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Slender snipe eel *Nemichthys scolopaceus* Richardson, 1848 (Pisces: Nemichthydae), a new member of the Adriatic Sea ichthyofauna

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The paper reports the first record of Nemichthys scolopaceus leptocephalus in the Adriatic Sea, including a detailed description of the specimen with morphometric measurements and meristic counts. A single leptocephalus specimen was caught on 18th September 2016 in south Adriatic with a small mid-water trawl at a depth of approx. 120 meters. Further research is needed to reveal more information about the distribution and potential spawning and nursery areas of slender snipe eel as well as the mechanism of retention and dispersion of their larvae in the Adriatic.

Key words: *anguilliform eel; deep-water species; leptocephali; leptocephalus*

INTRODUCTION

Slender snipe eel, *Nemichthys scolopaceus* Richardson, 1848, is a cosmopolitan bathypelagic species, distributed in tropical and temperate seas of the eastern Pacific Ocean (from Alaska to Central Chile), western Atlantic (from Nova Scotia to Brazil) and eastern Atlantic (from Iceland, Skagerrak, and Spain to southern Africa), including the Mediterranean Sea (FROESE & PAULY, 2021). In the western Mediterranean it is found off Algerian and northern Sicilian coasts (RELINI-ORSI & RELINI, 1973), in the Strait of Messina (BERDAR *et al.,* 1977) and southern Sardinian waters (CAU, 1979). Recently *N. scolopaceus* was found in various areas of the eastern Mediterranean Sea, namely the Ionian Sea (MYTILINEOU *et al.,* 2005), Aegean Sea (BILECENOĞLU *et al.,* 2006; FILIZ *et al.,* 2007) and northern Levantine Sea (GÖKOGLU *et al.,* 2009; AYAS & AGILKAYA, 2018; BAYHAN *et al.,* 2020). It should be mentioned that all the recent occurrences of *N. scolopaceus* in the Mediterranean Sea refer almost exclusively to adult individuals. D'ANCONA (1931) mentioned the finding of some leptocephali in the Messina Strait that were later attributed to this species according to the description of morphological and meristic characteristics (GENOVESE, 1954). Since then, we managed to find just one report on the leptocephalus stage of *N. scolopaceaus* which reffered to a single specimen collected in the Mediterranean Sea by GIORDANO *et al.* (2015).

Nemichthys scolopaceus is an oceanic species, which may be encountered in the pelagic zone from surface down to depths of 4000 m (LOVE *et al.,* 2005). Juveniles do not perform vertical migrations and generally occur at depths down to 100 m, but larger specimens (>80

mm) exhibit diurnal migration (CASTONGUAY & McCLEAVE, 1987). According to WIPPELHAUSER *et al*. (1996), small leptocephali (6-15 mm) of *N. scolopaceus* are abundant between February and April, and spawning occurs on both sides of thermal fronts throughout the western subtropical convergence zone of the Sargasso Sea. The maximum known size for adult fish is 130 cm (NIELSEN, 1984).

Until recently, investigation of the deep-sea fish fauna of the eastern Adriatic Sea have not been conducted systematically, and since the deep-sea areas do not represent major fishing grounds, data from the commercial fishery and official statistics are mostly lacking (ISAJLOVIĆ *et al.,* 2009). Therefore, knowledge about the biology and ecology of deep-sea organisms in the eastern Adriatic Sea is very limited (DULČIĆ, 2001; ISAJLOVIĆ *et al.,* 2009; BOJANIĆ VAREZIĆ *et al.,* 2013). Even accidental catches are rare due to inadequate sampling methods, small plankton nets, or unspecialized trawls (BOJANIĆ VAREZIĆ *et al.,* 2013). Furthermore, except for the paper by ANIBALDI *et al.* (2016) which describes leptocephali assemblages in Italian waters of central and southern Adriatic and MANDIĆ *et al.* (2021) which brings morphometric characteristics of Congridae family from southern Adriatic, no published data on similar leptocephali investigation appear in the literature, especially for Croatian waters, although many ichthyoplankton surveys have been carried out in that area, beginning with the THOR expedition (1908–1910).

So, up to date no record of any of the life stages of *N. scolopaceus* was properly documented for the Adriatic Sea (JARDAS, 1996; LIPEJ & DULČIĆ, 2010; DULČIĆ & KOVAČIĆ, 2020). The occurrence of a single specimen reported by UNGARO *et al.* (1999) in Albanian waters deserves to be mentioned, but this specimen was not properly documented, and can be considered questionable.

The aim of this paper is to report the first Adriatic finding of slender snipe eel *N. scolopaceus* Richardson, 1848 leptocephalus collected in the open waters of southern Adriatic Sea.

MATERIAL AND METHODS

A single *N. scolopaceus* leptocephalus was accidentally caught during the echo-survey on small pelagic fish (MEDIAS project) at a station located at 42.504 N, 18.122 E in the open waters in front of Dubrovnik (southern Adriatic). The sample was obtained at depths from 110 to 125 m by a small midwater trawl net with a 8 mm mesh cod end, on 18th September 2016. Wireless probes (NETMIND Trawl Monitor System, Crimond Enterprises Ltd., Dartmouth, Nova Scotia) were used to monitor the trawl location in terms of the vertical range of the net and the depth at which the net was towed. Immediately after collection, the leptocephalus was fixed in neutralized formaldehyde (4% final concentration) and subsequently transferred for preservation to absolute ethanol. The total length of leptocephalus was not adjusted according to a formaldehyde shrinkage regression equation (MILLER *et al.,* 2002) due to short time that specimen was kept in formaldehyde and in order to avoid errors in measuring other morphological characteristics and their ratios. The specimen is deposited in the Institute of Oceanography and Fisheries in Split, Croatia under the catalogue number Nemscol2016. In order to examine morphological features of the specimen such as pigmentation, morphometric and meristic characters, an Olympus stereomicroscope equipped with an ocular micrometer was used. Species was identified according to SMITH (1989), CHARTER (1996) and FAHAY (2007).

RESULTS AND DISCUSSION

The examined leptocephalus specimen was in a relatively poor condition mainly due to mechanical damage caused by the fishing gear and the specimen itself being very fragile. However, enough morphological characters were preserved for positive identification of the specimen as *N. scolopaceus* (Fig. 1). Namely, the total number of myomeres (TNM) of examined leptocephalus was 327 of which 245 predorsal ones (PDM) which is in agreement with the data reported by FAHAY (2007) and CHARTER (1996) for

Fig. 1. Nemichthys scolopaceus leptocephalus *(TL=190 mm). Scale bar is approximate*

N. scolopaceus. Such a large number of myomeres is typical for this species. The obtained morphometric values are given in Table 1. Unfortunately due to the specimens' poor state, the position of the anal opening couldn't be determined.

The total length of examined leptocephalus was 190 mm, its body was laterally compressed, extremely long and transparent with caudal fin tapering to a filament (Fig. 1). The gut was long and tubular positioned along the ventral margin of the body. Snout was pointed and prolonged, although head was still relatively short compared with rather long body (HL/TL=0.028). Large eyes were rounded, having a diameter of 1.1 mm (Fig. 2). Teeth in both jaws were forward pointing, relatively long and sharp. We managed to count 17 teeth in the upper and 21 in the lower jaw although it should be considered with caution due to damaged jaws, especially in the posterior part of the upper jaw which is reflected in the odd and lower number of teeth, even though the teeth were symmetrical, one side mirroring the other. Posterior teeth of the lower jaw were significantly smaller than those in the front while posterior teeth in the upper jaw could not be seen due to mentioned damage. The number of teeth is different than those reported by APPELBAUM & RIEHL (1993) probably due to the damage, but maybe also due to the variability of this feature.

Pectoral fins were very small, while dorsal, caudal and anal fins were joined/confluent.

Fig. 2. *Nemichthys scolopaceus* head with upper and lower jaws.

Black pigmentation was visible as a row of melanophores along the spine on the anterior part of the body which was much better preserved than the posterior part of the body.

Considering morphometric and meristic characters, the leptocephalus specimen was in the premetamorphic stage. *N. scolopaceus* is the largest commonly known leptocephali and, according to CASTLE (1959), can reach in extreme cases about 253 mm before metamorphosing into the young eel, but even longer leptocephali of 349 and 438 mm were recently reported from the Sargasso Sea (MILLER *et al.,* 2013).

The slender snipe eel belongs to a group of offshore pelagic species that can be found worldwide because the relative homogeneity of the deep oceans gives them access to a much larger area of suitable habitat (DALE *et al.,* 2019).

Table 1. Values of morphometric characteristics of Nemichthys scolopaceus leptocephalus

Parameter	(mm)	Parameter	(mm)	Parameter	
Total length	190	Head length	5.3	Body depth/total length (%)	3.2
Pre-orbital distance	3.1	Depth just before eye	2.4	Head/total length (%)	2.8
Eye diameter	1.1				
		Max body depth	6	Predorsal distance (mm)	162
Post-orbital distance	4.2	Pectoral fin length	0.6	Predorsal/total length (%)	85.3

Nevertheless, this species is rarely collected in the Mediterranean Sea (FOLLESA *et al.*, 2011). It is perhaps more common in the Adriatic Sea than the data suggests, mainly due to insufficient exploration of deep Adriatic area and due to not so intensive commercial fishery in the area. Also, the adults are difficult to collect in their deep-sea benthic habitats and their leptocephali are prone to escape through the mesh of the trawls (MILLER *et al.,* 2013). During many years of ichthyological research in the eastern Adriatic waters, a large number of leptocephali were accidentally caught with a midwater trawls. However, most of the caught individuals belong to three species of Congridae family, namely *Conger conger, Ariosoma balearicum* and *Gnatophys mystax* (BOJANIĆ VAREZIĆ *et al.,* 2013; MANDIĆ *et al.,* 2021). In the first assessment of eel diversity and abundance in the Italian waters of the southern Adriatic Sea (ANIBALDI *et al.,* 2016) no *N. scolopaceus* specimens were found, so the current finding can be considered the first confirmed record of this species in the Adriatic Sea. Also, this finding constitutes an extension of the previously known distribution of *N. scolopaceus,* which in the last decade has extended from the western Mediterranean to Ionian Sea (MYTILINEOU *et al.,* 2005), Aegean Sea (BILECENOĞLU *et al*., 2006; FILIZ *et al.,* 2007) and northern Levantine Sea (GÖKOGLU *et al.,* 2009; AYAS & AGILKAYA, 2018; BAYHAN *et al.,* 2020). Besides the records of adult individuals in the Mediterranean Sea, up to now there was only one record of *N. scolopaceus* leptocephalus, namely a 160 mm long specimen from the Southern Tyrrhenian Sea (GIORDANO *et al.,* 2015). Considering the circulation regime of Ionian and Adriatic Sea (CIVITARESE *et al.,* 2010) and the fact that leptocephali occupy the upper 200 m of the water column before descending to metamorphose (WIPPELHAUSER *et al.,* 1996), the assumption would be that the present specimen was transported with surface currents from the neighbouring Mediterranean areas into the Adriatic Sea. However, the origin of the specimen i.e. the spawning site, is unknown, but an interesting and not so unlikely hypothesis that the leptocephali could originate from the Sargasso sea should not be dismissed (MILLER *et al,* 1994; 2013; WIPPELHAUSER *et al.,* 1996; RICHARDSON & COWEN, 2004). Such possibility certainly has support if we consider the case of eel *Anguilla anguilla*, a species which spawns in the Sargasso Sea and through larval dispersal reaches Mediterranean and the Adriatic Sea where they live through adulthood and subsequently undertake their final trip back to Sargasso Sea to spawn (AMILHAT *et al.,* 2016; KANJUH *et al.,* 2018).

The presence of leptocephali in some area does not necessarily indicate the presence of adults in the area, as dispersal of larvae can result in their presence far from spawning sites (RICHARDSON & COWEN, 2004). The exact spawning areas of marine eels are generally not known due to difficulty in observing spawning eels, but for some species spawning areas are determined by the catches of small leptocephali (MILLER, 2009). Most species may typically spawn within or near their habitats of adults, with the exception of anguillids that undertake extensive migrations. That process of dispersal of the planktonic larval stages, which occurs between hatching and settling in juvenile habitats, is influenced by numerous factors. Besides oceanographic processes and sea currents, the locations of spawning, duration of pelagic larval phase and swimming ability of leptocephali play important role (DALE *et al.,* 2019). Owing to their large sizes and long larval duration (from few months to 3 years), leptocephali are able to drift for long distances (MILLER *et al.,* 2006; BONHOMMEAU *et al.,* 2010) using both, passive dispersal and active swimming (TSUKAMOTO *et al.,* 2009). Knowing all of the above is important in clarifying the presence of *N. scolopaceus*, but also other leptocephali in the Mediterranean and the Adriatic Sea. Anguillid eels and the mesopelagic eels of the Nemichthyidae and Serrivomeridae are closest relatives (INOUE *et al.,* 2010), with many similarities, such as spawning areas and dispersal strategies of their leptocephali. Nemichthydae leptocephali are abundant in some offshore areas during spawning period and then they become widely distributed during their larval development (MILLER *et al.,* 2006). Also, leptocephali with longer predorsal lengths (in this case 83.5%) and snout-to-anus lengths may

improve swimming ability and undertake larger movements as previously assumed (DALE et al., 2019), which support the thesis that *N. scolopaceus* leptocephali exhibit large migrations similar to anguillids. There is also a possibility that more frequent findings of marine eels in the Mediterranean are related to climate change as leptocephali are more commonly associated with warm water environments (MILLER, 2009). Whatsoever, much more research is needed on this species to explain whether the origin of Mediterranean and Adriatic *N. scolopaceus* is in the Sargasso Sea or there is another nearby spawning site and what are the processes and factors that enhance their larval dispersion.

CONCLUSIONS

Marine eels include around 800 species of mostly predatory reef fishes distributed in tropical and temperate seas. However, there is little information on their biology and ecology because adults usually prefer habitats that allow concealment, and their occasionally aggressive behaviour makes them difficult to observe and collect (SMITH, 1989; MILLER, 2009). Recent findings of leptocephali in the Adriatic Sea (BOJANIĆ VAREZIĆ *et al.,* 2014; ANIBALDI *et al.,* 2016; MANDIĆ *et al.,* 2021), together with this first record of *N. scolopaceus*, provide valuable insight into the status of eel populations in the area, as studies of leptocephali are often one of the best ways to learn about the reproductive ecology and life history of eels (MILLER *et al*., 2002). Further systematic studies are certainly needed, as any finding of a juvenile or adult specimen of this species, and of marine eels in general, would fill the gap in our knowledge of spawning areas, nurseries, and larval dispersal mechanisms as key processes in recruitment and survival of early developmental stages.

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Kljunasta končarica *Nemichthys scolopaceus* Richardson, 1848 (Pisces: Nemichthydae), novi pripadnik ihtiofaune Jadranskog mora

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SAŽETAK

U radu je prikazan prvi nalaz vrste kljunasta končarica *Nemichthys scolopaceus,* ulovljen 18. rujna 2016. godine u južnom Jadranu pelagičkom kočom na dubini od cca. 120 metara. Nalaz se odnosi na ličinku leptocefala te uključuje detaljan opis jedinke s morfometrijskim i meurističkim osobinama. Svakako su potrebna daljnja istraživanja kako bi se otkrilo više o rasprostranjenosti i potencijalnim područjima mrijesta i hraništima ove vrste, kao i o mehanizmu raspršivanja i zadržavanja njihovih ličinki u Jadranu.

Ključne riječi: anguilliform jegulja; dubokovodne vrste; leptocephali; leptocephalus