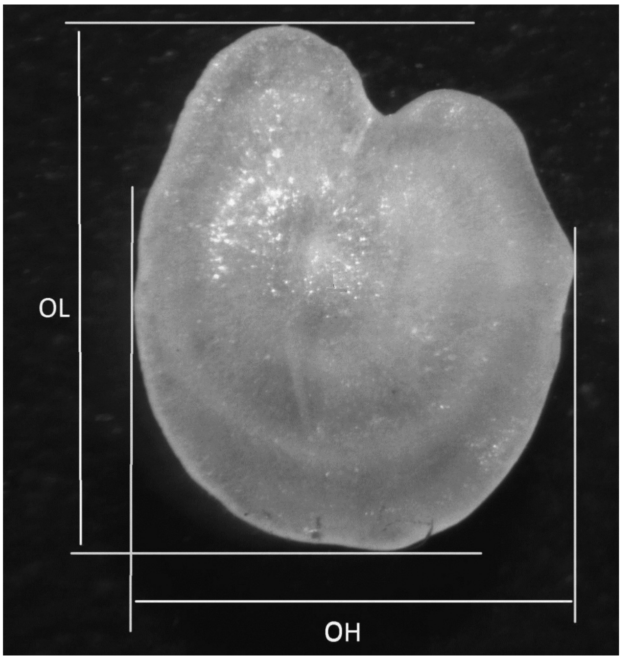

Fig. 1. Sagittal otolith of the jewel lanternfish, *Lampanyctus crocodilus*, sampled from the southern Aegean Sea in 2007; Standard length of the fish = 100 mm, otolith length = 2.3 mm; OL = otolith length, OH = otolith height

Table 1

Principal parameters of *Lampanyctus crocodilus* and their otoliths obtained from the southern Aegean Sea

Parameter	Value	
	Mean ± SD	Range
Standard length [mm]	115.89 ± 22.59	59–173
Total weight [g]	17.13 ± 10.67	1.47–58.21
Otolith length [mm]	2.84 ± 0.56	1.4–4.3
Otolith weight [g]	0.0044 ± 0.0022	0.0012–0.0124
Otolith height [mm]	2.50 ± 0.49	1.3–3.7

Table 2

The linear relations between otolith morphometric parameters and fish size of *Lampanyctus crocodilus* from the southern Aegean Sea

Relation	Regression parameter						r^2
	a			*b*			
	Mean	SE	*P*	Mean	SE	*P*	
SL–OL	38.518	0.708	<0.001	6.941	2.044	0.001	0.929
SL–OH	45.310	0.577	<0.001	2.704	1.470	0.067	0.965
SL–OW	9151.916	249.761	<0.001	75.987	1.229	<0.001	0.856
W–OL	17.346	0.495	<0.001	–31.932	1.428	<0.001	0.844
W–OH	20.364	0.516	<0.001	–33.738	1.313	<0.001	0.873
W–OW	4521.492	78.319	<0.001	–2.583	0.385	<0.001	0.936
OW–OL	0.004	0.0001	<0.001	–0.006	0.0003	<0.001	0.842
OH–OL	0.838	0.015	<0.001	0.128	0.042	0.003	0.935
OW–OH	0.004	0.0001	<0.001	–0.007	0.0003	<0.001	0.872

a = intercept value, *b* = regression slope, r^2 = coefficient of determination, *P* = *P* value, SE = standard error of the mean; SL = standard length (of fish), OL = otolith length, OH = otolith height, OW = sagittal otolith weight, *W* = fish weight.

As Belluscio et al. (2000) indicated, *L. crocodilus* was found in the stomach of two demersal elasmobranchs. Both of these species are also found in the Aegean Sea (Bilecenoglu et al. 2002). Concluding from the above-mentioned information, *L. crocodilus* may be the potential food for *G. melastomus* and *Etmopterus spinax* that share the same demersal habitat in the southern Aegean Sea. Tuset et al. (2008) reported the % ratio relations between fish (110, 136, and 145 mm TL, n = 3) and sagitta sizes but for the total length 100 OL · TL^{-1} = 2.2–2.4 and 100 · (OH · OL^{-1}) = 85.1–93.2). In the presently reported study, these ratios were calculated as 100 OL · SL^{-1} = 2.1–2.8 and 100 · (OH · OL^{-1}) = 65.0–102.3 for the standard length (59–173 mm SL, n = 228). Interval values of length and sample size of this study are larger than those of Tuset et al. (2008) and length measurement type (TL vs. SL) is different. The reported ratios, however, are similar to those found in the presently reported study. This paper supplies additional information about OW–W, OL–OW, SL–OH, OH–W, OW–OH, OL–W, and OW–SL relations for the same species. Fish growth rates may vary among populations (Campana and Casselman 1993). Therefore, the relations found in this study may not describe the otolith growth in other parts of the range. The otolith growth characteristics of *Lampanyctus crocodilus* should be studied separately throughout its distribution.

REFERENCES

Al-Mamry J., Jawad L., Al-Busaidi H., Al-Habsi S., Al-Rasbi S. 2010. Relationships between fish size and otolith size and weight in the bathypelagic species, *Beryx splendens* Lowe, 1834 collected from the Arabian Sea coasts of Oman. Quaderni del Museo di Storia Natturale di Livorno **2010** (23): 79–84. DOI: 10.4457/musmed.2010.23.79

Battaglia P. Malara D., Romeo T., Andaloro F. 2010. Relationships between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina, Italy). Scientia Marina **74** (3): 605–612. DOI: 10.3989/scimar.2010.74n3605

Belluscio A., Scacco U., Colloca F., Carpentiere P., Ardizzone G.D. 2000. Feeding strategies of two species of demersal chondrichthyans, *Galeus melastomus* (Rafinesque, 1810) and *Etmopterus spinax* (Linnaeus, 1758), in the central Tyrrhenian Sea. Biologia Marina Mediterranea **7** (1): 417–426.

Bilecenoglu M., Taskavak E., Mater S., Kaya M. 2002. Checklist of the marine fishes of Turkey. Zootaxa **2002** (113): 1–194.

Campana S.E. 2004. Photographic atlas of fish otoliths of the northwest Atlantic Ocean. Canadian Special Publication of Fisheries and Aquatic Sciences 133. NRC Research Press. Ottawa, ON, Canada.

Campana S.E., Casselman J.M. 1993. Stock discrimination using otolith shape analysis. Canadian Journal of Fisheries and Aquatic Sciences **50** (5): 1062–1083. DOI: 10.1139/f93-123

D'Onghia G., Politou C.-Y., Bozzano A., Lloris D., Rottlant G., Sion L., Mastrototaro F. 2004. Deep-water fish assemblages in the Mediterranean Sea. Scientia Marina **68** (Suppl. 3): 87–99. DOI: 10.3989/scimar.2004.68s387

Duffy D.C., Laurenson L.J.B. 1983. Pellets of cape cormorants as indicators of diet. Condor **85** (3): 305–307.

Fanelli E., Rey J., Torres P., Gil de Sola L. 2009. Feeding habits of blackmouth catshark *Galeus melastomus* Rafinesque, 1810 and velvet belly lantern shark *Etmopterus spinax* (Linnaeus, 1758) in the western Mediterranean. Journal of Applied Ichthyology **25** (Suppl. s1): 83–93. DOI: 10.1111/j.1439-0426.2008.01112.x

Granadeiro J.P., Silva M.A. 2000. The use of otoliths and vertebrae in the identification and size-estimation of fish in predator–prey studies. Cybium **24** (4): 383–393.

Härkönen T. 1986. Guide to the otoliths of the bony fishes of the northeast Atlantic. Danbiu ApS. Biological Consultants, Hellerup, Denmark.

Hulley P.A. 1989. Myctophidae. Pp. 429–483. *In*: Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielsen J., Tortonese E. (eds.) Fishes of the north-eastern Atlantic and the Mediterranean. Vol. 1. UNESCO, Paris, France.

Jacobsen J.A., Hansen L.P. 2001. Feeding habits of wild and escaped farmed Atlantic salmon, *Salmo salar* L., in the Northeast Atlantic. ICES Journal of Marine Science **58** (4): 916–933. DOI: 10.1006/jmsc.2001.1084

Johnstone I.G., Harris M.P., Wanless S., Graves J.A. 1990. The usefulness of pellets for assessing the diet of adult shags *Phalacrocorax aristotelis*. Bird Study **37** (1): 5–11. DOI: 10.1080/00063659009477030

Maisey J.G. 1987. Notes on the structure and phylogeny of vertebrate otoliths. Copeia **1987** (2): 495–499.

Mauchline J., Gordon J.D.M. 1991. Oceanic pelagic prey of benthopelagic fish in the benthic boundary layer of a marginal oceanic region. Marine Ecology Progress Series **74**: 109–115.

Merella P., Quetglas A., Alemany F., Carbonell A. 1997. Length–weight relationships of fishes and cephalopods from the Balearic Islands (western Mediterranean). Naga **20** (3–4): 66–68.

Morey G., Moranta J., Massutí E., Grau A., Linde M., Riera F., Morales-Nin B. 2003. Weight–length relationships of littoral to lower slope fishes from the western Mediterranean. Fisheries Research **62** (1): 89–96. DOI: 10.1016/S0165-7836(02)00250-3

Morrow J.E. 1976. Preliminary keys to otoliths of some adult fishes of the Gulf of Alaska, Bering Sea, and Beaufort Sea. NOAA Technical Reports NMFS Circular 420.

Navarro J., Louzao M., Igual J.M., Oro D., Delgado A., Arcos J.M., Genovart M., Hobson K.A., Forero M.G. 2009. Seasonal changes in the diet of a critically endangered seabird and the importance of trawling discards. Marine Biology **156** (12): 2571–2578. DOI: 10.1007/s00227-009-1281-3

Nelson J.S. 2006. Fishes of the world. 4th edn. Wiley, New York, NY, USA.

Nolf D. 1985. Otolithi piscium. Book series: Handbook of paleoichthyology. Vol. 10. Gustav Fischer Verlag, Stutgart, New York.

Pierce G.J., Boyle P.R. 1991. A review of methods for diet analysis in piscivorous marine mammals. Oceanography and Marine Biology: An Annual Review **29**: 409–486.

Pierce G.J., Boyle P.R., Diack J.S.W. 1991. Identification of fish otoliths and bones in faeces and digestive tracks of seals. Journal of Zoology **224** (2): 320–328. DOI: 10.1111/j.1469-7998.1991.tb04810.x

Smale M.J., Watson G., Hetch T. 1995. Otolith atlas of southern African marine fishes. Ichthyological Monographs No. 1. J.L.B. Smith Institute of Ichthyology, Rhodes University, Grahamstown, South Africa.

Stefanescu C., Cartes J.E. 1992. Benthopelagic habits of adult specimens of *Lampanyctus crocodilus* (Risso, 1810) (Osteichthyes, Myctophidae) in the western Mediterranean deep slope. Scientia Marina **56** (1): 69–74.

Tarkan A.N., Bilge G., Gaygusuz Ö., Tarkan A.S., Gürsoy Ç., Acıpınar H. 2007. On the use of otoliths of a Ponto-Caspian gobiid *Proterorhinus marmoratus* (Pallas, 1814) from lake İznik (Turkey) in prey–predator studies. International Journal of Natural and Engineering Sciences **1** (3): 29–33.

Tuset V.M., Lombarte A., Assis C.A. 2008. Otolith atlas for the western Mediterranean, north and central eastern Atlantic. Scientia Marina **72** (S1): 7–198. DOI: 10.3989/scimar.2008.72s17

Valls M., Quetglas A., Ordines F., Moranta J. 2011. Feeding ecology of demersal elasmobranchs from the shelf and slope off the Balearic Sea (western Mediterranean). Scientia Marina **75** (4): 633–639. DOI: 10.3989/scimar.2011.75n4633

Watanabe H., Kubodera T., Ichii T., Kawahara S. 2004. Feeding habits of neon flying squid *Ommastrephes bartramii* in the transitional region of the central North Pacific. Marine Ecology Progressive Series **266**: 173–184.

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