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IN MEMORIAM

SREDOZEMSKI MORSKI PSI

SQUALI MEDITERRANEI

MEDITERRANEAN SHARKS

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A REVIEW OF SHARK RESEARCH IN TURKISH WATERS

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ABSTRACT

Until the last quarter of the 20th century, most of our knowledge on the sharks of the Turkish waters was based on elasmobranch-specific chapters in general ichthyological inventory studies and on a limited number of anecdotal studies. Since the mid-1990s, however, there has been a remarkable rise in the number and quality of shark-specific studies and publications, resulting in a gradual filling of the gaps in our understanding of the sharks of the Turkish waters. Based on the publication dates, there were only 2 shark-specific articles published before 1990, 8 scientific articles about the sharks of the Turkish waters between 1990 and 2000, and as many as 88 papers dealing with several aspects of the sharks of Turkey since, for a total of 96 articles on the sharks of the Turkish waters published between 1968 and 2018. Hopefully, future studies by new generations of researchers will provide new data on several aspects of the sharks of the Turkish waters, which can deepen our understanding of them and complete their life stories.

Key words: shark research, publications, Turkish waters, eastern Mediterranean

REVISIONE DELLA RICERCA SUGLI SQUALI IN ACQUE DELLA TURCHIA

SINTESI

Fino all'ultimo quarto del XX secolo, la maggior parte delle nostre conoscenze sugli squali delle acque della Turchia si basava su capitoli specifici dedicati agli elasmobranchi pubblicati in studi generali di inventario ittologico e su un numero limitato di studi aneddotici. Dalla metà degli anni 90, tuttavia, c'è stato un notevole aumento del numero e della qualità degli studi e delle pubblicazioni specifici sugli squali, con un risultante riempimento graduale delle lacune nella comprensione degli squali delle acque turche. Sulla base delle date di pubblicazione, l'autore riscontra che solo due articoli specifici sugli squali sono stati pubblicati prima del 1990, 8 articoli scientifici sugli squali delle acque turche tra il 1990 e il 2000, e ben 88 articoli riguardanti diversi aspetti degli squali della Turchia da allora, per un totale di 96 articoli sugli squali delle acque turche pubblicati tra il 1968 e il 2018. L'autore spera che studi futuri di nuove generazioni di ricercatori possano fornire nuovi dati su diversi aspetti riguardanti gli squali delle acque turche, al fine di approfondirne la comprensione e completare le loro storie di vita.

Parole chiave: ricerca sugli squali, pubblicazioni, acque turche, Mediterraneo orientale

INTRODUCTION

Despite an anecdotal note on a great white shark, *Carcharodon carcharias* (Linnaeus, 1758), off the coast of İzmir (western Turkey) from the 16th century (Bellonii, 1553), the story of shark research in the seas of Turkey started in the early 1920s. Regardless of their remarkable ecological value, sharks have always been a short chapter in the general ichthyological inventory studies of Turkish marine waters (e.g., Ninni, 1923; Deveciyan, 1926; Ayaşlı, 1937; Akşıray, 1987). The first accounts of sharks in the seas of Turkey were by Ninni (1923) and Deveciyan (1926). Besides being two of the most wanted items among collectors of antique books on Turkey's ichthyofauna, these pioneering monumental studies also contain the first scientific inventories of the sharks of the Turkish waters. The chronology of shark research in the mentioned waters can be divided into two distinct eras, with the first reaching up to the last quarter of 20th century, and the second beginning in almost mid-1990s and still continuing. They each have peculiar characteristics that outline the general trends of shark research in the seas of Turkey. While the first era was dominated by a clear disregard of sharks in the general ichthyological studies and a lack of shark-specific research, the second has witnessed a boom in the study of the sharks of the seas of Turkey. In the present article, the author reviews the contemporary status of shark research in Turkish waters in the light of available data.

MATERIAL AND METHODS

The data of the present review were obtained from published journals and electronic sources. To extract data from electronic sources, a structured Boolean search was performed on search engines such as Google Scholar, ScienceDirect, etc., with the following keywords: "sharks", "elasmobranchii", "Turkey", "Levantine", "Black, Marmara, Aegean OR Mediterranean Seas", "distribution", "hexanchiformes", "lamniformes", "squaliformes", "carcharhiniformes". To extract data published in journals before 2000 and not accessible via internet, a manual search was performed. The collected data were arbitrarily grouped under the following headings: 'distribution, occurrence and first record; feeding biology; population dynamics, including studies on age, growth and length-weight relationship; reproduction, including studies on neonates, gravid females and nurseries; morphometry; underwater observations and behaviour; miscellaneous, including studies on conservation, fishery economy, anthropogenic injuries and newspaper portrayals; and general chondrichthyan studies including sharks'; and their contents were reviewed under the respective shark species. Since some of the articles dealt with more than one topic, each of these multi-topic articles was considered as a single article to prevent the overestimation of the total number of publications. The taxonomic nomenclature of the shark species follows Serena (2005). The distribution of sharks in Turkish waters was based on Akşıray (1987), Bilecenoğlu *et al*. (2014), Kabasakal (2011b) or Kabasakal *et al*. (2017). The tabulated results of the data search are available upon request to the author, for further investigation.

RESULTS AND DISCUSSION

Overview of the studies

The data search for the present review revealed a remarkable difference between the numbers of shark-specific articles published in each of the two eras of research on the sharks of the Turkish waters (Fig. 1). In the first era, the historical data about sharks in Turkish waters were comprised in general ichthyological inventories (Ninni, 1923; Deveciyan, 1926; Ayaşlı, 1937) and rare anecdotal notes (e.g., Erazi, 1942; Geldiay & Mater, 1968), which, however, provided occurrence data of some rare (e.g., *Oxynotus centrina*, *Echinorhinus brucus*) or questionable (e.g., *Lamna nasus*) or threatened sharks (e.g., *Hexanchus griseus*, *Squatina squatina*) in the mentioned marine region. These references also represent some of the earliest occurrence records of sharks in the Levantine Basin, and therefore, provide an understanding of the historical distribution of sharks in the eastern Mediterranean.

Based on publication dates, there were only 2 shark-specific articles published before 1990, 8 scientif-

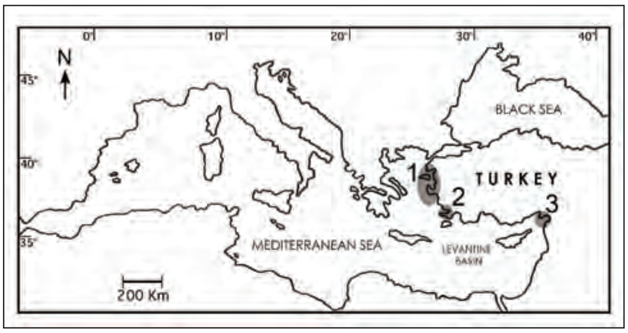

Fig. 1: Geographical location of Turkish waters in the Mediterranean ecosystem. The shaded areas indicate the approximate locations of the three possible sharks breeding grounds: (1) in the northern Aegean Sea, from Gökçeada to Foça, (2) Boncuk Bay in the southern Aegean Sea, and (3) in the Bay of İskenderun in the eastern Levant.

Sl. 1.: Geografska lega turških voda v Sredozemskem morju. Osenčeni predeli označujejo približne lokalitete treh možnih območij razmnoževanja morskih psov: (1) severno Egejsko morje, v predelu Gökçeada - Foça, (2) zaliv Boncuk v južnem Egejskem morju, in (3) zaliv İskenderun v vzhodnem Levantu.

ic articles about the sharks of the Turkish waters between 1990 and 2000, and as many as 88 papers dealing with several aspects of the sharks of Turkey since, for a total of 96 articles on the sharks of the Turkish waters published between 1968 and 2018.

With regard to the topics of the publications, the largest number of articles (n = 60) dealt with the occurrence, distribution and first records of sharks in Turkish waters, followed by articles about stomach contents and feeding bioecology of sharks (n = 13), reproduction and nurseries (n = 13), morphometrics (n = 13), population dynamics (n = 11), underwater observations and behaviour studies (n = 5), and miscellaneous topics (n = 5) (Fig. 2). The sharks of the Turkish waters were also discussed in general chondrichthyan studies, including those about the batoids of the mentioned marine region (n = 9) (Fig. 2).

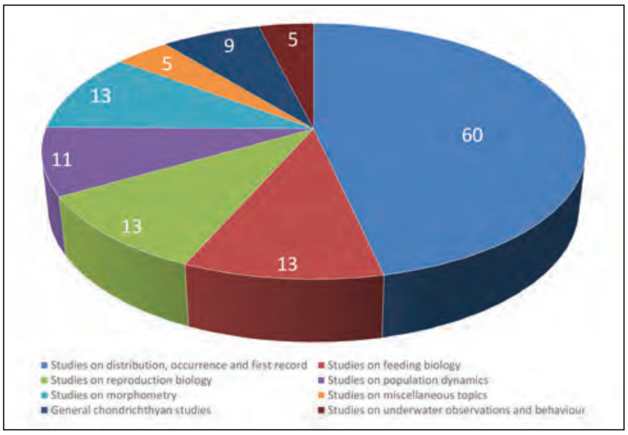

Fig. 2: Numerical distribution of the topics of articles on the sharks of the Turkish waters, published between 1968 and 2018.

Sl. 2: Številčna porazdelitev tematik prispevkov o morskih psih turških voda, objavljenih med leti 1968 in 2018.

Species accounts

HEXANCHIFORMES
HEXANCHIDAE
Heptranchias perlo (Bonnaterre, 1788)

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Hexanchus griseus (Bonnaterre, 1788)

Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on H. perlo and H. griseus in Turkish waters

The earliest records of the hexanchid sharks, *H. griseus* and *Heptranchias perlo,* in Turkish waters were reported in general ichthyological inventories by Ninni (1923), Deveciyan (1926) and Akşıraş (1987); their contemporary occurrences in the mentioned marine region were confirmed by Kabasakal (1998a, 2004a, 2005, 2009b, 2013a), Kabasakal and İnce (2008), and Başusta (2015). Among these, studies by Kabasakal (2005) and Başusta (2015) are particularly worth mentioning. On 19 November 2004, one male specimen of *H. griseus* of 300 cm TL and weighing 250 kg was captured by a commercial gill-netter nearly 3 miles off the coast of Amasra. This single capture extends the Mediterranean distribution of *H. griseus* to the Black Sea (Kabasakal, 2005). Occurrence of neonates of *H. perlo* in İskenderun Bay (north-eastern Mediterranean Sea) was recorded for the first time by Başusta (2015). In a recent review of large sharks caught by commercial fisheries in Turkish waters, *H. griseus* was the predominant species accounting for 169 specimens and 43.2% of total captures between 1990 and August 2015 (Kabasakal *et al*., 2017).

Following the capture of newborns of sevengill sharks in İskenderun Bay, Başusta (2015) suggested the possibility of a breeding ground of *H. perlo* in the north-eastern Mediterranean Sea. In Turkish waters, bony fish constitute the main prey of *H. griseus* (Kabasakal, 2004a). Available information suggests that *H. griseus* gives birth between October and late February in the northern Aegean and Marmara Seas (Kabasakal, 2004a). Morphometric measurements of the *H. griseus* caught in the Sea of Marmara were reported by Kabasakal (1998a). Based on the specimens captured by commercial fishermen in Turkish waters, the length-weight relationship for the bluntnose sixgill shark, *H. griseus*, was calculated as logTW=2.76xlogTL-4.6 (r=0.92; n=34; sexes combined; Kabasakal, 2006). Analysis of 81 articles related to *H. griseus* and published in major Turkish newspaper and internet media between 1974 and 2009 revealed that the tenor of the coverage was neutral in 49.3% of the articles, 45.6% were negative and only 4.9% were positive (Kabasakal, 2010c). The effect of anthropogenic and fishing-gear induced injuries on the survival and cryptic mortality of sharks were examined in two recent studies (Kabasakal 2010d, 2017a). Post-release behaviour of *H. griseus* in Saros Bay (north-eastern Aegean Sea) was also recorded via underwater videography (Kabasakal, 2010d).

SQUALIFORMES
ECHINORHINIDAE
Echinorhinus brucus (Bonnaterre, 1788)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on E. brucus in Turkish waters

In October 2002, a bramble shark *E. brucus* was imaged by means of a ROV camera at a depth of 1,214 m in the northern Sea of Marmara (Kabasakal *et al*., 2005). This single recording of the bramble shark shows that *E. brucus*, once thought extinct in Turkish seas, still occurs in this area. Recent studies provide further records confirming the contemporary existence of *E. brucus* in Turkish waters (Kabasakal & Dalyan, 2011; Kabasakal & Bilecenoğlu, 2014; Kabasakal, 2017a).

SQUALIDAE

Squalus acanthias Linnaeus, 1758

Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Squalus blainvillei (Risso, 1826)

Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on *S. acanthias* and *S. blainvillei* in Turkish waters

Subsequently to the pioneering study of Geldiay and Mater (1968), Kutaygil and Bilecik (1977) reported on the distribution and abundance of the spurdog, *S. acanthias*, which ranked the second and/or third among the demersal fish along the western and central Black Sea coasts of Turkey. Contemporary occurrence of the congeneric *S. blainvillei* in Turkish waters was confirmed by Kabasakal and Kabasakal (2004), and Başusta *et al*. (2016).

The main prey of *S. acanthias* and *S. blainvillei* is composed of decapod crustaceans and bony fish (Kabasakal 2002d; Demirhan *et al*., 2007; Özütemiz *et al*., 2009). Decapod crustaceans *Liocarcinus* sp. and the commercially important deep-water prawn, *P. longirostris*, constituted the main prey items recorded in the stomach contents of *S. blainvillei* (Kabasakal, 2002d). According to Demirhan *et al*. (2007), the availability of prey is the main criterion for the feeding strategy of *S. acanthias*; thus in winter, the main prey item of the spiny dogfish is anchovy (*Engraulis encrasicolus*). In the eastern Mediterranean population of *S. acanthias*, the length at 50% maturity was 87.57 cm for males and 102.97 cm for females (Demirhan & Seyhan, 2007). On the other hand, Yığın and İşmen (2013) estimated the mean length at 50% maturity for females and males of *S. acanthias* at 56.4 cm and 52.8 cm, respectively. The structural problems of using spines for determining the age of the spiny dogfish (*S. acanthias*) were examined by Demirhan *et al*. (2006), and the authors concluded that the percentage of age reading failure was 70% and 37% on the first and second spines, respectively. One of the previous studies investigated the population structure of *S. acanthias* along the south-eastern Black Sea coast of Turkey (Düzgüneş *et al*., 2006). In this study, a total of 267 specimens (85 male and 182 female) were collected and the mean (±se) length and weight were 88.25±2.157 cm and 3319±204 g for males, and 92.55±1.73 cm and 4387±217.6 g for females. The length-weight relationship for the stock was derived as $W=0.009*L3.3423$ ($r^2=0.9607$) (Düzgüneş *et al*., 2006). In a previous study carried out in the south-eastern region of the Black Sea, Avşar (1996) reported that male specimens of *S. acanthias* dominated the population, the age of this species in the region ranged between 1 and 14 years, and the mean annual growth rate was 7.2 cm. The growth parameters of *S. blainvillei* were examined based on the specimens captured in Sığacık Bay (Aegean Sea), and the mean size for the examined specimens of *S. blainvillei* was 21.46±2.21 cm, respectively (Özütemiz *et al*., 2009).

CENTROPHORIDAE

Centrophorus granulosus (Bloch & Schneider, 1801)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Centrophorus uyato (Rafinesque, 1810)

Distribution in Turkish waters: Marmara Sea (Bilecenoğlu *et al*., 2014).

Review of studies on *C. granulosus* and *C. uyato* in Turkish waters

In the early 1990s, the first record of the gulper shark, *Centrophorus granulosus*, in the Sea of Marmara was reported by Benli *et al*. (1993), based on specimens caught at a depth of 400 m. Although the congeneric *C. uyato* was also recorded in the Sea of Marmara in the mid-1990s (Meriç, 1995), White *et al*. (2013) suggested that *C. uyato* was not a valid species and that further research was necessary to clarify the taxonomic status of this species in Turkish waters (Kabasakal & Karhan, 2015).

ETMOPTERIDAE

Etmopterus spinax (Linnaeus, 1758)

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on *E. spinax* in Turkish waters

Kabasakal and Ünsal (1999) reported rare occurrences of *E. spinax* caught in deep-water bottom-trawl fishery in the northern Aegean Sea, together with the morphometric measurements of the examined specimens. In a previous study, 116 velvet belly lantern sharks, *E. spinax*, were caught at depths between 200 and 600 m, in Sığacık Bay (Aegean Sea), and the population was composed of more females than males, at 53.4% and 46.6%, respectively; the maximum total lengths for females and males were 20.5 cm and 18.9 cm, respectively (Bilge *et al*., 2010).

OXYNOTIDAE

Oxynotus centrina (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on *O. centrina* in Turkish waters

Based on the chronological order, the first shark-specific article on the distribution and occurrence of sharks in Turkish waters was published in late 1960s. It provided anecdotal data on an angular rough shark (*O. centrina*) caught in the Bay of İzmir (Geldiay & Mater, 1968). Studies on *O. centrina*, which is now considered a rare and threatened shark in the entire Mediterranean Sea, continued in the following decades and provided further understanding about the life story, occurrence and status of the angular rough shark in Turkish waters (Kabasakal, 2009a, 2010a, 2015a; Başusta *et al.*, 2015; Yığın *et al.*, 2016). A recent review on the occurrence and status of *O. centrina* in the eastern Mediterranean (Kabasakal, 2015a) revealed that between the late 1800s and 2012, the highest number of *O. centrina* specimens (72%) was recorded in the Aegean Sea, followed by the Sea of Marmara (21.5%). Contemporary occurrence of *O. centrina* in Turkish waters was also confirmed by two recent studies (Başusta *et al.*, 2015; Yığın *et al.*, 2016). Locomotory and feeding behaviour of the rare angular rough shark, *O. centrina*, were recorded by means of diver-operated camera in the northern Sea of Marmara (Kabasakal, 2009a). Measurements of *O. centrina* were reported by Yığın *et al.* (2016), based on a specimen caught in Saros Bay (north-eastern Aegean Sea). Based on the occurrence of a gravid female in İskenderun Bay, Başusta *et al.* (2015) suggested a possible breeding ground of *O. centrina* in the region.

DALATIIDAE
Dalatias licha (Bonnaterre, 1788)
Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on *D. licha* in Turkish waters

Kabasakal and Kabasakal (2002) reported rare occurrences of *D. licha* caught in deep-water bottom-trawl fishery in the northern Aegean Sea. Although the main prey of *D. licha* is comprised of decapod crustaceans (*Liocarcinus* sp. and *P. longirostris*), remains of the sympatric blackmouth dogfish (*G. melastomus*) were also found in the stomach contents of the kitefin shark (Kabasakal & Kabasakal, 2002). Based on the occurrence of newborn specimens of *D. licha*, Kabasakal and Kabasakal (2002) suggested a possible breeding area of the kitefin shark over the bathyal grounds of the north-eastern Aegean Sea. Morphometric measurements of 5 newborn *D. licha* from the north-eastern Aegean Sea were reported by Kabasakal and Kabasakal (2002). Recently, an adult female of *D. licha*, 118 cm TL, got entangled in a trammel net set at a depth of 40 m in Iskenderun Bay (NE Mediterranean sea) (Ergüden *et al.*, 2017)

SQUATINIFORMES
SQUATINIDAE

Squatina aculeata Dumeril, *in* Cuvier, 1817
Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).
Squatina oculata Bonaparte, 1840
Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).
Squatina squatina (Linnaeus, 1758)
Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on S. aculeata, S. oculata and S. squatina in Turkish waters

In Turkish waters, the angel shark family Squatinidae is represented by 3 species: *Squatina aculeata*, *S. oculata* and *S. squatina*, and their contemporary occurrences have been confirmed by a number of studies (Başusta, 2002; Başusta *et al.*, 1998; Kabasakal & Kabasakal, 2004, 2014; Yağlıoğlu *et al.*, 2015). *S. squatina* is considered one of the largest sharks in Turkish waters, and, historically, it was one of the commercially important shark species in Turkish demersal fishery. However, the remarkable decrease that has been recorded in angel shark populations is alarming, as the survival of the species may be threatened. As recent surveys show, *S. squatina* accounts for less than 2 percent of the total shark biomass incidentally caught by Turkish fishermen (Yağlığlu *et al.*, 2015; Kabasakal *et al.*, 2017).

LAMNIFORMES
ODONTASPIDIDAE
Carcharias taurus Rafinesque, 1810
Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).
Odontaspis ferox (Risso, 1810)
Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on C. taurus and O. ferox in Turkish waters

There is no specific study available on odontaspidid sharks in Turkish waters.

ALOPIIDAE
Alopias superciliosus (Lowe, 1839)
Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).
Alopias vulpinus (Bonnaterre, 1788)
Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on A. superciliosus and A. vulpinus in Turkish waters

Kabasakal (1998b) reported on the incidental capture of a female thresher shark, *A. vulpinus*, 453 cm TL, by a commercial purse-seiner off Şile coast (south-western Black Sea), on 8 November 1996, and this anecdotal note was followed by further records. Contrary to the species' open water habits, Kabasakal (2007) reported on the coastal occurrences of 19 common thresher sharks (*A. vulpinus*) that were incidentally captured by coastal stationary netters. Recently, Ergüden *et al.* (2015) reported on a single male thresher shark, 392 cm TL and weighing ca. 180 kg, captured incidentally in purse-

-seine fishery in İskenderun Bay; this was the first record of *A. vulpinus* from the north-eastern Mediterranean coast of Turkey. The first record of the congeneric bigeye thresher shark, *A. superciliosus*, in Turkish waters dates back to the early 2000s (Mater, 2005; Bay of Gökova, south-eastern Aegean Sea); a few years later it was recorded in the Sea of Marmara (Kabasakal & Karhan, 2008). The female bigeye thresher shark, 450 cm TL, caught on 28 February 2011 off Fethiye coast, is one of the largest specimens of *A. superciliosus* ever recorded in the Mediterranean Sea and worldwide (Kabasakal *et al.*, 2011). Based on the total number (n = 392) of large sharks caught by commercial fishermen between 1990 and August 2015 in Turkish waters, *A. superciliosus* and *A. vulpinus* accounted for 2.5% and 9.9% of the total catch, respectively (Kabasakal *et al.*, 2017).

CETORHINIDAE

Cetorhinus maximus (Gunnerus, 1765)

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on C. maximus in Turkish waters

Early writings on the occurrence of basking sharks in Turkish waters date back to the 1990s, when an anecdotal record of basking shark, *Cetorhinus maximus*, was reported from north-eastern Levantine waters (Kıdeyş, 1997). It was followed by further records off the Turkish coasts, particularly in the Bay of Antalya (Kabasakal, 2002a, 2004b, 2013b). In January of 2009, an adult male basking shark was accidentally caught in a stationary net in the waters some 2 nautical miles off Küçükkuyu (north Aegean Sea); its total length measured ca. 1,000 cm (Kabasakal, 2009c). According to Kabasakal (2009c), this specimen is the largest well-documented basking shark recorded in the Mediterranean to date. In a recent review of the status of basking sharks in the eastern Mediterranean, Kabasakal (2013c), based on the extremely low number of records off Turkish coast since the 1950s, emphasized the rarity of *C. maximus* in Turkish waters and the need for a specific monitoring program accompanied by zooplankton surveys that would determine the seasonal movements of basking sharks in the mentioned region and answer the questions whether the occurrence of this species in Turkish waters exhibits seasonality and site fidelity or not.

LAMNIDAE

Carcharodon carcharias (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on C. carcharias in Turkish waters

In a 16th century record, Bellonii (1553) reported on the occurrence of *C. carcharias* off İzmir coast. Following this historical note, this top predator was listed in the general ichthyological inventories of Turkish waters (Ninni,1923; Deveciyan, 1926; Ayaşlı, 1937; Akşıray, 1987) When talking about the sharks of the Mediterranean Sea, the great white shark, *C. carcharias*, has always been the “top star” of research efforts and incidental captures of this predator have always found room in newspaper reports as well. Therefore, a detailed search in newspaper archives covering the period between the early 1900s and the late 1960s yielded several articles about specimens of *C. carcharias* incidentally captured by tuna hand-liners in the Bosphorus Strait during that time (Kabasakal, 2003a, b). Further research revealed the presence of *C. carcharias* in Marmara and Turkish Aegean waters between the 1960s and the 1990s (Kabasakal 2008, 2011a; Kabasakal & Kabasakal, 2004). Following the capture of two newborns of the great white in Edremit Bay (northern Aegean Sea) in the summer of 2008, contemporary occurrence of *C. carcharias* in Turkish waters was confirmed (Kabasakal & Gedikoğlu, 2008) and this incidence was followed by the captures of additional specimens (4 newborns and 3 juveniles) in the north-eastern Aegean Sea, in the coastal zone extending from Foça (central Aegean Sea) to Gökçeada (north-eastern Aegean Sea) (Kabasakal, 2014; Kabasakal & Kabasakal, 2015; Kabasakal *et al.*, 2009). Among the captured newborns, a north Aegean Sea specimen (85 cm TL) caught by a coastal trammel netter in Edremit Bay on 6 July 2011, is possibly the smallest neonate great white shark reported from Mediterranean waters to date (Kabasakal, 2014). The capture of neonate, young-of-the-year and juvenile white sharks suggested the presence of a breeding ground of *C. carcharias* in the central and northern coasts of the Turkish Aegean Sea (Kabasakal, 2014; Kabasakal & Kabasakal, 2015; Kabasakal *et al.*, 2009). In light of the available data, *C. carcharias* is an extant lamnoid shark in the Aegean waters off the Turkish coast, but presently not occurring in the Sea of Marmara (Kabasakal, 2016a, Kabasakal *et al.*, 2018), contrary to the assertions in Bilecenoğlu *et al.* (2014), which are based on historical occurrence data of the species.

Isurus oxyrinchus Rafinesque, 1810

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al.*, 2014).

Review of studies on I. oxyrinchus in Turkish waters

A huge female shortfin mako shark, *Isurus oxyrinchus*, was caught in the late 1950s off Marmaris (south-eastern Aegean Sea; Kabasakal & De Maddalena, 2011). Photographic documentation was used by the authors to estimate the total length of this specimen at 585 cm, which greatly exceeded the previous maximum size recorded for the species (445 cm). Although recent studies have confirmed the contemporary occurrence of *I. oxyrinchus* in Turkish Aegean and Mediterranean waters (Ergüden *et al.*, 2013; Kabasakal 2015b, 2017b; Kabasakal & Kabasakal, 2013; Tunçer & Kabasakal, 2016), this is a rare lamnoid shark in Turkish waters. Therefore, the seasonal occurrence of both young and adult shortfin mako sharks off Turkey's Aegean and Mediterranean coasts should be monitored to clarify whether the shortfin mako shark is a resident or a vagrant species along the aforementioned coastline. According to Kabasakal *et al*. (2017), *I. oxyrinchus* accounted for 5.3% of the total number of large sharks captured by commercial fishermen in the 1990–2015 period in Turkish waters. Occurrences of *I. oxyrinchus* newborns and youngs-of-the-year off Foça and in İskenderun Bay suggest the possibility of a mating region in the northern Aegean and north-eastern Mediterranean Seas (Ergüden *et al*., 2013; Kabasakal, 2015b).

Lamna nasus (Bonnaterre, 1788)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on L. nasus in Turkish waters

Occurrence of the porbeagle shark, *Lamna nasus*, in Turkish waters was reported by Deveciyan (1926), Akşıray (1987) and Kabasakal (2002b). Kabasakal and Kabasakal (2004) reported on a porbeagle shark, 250 cm TL, caught off Bozcaada (northern Aegean Sea), on 11 April 2004. *L. nasus* is a rare shark in Turkish waters and its questionable presence in Marmaric waters requires confirmation (Kabasakal & Karhan, 2015).

CARCHARHINIFORMES

SCYLIORHINIDAE

Galeus melastomus Rafinesque, 1810

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Scyliorhinus canicula (Linnaeus, 1758)

Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Scyliorhinus stellaris (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on G. melastomus, S. canicula and S. stellaris in Turkish waters

Contemporary occurrences of cat sharks (family Scyliorhinidae), *Galeus melastomus*, *Scyliorhinus canicula* and *S. stellaris*, in Turkish waters were confirmed by Başusta *et al*. (2016), Kabasakal (2002b), Kabasakal and Kabasakal (2004), Kabasakal and Karhan (2015), Keskin and Karakulak (2006), İşmen *et al*. (2013), and Yağlıoğlu *et al*. (2015). *S. canicula* is the most abundant cartilaginous fish species caught in demersal fishery in Turkish waters (Cihangir *et al*., 1997; Kabasakal, 2002b; Keskin & Karakulak, 2006; İşmen *et al*., 2013; Yağlıoğlu *et al*., 2015).

Investigations carried out since 1997 have revealed that, in Turkish waters, the main prey items of *S. canicula* are decapod crustaceans (*Parapenaeus longirostris*, *Liocarcinus* sp., *Goneplax rhomboides*, *Xantho* sp. and *Munida* sp.) and teleostean fish, while secondary food items comprise polychaetes (e.g., Sipinculida) and cephalopods (Cihangir *et al*., 1997; Kabasakal, 2001, 2002c; Filiz & Taşkavak, 2006; Türker Çakır 2006). A previous study on the stomach contents and feeding ecologies of the *S. canicula* and thornback ray, *Raja clavata*, caught in the northern Aegean Sea, revealed a clear niche overlap between *S. canicula* (all sizes) and *R. clavata* (>50 cm TL), and competition for similar prey items (Kabasakal, 2001). In a broader perspective, in Turkish waters, *G. melastomus* preys mainly on crustaceans, teleosteans and cephalopods (Kabasakal, 2002c; Özütemiz *et al*., 2009), while in the deep zones (>1000 m depth) of the Sea of Marmara, the blackmouth catshark feeds mainly on crustaceans, *Calocaris macandreae* and *Sergestes robustus* (Oral, 2010).

In a previous study on the distribution and determinate biological aspects of the lesser spotted dogfish in the north-eastern Aegean Sea, Cihangir *et al*. (1997) reported that the reproduction of *S. canicula* occurs year-round, with a relatively low rate of oogenesis in winter and early spring. Demersal trawl surveys carried out in the northern Aegean Sea showed that seasonal biomass of *S. canicula* in shallow waters (≤100 m depth) varied from 576 to 2,958 tonnes (Cihangir *et al*., 1997). Filiz and Mater (2002) examined the length-weight relationships of seven elasmobranch species sampled from the north Aegean Sea, and calculated the length-weight equations for *S. canicula*, *M. mustelus* and *S. acanthias* as follows: WT= 0.0016TL x 3.1804 ($r^2 = 0.9795$), WT= 0.0008TL x 3.3259 ($r^2 = 0.9745$) and WT= 0.0031TL x 3.1056 ($r^2 = 0.9814$), respectively. According to Türker-Çakır *et al*. (2006), the weight increased allometrically in the both sexes of the *S. canicula* sampled in the northern Aegean Sea (b = 2.93). Sexual dimorphism, dentition and morphometry of the *S. canicula* caught in Turkish waters were studied by Erdoğan *et al*. (2004) and Filiz and Taşkavak (2006).

Growth parameters of *G. melastomus* were examined based on specimens captured in Sığacık Bay (Aegean Sea), and the mean size for the examined specimens was 14.01±1.96 cm (Özütemiz *et al*., 2009). The length-weight relationship parameters of 16 out of the 30 cartilaginous fish species (11 sharks, 18 batoids and 1 chimaera) caught in the central Aegean Sea were examined; the values of the slope b in the length-weight relationship parameters ranged from 2.79 (*Torpedo marmorata*) to 3.78 (*Scyliorhinus stellaris*), a values from 0.0002 (*Scyliorhinus stellaris*) to 0.9713 (*Dasyatis pastinaca*) (Eronat and Özaydın, 2014).

TRIAKIDAE

Galeorhinus galeus (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Mustelus asterias Cloquet, 1821

Distribution in Turkish waters: Black, Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Mustelus mustelus (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Mustelus punctulatus Risso, 1826

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on G. galeus, M. asterias, M. mustelus and M. punctulatus in Turkish waters

Contemporary occurrences of triakid sharks (family Triakidae), *Galeorhinus galeus*, *Mustelus asterias*, *M. mustelus* and *M. punctulatus*, in Turkish waters have been confirmed by a number of studies (Filiz and Mater, 2002; Kabasakal, 2002b; Kabasakal & Kabasakal, 2004; Başusta *et al*., 1998, 2016; Yağlıoğlu *et al*., 2015). Two specimens of the starry smoothhound, *M. asterias*, were captured three miles off the coast of Şile (south-western Black Sea) on 19 November 2000 at a depth of ca. 90 m, and this previous record extended the Mediterranean distribution of *M. asterias* to the Black Sea (Eryılmaz *et al*., 2011). The tope shark, *G. galeus,* is one of the largest shark species occurring in Turkish waters, and the recent remarkable decrease in its populations is alarming. Between 1990 and 2015, *G. galeus* accounted for less than 2 percent of the total shark biomass recorded in the Turkish commercial fisheries (Kabasakal *et al*., 2017). The diet of *M. mustelus* is heterogeneous and generalized, and the main prey item found in the stomach contents is decapod crustaceans, with teleosteans and cephalopods featuring as secondary important food items (Kabasakal, 2002c; Filiz, 2009; Özcan & Başusta, 2016).

CARCHARHINIDAE

Carcharhinus altimus (Springer, 1950)

Distribution in Turkish waters: Mediterranean Sea (Bilecenoğlu *et al*., 2014).

Carcharhinus brevipinna (Müller & Henle, 1839)

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Carcharhinus limbatus (Müller & Henle, 1839)

Distribution in Turkish waters: Mediterranean Sea (Bilecenoğlu *et al*., 2014).

Carcharhinus melanopterus (Quoy & Gaimard, 1824)

Distribution in Turkish waters: Mediterranean Sea (Akşıray, 1987; Kabasakal, 2011b).

Carcharhinus obscurus (Lesueur, 1818)

Distribution in Turkish waters: Mediterranean Sea (Akşıray, 1987; Kabasakal, 2011b).

Carcharhinus plumbeus (Nardo, 1827)

Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Prionace glauca (Linnaeus, 1758)

Distribution in Turkish waters: Marmara, Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on Carcharhinus species and P. glauca in Turkish waters

Despite historical and contemporary occurrences of carcharhinid sharks (family Carcharhinidae) in Turkish waters have been noted in general ichthyological or chondrichthyan inventories of the mentioned region (e.g., Ninni, 1923; Akşıray, 1987; Başusta *et al*., 1998; Kabasakal, 2002b, 2003b; Kabasakal & Kabasakal, 2004; Kabasakal *et al*., 2017; Yağlıoğlu *et al*., 2015), the paucity of species specific studies is obvious. In a previous report on the status of the blue shark, *Prionace glauca*, in the northern Aegean Sea, Kabasakal (2010b) emphasized that coastal trammel- and gill-netting is a serious threat to the survival of the young populations of the species in Edremit Bay. In an extensive survey on the chondrichthyan fish of İskenderun Bay (north-eastern Mediterranean Sea), Başusta *et al*. (1998) recorded the bignose shark, *Carcharhinus altimus*, for the first time in Turkish waters and confirmed the contemporary presence of the sandbar shark, *C. plumbeus*, as well. Underwater observations carried out in Boncuk Bay (south-eastern Aegean Sea) and the knowledge gathered from these surveys played a critical role in declaring *C. plumbeus* a protected species in Turkish seas (Akça, 2010; Öztürk, 2006). Recent surveys have confirmed the occurrence of the dusky shark, *C. obscurus*, in the Bay of İskenderun (Kabasakal *et al*., 2017). The spinner shark, *C. brevipinna*, is considered a rare shark and has only been listed in the general ichthyological and chondrichthyan inventories of Turkish waters (Akşıray, 1987; Kabasakal, 2002b); recently, Filiz and Kabasakal (2015) reported on a specimen of this species photographed in the Bay of Gökova. The recently discovered photographic evidence suggests that *Carcharhinus* spp. were present in the Sea of Marmara in the 1950s (Kabasakal, 2015c), and this evidence also extends the known historical distributional range of *Carcharhinus* spp. into Marmaric waters, a northern extension of the Mediterranean Basin.

In a pioneering study in which the length-weight relationship (LWR) of the sandbar shark, *C. plumbeus*, from the northeastern Mediterranean Sea population was examined for the first time, the LWR estimated for combined sexes, females and males, were W= 0.01*TL (r=0.915, *SE* =0.174), W= 0.0034*TL (r =0.912, *SE* =0.278) and W= 0.0039*TL (r =0.915, *SE* =0.231), respectively (Başusta, 2016). According to Başusta (2016), the type of allometric growth in the examined population of *C. plumbeus* was negative ($b < 3$) for all sexes and for males, and positive ($b > 3$) for females. Seeing that Boncuk Bay (south-eastern Aegean Sea) is of critical importance for the reproduction of *C. plumbeus*, Öztürk (2006) suggested that the bay should be declared a protected area and all fishery should be banned in its waters. Underwater observations to record the bioecological characteristics of the sandbar shark, *C. plumbeus*, were also carried out in Boncuk Bay (south-eastern Aegean Sea) during a 39-day expedition in 2009 (Akça, 2010). A study has also been carried out which confirmed the year-round aggregations of sandbar sharks in the area and provided new and solid evidence for banning all fishing activities in this marine protected area (Filiz, 2018).

SPHYRNIDAE
Sphyrna (Sphyrna) zygaena (Linnaeus, 1758)
Distribution in Turkish waters: Aegean and Mediterranean Seas (Bilecenoğlu *et al*., 2014).

Review of studies on S. zygaena in Turkish waters

Our knowledge on hammerhead sharks (family Sphyrnidae) in Turkish waters consists of rudimentary data. Ulutürk (1987) and Kabasakal and Kabasakal (2004) reported rare occurrences of the smooth hammerhead shark, *Sphyrna zygaena*, off Gökçeada coasts (northern Aegean Sea), and the species was observed off the Kaş Peninsula (western Levantine Basin) in August 2015 (Kabasakal *et al*., 2017). Although its occurrence was confirmed, *S. zygaena* is a rare shark in Turkish waters (Kabasakal *et al*., 2017).

Review of general studies on chondrichthyan fish in Turkish waters

In an extensive survey of the chondrichthyan fish of İskenderun Bay, the bignose shark, *C. altimus*, was recorded for the first time in Turkish waters and the presence of *C. plumbeus*, *O. centrina* and *S. oculata* in the bay waters were confirmed as well (Başusta *et al*., 1998). Based on the results of field surveys and a review of available data, Kabasakal (2002b) reported on the presence of 39 shark species in Turkish waters, defining the occurrence of 8 of them questionable and requiring confirmation. The results of an extensive trawl survey carried out in the northern Aegean Sea determined *S. canicula* as the most abundant cartilaginous fish species, with a total mass estimated at 2,850.6 kg/nm^2 (Keskin & Karakulak, 2006). Between March 2005 and June 2008, in Saros Bay, Turkey, ten shark species were sampled from depths ranging from 5 to 500 m for length-weight relationship using a commercial trawl vessel. The values of the exponent b of the length-weight relationships ranged from 2.6816 to 3.6060 (İşmen *et al*., 2009). In rare occasions, selected measurements of lamniform sharks (*C. maximus*, *A. superciliosus*, *A. vulpinus*, *C. carcharias* and *I. oxyrinchus*) were also reported by Kabasakal (2002a, 2017b), Kabasakal and Gedikoğlu (2008), Kabasakal and Karhan (2008), Kabasakal and Kabasakal (2013), Ergüden *et al*. (2013, 2015) and Tunçer and Kabasakal (2016).

Between October 2011 and February 2013, the composition of by-catch in the beam trawls used in the pink shrimp (*Parapenaeus longirostris*) fishery was surveyed seasonally and *S. canicula*, *S. stellaris*, *S. acanthias* and *O. centrina* were recorded (İşmen *et al*., 2013). Between 2009 and 2010, the total biomass, species composition, depth distribution, seasonal distribution and abundance of elasmobranchs caught by commercial bottom-trawlers in İskenderun Bay (north-eastern Levantine Sea) were also examined (Yağlıoğlu *et al*., 2015). In this study, *M. mustelus*, *S. canicula*, *S. stellaris*, *G. melastomus* and *S. squatina* represented between 0.45% and 1.7% of the total biomass of the examined cartilaginous fish. Single or sporadic captures were also recorded for *I. oxyrinchus*, *C. altimus*, *C. plumbeus* and *O. centrina* (Yağlıoğlu *et al*., 2015). In a recent review on cartilaginous fish and fisheries along the Mediterranean coast of Turkey, Başusta *et al*. (2016) recorded 32 species from 16 families, and concluded that the landings of elasmobranchs were reduced from 3,980 tonnes in 2000 to 246.2 tonnes in 2015. The production and economic values of sharks and their relatives in Turkey have been analysed for the last 34 years, and according to Doğan (2006), the maximum catch level was recorded in 1979 (11,125 t), followed by a significant decrease after 1989 and reaching the minimum level of 400 t in 2003. The current status of sharks and shark fisheries in the waters of the Sea of Marmara has been of late extensively reviewed (Kabasakal, 2016b; Yığın *et al*., 2016). Last but not least, in a recent survey of shark attacks against humans and boats, 13 shark attacks were recorded in Turkey's waters between 1931 and 1983, 2 of which fatal (Kabasakal & Gedikoğlu, 2015).

CONCLUSIONS

Until the last quarter of the 20th century, most of our knowledge on the sharks of the Turkish waters was based on elasmobranch-specific chapters in general ichthyological inventory studies and on a limited number of anecdotal studies. Since the mid-1990s, however, there has been a remarkable rise in the number and quality of shark-specific studies and publications, resulting in a gradual filling of the gaps in our understanding of the sharks of the Turkish waters. The reference list of the present article also serves as a bibliographical archive of the shark- and elasmobranch-specific studies related to Turkish waters that were published between 1968 and 2018. The next step in shark- and elasmobranch-specific studies should involve designing a master plan for the management of sharks and their relatives in Turkish waters, and implementing the conservatory acts that would be based on the available data.

Currently, 36 species of sharks with confirmed occurrence are present in Turkish waters (Akşıray, 1987; Kabasakal, 2011b; Bilecenoğlu *et al*., 2014; Kabasakal *et al*., 2017): *Hexanchus griseus*, *Heptranchias perlo*, *Echinorhinus brucus*, *Squalus acanthias*, *S. blainvillei*, *Centrophorus granulosus*, *C. uyato*, *Etmopterus spinax*, *Oxynotus centrina*, *Dalatias licha*, *Squatina aculeata*, *S. oculata*, *S. squatina*, *Carcharias taurus*, *Odontaspis ferox*, *Alopias superciliosus*, *A. vulpinus*, *Cetorhinus maximus*, *Carcharodon carcharias*, *Isurus oxyrinchus*, *Lamna nasus*, *Galeus melastomus*, *Scyliorhinus canicula*, *S. stellaris*, *Galeorhinus galeus*, *Mustelus asterias*, *M. mustelus*, *M. punctulatus*, *Carcharhinus altimus*, *C. brevipinna*, *C. limbatus*, *C. melanopterus*, *C. obscurus*, *C. plumbeus*, *Prionace glauca*, and *Sphyrna zygaena*. There are also species of questionable occurrence, which are included in one of the noteworthy ichthyological inventories of Turkish waters (Akşıray, 1987), but require confirmation, namely: *C. longimanus, S. lewini*, *S. tudes* and *Somniosus rostratus*.

The continuous rise in the number of articles and chapters on the sharks of the Turkish waters published annually is promising. The seasonal occurrence of neonate and young-of-the-year specimens of several shark species in Turkish waters, as well as the presence of documented breeding and nursery grounds in the region form a solid basis for the implementation of seasonal restrictions of commercial fisheries in these grounds. Based on the by-catch records of neonates and juvenile specimens of some rare sharks, such as *D. licha* and *O. centrina*, or some large sharks, for example, *H. griseus*, *C. carcharias*, *I. oxyrinchus* and *C. plumbeus*, it is possible to speculate that sharks, at least the mentioned species, could reproduce in Turkish waters throughout the vast coastal zone spreading from the north Aegean Sea to the eastern Levant. In light of available and confirmed data, there are three possible breeding grounds; (1) in the northern Aegean Sea, between Gökçeada and Foça, (2) in Boncuk Bay in the southern Aegean Sea, and (3) in the Bay of İskenderun, eastern Levant (Fig. 1). To allow the survival of shark species, these areas should be declared seasonally protected or at least restricted zones for commercial fisheries. Currently, Boncuk Bay is the only protected area.

Different geographical populations of the same shark species can exhibit different growth parameters, which should be taken into account in their management. For instance, available data on the parameters of the Aegean Sea and Black Sea populations of *S. acanthias* present a clear difference in length at 50% maturity (Demirhan & Seyhan, 2007; Yığın & İşmen, 2013) – a critical detail that should not be overlooked in the regional management of *S. acanthias* in Turkish waters.

Populations of many large shark species in Turkish waters have drastically declined; a recent review of the distribution of large sharks captured mostly by commercial fishermen in the 1990–2015 period in Turkish waters showed that large sharks accounted for less than 2 percent of the total captured biomass (Kabasakal *et al*., 2017). According to Kabasakal *et al*. (2017), large sharks in Turkish waters are threatened by multi-parameter fishing pressure of demersal and pelagic fisheries of artisanal to industrial scale that operate in coastal to open waters and in shallow to deep fishing grounds almost year-round. Last but not least, fishing-gear induced injuries and harsh handling are overlooked contributors to the cryptic mortality of sharks in Turkish waters. Hopefully, future studies by new generations of researchers will provide new data on several aspects of the sharks of the Turkish waters, which can deepen our understanding of them and fill in the blanks in their life stories.

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PREGLED RAZISKAV O MORSKIH PSIH V TURŠKIH VODAH

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POVZETEK

Do zadnje četrtine 20. stoletja je bilo poznavanje o morskih psih v turških vodah omejeno na poglavja v specifičnih monografijah o morskih psih v splošnih ihtioloških pregledih in manjšem številu anekdotičnih raziskav. Od srede devetdesetih let pa je prišlo do občutnega povečanja v številu in kvaliteti specifičnih raziskav in publikacij o morskih psih, ki je počasi mašilo vrzel o poznavanju morskih psov v turških vodah. Pred letom 1990 sta bila objavljena le dva specifična prispevka o morskih psih, 8 prispevkov med leti 1990 in 2000 ter 88 prispevkov po letu 2000. Skupno je bilo objavljeno 96 prispevkov o morskih psih v turških vodah med leti 1968 in 2018. Smiselno je upati, da bodo nove generacije raziskovalcev odkrile nove podatke o morskih psih iz turških morij iz vseh vidikov, kar bo poglobilo in izpopolnilo znanje o njih in njihovem življenju.

Ključne besede: raziskave morskih psov, objave, turške vode, vzhodno Sredozemlje

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FINALLY UNDER PROTECTION! STATUS OF THE ANGEL SHARK, *SQUATINA SQUATINA* (LINNAEUS, 1758) IN TURKISH SEAS, WITH NOTES ON A RECENT SIGHTING AND INCIDENTAL CAPTURES

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ABSTRACT

Nine angel sharks, Squatina squatina*, were recorded in different regions of Turkish waters between 21 March 2009 and February 2019. Eight specimens were captured by different means of bottom fishing gear (e.g., gill or trammel net, or longline) or harpoon, and 1 specimen was sighted alive. Considering the fishery statistics of* angel sharks *in the last 10 years and biomass and numerical abundance data on the species in Turkish waters as baseline data, an alarming reduction in the populations of* S. squatina *in the mentioned regions has been observed. An extensive study providing baseline information on the current spatial distribution patterns, habitat use, abundance and population structure of* S. squatina *in Turkish waters is an urgent necessity.*

Key words: Angelshark, *Squatina*, protection, baseline shift, rarity, eastern Mediterranean

FINALMENTE PROTETTO! STATO DELLO SQUALO ANGELO, *SQUATINA SQUATINA* (LINNAEUS, 1758) IN MARE TURCO, CON NOTE SU AVVISTAMENTI RECENTI E CATTURE ACCIDENTALI

SINTESI

Nove squali angelo, Squatina squatina*, sono stati registrati in diverse regioni delle acque turche tra il 21 marzo 2009 e il febbraio 2019. Otto esemplari sono stati catturati con diversi attrezzi da pesca a fondo o con l'arpione, mentre un esemplare* è stato avvistato vivo. Considerando le statistiche sulla pesca degli squali angelo *negli ultimi 10 anni e i dati di biomassa e abbondanza numerica delle specie presenti nelle acque turche come dati di riferimento, è stata osservata una riduzione allarmante delle popolazioni di* S. squatina *nelle regioni considerate. Uno studio approfondito che fornisca informazioni di base sugli attuali modelli di distribuzione spaziale, sull'uso dell'habitat, e sull'abbondanza e la struttura demografica di* S. squatina *nelle acque turche è una necessità urgente.*

Parole chiave: squalo angelo, *Squatina*, protezione, deviazione dal riferimento, rarità, Mediterraneo orientale

INTRODUCTION

In natural systems, rarity of a species is a common phenomenon and most often defined by two attributes: the species' distribution and its abundance (Flather & Sieg, 2007). According to Flather and Sieg (2007), a species is considered rare if its area of occupancy or its number is small when compared to the other species that are taxonomically or ecologically comparable. The angel shark, *Squatina squatina* (Linnaeus, 1758), used to be reported as abundant in the entire Mediterranean Sea (Serena, 2005). Nowadays, it is supposed to be absent or even extirpated from several areas in the region (Bradai *et al*., 2012).

Due to the low overall number of records or a complete absence of the species in scientific trawl surveys conducted since 1958 (Holcer & Lazar, 2017), *S. squatina* is today considered a rare shark species throughout the Mediterranean Sea and its rarity has been emphasized by several researchers from different parts of the region (e.g., Golani, 2006; Serena & Relini, 2006; Kabasakal & Kabasakal, 2014; Akyol *et al*., 2015; Cavallaro *et al*., 2015).

Although the occurrence of *S. squatina* in Turkish waters has been noted in historical inventory studies of Turkish marine fishes (*e.g*., Ninni, 1923; Deveciyan, 1926; Akşıray, 1987), all of which attributed an economic value to the species and mentioned mass captures, current statistics indicate a drastic decline in annual landings of incidentally captured angel sharks in Turkish waters (TUIK, 2017). As in many parts of the Mediterranean, populations of *S. squatina* have been severely depleted in Turkish waters as well, which calls for the protection of the species.

The present article provides a summary of the captures and of the single sighting of *S. squatina* in Turkish waters in the last 10 years, and discusses the causes of the species' depletion. These events have eventually resulted in the implementation of effective protective measures for the species in the mentioned region.

MATERIAL AND METHODS

Data on captures and a single sighting of *S. squatina* in Turkish waters were obtained from the following sources: (1) scientific literature; (2) preserved samples in public or private collections; (3) newspaper accounts or internet news reporting on the capture of angel sharks in the studied area and (4) visits to fishing ports. As far as popular sources are concerned, the validity of the records was confirmed through direct contact with the fishermen cited by the sources, or else, based on a reliable photograph of the specimen accompanying such news. The following data were recorded for the examined specimens of angel shark: date, depth and locality of capture, total length (TL), weight (W), sex and fishing gear.

Commercial landings data on angel sharks from 2008 to 2017 were used to indicate the trend of annual

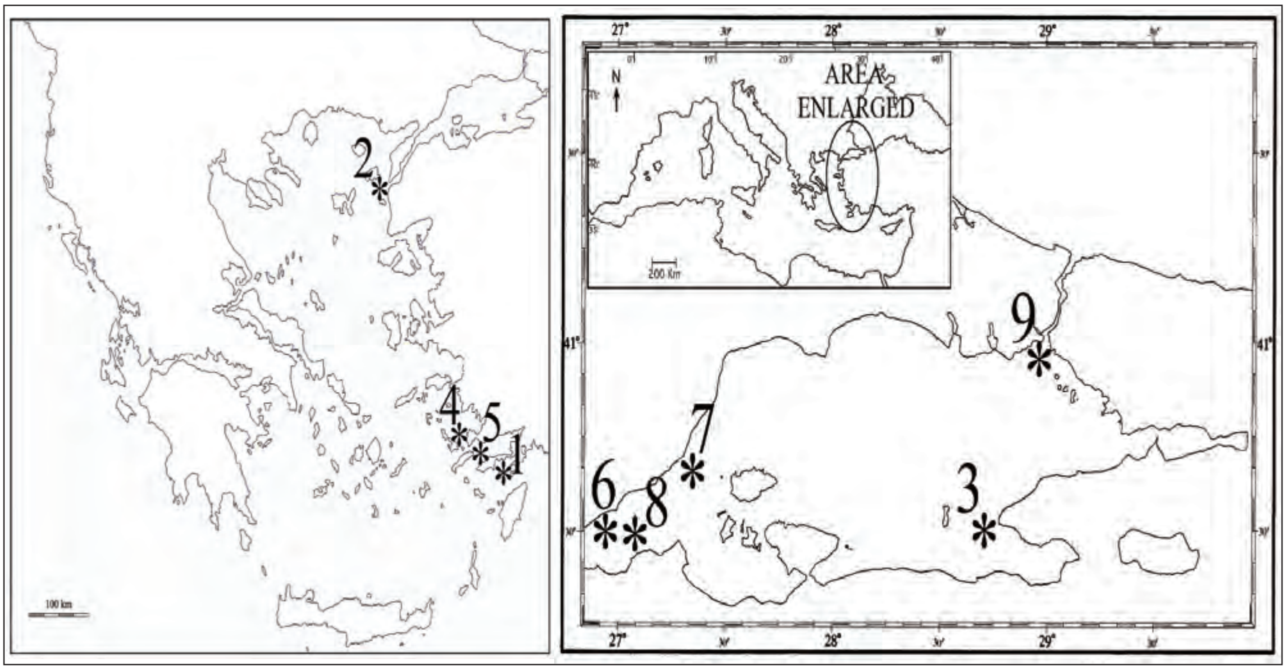

Fig. 1: Maps showing the approximate locations of recent captures and the single sighting of S. squatina*, in Turkish waters. The numbers correspond to those in Table 1.*

Sl. 1: Zemljevidi o recentnih ulovih in opazovanjih navadnega sklata v turških vodah. Številke ustrezajo tistim v Tabeli 1.

Tab. 1: Old and recent captures or sightings of the angel shark,* Squatina squatina*, in Turkish waters since 2009. The numbers in the "No." column are same as those in Fig. 1 indicating the approximate localities of capture.
Tab. 1: Stari in novejši zapisi o opazovanju navadnih sklatov,* Squatina squatina*, v turških vodah od leta 2009. Številke v stolpcih so enake kot v Sliki 1 in ponazarjajo približno lokaliteto ulova.

No	Date	Locality	Depth (m)	Sex	TL (cm)	W (kg)	Remarks
1	21 March 2009	Bodrum	-	♀	160	ca. 60	Entangled in coastal stationary-nets
2	October 2013	Çanakkale	1.5	-	ca. 100	-	Harpooned by a freediver in shallow water
3	4 January 2014	Mudanya	ca. 50	♀	174	35	Entangled in a trammel-net, after the auction it was sold (Kabasakal & Kabasakal, 2014)
4	5 February 2015	Gökova Bay	20	♀	156	32.6	Entangled in a trammel-net; it was a pregnant female carrying at least four developping embryos, which were expelled during the handling (Akyol *et al.*, 2015)
5	5 March 2015	Gökova Bay	-	♀	160	-	Found dead while entangled in a stationary-net (unpublished data)
6	December 2015	Dardanelles Strait	ca. 30	♀	ca. 150	-	Sighted by Mr. Mert Gökalp during a SCUBA diving expedition in the vicinity of the northern entrance of the Dardanelles Strait (unpublished data) (Fig. 2)
7	21 March 2018	Şarköy	ca. 40	♂	114	-	Captured by long-lining set for sea breams (Sparidae), displayed in Beşiktaş fishmarket in İstanbul (unpuplished data) (Fig. 3).
8	3 April 2018	Dardanelles Strait	ca. 30	♂	90	-	Captured by stationary-netting, displayed in Beşiktaş fishmarket in İstanbul (unpublished data) (Fig. 4).
9	February 2019	Bosphorus Strait	20 m	♀	ca. 140	30	Captured by gill-netting around the southern entrance of the Bosphorus Strait, transported to Edirne city and sold (unpublished data)

catches of *Squatina* species in Turkish waters (TUIK, 2017). To date, three species of angel shark, *S. aculeata* Dumeril*, in* Cuvier, 1817, *S. oculata* Bonaparte, 1840 and *S. squatina* have been recorded in Turkish waters (Bilecenoğlu *et al.*, 2014). Since no species-specific discrimination of angel shark catches is reported in TUIK statistics, the annual landings data represent the combined data on the landings of three congeneric angel sharks in Turkish waters. Raw data and individual records of angel sharks are kept in the archive of the Ichthyological Research Society.

RESULTS AND DISCUSSION

Nine angel sharks, *S. squatina*, were recorded in several regions of Turkish waters between 21 March 2009 and February 2019 (Tab. 1; Fig. 1). Eight specimens were captured by different means of bottom fishing gear (e.g., gill or trammel net, or longline) or harpoon, and 1 specimen was sighted alive (see Tab. 1 for specimen-specific details). Six specimens were females, 2 were males and the sex of 1 angel shark was unknown. The total length of the specimens varied from 90 to 174 cm. Five angel sharks were captured in Aegean waters, three in the Sea of Marmara and 1 specimen was sighted in the south-eastern part of the region near the northern entrance to the Dardanelles Strait (Fig. 1). The angel sharks were recorded in very shallow (specimen no. 2 at a depth of 1.5 m) to quite deep waters (specimen no. 3 at a depth of ca. 50 m) of the coastal zone (Tab. 1).

Based on the information obtained from available literature, the occurrence of the angel shark, *S. squatina*, in Turkish waters dates back to the early 20th century, when Deveciyan (1926) reported on angel sharks landed

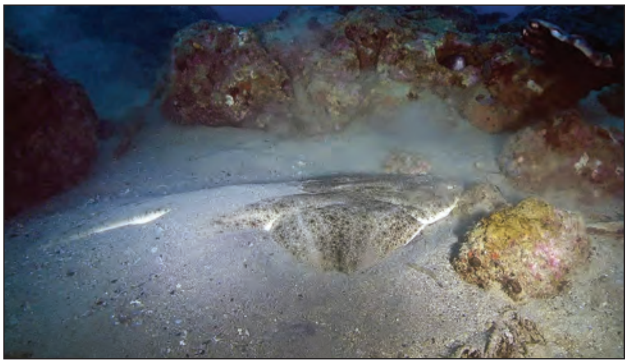

Fig. 2: A live specimen of *S. squatina* ***(specimen no. 6 in Table 1) sighted in the Dardanelles Strait at a depth of 30 m (Photo: Mert Gökalp).***
Sl. 2: Opaženi primerek navadnega sklata (primerek št. 6 v Tabeli 1), opažen v prelivu Dardanel na globini 30 m (Foto: Mert Gökalp).

at the İstanbul fish market. According to his report (Deveciyan, 1926), angel shark was a regularly captured, landed and consumed shark species; however, the author did not provide any specific information, such as annual catch data, etc., on the species. Kabasakal (2002) reported captures of 51 angel sharks in total off the coast of Turkey between 1995 and 1999. Kabasakal (2003) reported the capture of a female angel shark of 87 cm TL in the southern Sea of Marmara, in November 1995. According to Kabasakal and Kabasakal (2004), 5 males in total were captured off the coast of Gökçeada in the northeastern Aegean Sea in October 1996 (3 specimens) and July 1997 (2 specimens), all by means of bottom fishing gear. In the 1950s, *S. squatina* was a popular gamefish among spearfishermen in the Sea of Marmara (Kabasakal & Kabasakal, 2014).

According to Deveciyan (1926), Akşıray (1987) and Kocataş *et al*. (1993), *S. squatina* is a valuable commercial species of shark in Turkish marine fishery. Deveciyan (1926) and Akşıray (1987) in particular pointed out the significant landings and high economical value of angel sharks captured in Turkish waters in the 20th century. However, like many other shark species, populations of *S. squatina* in Turkish waters have drastically declined and the rarity or the absence of angel shark from the general ichthyological inventory or shark specific studies provides alarming evidence that the survival of the species is threatened. In two recent surveys on the composition of bycatch in pink-shrimp (*Parapenaeus longirostris*) beam trawl fishery in southern and northern Sea of Marmara, Bayhan *et al*. (2006) and Bök *et al*. (2011) reported the absence of *S. squatina* from both marine regions. Karakulak *et al*. (2000) also reported the absence of *S. squatina* in surveys on demersal fish populations of the northern Sea of Marmara. Keskin and Eryılmaz (2010) reviewed the demersal fish populations of the Sea of Marmara and found *S. squatina* to be rare in the mentioned region, which was further corroborated by Kabasakal (2016).

The rarity of *S. squatina* in Turkish waters was also emphasised by Kabasakal and Kabasakal (2014) and Akyol *et al*. (2015). According to Başusta *et al*. (2016), the paucity of publications on *S. squatina* (less than 5) is conspicuous among the studies on cartilaginous fishes occurring in Turkish Mediterranean waters. Recently, Filiz *et al*. (2018) estimated the biomass and numerical

Fig. 3: A *S. squatina* ***incidentally captured off Şarköy coast (southwestern Sea of Marmara; specimen no. 7 in Tab. 1), on display at the fishmonger's (Photo: Hakan Kabasakal).***
Sl. 3: Naključno ujeti primerek navadnega sklata ob obali Şarköy (jugozahodno Marmarsko morje; primerek št. 7 v Tabeli 1), razkazan na ribji tržnici (Foto: Hakan Kabasakal).

Fig. 4: A** S. squatina **incidentally captured in Dardanelles Strait (specimen no. 8 in Tab. 1), on display at the fishmonger's (Photo: Hakan Kabasakal).

Sl. 4: Navadni sklat naključno ujet v prelivu Dardanel (primerek št. 8 v Tabeli 1), razkazan na ribji tržnici (Foto: Hakan Kabasakal).

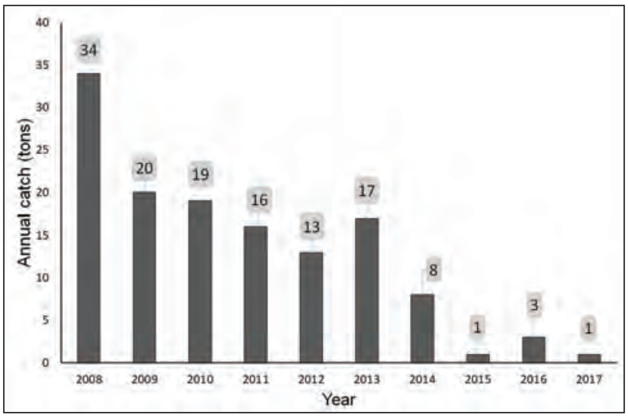

Fig. 5: Annual landings of** Squatina **species by Turkish fishermen in the 2008–2017 period. The graph based on the annual landings data of** Squatina **species is extracted from fisheries statistics (TUIK, 2017).

Sl. 5: Letni ulov različnih vrst iz rodu** Squatina**, ki so jih ujeli turški ribiči v obdobju 2008-2017. Graf temelji na letnih ulovih sklatov, pridobljenih iz statističnih ribiških podatkih (TUIK, 2017).

abundance of *S. squatina* at 13 kg/km^2 and 5 individuals/km^2 based on the bycatch composition of bottom trawl fishery in southern Aegean Sea. Since no species-specific discrimination of angel shark catches is reported in TUIK statistics, the annual landings data represent the combined data on the landings of three congeneric angel sharks, *S. aculeata*, *S. oculata* and *S. squatina,* captured in Turkish waters. A dramatic decline in the annual landings of *Squatina* species is clear from the fishery statistics for the 2008–2017 period (TUIK, 2017; Fig. 5). While in 2008 the annual landings of *Squatina* species by commercial fishermen amounted to 34 tons, in 2017 they came nearly 1 ton (Fig. 5). Although the landings rose to 17 tons in 2013, the declining trend in the annual landings during the 2008–2017 period did not change (Fig. 5).

The first records of *S. squatina* in Turkish waters date back to the early 20th century (Ninni, 1923; Deveciyan, 1926). The occurrence of *S. squatina* in Turkish waters was also reported in later studies (*e.g.*, Roux, 1984; Akşıray, 1987). Both in the earliest and later studies, *S. squatina* was reported as an abundant shark population sustaining a fishery based on it (Deveciyan, 1926; Akşıray, 1987). Furthermore, the maximum total lengths reported for the species ranged between 200 cm (Akşıray, 1987) and 250 cm (Roux, 1984). Unfortunately, there are no studies reporting about the population dynamics and abundance of *S. squatina* in Turkish waters during the last century, however, recent data show drastic declines in terms of biomass, numerical abundance and annual landings (TUIK, 2017; Filiz *et al*., 2018; Fig. 5). Also, the maximum total length of angel sharks captured in recent years (174 cm TL in the present study; specimen no: 3, Tab. 1) is remarkably below the historically reported sizes (200 to 250 cm TL).

Based on the limited historical and contemporary data on biomass, numerical abundance, annual landings and maximum total length of the *S. squatina* observed in Turkish waters, the 'shifting baseline syndrome' outlined by Pauly (1995) is dramatically present among young generations of fishermen, a common phenomenon that was also highlighted by Holcer and Lazar (2017) for the angel sharks from the Adriatic Sea. Due to the absence of baseline data indicating the status of *S. squatina* in Turkish waters during the last century, we cannot carry out a reasonable comparison between the historical and contemporary statuses of the species. However, based on available data it is possible to speculate that the abundance of *S. squatina* in demersal catch composition significantly declined over time, with the maximum total length of the species decreasing (Deveciyan, 1926; Roux, 1984; Akşıray, 1987; TUIK, 2017; Filiz *et al*., 2018). According to Meyers *et al*. (2017), in regions where baseline information on the current spatial distribution patterns, habitat use, abundance and population structure of the angel shark is lacking, urgent conservation policies should be implemented. Therefore, the inclusion of *S. squatina,* as well as the congeneric angel sharks, *S. aculeata* and *S. oculata*, in the list of marine protected species, which was declared in the Official Gazzette in 2018 (Resmi Gazete, 2018), was a correct decision with respect to the status of angel shark in Turkish seas, where the baseline data of squatinid sharks is inadequate.

Except for the single live sighting, the angel sharks examined in the present study were incidentally captured specimens (Tab. 1); however, bycatch pressure on this rare shark by untargeted fisheries can also become a serious threat to its future survival. In an extensive study on the reproductive biology of *S. squatina* in the Mediterranean Sea, Capapé *et al*. (1990) reported that males and females mature between the total lengths of 80–132 cm and 128–169 cm, respectively. According to Capapé *et al*. (1990), males and females of over 80 cm and 128 cm in TL, respectively, can be considered as reproducing adult angel sharks. Recently, a pregnant female angel shark of 156 cm TL got entangled in a trammel net in Gökova Bay (southern Aegean Sea) and expelled its developing embryos during handling (Akyol *et al*., 2015). Based on the sizes of the reproducing adults of angel sharks reported by Capapé *et al*. (1990) and Akyol *et al*. (2015), it can be concluded that all of the specimens examined in the present study were mature males and females (Tab. 1). Incidental captures of reproducing adults create another threat to the survival of *S. squatina*. Fishing-gear induced injuries, keeping sharks on the deck in rough conditions and subjecting them to harsh handling before releasing them into the sea negatively impact the post-release survival rate of specimens (see Kabasakal, 2010 for relevant references), and cannot be ruled out as causes of mortality in the incidentally captured specimens of *S. squatina* in the present study.

CONCLUSIONS

Although the protective legislation concerning angel sharks applies to all 3 species, *S. aculeata, S. oculata* and *S. squatina* (Resmi Gazete, 2018), it is still very early to observe any positive results of the recent enactment of this legal protection on the angel shark populations occurring in Turkish waters. Since a "shifting baseline" effect is possibly present among younger fishermen, as reported by Holcer & Lazar (2017), the latter can lack incentive to act upon catching angel sharks, not recognising that as important. Due to life history parameters of *S. squatina*, such as low fecundity, long reproductive cycle (2 year) and the large size at which females reach sexual maturity (128 cm, which equals 51.2% of the reported maximum total length, 250 cm) (Roux, 1984; Capapé *et al*., 1990), the species is considered as highly vulnerable to targeted and untargeted fisheries alike. Taking the fishery statistics of *Squatina* species during the last 10 years (TUIK, 2017) and the biomass and numerical abundance data on the species in Turkish waters (Filiz *et al*., 2018) as baseline data, we should point out an alarming reduction in the populations of *S. squatina* in the mentioned region. An extensive study providing baseline information on the current spatial distribution patterns, habitat use, abundance and population structure of *S. squatina* in Turkish waters is therefore an urgent necessity. Given the Red List status of *S. squatina* (critically endangered; Cavanagh & Gibson, 2007) and its rarity (Golani, 2006; Serena & Relini, 2006; Kabasakal & Kabasakal, 2014; Akyol *et al*., 2015; Cavallaro *et al*., 2015), the proposed study should employ non-invasive methods, such as capture and release of live specimens after satellite tagging and underwater imaging, perhaps with the contribution of citizen scientist divers. Last but not least, although *S. aculeata, S. oculata* and *S. squatina* are currently under full protection in Turkish seas (Resmi Gazete, 2018), it would be reasonable to expect cryptic mortality of the released angel sharks due to fishing-gear induced injuries and harsh handling before release. To prevent this and insure the safety of both fishermen and captured sharks, training of fishermen on which species of sharks are endangered and under protection and how these species should be kept alive on deck and handled before release, is critical.

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KONČNO ZAVAROVAN! STATUS NAVADNEGA SKLATA, *SQUATINA SQUATINA* (LINNAEUS, 1758) V TURŠKIH MORJIH S POSEBNIM POUDARKOM NA NOVEJŠA OPAZOVANJA IN NAKLJUČNE ULOVE

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POVZETEK

Devet navadnih sklatov, Squatina squatina*, je bilo popisanih v različnih predelih turških voda med 21. marcem 2009 in februarjem 2019. Osem primerkov je bilo ujetih z različnimi ribiškimi orodji (npr. zabodne in trislojne mreže, ribolov s parangali) ali harpuno, en primerek pa je bil opažen. Upoštevaje ribiško statistiko v zvezi s sklati v zadnjih desetih letih in podatke o abundanci in biomasi o vrsti v turških morjih kot temeljne podatke, je razviden veliki upad populacij sklatov v omenjenih okoljih. Zato je potrebno čimprej pripraviti obsežno raziskavo o vzorcih prostorske razširjenosti, izbiri habitata, abundanci in populacijski strukturi navadnega sklata v turških morjih.*

Ključne besede: sklat, *Squatina*, varovanje, bazični odmik, redkost, vzhodno Sredozemlje

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ADDITIONAL RECORDS OF RARE SHARKS FROM NORTHERN TUNISIA (CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

Routine investigative monitoring conducted along the northern Tunisian coast allowed us to collect some specimens of large predatory sharks, such as the great white shark, Carcharodon carcharias *(Linnaeus, 1758), the shortfin mako* Isurus oxyrinchus *Rafinesque, 1810, and the common thresher shark* Alopias vulpinus *(Bonnaterre, 1788). These captures indicate that these sharks occur in the Mediterranean Sea, however, further records are needed before declaring that viable populations may still be established in the region. On the other hand, the captured specimen of smoothback angelshark* Squatina oculata *Bonaparte, 1840 could probably be considered as one of the last ones recorded to date in the Mediterranean Sea. The status of the species remains undetermined between extinct and critically endangered.*

Key words: Large predatory sharks, distribution, status, central Mediterranean, endangered species

NUOVI RITROVAMENTI DI SQUALI RARI NELLE ACQUE DELLA TUNISIA SETTENTRIONALE (MEDITERRANEO CENTRALE)

SINTESI

Il monitoraggio investigativo di routine condotto lungo la costa tunisina settentrionale ci ha permesso di raccogliere alcuni esemplari di grandi squali predatori, come il grande squalo bianco, Carcharodon carcharias *(Linnaeus, 1758), il mako* Isurus oxyrinchus *Rafinesque, 1810, e lo squalo volpe* Alopias vulpinus *(Bonnaterre, 1788). Queste catture indicano che tali squali sono presenti nel mare Mediterraneo; sono tuttavia necessari ulteriori ritrovamenti al fine di asserire che nella regione possano essersi stabilite popolazioni vitali. D'altra parte, l'esemplare catturato di squalo angelo* Squatina oculata *Bonaparte, 1840, potrebbe venir considerato come uno degli ultimi ritrovamenti nel mare Mediterraneo. Lo stato della specie rimane indeterminato, tra estinto e in pericolo critico.*

Parole chiave: grandi squali predatori, distribuzione, stato, Mediterraneo centrale, specie in via di estinzione

INTRODUCTION

Studies carried out during the last two decades showed migrations of elasmobranch species towards northern areas, including brackish lagoons (Méjri *et al.*, 2004; El Kamel *et al.*, 2009, 2010; Rafrafi-Nouira *et al.*, 2015). The species identified among these were the blackchin guitarfish *Glaucostegus cemiculus* (E. Geoffroy Saint Hilaire, 1817), the spiny butterfly ray *Gymnura altavela* (Linnaeus, 1758), and the sandbar shark *Carcharhinus plumbeus* (Nardo, 1827). Several large specimens of the latter were recorded (Rafrafi-Nouira *et al.*, 2015; Soufi-Kechaou *et al.*, 2018; Capapé *et al.*, 2018a). Since the capture included male and female adults, it suggested that a viable population was established in an area where the species was formerly unknown (Capapé, 1989).

Additionally, these studies enabled the finding of species considered to be highly threatened, such as the sharpnose sevengill shark *Heptranchias perlo* (Bonnaterre, 1788), a deep-sea species recorded in the Eskerkis Bank (El Kamel-Moutalibi *et al.*, 2014), which migrated southward to lower than usual depths (Capapé *et al.*, 2018b), and a critically endangered species, the Maltese skate *Leucoraja melitensis* (Clark, 1926), which is the latest specimen recorded to date (Ben Amor *et al.*, 2018).

In this paper, we report additional and unusual records of rare species from northern Tunisian waters, among them the smoothback angelshark *Squatina oculata* Bonaparte, 1840, which is affected by drastic population decline.

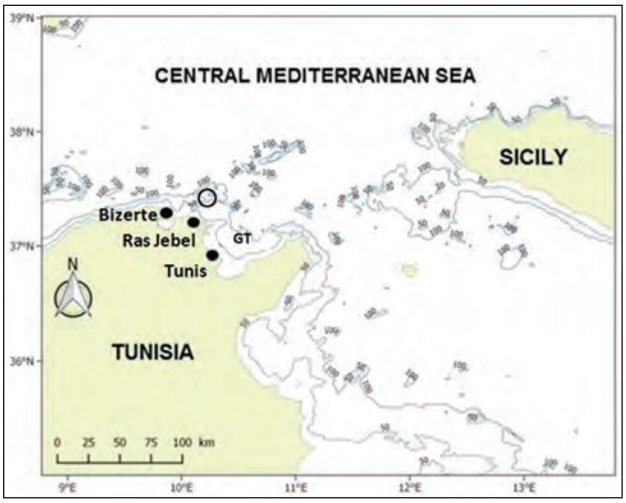

Fig. 1: Map of the northern coast of Tunisia indicating (circle) the capture sites of the elasmobranch species presented in the paper.
Sl. 1: Zemljevid severno tunizijske obale z označenimi (krogec) lokalitetami ulova vrst, ki jih avtorji obravnavajo v prispevku.

MATERIAL AND METHODS

The four studied species reported in the present article were caught in marine waters of northern Tunisia and directly landed at the fishing sites of Bizerte and Ras Jebel (Fig. 1), where they were examined, measured for total length (TL) and weighed for total body weight (TBW). They were identified *in situ* using field guides, such as Whitehead *et al.* (1984), Louisy (2002) and Quéro *et al.* (2003), then delivered to the laboratory for confirmation and a thorough scientific analysis. Some specimens were measured to the nearest mm (including the percentage of total length), and the total body mass was weighed to the nearest gram following Compagno (1984a) for sharks, and Capapé & Roux (1980) for *Squatina oculata*. For each specimen, all available data related to their capture were given, including fishing gear, depth, type of bottom and, wherever possible, associated ichthyofauna. After being carefully measured and analysed, each specimen was fixed in 10% buffered formaldehyde, preserved in ethanol and deposited in the Ichthyological Collection of the Institut Supérieur de Pêche et d’Aquaculture de Bizerte, where it was assigned a catalogue number.

RESULTS

Great white shark, *Carcharodon carcharias* (Linnaeus, 1758)

Carcharodon carcharias is a large shark with worldwide distribution, inhabiting temperate waters especially, but known to penetrate tropical marine areas, too. Its occurrence is well documented in the entire Mediterranean Sea (De Maddalena & Heim, 2012). However, most of these records occurred in the central Mediterranean, especially in the Strait of Sicily, where several juvenile and adult specimens were recorded. Some authors consider this area a nursery ground for the species (Saïdi et *al.*, 2005; Maliet *et al.*, 2013; Bradaï & Saïdi, 2013). Historical and contemporary occurrences of *C. carcharias* in eastern Mediterranean are also well documented (Kabasakal, 2014, 2016). Based on the recent captures of newborn, young-of-the-year and juvenile specimens, a possible nursery ground for the great white shark in the Aegean Sea was also suggested (Kabasakal & Gedikoğlu, 2008; Kabasakal *et al.*, 2018).

C. carcharias is known off the Tunisian coast, and Bradaï & Saïdi (2013) noted that 59 reliable captures had been reported in the region between 1953 and 2012, with most captures (56%) occurring in the Gulf of Gabès, which was considered as a probable nursery area for the species. On 12 April 2015, a male measuring 1.8 m approximately was caught by longline in the waters surrounding the Cani Rocks (37°25’35.90” N and 10°08’43.28” E), at a depth of approximately 100 m, on rocky bottom. More recently, on 26 December 2018, a female was captured by a benthic trawl at the same

Fig. 2: Snout of *Carcharodon carcharias* ***(Ref. ISPB-Car-carch-01), scale bar = 200 mm.***
Sl. 2: Gobec velikega belega morskega volka (Ref. ISPB-Car-carch-01), merilo = 200 mm.

depth on sandy-muddy bottom (37° 25′ 50.08″ N and 10°02′ 50. 96 E). It reached 2.80 m in total length and weighed 400 kg. As soon as it was landed on deck, the specimen was cut into slices to be sold, but it was still identified as a great white shark by experienced fishermen. Only the head of the specimen was preserved, which was more conical, sharper and pointier than it usually appears in this species. It was also slightly curved, but since no injuries or scars were observed in this atypical formation (Fig. 2), this could be considered an abnormality that had not been recorded before in any shark species. The teeth of both upper and lower jaws were huge, triangular, bladelike and serrated, confirming the identification made by the fishermen. The head was deposited in the ichthyological collection of the Institut Supérieur de Pêche et d’Aquaculture de Bizerte (Tunisia) under catalogue number ISPB-Car-carch -01.

In addition, on 11 April 2019, a second female of *C. carcharias* was captured by a bottom trawler in the very same area, measuring 2 m in TL and weighing 250 kg according to the information given by fishermen. It was sold immediately, but the fishermen provided us with a photograph, based on which we could confirm the identification of the species (Fig. 3).

Fig. 3: The *Carcharodon carcharias* ***specimen captured on 11 April 2019, scale bar = 200 mm.***
Sl. 3: Primerek velikega belega morskega volka, ujet 11. aprila 2019, merilo = 200 mm.

Shortfin mako *Isurus oxyrinchus* Rafinesque, 1810

Isurus oxyrinchus is a pelagic, coastal and oceanic shark that can be found in tropical and temperate waters worldwide ranging from the surface to depths of 400 m. It is well known in the eastern Atlantic and throughout the Mediterranean Sea (Quéro, 1984). The species was first recorded in the northern Tunisian area

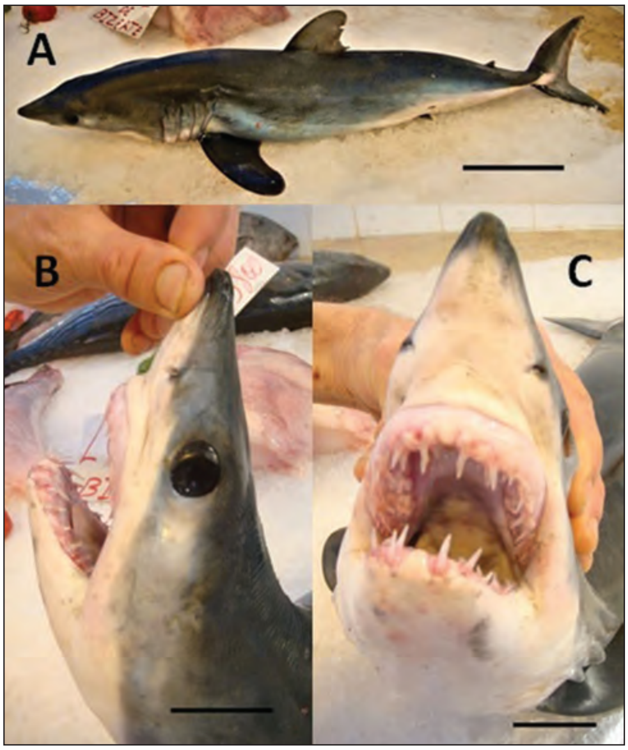

Fig. 4: *Isurus oxyrinchus* ***(Ref. FSB-Isu-oxy-01). A. General morphology, scale bar: 150 mm. B. Snout lateral view, scale bar = 40 mm. Snout ventral view, scale bar = 30 mm.***
Sl. 4: *Isurus oxyrinchus* ***(Ref. FSB-Isu-oxy-01). A. Morfologija, merilo: 150 mm. B. stranski pogled na gobec, merilo = 40 mm. Pogled na gobec od spodaj, merilo = 30 mm.***

Tab. 1: Morphometric measurements (mm and %TL) of the specimen of** Isurus oxyrinchus **(Ref. FSB-Isu-oxy-01).
Tab. 1: Morfometrične meritve (mm in %TL) primerka vrste** Isurus oxyrinchus **(Ref. FSB-Isu-oxy-01).

Reference	**FSB-Isu-oxy-01**	
Sex	**Female**	
Morphometric measurements	**mm**	**% TL**
Total length (TL)	880	100
Head length	270	30.7
Prebranchial length	190	21.6
Preorale length	60	6.8
Prenasal length	45	5.1
Intergill length	80	9.1
Eye with	22	2.5
Eye height	18	2.0
Internasal length	4	0.5
Mouth width	85	9.7
Distance between snout 1st gill	210	23.9
Precaudal length	670	76.1
Pelvic fin length	45	5.1
Pelvic height	45	5.1
Pelvic inner margin	20	2.3
Pelvic anterior margin	30	3.4
Pelvic posterior margin	30	3.4
First dorsal height	55	6.3
First dorsal base	75	8.5
First dorsal inner margin	25	2.8
First dorsal posterior margin	43	4.9
First dorsal anterior margin	80	9.1
Second dorsal height	13	1.5
Second dorsal base	15	1.7
Second dorsal inner margin	10	1.1
Second dorsal posterior margin	10	1.1
Second dorsal anterior margin	23	2.6
Pectoral inner margin	35	4.0
Pectoral anterior margin	160	18.2
Pectoral posterior margin	90	10.2
Pectoral fin length	50	5.7
Total body mass (g)	**4200**	

by Vinciguerra (1884). The shortfin shark is sporadically captured throughout the Tunisian coast. (Capapé, 1989; Bradaï *et al.*, 2002). Additionally, Capapé (1980) noted that *I. oxyrinchus* is caught off the northern Cape Bon Peninsula in spring and early summer, and following Bradaï *et al.* (2002), it rarely occurs in southern regions.

Recently, investigations conducted in the same study area have allowed us to record the capture of several mako specimens. On 15 May 2015 and 7 July 2015, two males were caught by longline at a depth of approximately 150 m. They measured 1300 mm and 800 mm and weighed 24 kg and 4.2 kg, respectively. Several other specimens were collected during June 2018 by bottom trawlers according to the information provided by fishermen. The smallest specimen was delivered to our laboratory for examination and measurements (Fig. 4, Tab. 1).

All specimens were identified as *Isurus oxyrinchus* based on the combination of the following characters: body fusiform, snout very pointed; first dorsal with apex acutely pointed, pectoral fins shorter than head fins and falcate, origin of anal fin below the middle of second dorsal fin base, teeth very slender, alike in both jaws. Such description is in total accordance with Cadenat & Blache (1981), Compagno (1984b) and Quéro (1984). *Isurus oxyrinchus'* congeneric species, the longfin mako *I. paucus* Guitart Manday, 1966, occurs off the Algerian coast (Hemida & Capapé, 2008). It differs from *I. oxyrinchus* in pectoral fins being as long as the head, anal fin originating below the posterior end of the second dorsal fin base, and teeth widening towards the base.

The smallest specimen was deposited in the Ichthyological Collection of the Faculté des Sciences de Bizerte (Tunisia) under catalogue number FSB-Isu-oxy-01 (see Tab. 1). All these captures suggest that the species is not extinct in this area and that the presence of a viable population remains a hypothesis that cannot be totally ruled out.

Common thresher shark *Alopias vulpinus* (Bonnaterre, 1788)

Alopias vulpinus is a large global coastal and pelagic shark occurring in depths up to 650 m (Compagno, 1984b). The species is present in the entire Mediterranean, but commoner in the western basin (Capapé, 1989). The species seems to be rather abundant off the Algerian coast, where it is caught as target or bycatch in pelagic and coastal commercial and small-scale longline, purse seine and gillnet fisheries. It is locally used for human consumption, especially the meat and fins, despite the fact that international regulations prohibit retention. Observations were carried out from 1999 to 2002 in the great fish market of Algiers, where all captures occurring throughout the Algerian coast are landed. A total of 194 specimens were examined. Conversely, recent observations carried out in the area and information provided by fishermen indicated a drastic decline of captures of the species (Hemida *et al.*, *in press*).

Quignard & Capapé (1971) noted that *A. vulpinus* occurs throughout the Tunisian coast, but more

Tab. 2: Morphometric measurements (mm and %TL) of the specimen of* Alopias vulpinus *(Ref. ISPB-Alo-vul-01).
Tab. 2: Morfometrične meritve (mm in %TL) primerka vrste* Alopias vulpinus *(Ref. ISPB-Alo-vul-01).

Reference	**ISPB- Alo-vul-01**	
Sex	**Male**	
Morphometric measurements	**mm**	**% TL**
Total length (TL)	3775	100.00
Precaudal length	1840	48.74
Pre first dorsal length	830	21.99
Pre first dorsal length	160	4.24
Pre pectoral length	530	14.04
Head length	580	15.36
Prebranchial length	430	11.39
Preorale length	120	3.18
Pre-pelvic length	1350	35.76
Distance between	210	5.56
Eye with	35	0.93
Eye height	50	1.32
Mouth width	170	4.50
Pectoral fin length	335	8.87
Pectoral inner margin	480	12.72
Pectoral anterior margin	605	16.03
Pectoral posterior margin	200	5.30
Anal fin length	30	0.79
First dorsal posterior margin	290	7.68
First dorsal base	230	6.09
First dorsal inner margin	260	6.89
First dorsal anterior margin	345	9.14
Second dorsal height	30	0.79
Second dorsal base	35	0.93
Second dorsal inner margin	20	0.53
Second dorsal anterior margin	40	1.06
Second dorsal posterior margin	220	5.83
Tail anterior margin	1935	51.26
Total body mass (kg)	**120**	

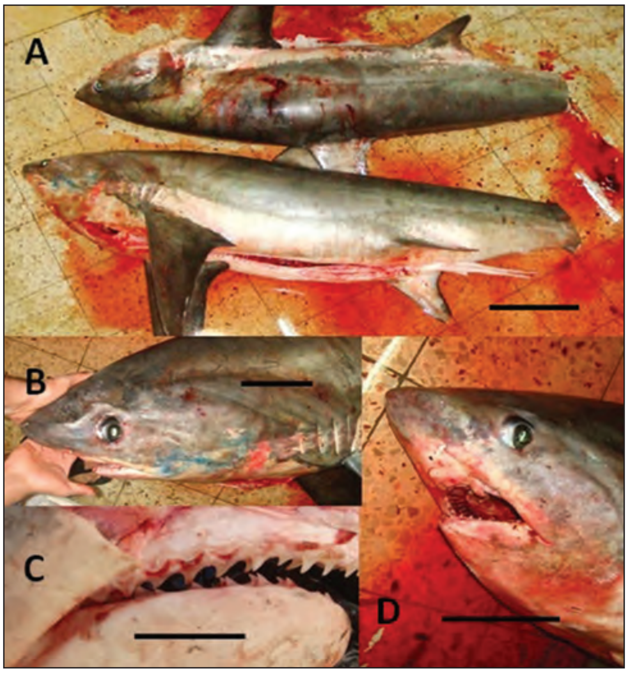

Fig. 5:* Alopias vulpinus *(Ref. ISPB-Alo-vul-01). A. General morphology without tail, scale bar = 300 mm. B. Head, lateral view, scale bar = 100 mm. C. Jaws, lateral view, scale bar = 30 mm. D. Snout, lateral view, scale bar = 200 mm.
Sl. 5:* Alopias vulpinus *(Ref. ISPB-Alo-vul-01). A. Morfologija morskega psa brez repa, merilo = 300 mm. B. Glava s strani, merilo = 100 mm. C. čeljusti s strani, merilo = 30 mm. D. Gobec s strani, merilo = 200 mm.

frequently in northern areas. However, Bradaï *et al.* (2002) reported the capture of 3 specimens in the Gulf of Gabès in the south. Routine monitoring of elasmobranch species in the area of Bizerte-Ras Jebel offered us the opportunity to collect 4 specimens: on 14 May 2015, two specimens were captured measuring 4 m and 3.8 m, and weighing 130 kg and 120 kg, respectively. Morphometric measurements were recorded for the smallest *A. vulpinus* and summarized in Table 2, its head was recovered and deposited in the Institut Supérieur de Pêche et d'Aquaculture de Bizerte (Tunisia), under catalogue number ISPB-Alo-vul-01 (Fig. 5). On 5 December 2018, a third specimen measuring 3.0 m in TL and weighing 80 kg was captured. A fourth specimen was captured on 4 April 2019 measuring 4.0 m and weighing 150 kg.

The four specimens were captured by longlines at a depth of approximately 100 m, on muddy-sandy bottoms. They were identified as *A. vulpinus* following the main characters: short snout, eyes rather small and not reaching the dorsal surface of the head, first dorsal fin closer to pectoral than pelvic fins. A related thresher shark, *A. superciliosus*, differs from *A. vulpinus* in having larger eyes, which reach the dorsal surface of the head, and the first dorsal closer to pelvic than pectoral fins (Quéro *et al.*, 2003). It is the first time that so many specimens were captured in such a short time, though according to fishermen such captures are rather common in the area, which may indicate a viable population inhabiting the area.

Smoothback angelshark *Squatina oculata* Bonaparte, 1840

Squatina oculata is known in the eastern Atlantic, south of the Strait of Gibraltar, from Morocco (Lloris & Rucabado, 1998) to Angola (Capapé *et al.*, 2002). The species is rather abundant off the coast of Senegal, where it plays an important role in craft fishery. There the sharks are exploited for their fins, meat and the oil extracted from their livers for therapeutic purposes (Capapé *et al.*, 2002).

Roux (1984) wrongly noted that *S. oculata* is only present in the western Mediterranean Basin, however, the species is indeed unknown off the Mediterranean coast of France (Capapé *et al.*, 2000). Tortonese (1956) noted its occurrence in Italian waters, and Zava *et al.* (2016) collected 4 juvenile specimens from the Strait of Sicily. Ergüden *et al.* (2019) found a female *S. oculata* in Turkish waters and eastwards the species is also recorded in the Levant Basin (Golani, 2005).

S. oculata used to be caught quite abundantly off the Tunisian coast, especially in northern areas. The captured specimens were used to provide information about the species' reproductive biology (Capapé *et al.*, 1991). Additionally, Bradaï *et al.* (2002) noted the captures of some specimens southwards, in the Gulf of Gabès. Later, 4 adult specimens, 2 males and 2 females, were caught in the study area, their average total length was 1020 mm (Mnasri, 2008). On 26 December 2018, a female was captured in our study area, reaching 1300 mm in TL and weighing 5 kg. It was recorded based on a photograph taken by a fisherman (Fig. 6), which was helpful in identifying the specimen as *S. oculata* owing to the lack of the median line of spines, the hind tips of pelvic fins not reaching the level of first dorsal fins, and the specimen displaying a greyish colour with white spots on dorsal surface and dark bars on tail. This was probably one of the latest Mediterranean specimens found to date and confirmed the scarcity of the species in this sea. Similarly, its closely related congeneric species *S. squatina* (Linnaeus, 1758) has also been subjected to fishing pressure and has, following Giusto & Ragonese (2014), almost disappeared not only from Sicilian waters, but other areas as well.

DISCUSSION

Previous and new discoveries of the mentioned elasmobranch species suggest that the northern Tunisian

Fig. 6: Smoothback angelshark** Squatina oculata**, general morphology, scale bar = 200 mm.
Sl. 6: Pegasti sklat** Squatina oculata**, morfologija, merilo = 200 mm.

coast could be a hotspot for large sharks. Such phenomenon could be explained by the geographical location of the Tunisian waters in the central Mediterranean Sea, an inevitable passageway between western and eastern basins at a halfway between Atlantic and sub-tropical marine influences. Additionally, the richness of marine biodiversity sustains the hypothesis of nursery areas, especially for viviparous species, which look for the best environmental conditions before laying their litters in the wild (Rafrafi-Nouira, 2016). Biological richness minimizes the pressure of inter- and intraspecific competition for food between sharks considered as top predators (Stergiou & Karpouzi, 2002).

On the other hand, the warming of the Mediterranean waters encourages the occurrence of species in areas where they were previously unknown or rare. The best instance of this phenomenon is *Carcharhinus plumbeus,* abundantly captured in the Gulf of Gabès and at present in northern areas as well (Capapé *et al*., 2018a). Captures of *C. plumbeus* are equally numerous off the Algerian coast (Hemida *et al.*, 2002), the sharks probably migrating along Maghreb shores from west to east. Similar patterns could also be taken into consideration in relation to the recent abundance of *Isurus oxyrinchus* and *Alopias vulpinus* off the northern Tunisian coast. Information provided by experienced fishermen indicates that both species are regularly captured there.

Since large sharks are locally targeted due to their high economical value, they are not discarded at sea after the capture. They are landed at fishing sites, where they are immediately sold, despite recommendations from Tunisian authorities. Thus, it appears that large sharks have not disappeared from Tunisian waters completely, therefore the opinion of Ferretti *et al.* (2008) about the loss of large sharks in the area is partially contrasted. However, due to their K-selected characteristics (Camhi *et al*., 1998), most elasmobranch species are considered to be threatened. Still, the actual relative abundance of large sharks captured from the northern Tunisian coast shows their populations have not experienced a drastic decline in this area.

The captures of few *S. oculata* along the northern Tunisian coast remain questionable. Were they occasional or is a viable population of this species still present? For fishermen, captures of squatinid species are considered a rather amazing event. Recent findings of *S. oculata* (Mnasri 2008; Zava *et al.*, 2016; Ergüden *et al.*, 2019; this study) suggest that the species is critically endangered, following Morey (2019), yet not extirpated. In any case, further records are needed before it is possible to confirm or refute the presence of a viable population of this species in the central Mediterranean.

DODATNI ZAPISI O POJAVLJANJU REDKIH MORSKIH PSOV IZ SEVERNE TUNIZIJE (OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

Na podlagi rutinskega monitoringa vzdolž severne tunizijske obale so bili pridobljeni podatki o primerkih nekaterih večjih plenilskih vrst kot so beli morski volk, Carcharodon carcharias *(Linnaeus, 1758), atlantski mako* Isurus oxyrinchus *Rafinesque, 1810, in navadna morska lisica* Alopias vulpinus *(Bonnaterre, 1788). Ti ulovi kažejo, da se ti morski psi še vedno pojavljajo v Sredozemskem morju, vendar so za oceno prisotnosti viabilne populacije na raziskanem predelu potrebni še dodatni podatki. Ujeti primerek pegastega sklata* Squatina oculata *Bonaparte, 1840 pa je verjetno eden izmed zadnjih primerkov te vrste v Sredozemskem morju. Status te vrste je tako še vedno nejasen, saj ni jasno ali je vrsta kritično ogrožena ali morda izumrla.*

Ključne besede: veliki plenilski morski psi, razširjenost, status, osrednje Sredozemsko morje, ogrožene vrste

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ESTABLISHMENT OF THE NON-INDIGENOUS PRAWN *PENAEUS PULCHRICAUDATUS* STEBBING, 1914 IN THE MARINE AREA OF CYPRUS

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ABSTRACT

The paper provides strong evidence on the establishment of the Lessepsian prawn Penaeus pulchricaudatus *(Decapoda, Dendrobranchiata, Penaeidae) in Cypriot waters based on the occurrences reported in the present study and in previous records. On 3 September 2018, several* P. pulchricaudatus *individuals of different sizes were observed and one photographed* in situ *in Protaras, Trinity Beach. The individual, upon sight, was estimated to measure 15-17 cm in total length. The crustacean diversity of Cyprus is rather underestimated, even in common native species. This species should be considered as established in Cyprus, since several individuals of various sizes were observed during the sighting described herein and the species has so far been reported from three different locations along the coast of Cyprus (considering the previous records from Cape Greco and Cape Andreas).*

Key words: *Penaeus pulchricaudatus*, Decapoda, non-indigenous species, Cyprus, Levantine Sea, eastern Mediterranean Sea

STABILIMENTO DEL GAMBERO NON INDIGENO *PENAEUS PULCHRICAUDATUS* STEBBING, 1914 NELL'AREA MARINA DI CIPRO

SINTESI

L'articolo fornisce una forte evidenza dello stabilimento del gambero lessepsiano Penaeus pulchricaudatus *(Decapoda, Dendrobranchiata, Penaeidae) nelle acque cipriote, in base ai ritrovamenti riportati nel presente studio e a segnalazioni precedenti. Il 3 settembre 2018 sono stati osservati diversi esemplari di* P. pulchricaudatus *di dimensioni diverse, uno dei quali fotografato* in situ *a Protaras, Trinity Beach. La lunghezza totale di questo esemplare è stata stimata a vista (15-17 cm). La diversità dei crostacei di Cipro è piuttosto sottostimata, anche per le comuni specie autoctone. Questa specie lessepsiana dovrebbe venir considerata come stabilita a Cipro, poiché durante l'avvistamento qui riportato sono stati osservati diversi individui di varie dimensioni. La specie è stata finora segnalata in tre diverse località lungo la costa di Cipro (considerando anche i ritrovamenti precedenti di Capo Greco e Capo Andreas).*

Parole chiave: *Penaeus pulchricaudatus*, Decapoda, specie non indigena, Cipro, Mar di Levante, Mediterraneo orientale

INTRODUCTION

Citizen-scientists are contributing to monitoring alien and rare species in the Mediterranean Sea (e.g., Giovos *et al.,* 2018; Kampouris *et al.*, 2018a, b & c). There are several projects and initiatives successfully underway in the basin (e.g., Kondylatos *et al.,* 2017; Zenetos *et al.*, 2017; Bariche *et al.,* 2018; Giovos *et al.,* 2018). But although the social media are increasing the probability of data collection through direct involvement, some scientists remain sceptical (Katsanevakis & Moustakas, 2018).

It should not be a surprise that Cyprus, which is less than 400 nm distant from the Suez Canal, is heavily impacted by the introduction of non-indigenous species (Chartosia & Michailidis, 2016). The crustacean diversity of Cyprus is rather underestimated, even in common native species (Chartosia & Theodosiou, 2018). Perhaps the most comprehensive work is the study by Lewinsohn & Holthuis (1986), which inevitably lacks information, especially in relation to non-indigenous and rare species.

The name *Penaeus pulchricaudatus* (Stebbing, 1914) was believed to be a junior synonym of a species of global economic importance, *Penaeus japonicus*. The *Penaeus japonicus* species complex exhibits genetic differences throughout its geographical distribution (Tsoi *et al*., 2014). *P. pulchricaudatus* occurs naturally in Australia, the western Indian Ocean, the South China Sea and the Red Sea. The population in the Mediterranean Sea, which originated from the Red Sea, is expanding northwards and the species is considered a Lessepsian migrant (Tsoi *et al*., 2014). Regarded as an established species in the south Aegean Sea (Kampouris *et al.,* 2018b, and references within), it constitutes an important component of prawn fishery in Greece and Turkey (Can *et al.,* 2004; Corsini-Foka *et al.,* 2015). In Cyprus, the first report of the species (as *P. japonicus*) dates to 1986 (Lewinsohn & Holthuis, 1986), but it is still undetermined if *P. pulchricaudatus* is established in Cyprus and what its population status is.

MATERIAL AND METHODS

On 3 September 2018, several *P. pulchricaudatus* individuals of different sizes were observed and one photographed *in situ* (Fig. 1) by one of the authors (C.C.) of the paper in Protaras, Trinity Beach, Cyprus (35°03′05.2″N 34°01′23.2″E, approximately), on a sandy bottom at a depth of 3-7 m, during a night dive with a Nikon D810 camera. For the purposes of the present paper only one photograph is presented.

RESULTS AND DISCUSSION

The identification of the species was based on high-resolution photos taken by one of the authors (C.C.) and on the visual identification criteria described in earlier studies (Tsoi *et al.*, 2014; Kampouris *et al.*, 2018b). WoRMS (2018) was used for taxonomy and systematics. The individual's total length was estimated as 15-17 cm. It was sighted as crawling slowly across the bottom (Fig. 2). The visual identification criteria are: 1. well-developed ridges and grooves on carapace, 2. body colour beige with brown transverse bands extending from top to midline, 3. pereiopods yellow to cream-whitish, 4. flagella brown, 5. pleopods yellowish to reddish with white and brown spots/blotches at base (Tsoi *et al.*, 2014; Kampouris *et al.,* 2018b).

The present work provides further evidence that citizen science can contribute importantly to non-indigenous species monitoring by complementing scientific knowledge. The *P. pulchricaudatus* species should be considered as established in Cyprus, based on the obser-

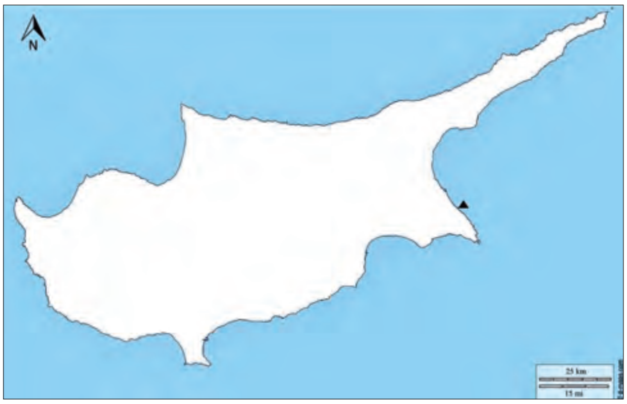

Fig. 1: Map of Cyprus, indicating sampling location (black triangle).
Sl. 1.: Zemljevid Cipra z označeno lokaliteto vzorčenja (črn trikotnik).

Fig. 2. The** Penaeus pulchricaudatus **from Protaras, Trinity Beach, Cyprus, and its microhabitat.
Sl. 2: Kozica vrste** Penaeus pulchricaudatus **iz lokalitete Protaras, Trinity Beach, Ciper, in njen mikrohabitat.

vation of several individuals of various sizes in the wider area on this occasion and based on previous records, all following the methodologies used in earlier studies on non-indigenous species assessments (Thessalou-Legaki *et al.,* 2006; Dulčić *et al.,* 2011; Katsanevakis, 2011). Moreover, considering earlier records (Lewinsohn & Holthuis, 1986), the species has been observed in three different areas along the coast of Cyprus.

Underwater photography and videography are nowadays extensively used for non-indigenous and rare species detection and monitoring. They have proven very successful and useful in many cases, sometimes providing unique findings (e.g., Marcelli *et al.,* 2016, Kondylatos *et al.*, 2017; Bariche *et al.*, 2018; Deidun *et al.*, 2018; Kampouris *et al.,* 2018c).

The taxonomy of the Dendrobranchiata, the penaeid prawns, is a rather typical example of uncertainty and controversy in science (see De Grave & Fransen, 2011). Perhaps the most striking example is the *Penaeus,* where even the correct spelling of the genus is a matter of controversy (see Tsoi *et al.*, 2014 and references within for details). *P. pulchricaudatus* was introduced via the Suez Canal, contributing to an even wider phenomenon of the Lessepsian migration (Tsoi *et al.*, 2014).

CONCLUSIONS

The concurrently present kuruma prawn *P. japonicus* should not be excluded as a potential non-indigenous species in the Mediterranean Sea, since it is cultivated in many European and Mediterranean countries (Quigley *et al.,* 2013 and references therein). Further research, perhaps on a molecular basis, would be required to support this hypothesis.

The establishment of *P. pulchricaudatus* along the coast of Cyprus is not surprising, since there are many other Lessepsian species already regarded as established in the marine area of Cyprus, *Parupeneus forsskali*, Chartosia & Michailidis (2016), for example. Moreover, other penaeid species, such as *P. monodon* (e.g., Alfaro--Montoya *et al.,* 2015; Zink *et al.,* 2018), *P. japonicus* and *P. pulchricaudatus* (e.g,. Quigley *et al*., 2013; Kampouris *et al.,* 2018b) and *P. aztecus* (e.g., Kampouris *et al.,* 2018a, b; Zava *et al*., 2018) are acknowledged as aliens in many other parts of the world, which corroborates their invasive nature.

To better understand the geographical extent of *P. pulchricaudatus'* establishment and the factors affecting it, systematic surveys are needed (Maceda-Veiga *et al.,* 2013; Nunes *et al.,* 2017). Other penaid species that might already be established in Cyprus are *P. hathor* and *P. aztecus*, both extensively recorded in the Levantine and south Aegean Seas (see Kampouris *et al*., 2018b and references therein for details).

TUJERODNA KOZICA *PENAEUS PULCHRICAUDATUS* STEBBING, 1914, USTALJENA VRSTA V VODAH CIPRA

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POVZETEK

Avtorji poročajo o lesepski selivki, tujerodni kozici Penaeus pulchricaudatus *(Decapoda, Dendrobranchiata, Penaeidae) v ciprskih vodah, ki jo lahko na podlagi novih podatkov iz pričujoče študije in predhodnih zapisov smatramo za ustaljeno vrsto. Tretjega septembra 2018 so bili številni različno veliki osebki kozice* P. pulchricaudatus *opaženi, eden od njih pa fotografiran v naravnem okolju na lokaliteti Protaras, Trinity Beach. Slednji naj bi meril med 15-17 cm totalne dolžine. Biodiverziteta rakov Cipra je razmeroma podcenjena, tudi na nivoju domorodnih rakov. Na podlagi opazovanj in drugih predhodnih zapisov s treh lokalitet (upoštevaje zapise iz lokalitet Cape Greco in Cape Andreas) vzdolž ciprske obale bi morali tujerodno kozico obravnavati kot ustaljeno vrsto.*

Ključne besede: *Penaeus pulchricaudatus*, Decapoda, tujerodne vrste, Ciper, Levantsko morje, vzhodno Sredozemsko morje

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OCCURRENCE OF A LESSEPSIAN SWIMMING CRAB, PORTUNUS SEGNIS (CRUSTACEA: DECAPODA), IN SOUTHERN AEGEAN SEA, TURKEY

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ABSTRACT

On 19 June 2018, two specimens of Portunus segnis (Forskål, 1775) *were observed at a fish market in Urla, Izmir. According to the fishmonger, these blue swimming crabs had been caught incidentally with a gill net in the Akköy Lagoon, Didim in the southeastern Aegean Sea. This paper presents a new record confirming a northward extension of the range of* P. segnis *in the Aegean Sea.*

Key words: Portunidae, Blue swimming crab, Lessepsian species, Aegean Sea

PRESENZA DEL GRANCHIO NUOTATORE LESSEPSIANO, PORTUNUS SEGNIS (CRUSTACEA: DECAPODA), NEL MAR EGEO MERIDIONALE, TURCHIA

SINTESI

Il 19 giugno 2018, due esemplari di Portunus segnis *(Forskål, 1775) sono stati trovati in un mercato del pesce a Urla, Smirne (Izmir). Secondo il pescivendolo, questi granchi nuotatori blu erano stati catturati accidentalmente con una rete da posta nella laguna di Akköy, Didim nel mar Egeo sudorientale. L'articolo presenta un nuovo ritrovamento della specie, che conferma un'estensione verso nord della distribuzione di* P. segnis *nel mar Egeo.*

Parole chiave: Portunidae, granchio nuotatore blu, specie lessepsiana, mar Egeo

INTRODUCTION

Portunus segnis (Forskål, 1775) is a marine nocturnal blue swimming crab living in coastal and brackish waters on muddy and sandy bottoms at depths of 0-40 m, characterised by seasonal migration to estuaries and lagoons (CABI, 2018). Native to the western Indian Ocean from Pakistan to South Africa, *P. segnis* spread from the Red Sea (Lai *et al.*, 2010) into the Mediterranean as a Lessepsian migrant, and is now found throughout the eastern and central regions of the Mediterranean Sea (CABI, 2018).

As a history of introduction, it was one of the earliest species (as *Neptunus pelagicus*) to enter the Mediterranean through the Suez Canal, as it was recorded in Port Said, Egypt, as early as 1898. During the 1920s, it was widely recorded in the Levant (i.e., Israel, Lebanon, Syria and Turkey) (CABI, 2018). It has since spread as far west as the northern Tyrrhenian Sea, Italy (Crocetta, 2006), the Gulf of Gabes, Tunisia (Rabaoui *et al.*, 2015) and Maltese waters (Deidun & Scibarras, 2016).

In Turkey, *P. segnis* is one of the 50 exotic crustaceans, 19 of which belong to the infraorder of Brachyura; seven of these species, namely *Callinectes sapidus, Marsupenaeus japonicus, Melicertus hathor, Metapenaeus monoceros, M. stebbingi, Penaeus semisulcatus,* and *P. segnis* are of commercial importance to fisheries (Ateş *et al.*, 2013). The swimming crab is well-known in the southeastern Anatolian coast. Özcan (2012) stated that *P. segnis* was commercially important for local fish markets in the Bays of Mersin and Iskenderun. Altuğ *et al.* (2011) mentioned *P. segnis* both in the Sea of Marmara and the northern Aegean Sea, but failed to provide any concrete details.

In the Aegean Sea, *P. segnis* has been reported from the Rhodes Island (Greece), southern Aegean Sea (Corsini-Foka *et al.*, 2004). Yokeş *et al.* (2007) reported one female specimen of *P. segnis* (CL = 56 mm) from Palamutbükü, and one female (CL = 65 mm) and one male (CL = 61 mm) specimen from Karacasöğüt, Gökova Bay. These were the first records of *P. segnis* in the Turkish Aegean Sea (Fig. 1). This paper presents a new record confirming a northward extension of the range of *P. segnis* in the Aegean Sea.

MATERIAL AND METHODS

On 19 June 2018, two specimens of *Portunus segnis* (Fig. 2) measuring 75 mm (male) and 81 mm (female) in carapace length (CL) were purchased at a fish market in Urla, Izmir. According to the fishmonger these swimming blue crabs had been caught incidentally with a gill net in the Akköy Lagoon, Didim (approx. coordinates: 37°28′N - 12°23′E), in the southeastern Aegean Sea, on a sandy/muddy bottom at a depth of 2-3 m (Fig. 1). Once the existence of these blue crabs in the Akköy Lagoon had been confirmed (C. Ovalıoğlu,

Fig. 1: Capture sites of *Portunus segnis* ***specimens in the Aegean Sea between 1991 and 2018: (1) Plimmiris (SE Rhodes), August 1991, 1♂ / Karakonero (NE Rhodes), March 2000, 1♀ / Gulf of Trianda (NW Rhodes), March 2000, 2♀ (Corsini-Foka et al. 2004); (2) Palamutbükü, 12 August 2004, 1♀ / Karacasöğüt, Gökova Bay, 26 June 2006, 1♀ 1♂ (Yokeş et al., 2007); (3) Akköy Lagoon, 19 June 2018, 1♀ 1♂ (this study).***

Sl. 1.: Lokalitete, kjer so bili ujeti primerki rakovice vrste *Portunus segnis* ***v Egejskem morju med leti 1991 in 2018: (1) Plimmiris (JV Rodos), Avgust 1991, 1♂ / Karakonero (JV Rodos), Marec 2000, 1♀ / Zaliv Trianda (SZ Rodos), Marec 2000, 2♀ (Corsini-Foka et al., 2004); (2) Palamutbükü, 12 Avgust 2004, 1♀ / Karacasöğüt, Zaliv Gökova, 26 junij 2006, 1♀ 1♂ (Yokeş et al., 2007); (3) laguna Akköy, 19 junij 2018, 1♀ 1♂ (pričujoča raziskava).***

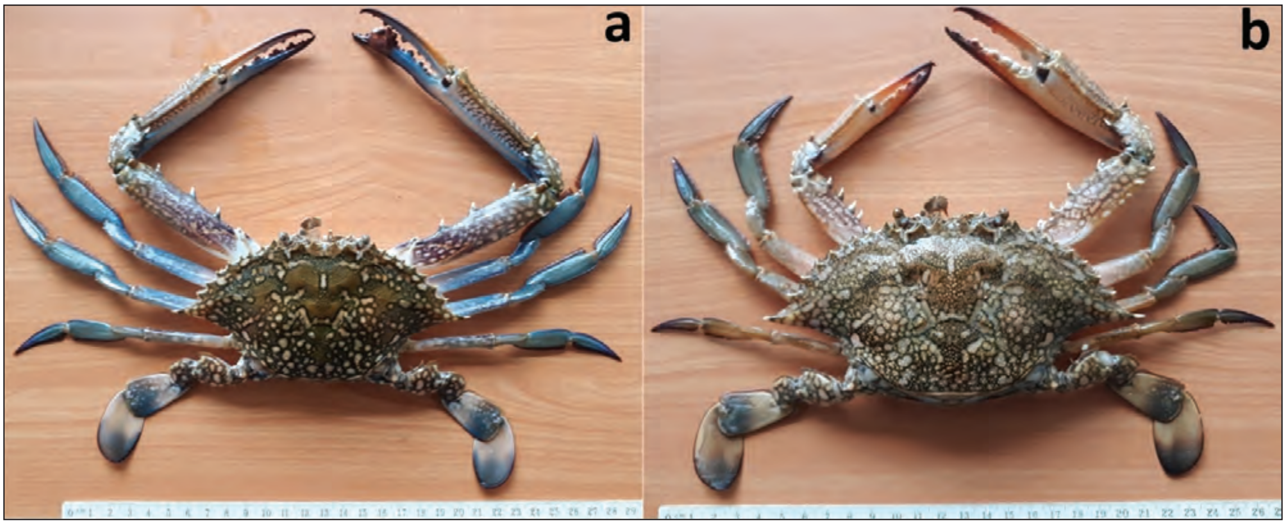

Fig. 2: Specimens of *Portunus segnis* **captured in the SE Aegean Sea; (a) male, (b) female (Photo: O. Akyol).**
Sl. 2: Primerki vrste *Portunus segnis* **ujeti v JV Egejskem morju; (a) samec, (b) samica (Foto: O. Akyol).**

pers. comm.), the specimens were measured to the nearest millimetre, fixed in 5% formaldehyde solution and deposited in the Ichthyological Collection of Ege University, Faculty of Fisheries, under the catalogue number ESFM-MAL/2018-01. Findings: Carapace width 2.2–2.3 times the length, median frontal teeth minute or obsolete, usually inconspicuous, appearing confluent or with wide gap between lateral median teeth. Chelipeds narrow, elongated, merus length in adult males up to 4.5 times the width, but in most specimens with shorter; anterior margin of merus of cheliped usually with 3 spines. Ambulatory legs relatively more elongated, slender, merus length of 4th pereiopod 3.3–4.4 times the width. Colour: Males with dark olive green/blue carapace with numerous pale white spots on surface particularly posteriorly and antero-laterally; the spots do not tend to merge to form reticulating bands. Females similar in pattern to males except for the tips of chelipeds, which are red tinged with a brownish red, instead of blue tinged with a deep rust red (Lai *et al*., 2010). Description and measurements of *P. segnis* are in complete accordance with those in Lai *et al*. (2010), Özcan (2012), Rabaoui *et al*. (2015) and Hajjej *et al*. (2016).

RESULTS AND DISCUSSION

The morphometric measurements of *P. segnis* are indicated in Table 1. The CL in both samples is larger than that of the samples of Gökova and Palamubükü reported by Yokeş *et al*. (2007). The population of the blue swimming crab along the Turkish Aegean Sea is on the rise and gaining commercial importance. While crabs are normally caught using a special fish basket, some are also incidentally captured by gill nets, particularly in the Akköy Lagoon, Southern Aegean Sea. The fishermen complain over the crab causing a lot of damage to their gill nets (C. Ovalıoğlu, *pers. comm.*).

It is manifest that *P. segnis* is gradually widening its expansion range towards northern latitudes of the Aegean Sea. Therefore, it might soon find its way to the Bay

Tab: 1: Morphometric characteristics of the *Portunus segnis* ***captured in the SE Aegean Sea.***
Tab. 1: Morfometrične značilnosti primerkov vrste *Portunus segnis****, ujetih v JV Egejskem morju.***

	Dimensions (mm)	
Characteristics	♂	♀
Carapace length (CL)	75	81
Carapace width (CW)	145	157
Frontal margin (FM)	24	26
Posterior margin (PM)	49	61
Anterio-lateral border (ALB)	62	67
Posterio-lateral border (PLB)	59	61
Dactylus length (DAL)	56	46
Manus length (MAL)	116	102
Merus length (MEL)	86	61
Merus width (MEW)	19	19
Abdomen length (AL)	47	55
Abdomen width (AW)	49	62
Telson length (TL) in the abdomen	9	9
Telson width (TW) in the abdomen	7	12
Penultimate segment length (PL)	16	17
Penultimate segment width (PW)	17	46

of Izmir, in the northern Aegean Sea, as it occurred with the Atlantic blue crab, *Callinectes sapidus* (Dailianis *et al.*, 2016). The blue crab should be monitored and new fishing gears should be developed to help reduce the damage to fish gill nets in the area.

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The authors thank Rüzgar Özgül, who is little son of A. Özgül, for directing our attention to the crabs.

POJAVLJANJE LESEPSKE PLAVAJOČE RAKOVICE, PORTUNUS SEGNIS (CRUSTACEA: DECAPODA), V JUŽNEM EGEJSKEM MORJU, TURČIJA

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POVZETEK

Devetnajstega junija 2018 sta bila opažena dva primerka rakovice vrste Portunus segnis *(Forskål, 1775) na ribji tržnici v mestu Urla, Izmir. Sodeč po izjavi ribjega trgovca sta bili plavajoči rakovici slučajno ujeti v ribiško mrežo v laguni Akköy Lagoon (Didim) v jugovzhodnem Egejskem morju. Pričujoči zapis predstavlja nov podatek o širjenju areala rakovice* P. segnis *proti severu Egejskega morja.*

Ključne besede: Portunidae, modra plavajoča rakovica, lesepska selivka, Egejsko morje

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OCCURRENCE AND UNUSUAL ABUNDANCE OF RETICULATED LEATHERJACK *STEPHANOLEPIS DIASPROS* (OSTEICHTHYES: MONACANTHIDAE) FROM THE LAGOON OF BIZERTE (NORTHERN TUNISIA, CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

This paper reports some unusual captures of the Lessepsian migrant identified as Stephanolepis diaspros *Fraser-Brünner, 1940 in the Lagoon of Bizerte, a brackish area located in northeastern Tunisia. It appears that at present a viable population is successfully established in this restricted area due to the fact that the species finds the local environmental conditions adequate for living and reproducing.*

Key words: distribution, expansion range, brackish area, description, colour patterns

PRESENZA E ABBONDANZA INUSUALE DI MONACANTO RETICOLATO *STEPHANOLEPIS DIASPROS* (OSTEICHTHYES: MONACANTHIDAE) NELLA LAGUNA DI BIZERTA (TUNISIA SETTENTRIONALE, MEDITERRANEO CENTRALE)

SINTESI

L'articolo riporta alcune insolite catture del migrante lessepsiano identificato come monacanto reticolato Stephanolepis diaspros *Fraser-Brünner, 1940 nella Laguna di Biserta, un'area salmastra situata nel nordest della Tunisia. Attualmente sembra che una popolazione vitale si sia stabilita con successo in quest'area ristretta, dove la specie probabilmente trova condizioni ambientali locali adeguate per vivere e riprodursi.*

Parole chiave: distribuzione, intervallo di espansione, area salmastra, descrizione, modelli di colore

INTRODUCTION

The reticulated leatherjack *Stephanolepis diaspros* Fraser-Brünner, 1940 is a Lessepsian migrant *sensu* Por (1948) which entered the Mediterranean Sea through the Suez Canal. Since its first record from the Levant Basin (Steinitz, 1927), the species has successfully invaded the eastern Mediterranean Sea (Golani, 1998; Golani *et al.*, 2017), currently maintaining a viable population in Turkish waters (Taskavak & Bilecenoglu, 2001).

Furtherly, *S. diaspros* migrated toward western Mediterranean areas and reached the Gulf of Gabès, southern Tunisia (Chakroun, 1966), where it found adequate environmental conditions to develop and reproduce in the wild (Zouari-Ktari *et al.*, 2008; Zouari-Ktari & Bradaï, 2011). The first specimen from northern Tunisia was recorded in the Lagoon of Bizerte (Bdioui *et al.*, 2004) and subsequent ones off Tabarka, a city located close to the Algerian border (Ben Amor & Capapé, 2008).

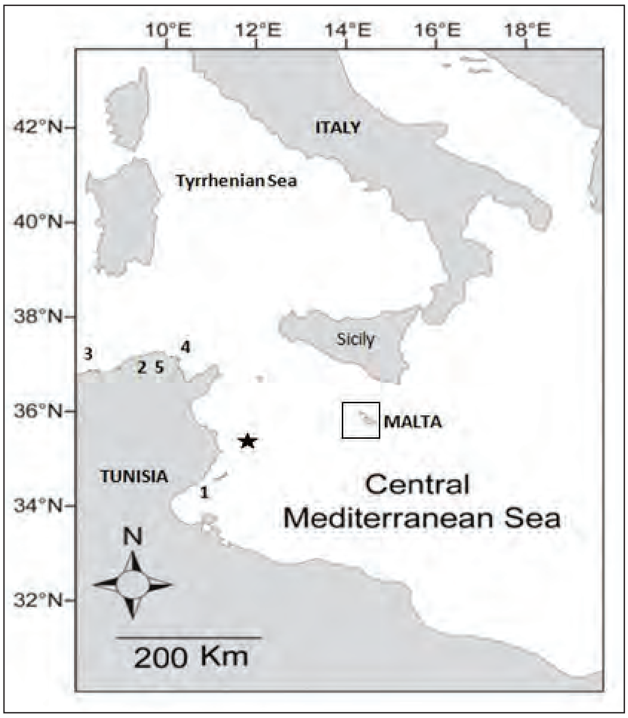

Fig. 1: Capture sites of *Stephanolepis diaspros* **in the central Mediterranean Sea. 1. Gulf of Gabès (Chakroun, 1966). 2. Lagoon of Bizerte (Bdioui et al., 2004). 3. Off Tabarka (Ben Amor & Capapé, 2008). 4. Off Bizerte (this study). 5. Lagoon of Bizerte (this study). The black star and square indicate the captures of the species in the waters surrounding the Island of Lampedusa and the Islands of Malta, respectively (Deidun** *et al.***, 2015).**
Sl. 1: Lokalitete, kjer so bili ujeti primerki vrste *Stephanolepis diaspros* **v osrednjem Sredozemskem morju. 1. Gabeški zaliv (Chakroun, 1966). 2. Laguna pri Bizerti (Bdioui et al., 2004). 3. Pri Tabarki (Ben Amor & Capapé, 2008). 4. Pri Bizerti (ta študija). 5. Laguna pri Bizerti (ta študija). Črna zvezdica in kvadrat prikazujeta lokaliteti ulova v vodah okoli otoka Lampedusa in Malte (Deidun** *et al.***, 2015).**

Through routine monitoring regularly and frequently conducted in northern Tunisian waters other *S. diaspros* have been found in the area, mainly in the Lagoon of Bizerte. These new records are presented herein and commented to explain this unusual occurrence of *S. diaspros* as a possible settlement of the species in this lagoon.

MATERIAL AND METHODS

On 7 July 2018, a specimen of *Stephanolepis diaspros* was captured off Bizerte (Fig. 1), a city located in northern Tunisia (37° 17′ 40.4″ N and 9° 56′ 05.0″ E), by trammel net on sandy bottom at a depth of 20 m approximately, together with some grey triggerfish *Balistes capriscus* Gmelin, 1789.

The Lagoon of Bizerte is a brackish water body located in northeastern Tunisia, between 37° 8′ and 37° 14′ N, and between 9° 46′ and 9° 56′ E. It appears as an ellipse, 11 km wide and 13 km long, connected to the Mediterranean Sea by an artificial navigation channel with a maximum depth of 12 m, which facilitates the invasion of the area by *S. diaspros*. The average and maximum depths of the lagoon are 7 m and 12 m, respectively, the bottoms sandy, muddy and detritic and in places covered by seagrass meadows (Zaouali, 1974). At least 15 teleost and 8 elasmobranch species have been recorded in the Lagoon of Bizerte, an area with two landing sites, commercially exploited by artisanal craft fisheries (Harzallah, 2003; El Kamel *et al.*, 2009).

A total of 32 specimens of *S. diaspros* were collected with the assistance of local fishermen working in the area and aware of the fishing grounds. This participative monitoring method combined with interviews of fishermen is known as local ecological knowledge (LEK). It constitutes complementary support and a source of information increasing and improving the reliability and therefore the quality of our data, following the protocols of Azzurro *et al.* (2011) and CIESM (2018).

All fresh specimens were measured to the nearest millimetre and weighed to the nearest gram. The Shapiro–Wilk test for normality of the sample was performed, with $P < 0.05$. The chi-square test was used to determine the significance ($P < 0.05$). The relation between total length (TL) and total body weight (TBW) was used as a complement to feeding studies following Froese *et al.* (2011), to assess if *Stephanolepis diaspros* is able to develop in its new habitat. This LWR is $\mathrm{TBW} = a\mathrm{TL}^{b}$, and was converted into its linear regression, expressed in decimal logarithmic coordinates and correlations were assessed by least-squares regression ($\log \mathrm{TBW} = \log a + b \log \mathrm{TL}$). Significance of constant b differences was assessed to the hypothesis of isometric growth if *b* = 3, positive allometry if *b* > 3, negative isometry if *b* > 3 (Pauly, 1983). A comparison of means was carried out using ANOVA. These two latter tests were performed using the STAT VIEW 5.0 logistic model.

Morphometric measurements and meristic counts were recorded, following Ben Amor & Capapé (2008), in the specimen caught off Bizerte and three specimens from the Lagoon of Bizerte (see Table 1). These four specimens were fixed in 10% buffered formaldehyde and preserved in 75% ethanol. One specimen was deposited in the Ichthyological Collection of the Faculté des Sciences de Bizerte, under the catalogue number FSB-Ste-dia-01, and the other 3 in the Ichthyological Collection of the Institut de Pêche et d'Aquaculture de Menzel Jemil under catalogue numbers ISPAB-Ste-dia-01, ISPAB-Ste-dia-02 and ISPAB-Ste-dia-03, respectively.

RESULTS AND DISCUSSION

The occurrence of *Stephanolepis diaspros* in those Tunisian regions where the species was previously unknown or rare could result from hydrobiological changes, especially temperature rise, which has affected Tunisian waters and the entire Mediterranean Sea for several decades (Francour *et al.*, 1994; Ben Raïs Lasram & Mouillot, 2009). Such occurrence in restricted areas is not a fortuitous event, it confirms the opinion of Ounifi-Ben Amor *et al.* (2019), who noted that Tunisian lagoons are hotspots for intrusion of non-indigenous species.

All specimens were identified as *Stephanolepis diaspros* in complete agreement with Tortonese (1967, 1986), Golani *et al.* (2017), Dulčić & Pallaoro (2003) and Bdioui *et al.* (2004). The specimen from off Bizerte displayed a brown to green-grey colour, with posterior dark areas and sinuous grey lines on the sides, dark bands non visible in caudal (Fig. 2). The specimens from the Lagoon of Bizerte exhibited a diversity of colour patterns and the phenomenon of polychromatism cannot be totally ruled out (Fig. 3). These colour differences suggest that the specimens caught off the northern coast of Tunisia could be *S. hispidus* (Linnaeus, 1766) according to Ben Amor & Capapé (2008). However, a new revision of the genus *Stephanolepis* Gill, 1862 is needed prior to drawing any definite conclusions; *S. hispidus* and *S. diaspros* are well separated geographically, the former occurs in the Atlantic Ocean and the latter in the eastern Mediterranean (Tortonese, 1986).

At present, *S. diaspros* occurs throughout the central Mediterranean Sea, and a viable population is successfully established in the Gulf of Gabès, southern Tunisia (Zouari-Ktari & Bradaï, 2011). The species is continuing its migration toward northern areas, as corroborated by

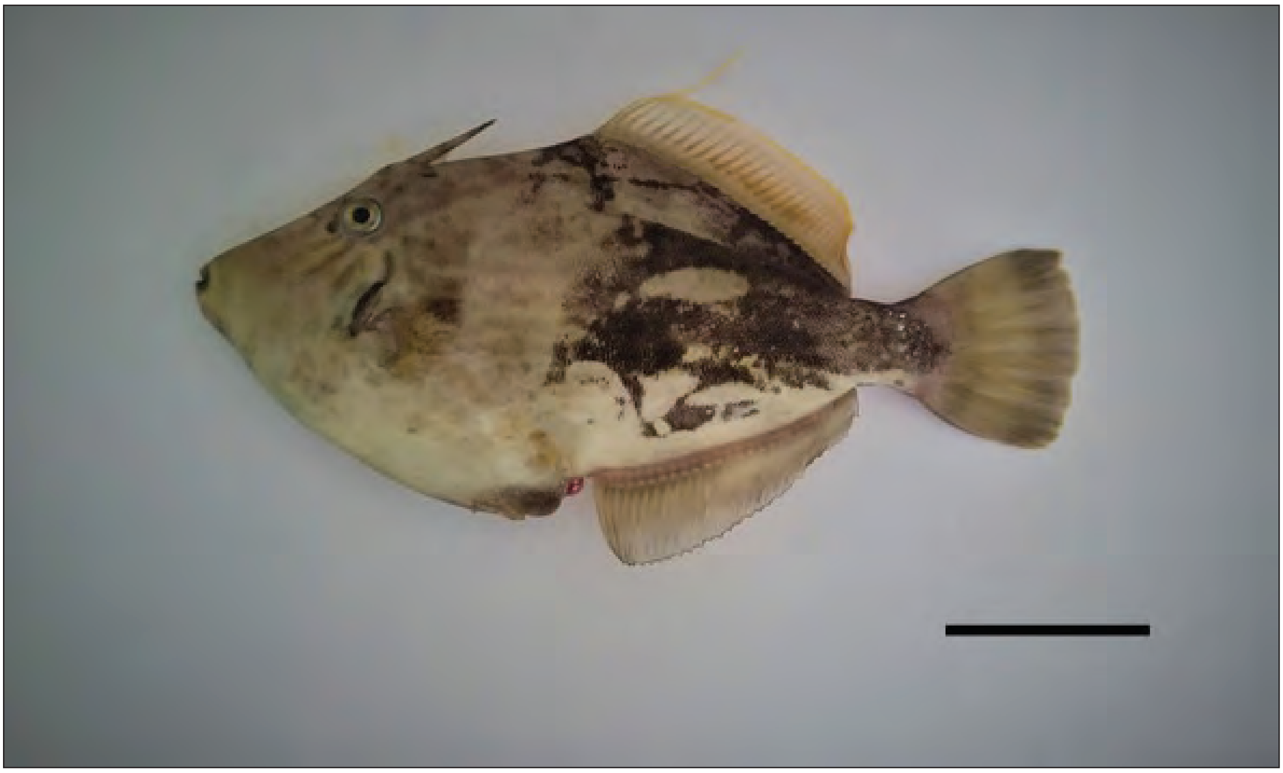

Fig. 2: The specimen of Stephanolepis diaspros *captured off Bizerte (ref. FSB-Ste-dia-01), scale bar = 50 mm.*
Sl. 2: Primerek vrste Stephanolepis diaspros *ujet pri Bizerti (ref. FSB-Ste-dia-01), merilo = 50 mm.*

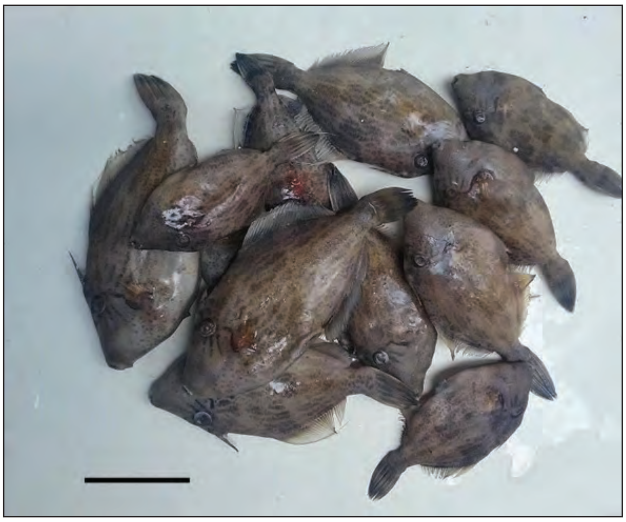

Fig. 3: The lot of specimens of* Stephanolepis diaspros *collected in the Lagoon of Bizerte, scale bar = 80 mm.
Sl. 3: Številni primerki vrste* Stephanolepis diaspros, *ujeti v laguni pri Bizerti, merilo = 80 mm.

the single specimen reported from the Lagoon of Bizerte by Bdioui *et al.* (2004) and now by the 32 specimens included in this study. Some of the latter were collected off the city of Tabarka close to the Algerian border (Ben Amor & Capapé, 2008) and one specimen was captured off Bizerte (this study). Additionally, findings of the species in waters surrounding the Island of Lampedusa, close to the Tunisian coast, and the Islands of Malta confirm such hypothesis (Deidun *et al.*, 2015).

Some fishermen working in the Lagoon of Bizerte were interviewed to provide further substantiating information about the captures of *S. diaspros* in the area. These captures occurred in May, June and, to a smaller extent, July. The fishermen would find 4–6, maximum 8 specimens per fishing trip and the captures occurred throughout the lagoon, so apparently there was no preferential site (Fig. 4). *S. diaspros* has a low economic value in the area, so the collected specimens were not auctioned and sold at landing sites, rather consumed by the fishermen themselves and their families. The abundance of captures in the Lagoon of Bizerte is a recent phenomenon – just two years ago, *S. diaspros*

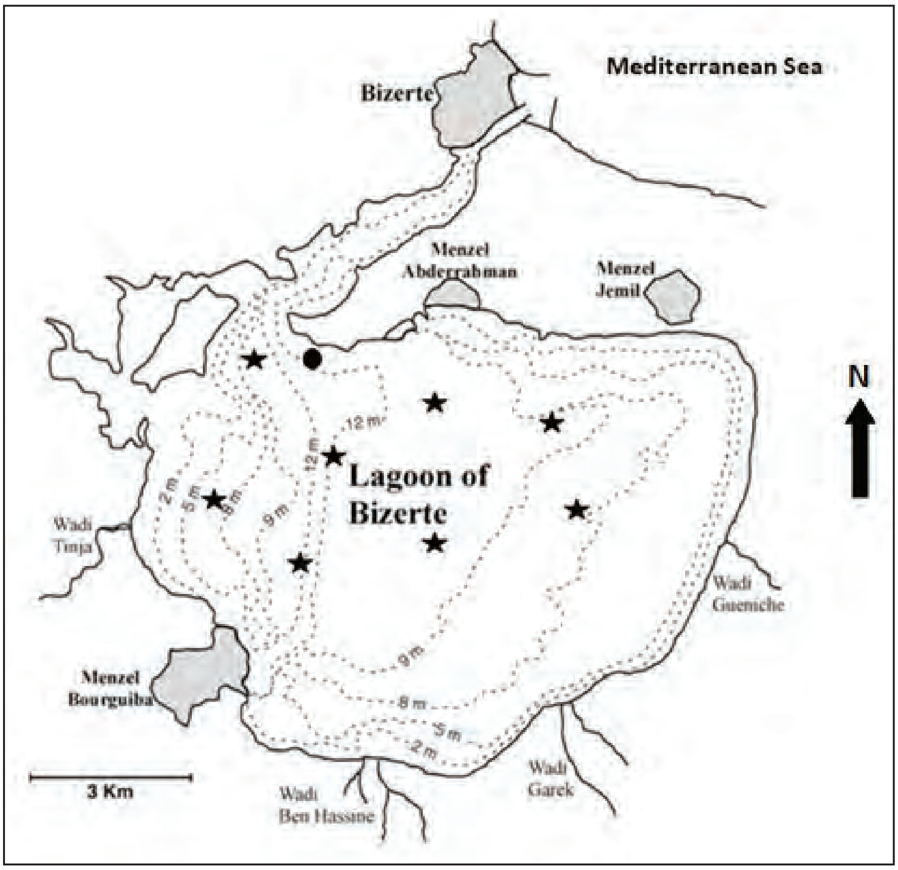

Fig. 4: Map of the Lagoon of Bizerte indicating the capture sites of* Stephanolepis diaspros*: black disc (Bdioui et al., 2004), black stars (this study).
Sl. 4: Zemljevid lagune pri Bizerti z označenimi lokalitetami, kjer so bili ujeti primerki vrste: črni krogec (Bdioui et al., 2004), črne zvezdice (ta študija).

was still unknown to the local fishermen and often misidentified as the grey triggerfish *B. capriscus*.

The specimen of *S. diaspros* caught off Bizerte measured 215 mm in TL and its total body weight was 186 g. The TL of the 32 specimens collected in the Lagoon of Bizerte ranged between 96 mm and 235 mm, their TBW between 14 g and 235 g. Zouari-Ktari & Bradaï (2011) noted that the Tunisian specimens sampled in the Gulf of Gabès reached the first sexual maturity at about 80 mm in females and 110 mm in males, thus we assume that our specimens were probably adults. Additionally, Zouari-Ktari *et al*. (2008) noted that specimens from the same area fed on benthic organisms and phytobenthos, and the large diversity of prey species found in the stomach contents indicated that *S. diaspros* is omnivorous and opportunistic. Availability and accessibility of similar prey species and the presence of large seagrass meadows (Zaouali, 1974) could explain the successful settlement of *S. diaspros* in this brackish area. This may be confirmed by the LWR (log TBW = -4.73 3.01 + log TL; r = 0.98; n = 32), a slightly positive allometry indicating that *S. diaspros* found sufficient resources locally to live in the area (Fig. 5).

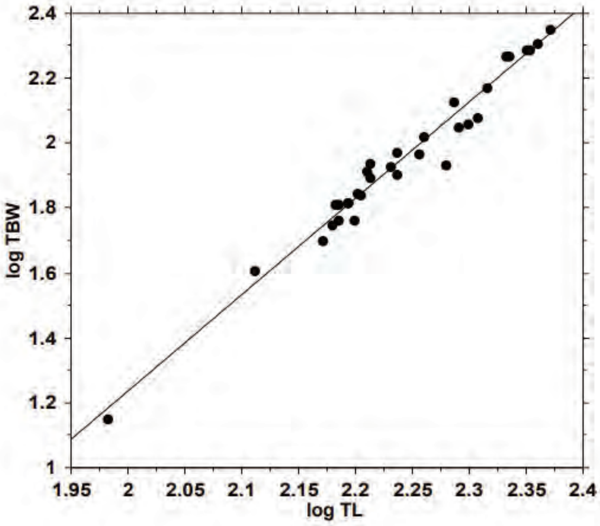

Fig. 5: The size (TL) versus total body weight (TBW) relationship in the specimens collected in the Lagoon of Bizerte (this study) expressed in logarithmic coordinates.

Sl. 5: Razmerje med velikostjo (TL) in celotno telesno težo (TBW) pri primerkih ujetih v laguni Bizerte (ta študija), izraženo v logaritmičnih koordinatah.

Information provided by the fishermen working in this area (LEK) showed that other species with a diet similar to that of *S. diaspros*, such as the grey triggerfish *Balistes capriscus* or the salema *Sarpa salpa* (Linnaeus, 1758), are rarely captured. There was a single capture of the Lessepsian migrant dusky spinefoot *Siganus luridus* (Rüppell, 1829) in the lagoon (Ounifi-Ben Amor *et al*., 2016), but with no new records following. However, the pressure of interspecific and/or intraspecific competition for food among these omnivorous teleost species cannot be totally ruled out. Therefore, regular monitoring of *S. diaspros* should be carried out to assess the role of the species in its new environment. To reach this goal, further captures of the species are necessary for studying, in particular, its reproductive biology, diet and feeding habits.

Tab. 1: Morphometric measurements, meristic counts and total body weight recorded in the specimens of *Stephanolepis diaspros* ***collected off Bizerte (ref. FSB-Ste-dia-01) and in the Lagoon of Bizerte (ISPAB-Ste-dia-01, ISPAB-Ste-dia-02 and ISPAB-Ste-dia-03).***

Tab. 1: Morfometrične meritve, meristična štetja in celotna masa telesa primerkov afriškega kostoroga, ujetih pri Bizerti (ref. FSB-Ste-dia-01) in v laguni pri Bizerti (ISPAB-Ste-dia-01, ISPAB-Ste-dia-02 in ISPAB-Ste-dia-03).

References	**FSB-Ste-dia-01**		**ISPAB-Ste-dia-01**		**ISPAB-Ste-dia-02**		**ISPAB-Ste-dia-03**	
Measurements	**mm**	**% TL**	**mm**	**% TL**	**mm**	**% TL**	**mm**	**% TL**
Total length (TL)	215	100	235	100	180	100	160	100
Standard length (SL)	185	86.05	200	85.11	150.00	83.33	137	85.63
Head length	55	25.58	56.96	24.24	43.85	24.36	40.02	25.01
First predorsal length	48.66	22.63	56.98	24.25	43.45	24.14	36.07	22.54
Second predorsal length	94.52	43.96	100.5	42.77	80.47	44.71	74.59	46.62
Preanal length	97.51	45.35	108.68	46.25	86.85	48.25	78.05	48.78
Prepectoral length	49.49	23.02	52.5	22.34	44.38	24.66	40.15	25.09
First dorsal fin length	13.57	6.31	14.31	6.09	12.50	6.94	12.58	7.86
Second dorsal fin length	73.43	34.15	74.64	31.76	57.04	31.69	52.86	33.04
Anal fin length	65.84	30.62	69.59	29.61	54.58	30.32	47.02	29.39
Pectoral fin length	9.36	4.35	11.62	4.94	8.40	4.67	7.56	4.73
Caudal fin length	24.29	11.30	25.83	10.99	20.58	11.43	16.43	10.27
Maximal body length	85.55	39.79	87.89	37.40	70.44	39.13	65.67	41.04
Eye diameter	11.44	5.32	14.2	6.04	10.63	5.91	9.59	5.99
Interorbital length	12.39	5.76	14.41	6.13	11.44	6.36	9.67	6.04
Preorbital length	35.68	16.60	39.6	16.85	32.62	18.12	25.62	16.01
Postorbital length	6.12	2.85	9.29	3.95	7.21	4.01	6.74	4.21
Meristic counts								
First dorsal fin rays	I		I		I		I	
Second dorsal fin rays	31		31		31		31	
Anal fin rays	31		31		31		31	
Pectoral fin rays	13		13		13		13	
Caudal fin rays	12		12		12		12	
Total body mass (gram)	**186**		**225**		**93**		**70**	

POJAVLJANJE IN NENAVADNA ŠTEVILČNOST AFRIŠKEGA KOSTOROGA, *STEPHANOLEPIS DIASPROS* (OSTEICHTHYES: MONACANTHIDAE) IZ LAGUNE PRI BIZERTI (SEVERNA TUNIZIJA, OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

Avtorji poročajo o nenavadnih ulovih ribje lesepske selivke vrste Stephanolepis diaspros *Fraser-Brünner, 1940 v laguni pri Bizerti, brakičnem okolju v severovzhodni Tuniziji. Kaže, da se je v tem omejenem okolju zaradi ugodnih življenjskih razmer za preživetje in razmnoževanje vzpostavila viabilna populacija te vrste.*

Ključne besede: razširjenost, širjenje areala, brakično okolje, opis, barvni vzorci

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IHTIOLOGIJA

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MARINE CRYPTOBENTHIC FISH FAUNA OF SLOVENIA (NORTHERN ADRIATIC SEA)

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ABSTRACT

Cryptobenthic fish fauna constitute one of the less studied fish groups in the Adriatic Sea. As regards Slovenian coastal waters, only few papers dealing with cryptobenthic fish assemblages have been published to date. All the available data about cryptobenthic fish species in the Slovenian sea are presented in this paper, with particular interest in their geographic and depth distribution. Altogether 798 specimens of 11 different species were collected. Thorogobius macrolepis *and* Chromogobius quadrivittatus *were found in Slovenian territorial waters for the first time only recently. The majority of fishes have been recorded using new techniques, associated with SCUBA diving equipment and the use of the narcotic Quinaldine.*

Key words: cryptobenthic habitats, fish assemblage, coastal waters, northern Adriatic Sea

FAUNA ITTICA CRIPTOBENTONICA MARINA DELLA SLOVENIA (ADRIATICO SETTENTRIONALE)

SINTESI

La fauna ittica criptobentonica costituisce uno dei gruppi di pesci meno studiati nel mare Adriatico. Per quanto riguarda le acque costiere della Slovenia, finora sono stati pubblicati solo pochi articoli riguardanti questo gruppo. L'articolo presenta tutti i dati disponibili sulle specie ittiche criptobentoniche del mare sloveno, con particolare interesse per la loro distribuzione geografica e batimetrica. Complessivamente sono stati raccolti 798 esemplari di 11 specie. Thorogobius macrolepis e Chromogobius quadrivittatus *sono stati trovati per la prima volta nelle acque territoriali slovene solo di recente. La maggior parte dei pesci è stata catturata usando nuove tecniche associate alle attrezzature subacquee e all'uso di narcotici.*

Parole chiave: habitat criptobentonici, comunità ittiche, acque costiere, mare Adriatico settentrionale

INTRODUCTION

Despite the fact that the ichthyofauna of the Adriatic Sea is relatively well studied, information about the Slovenian part of Gulf of Trieste is still scant (Lipej *et al.*, 2005). Numerous recent studies have contributed to filling the gap in the knowledge of the marine ichthyofauna in the Slovenian sea (*e.g.* Lipej *et al.*, 2005; 2016a; 2018a; Orlando-Bonaca & Lipej, 2005; Orlando-Bonaca & Trkov, 2016). However, little is known about cryptobenthic fish fauna and its occurrence in the area. "Cryptobenthic" (Miller, 1979) species are species whose "small body size permits exploitation of restricted habitats, where food and shelter are obtained in, or in relation to, conditions of substrate complexity and/or restricted living space, with a physical barrier likely to be interposed between the small fish and sympatric predators". Therefore, they are hardly observed by divers and are usually not detected in conventional ichthyofaunal surveys (Henriques, 2002). The qualitative definition of cryptobenthic fish (Depczynski & Bellwood, 2003) and the recent quantitative definition of cryptobenthic reef fish (Brandl *et al.*, 2018) were based exclusively on fish size, while Kovačić *et al.* (2012) suggested that cryptobenthic refers to benthic positioning, since it is ecologically meaningful. Lipej *et al.* (2016b) divided cryptobenthic fish species into real cryptobenthic species (that are always hidden) and large cryptobenthic fish species (large-sized fish species that occasionally leave their hiding places, but more or less permanently use them). Exhibiting such cryptic life style, affords them protection against predators (Hofrichter & Patzner, 2000). Smith-Vaniz *et al.* (2006) concluded that around 64% of fish fauna can be missed by visual census due to their hiding habits. Therefore, knowledge about the occurrence and ecology of cryptobenthic remains very fragmented at global scale.

Cryptobenthic fish species in the Adriatic Sea have attracted scientific interest in the last two decades, as evidenced by various studies (*e.g.* Kovačić, 1997, 2005; Santin *et al.*, 2005; Santin, 2008; Brandl *et al.*, 2012; Kovačić *et al.*, 2012, Glavičić *et al.*, 2016). Some papers highlighting the occurrence of cryptobenthic species have also been published for the Slovenian part of the Adriatic Sea, such as those of Lipej & Richter (1999), Lipej *et al.* (2005, 2012, 2016b), Orlando-Bonaca & Lipej (2007, 2008) and Orlando-Bonaca & Trkov (2016). Moreover, knowledge about cryptobenthic fish assemblages is increasing due to the development of new approaches and techniques, associated with SCUBA diving and suitable fish sampling (Glavičić & Kovačić, 2016).

The aim of the current study is to present all available information about the occurrence of cryptobenthic fish species (including new unpublished data), their habitat preferences and depth distribution in Slovenian coastal waters.

MATERIAL AND METHODS

Study area

The study was conducted in the Slovenian part of the Gulf of Trieste, the northernmost part of both the Adriatic and Mediterranean Seas. Although the sea-bed of the Slovenian sea is predominantly soft sedimentary of fluvial origin, the bottom along the coastline (approximately 46.7 km) is mostly rocky, consisting mainly of Eocene Flysch layers, with alternating solid sandstone and soft maerl (Ogorelec *et al.*, 1997). The area is characterized by the lowest winter temperatures (usually below 10°C) in the Mediterranean Sea (Boicourt *et al.*, 1999). Average salinity is about 37, influenced by fresh water inputs near the coast, mainly from the Isonzo River (Mozetič *et al.*, 1998). The embayed situation of the Gulf of Trieste, with dominant winds blowing in an offshore direction (mainly from the North-East) and very shallow waters, creates quite sheltered conditions (Boicourt *et al.*, 1999). In the past decades, the Slovenian coastal area has suffered from many anthropogenic impacts such as new infrastructure, intensive fishing, sewage outfalls and mariculture; therefore, only 18% of the coastline is still in its natural state (Turk, 1999).

Fieldwork

The information about cryptobenthic specimens was obtained from: a) existing published literature sources (Lipej & Richter, 1999; Lipej *et al.*, 2005; Orlando-Bonaca & Lipej, 2007, 2008; Orlando-Bonaca &Trkov, 2016), b) specific sampling of cryptobenthic fish fauna performed from July 1998 to March 2019, and c) specific sampling of clingfish (Gobiesocidae) fauna performed from October 2016 to March 2019.

All sampling surveys were carried out in Slovenian coastal waters. Specimens were collected or recorded by snorkelling or SCUBA diving in mediolittoral and infralittoral belts. Additionally, some specimens were also collected in shallow waters and tide pools during low tide. Fish were searched for in different hiding places such as under stones, boulders, shells, empty *Lithophaga lithophaga* (Linnaeus, 1758) burrows or inside natural cavities such as caves, cavities, holes, clefts etc. Searches for fish were also carried out in *Posidonia oceanica* meadows, in rhizomes (matte) in particular.

To facilitate the collection of fish, the narcotic Quinaldine (Sigma-Aldrich) was used (in Lipej *et al.*, 2005, specific sampling of cryptobenthic fish fauna and specific sampling of clingfish fauna). Quinaldine was diluted to 1:15 solution with alcohol. When a cryptobenthic fish was sighted, the narcotic was sprayed into the hiding place using a laboratory wash bottle. The anesthetized fish were then caught with a hand net. Endolithic specimens were expelled from

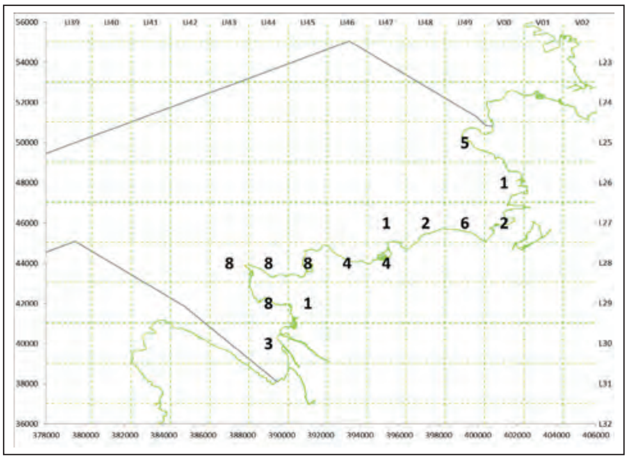

Fig. 1: UTM quadrants with numbers of cryptobenthic species present within.
Sl. 1: UTM kvadrati z označenim številom kriptobentoških vrst, ugotovljenih v njih.

the burrows with the help of a thin stick, and caught using a plastic bag placed over the burrow opening, as proposed by Kotrschal (1988). This method was used to assess blennioid fish assemblages in Slovenian coastal waters by Orlando-Bonaca & Lipej (2007, 2008). Basic ecological data on the sampling locality were collected at each site. For identification purposes, one specimen of each species per location was taken; the others were recorded and then released. All collected specimens are kept, and identified by a collection number, in the collection of the Marine Biology Station in Piran (MBS), National Institute of Biology, and fulfil the standards proposed by Bello *et al.* (2014). For identification purpose, the fish identification keys of Jardas (1996), Marčeta (1999) and Kovačić (2008) were used.

Data analyses

In order to present the data on cryptobenthic fish occurrence, the Slovenian sea was divided into 73 UTM quadrants (2 x 2 km) according to the approach of Lipej *et al.* (2018b). The coastal area considered in this study is comprised within 24 UTM quadrants. On the maps for single species, increasing dot size denotes the increasing number of specimens found within a quadrant.

RESULTS

In the last two decades, a total of 798 cryptobenthic specimens were found at 45 localities, within 14 different UTM quadrants (58.3% of 24 coastal quadrants; Fig. 1) along the Slovenian coastline. Specimens belong to 11 cryptobenthic fish species from four families (Tab. 1; Figs. 2 and 3).

The number of collected specimens was the highest in 2 quadrants: the first covering the area of Piran (305 specimens), and the second comprising the area from Piran to Portorož, including the waters in front of the MBS (263 specimens). The highest number of species (8 species) were recorded in 4 adjacent quadrants, ranging from Strunjan to Portorož including protected area of Natural Monument Cape Madonna Piran. The absence of cryptobenthic fish in some coastal quadrants is due to the lack of sampling surveys in inaccessible areas

Tab. 1: Number of specimens per fish species and their proportion according to the number of all cryptobenthic fish found in Slovenian coastal waters.
Tab. 1: Število primerkov posameznih ribjih vrst in njihov delež glede na celotno število kriptobentoških rib, ugotovljenih v slovenskih obalnih vodah.

Family	Number of species	Species	Number of Specimens	Percentage (%)
Gobiidae	5	*Chromogobius quadrivittatus*	1	0.1
		Millerigobius macrocephalus	53	6.6
		Thorogobius ephippiatus	1	0.1
		Thorogobius macrolepis	2	0.3
		Zebrus zebrus	38	4.8
Gobiesocidae	3	*Apletodon incognitus*	202	25.3
		Lepadogaster candolii	173	21.7
		Lepadogaster lepadpogaster	237	29.7
Blenniidae	2	*Microlipophrys nigriceps*	48	6.0
		Parablennius zvonimiri	33	4.1
Clinidae	1	*Clinitrachus argentatus*	10	1.3

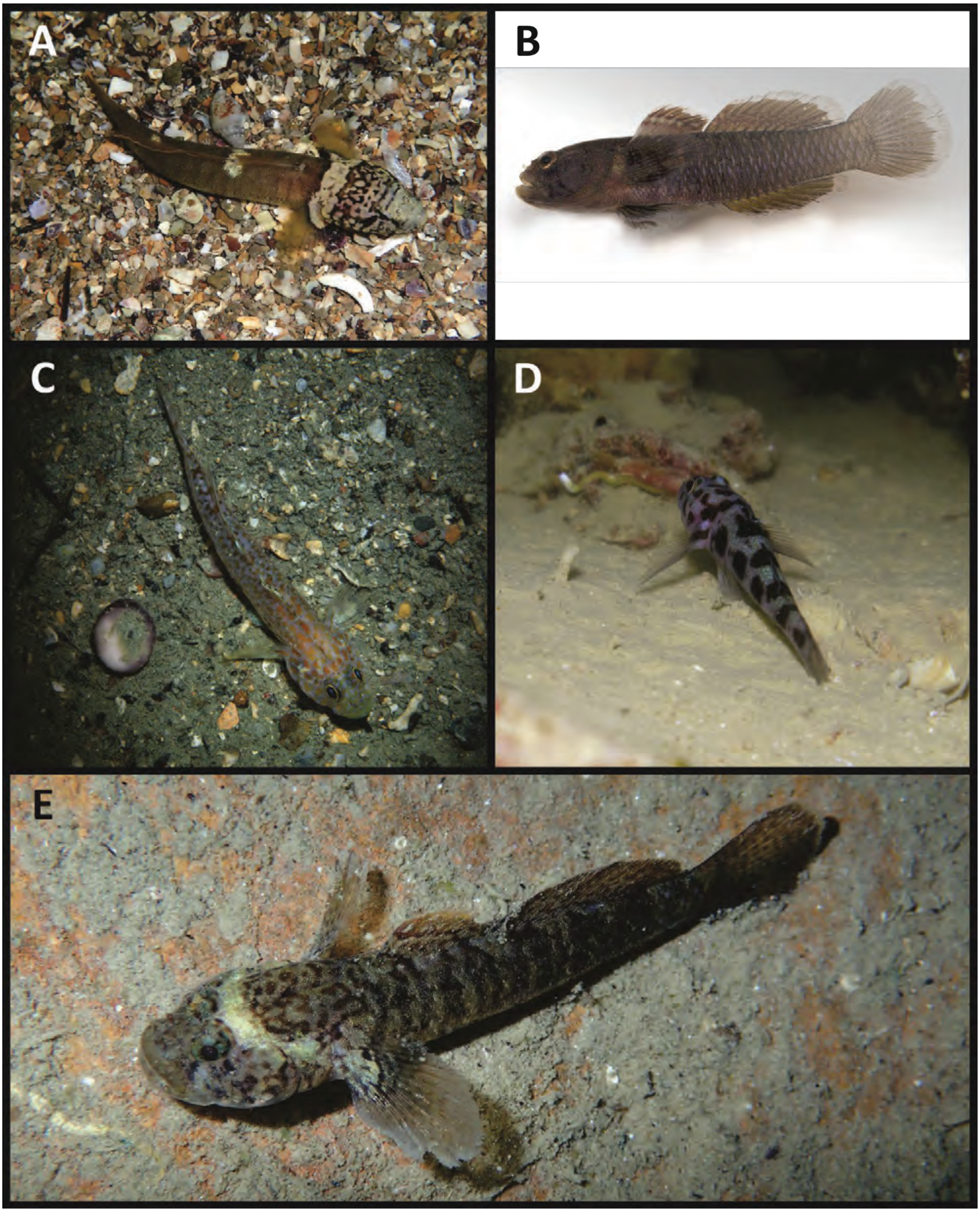

Fig. 2: Cryptobenthic gobies in the Slovenian Sea: A) *Chromogobius quadrivittatus*, ***B)*** *Millerigobius macrocephalus*, ***C)*** *Thorogobius macrolepis*, ***D)*** *Thorogobius ephippiatus* ***and E)*** *Zebrus zebrus*.
Sl. 2: Kriptobentoški glavači v slovenskem morju: A) *Chromogobius quadrivittatus*, ***B)*** *Millerigobius macrocephalus*, ***C)*** *Thorogobius macrolepis*, ***D)*** *Thorogobius ephippiatus* ***in E)*** *Zebrus zebrus*.

such as ports and harbours rather than to unsuitable habitats for these species. It should also be taken into consideration that the sampling effort and sampling methods were not the same in all UTM quadrants. Thus, data on the abundance or on the diversity of the UTM quadrants are not comparable. On coastal rocky bottoms, 10 cryptobenthic fish species were found, while on sedimentary bottom only 4 species were observed. The distribution of the fish according to depth is presented in Fig. 4.

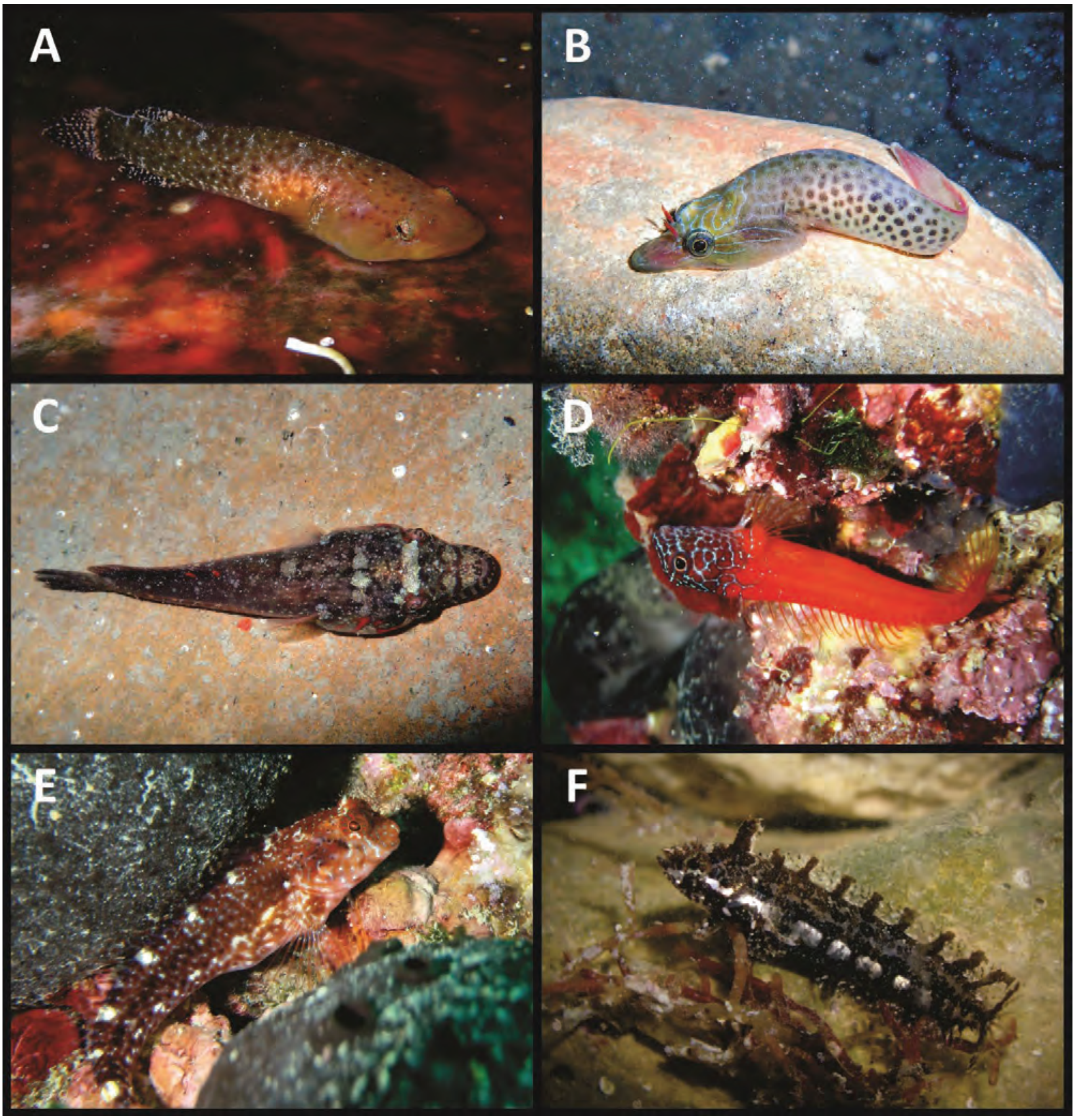

Fig. 3: Cryptobenthic fish species in the Slovenian Sea: A) *Apletodon incognitus,* ***B)*** *Lepadogaster lepadogaster,* ***C)*** *Lepadogaster candolii,* ***D)*** *Microlipophrys nigriceps,* ***E)*** *Parablennius zvonimiri* ***and F)*** *Clinitrachus argentatus.*
Sl. 3: Kriptobentoške vrste rib v slovenskem morju: A) *Apletodon incognitus,* ***B)*** *Lepadogaster lepadogaster,* ***C)*** *Lepadogaster candolii,* ***D)*** *Microlipophrys nigriceps,* ***E)*** *Parablennius zvonimiri* ***in F)*** *Clinitrachus argentatus.*

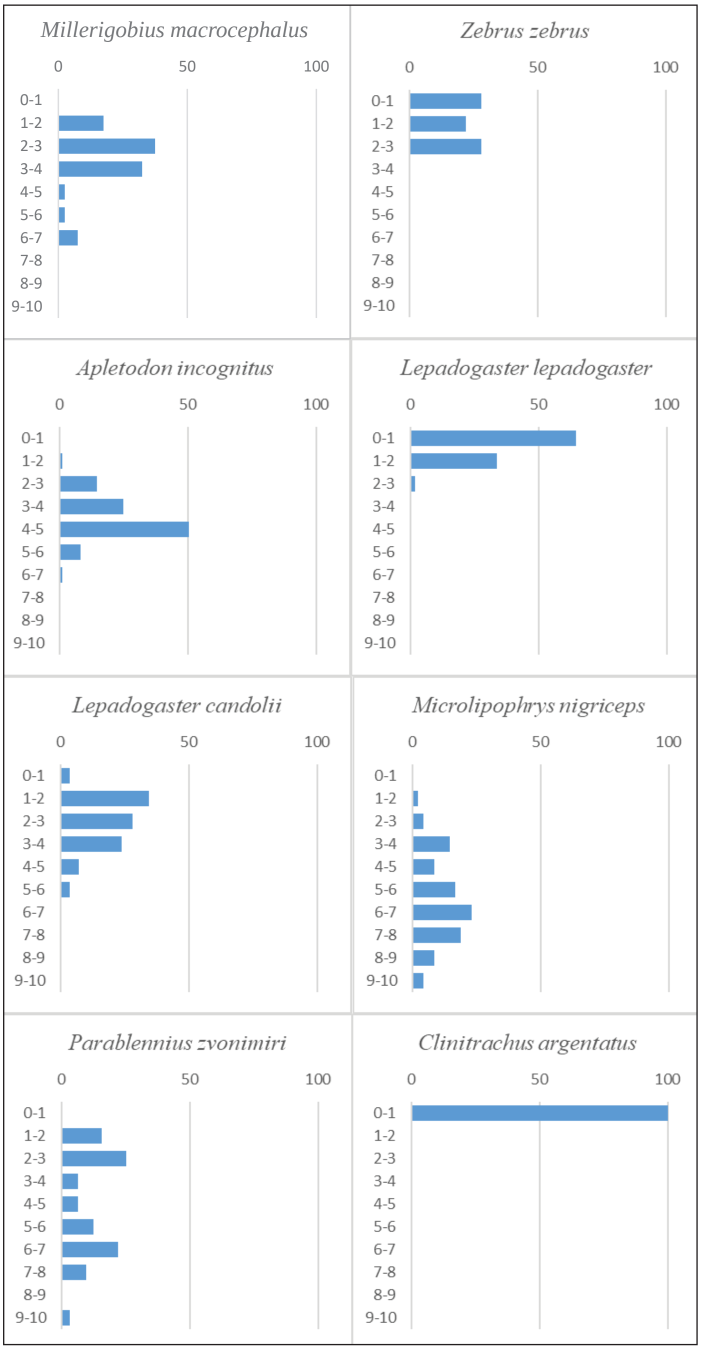

Fig. 4: Depth distribution of cryptobenthic fish species in the Slovenian Sea: *Millerigobius macrocephalus; Zebrus zebrus; Apletodon incognitus; Lepadogaster lepadogaster; Lepadogaster candolii; Microlipophrys nigriceps; Parablennius zvonimiri; Clinitrachus argentatus*. **On abscissa axis are relative frequencies of occurrence (%), on ordinary axis is shown depth range (m).**

Sl. 4: Globinska razširjenost kriptobentoških vrst rib v slovenskem morju: *Millerigobius macrocephalus; Zebrus zebrus; Apletodon incognitus; Lepadogaster lepadogaster; Lepadogaster candolii; Microlipophrys nigriceps; Parablennius zvonimiri; Clinitrachus argentatus*. **Na abscisi so relativne frekvence pojavljanja (%), na ordinati pa je prikazan globinski razpon (m).**

Family Gobiidae

Chromogobius quadrivittatus (Steindachner, 1863)

A single specimen of *C. quadrivittatus* was captured on 26th July 2018 between Salinera and Pacug (Fig. 5). It was found in a rocky environment (boulder field) where it was hiding under a stone at a depth of 1.5. This finding represents the first record of this species in Slovenia. The specimen is housed in the ichthyological collection of the MBS: IC-MBP 334.

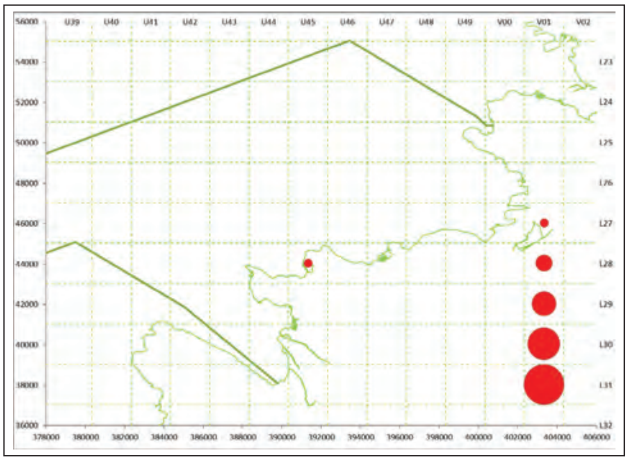

Fig. 5: Occurrence of *Chromogobius quadrivittatus* **in the Slovenian Sea. The size of the dots is shown at the right of the map and is ranking from the smallest to the biggest, based on number of specimens found within quadrant: 1 specimen, 2-3 specimens, 4-5 specimens, 6-15 specimens, > 16 specimens.**
Sl. 5: Pojavljanje vrste *Chromogobius quadrivittatus* **v slovenskem morju. Velikost krogcev je prikazana na desni strani zemljevida z naraščajočim zaporedjem števila ugotovljenih primerkov na kvadrat: 1 primerek, 2-3 primerki, 4-5 primerkov, 6-15 primerkov, > 16 primerkov.**

Millerigobius macrocephalus (Kolombatović, 1891)

Altogether, 53 specimens of *M. macrocephalus* were found within 8 UTM quadrants (Fig. 6). The majority of the specimens were found in rocky environments at depths between 1 and 4 m (87.5%), where they were hiding mostly under stones or in rocky clefts. Few specimens were found also in seagrass meadow under isolated stones. Specimens are housed in the ichthyological collection of the MBS: IC-MBP 006 and IC-MBP 023.

Thorogobius ephippiatus (Lowe, 1839)

Only one specimen of *T. ephippiatus* was found. It was observed on 9th August 2005 within the Cape Madonna Nature Monument of Piran (Fig. 7). The specimen was observed at a depth of 10 m in a cavity beneath sandstone rocks, covered with sand (Lipej *et al.*, 2005).

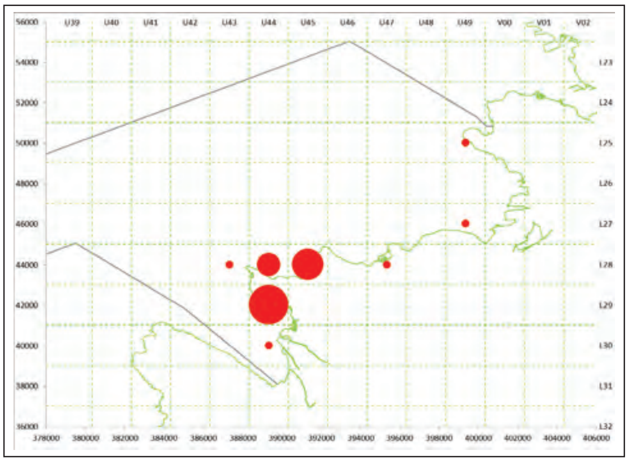

Fig. 6: Occurrence of *Millerigobius macrocephalus* **in the Slovenian Sea. For explanation of dot size see Fig. 5.**
Sl. 6: Pojavljanje vrste *Millerigobius macrocephalus* **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.**

Thorogobius macrolepis (Kolombatović, 1891)

Two specimens of *T. macrolepis* were found in Slovenian coastal waters, both of them in the Cape Madonna Natural Monument of Piran (Fig. 8). The first specimen was observed by one of the authors (B.M.) on 22th September 2015, while the second specimen was observed by a photographer, Borut Furlan, on 18th March 2017. Both specimens were found in a sheltered cavity covered with rough sand at a depth of around 10 m.

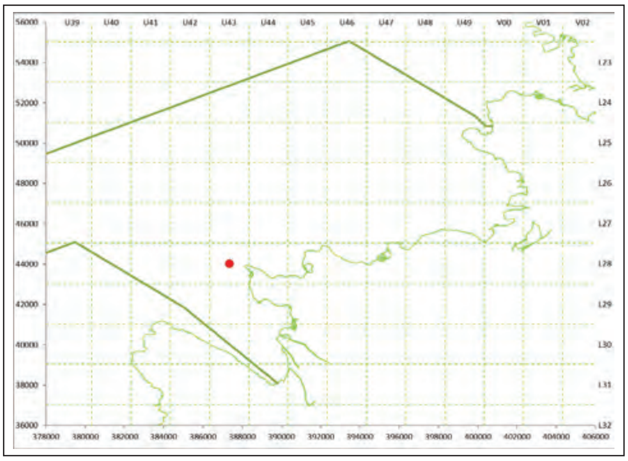

Fig. 7: Occurrence of *Thorogobius ephippiatus* **in the Slovenian Sea. For explanation of dot size see Fig. 5.**
Sl. 7: Pojavljanje vrste *Thorogobius ephippiatus* **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.**

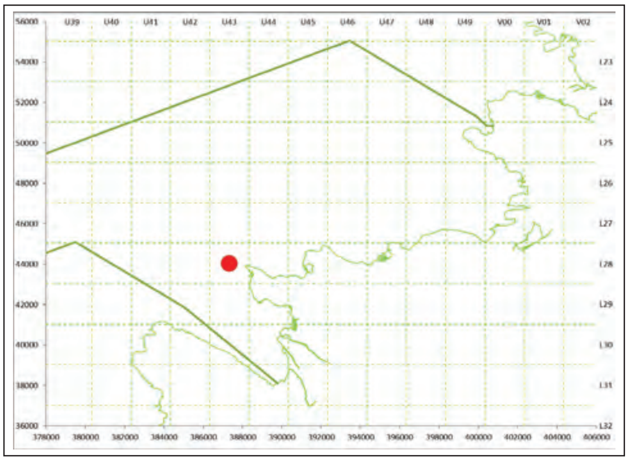

Fig. 8: Occurrence of* Thorogobius macrolepis *in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 8: Pojavljanje vrste* Thorogobius macrolepis *v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

Zebrus zebrus (Risso, 1827)

Specimens of *Z. zebrus* were found in 8 UTM quadrants (Fig. 9). Altogether, 38 specimens were recorded in shallow waters, less than 3 m deep. Specimens were mostly found in rocky environments under stones and in rocky clefts, while some of them were also recorded in *Cymodocea nodosa* and *P. oceanica* meadows, where they were hiding under seashells and single stones. Some specimens were also found under stones in tide pools in lower mediolittoral areas. Specimens are housed in the ichthyological collection of the MBS: IC-MBP 063 and IC-MBP 066.

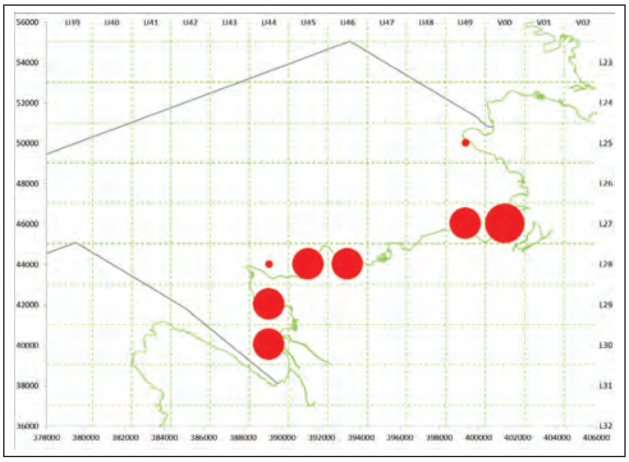

Fig. 9: Occurrence of* Zebrus zebrus *in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 9: Pojavljanje vrste* Zebrus zebrus *v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

Family Gobiesocidae

Apletodon incognitus Hofrichter & Patzner, 1997

Altogether, 202 specimens of *A. incognitus* were found that were present in 10 UTM quadrants (Fig. 10). Specimens were found in *C. nodosa* and *P. oceanica* meadows or nearby, where they were hiding on noble pen shells (*Pinna nobilis*), in dead oyster shells (*Ostrea edulis*), attached to noble pen shells and in dead seashells on the sea bottom. More than 97% of the speci-

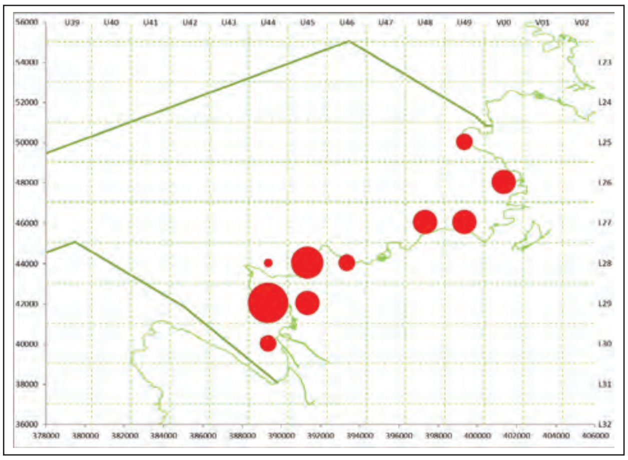

Fig. 10: Occurrence of* Apletodon incognitus *in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 10: Pojavljanje vrste* Apletodon incognitus *v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

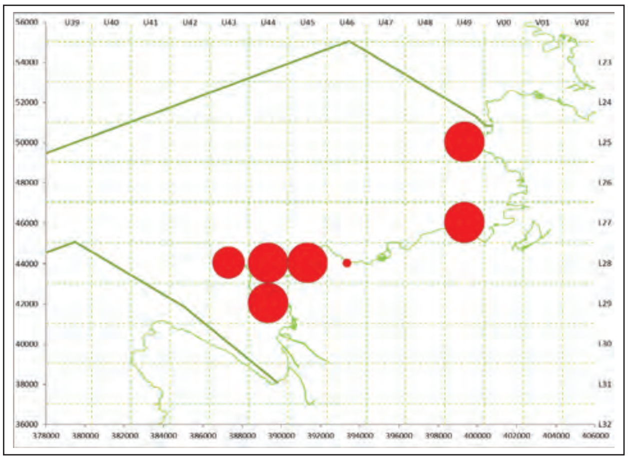

Fig. 11: Occurrence of* Lepadogaster candolii *in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 11: Pojavljanje vrste* Lepadogaster candolii *v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

mens were found at depths between 2 and 6 m, while the majority were present at depths between 4 and 5 m. Specimens are housed in the ichthyological collection of the MBS: IC-MBP 252 and IC-MBP 253.

Lepadogaster candolii Risso, 1810

Altogether, 173 specimens of *L. candolii* were found in 7 UTM quadrants (Fig. 11). Specimens were mostly found under stones in rocky environment, while a small proportion of them were also found in *C. nodosa* and *P. oceanica* meadows, where they were hiding under stones and on or under seashells (*e.g. P. nobilis, O. edulis*). Most of the specimens (86.0%) were present in the depth range from 1 to 4 m. The specimens are housed in the ichthyological collection of the MBS: IC-MBP 031 and IC-MBP 038.

Lepadogaster lepadogaster (Bonnaterre, 1788)

Specimens of *L. lepadogaster* were found in 8 UTM quadrants (Fig. 12). Altogether, 237 specimens were observed and all of them were found under stones in rocky environment (boulder field). The specimens were observed in shallow waters, mostly less than 2 m deep (98.3%), with the majority (64.7%) above 1 m. The specimens were housed in the ichthyological collection of the MBS: IC-MBP 281.

Family Blenniidae

Microlipophrys nigriceps (Vinciguerra, 1883)

Altogether, 48 specimens of *M. nigriceps* were observed in 4 UTM quadrants (Fig. 13). The majority of specimens (89.6%) were observed in the depth range from 3 to 9 m. The specimens were found in the rocky littoral, mostly in dimly lit habitats such as the underside of boulder terraces. They were hiding in precoralligenous formations, where they also occupied empty burrows excavated by *L. lithophaga*. The specimens are housed in the ichthyological collection of the MBS: IC-MBP 124.

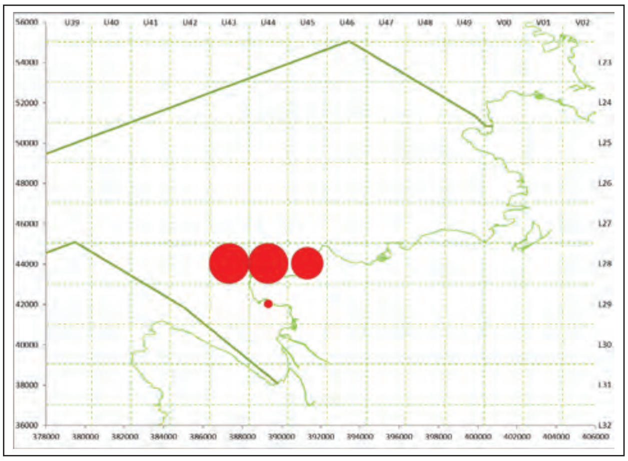

Fig. 13: Occurrence of *Microlipophrys nigriceps* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 13: Pojavljanje vrste *Microlipophrys nigriceps* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

Parablennius zvonimiri (Kolombatović, 1892)

Specimens of *P. zvonimiri* were observed on the shady side of boulders and in precoralligenous formations in

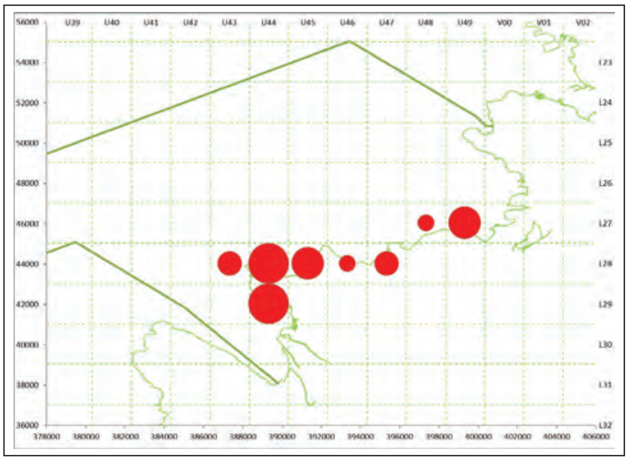

Fig. 12: Occurrence of *Lepadogaster lepadogaster* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 12: Pojavljanje vrste *Lepadogaster lepadogaster* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

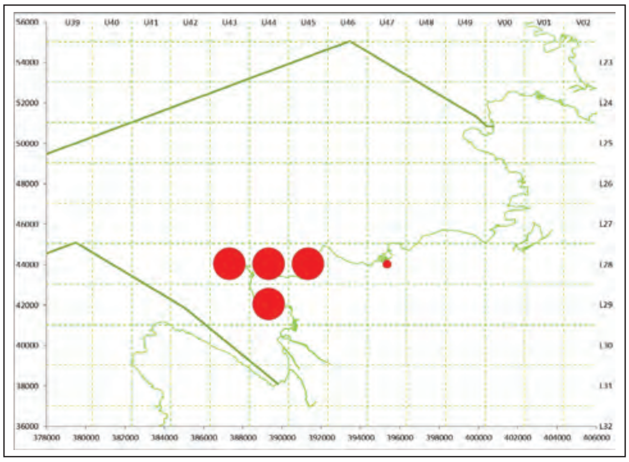

Fig. 14: Occurrence of *Parablennius zvonimiri* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 14: Pojavljanje vrste *Parablennius zvonimiri* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

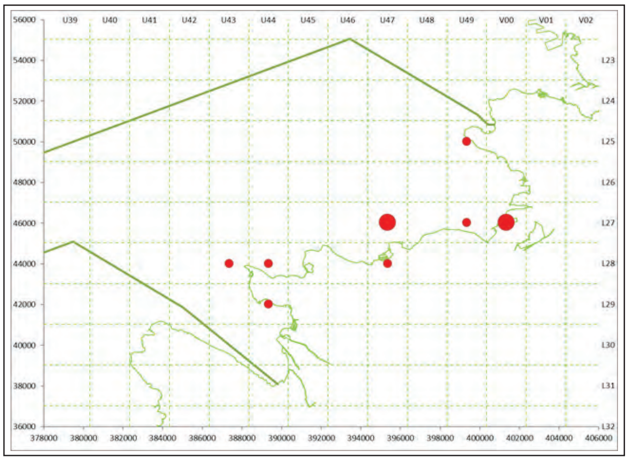

Fig. 15: Occurrence of** Clinitrachus argentatus **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 15: Pojavljanje vrste** Clinitrachus argentatus **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

a rocky environment. They were recorded in dimly lit habitats such as overhanging rocks, where they were dwelling in empty *L. lithophaga* burrows. The specimens were found at depths from 1 to 10 m. Altogether, 33 specimens were found in 5 UTM quadrants (Fig. 14). The species share the same microhabitat with *M. nigriceps*. The specimens are housed in the ichthyological collection of the MBS: IC-MBP 145.

Family Clinidae

Clinitrachus argentatus (Risso, 1810)

All specimens of this species were observed in shallow waters less than 1 m deep. With the exception of one, the specimens were found in algal cover, such as *Cystoseira* spp., *Halopithys incurva* and *Dictyota dichotoma*. Altogether, 10 specimens were recorded in 8 different UTM quadrants (Fig. 15). The specimens are housed in the ichthyological collection of the MBS: IC-MBP 146.

DISCUSSION

Cryptobenthic fish species are often overlooked due to their cryptic life style (Henriques, 2002). Because they live in heterogeneous environments such as caves, cavities, holes, under stones and clefts, sampling is very demanding. In such cases, anaesthetics such as Quinaldine, proved to be helpful in facilitating the collection of specimens.

Among the 11 cryptobenthic species found in Slovenian coastal waters, two species of the family Gobiidae, *T. macrolepis* and *C. quadrivittatus,* were observed for the first time in Slovenian territorial waters in recent years. Marčeta (1999) mentioned at least one finding of *C. quadrivittatus* near Trieste, and that considered it as an expected species for the adjacent Slovenian waters. *T. macrolepis* and *C. quadrivittatus* were both recorded in the nearby Kvarner area, as well (Ahnelt & Kovačić, 1997; Kovačić, 1997, 2005). *T. macrolepis* was often overlooked in the past, probably not only due to its cryptic lifestyle, but also because it occurs in deeper environments (Miller, 1986; Bilecenoğlu & Yokes, 2016). These new observations indicate that the species is more widespread than it was previously assumed (Kovačić, 2005; Bilecenoğlu & Yokes, 2016). According to Bilecenoğlu & Yokes (2016), the species appears on sediments near small caves, sloping rocky bottoms and coralligenous grounds, where it hides when divers try to approach. *C. quadrivittatus* was also often overlooked in the past, but new findings show that it is more widespread than previously assumed (Ahnelt, 1990, 1991; Kovačić, 2005, 1997). Specimens are rarely found, and it is presumed that they are not numerous (Ahnelt, 1991). The species occurs in shallow waters, often in tide pools, where it hides under stones (Ahnelt, 1990, 1991).

Among cryptobenthic fish fauna in Slovenian waters, gobies are represented with the highest number of species (Tab. 1), which is in accordance with the results obtained for nearby areas, as reported in many studies (Kovačić, 1997; Kovačič *et al*., 2012; Glavičić *et. al*., 2016). Clingfishes were by far the most numerous cryptobenthic fish. *L. lepadogaster* was the most numerous species (n = 237), followed by *A. incognitus* (n = 202) and *L. candolii* (n = 173). These 3 species represent 76.7% of all observed cryptobenthic specimens, but the number does not reflect the actual density of fish species, as they were sampled with the highest effort.

Two species - *C. quadrivittatus* and *L. lepadogaster* – occurred only in rocky environment, where they were hiding under stones. Species as *T. ephippiatus* and *T. macrolepis* require a specific rocky habitat type with caves and cavities of steep rock faces (Miller, 1986; Kovačić, 1997). Probably, as regards Slovenian waters, this type of habitat is only found in the Natural Monument Cape Madonna protected area, where the species were in fact recorded. Moreover, this restricted area is inhabited by high number of cryptobenthic fish species per UTM quadrant, as well. This is in accordance with Lipej *et al*. (2003), who reported on the correlation between the high diversity of a fish assemblage and the diversity of habitat types in this area. Similar dimly lit habitats, such as overhanging rocks, are also important habitats for two syntopical sciaphilic blennies, *M. nigriceps* and *P. zvonimiri*, which generally hide in precoralligenous formations and dwell in empty *L. lithophaga* burrows (Lipej *et al.*, 2005; Orlando-Bonaca & Lipej, 2008; Lipej *et al.*, 2016b). The presence of three other cryptobenthic species, *L. candolii, M. macrocephalus* and *Z. zebrus,* are not related only to rocky environment, but were also observed in seagrass meadows where they were hiding under shells and other objects on the sea bottom. *C. argentatus* also occurs in rocky environment, but it is the only species that is strongly associated with a dense macroalgal belt (*e.g. Cystoseira* spp.), which provides shelter to this species (Orlando-Bonaca & Trkov, 2016). Santin (2008) reported that the removal of canopy forming algae did not affect the structure of cryptic fish assemblages, but we believe this result does not apply to *C. argentatus*.

Regarding depth distribution, three species, *C. argentatus, L. lepadogaster* and *C. quadrivittatus,* occur only in very shallow waters, mostly less than 2 m deep, while *Z. zebrus* also occurs in slightly deeper areas (down to 3 m). As tidal amplitude is around ± 90 cm in this part of the Adriatic (Janeković & Kuzmić, 2005; Cosoli *et al*., 2013), tidal dynamics have a big impact on the distribution of these species. With the exception of *C. argentatus*, which probably withdraws to deeper water at the low tide, the other 3 mentioned species can also be found in tide pools in the lower mediolittoral. The occurrence of *Z. zebrus* and *C. quadrivittatus* in tide pools has already been reported by some authors (*e.g.* Ahnelt, 1990, 1991; Nieto & Alberto, 1992). Other species, such as *M. macrocephalus, L. candolii* and *A. incognitus*, were mostly present in deeper waters in the infralittoral belt (depth range from 1 to 7 m). The presence of *M. nigriceps* and *P. zvonimiri* is mainly related to the availability of suitable hiding habitats, which occur deeper on the sea bottom (depth range from 1 to 10 m). Overall, *T. ephippiatus* and *T. macrolepis* were observed in the deepest areas, which is in accordance with (Miller, 1986), who stated that other species from this genus also prefer habitats somewhat deeper than other gobiid species.

Unlike the rocky environment, the sedimentary environment is much poorer in number of cryptobenthic fish species (Tab. 2). In the shallowest part of the sedimentary coast, no cryptobenthic fish species were observed, probably due to the lack of hiding places, which is related to the low spatial heterogeneity of this habitat. Deeper on the sedimentary bottom, where seagrass meadows appear, 4 cryptobenthic fish species were recorded. *L. candolii, M. macrocephalus* and *Z. zebrus,* also found on the rocky bottom, were present in seagrass meadows too. Only *A. incognitus* showed a strong preference for seagrass meadows, where it occupies seashells, which is in accordance with the conclusions of Hofrichter & Patzner (2000). The latter researchers also observed juvenile and subadult specimens of *A. incognitus* on seagrass leaves and under sea urchins. Unlike Horichter & Patzner (2000), we did not observe any cryptobenthic fish under sea urchins.

Cryptobenthic fish were found only down to a depth of 10 m, since in deeper waters the bottom is mainly sedimentary and there is a lack of cryptic habitats. This is also the reason why cryptobenthic species were found only in the quadrants located near the coast. Shallow waters and the lack of cryptic habitats on sedimentary bottom, are probably the main reasons for lower species richness and absence of some species compared to the results of other authors (*e.g.* Kovačić, 1997; Patzner 1999; Kovačić *et al*., 2012; Glavičić *et al*., 2016). In our research, stones (5 species; Tab. 2.) were the most common hiding place in the rocky environment, followed by

Tab. 2: Hiding places occupied by cryptobenthic fish species.
Tab. 2: Skrivališča kriptobentoških vrst rib.

	Stones and rocks	**Precoralligen with endolithic burrows***	**Overhanging rocks***	**Seagrass meadows****	**Dense algal belt**
Lepadogaster lepadpgaster	+	-	-	-	-
Lepadogaster candolii	+	-	-	+	-
Apletodon incognitus	-	-	-	+	-
Cliniceps argentatus	-	-	-	-	+
Chromogobius quadrivittatus	+	-	-	-	-
Millerigobius macrocephalus	+	-	-	+	-
Zebrus zebrus	+	-	-	+	-
Thorogobus ephippiatus	-	-	+	-	-
Thorogobus macrolepis	-	-	+	-	-
Microlipophrys nigriceps	-	+	-	-	-
Parablennius zvonimiri	-	+	-	-	-

cavity beneath boulders*, seashells**

overhanging rocks (4 species), which is in accordance with the results published by Kovačić (1997). Within seagrass meadows, seashells seem to be an important microhabitat, since 3 cryptobenthic fish species were observed using them as a hiding place.

Clearly, the results show that cryptobenthic species richness is much higher on the rocky coast than on sedimentary bottoms, due to the higher spatial heterogeneity of the first environment. Santin *et al*. (2005) reported that rugosity, as a qualitative measure of habitat complexity, is important for explaining the variability in cryptic assemblages, underlining the importance of hiding places for the occurrence of cryptobenthic fish. Certain epibenthic fishes, such as other gobies (*Gobius cruentatus*, *G. cobitis*, *G. paganellus*) and blennies (*Microlipophrys canevae*, *Parablennius incognitus*) were found in similar hiding places. Kovačić (1997) also reported on similar observations of hiding non-cryptobenthic fish species in cryptic habitats, leading to interspecific competition for space, which is well-known for blennies (Goldschmid & Kotrschal, 1981; Koppel, 1988).

Up to now, 243 fish species have been confirmed in the Slovenian sea (Lipej & Orlando-Bonaca, 2019). Based on that, cryptobenthic fish species represent 4.5% of fish fauna in the Slovenian sea and 5.3% in term of bony fish species. A comparison between cryptobenthic fish fauna lists produced by other northern Adriatic authors (Kovačić, 1997, 8 species; Kovačić *et al*., 2012, 6 species; Santin *et al*., 2005, 17 species) can be misleading as some species of epibenthic fish were considered as cryptobenthic by certain authors (Santin *et al*., 2005), while for some fish species, such as *P. zvonimiri*, classification differs between authors (*e.g*. Illich & Kotrschal, 1990; Kovačić *et al*., 2012). In this research, *P. zvonimiri* and *M. nigriceps*, were considered as cryptobenthic species, as they occupy empty *L. lithophaga* burrows and inhabit dimly lit habitats. However, based on the published literature (*e.g*. Kovačič, 1997; Horichter & Patzner, 2000; Kovačić *et al.,* 2012; Brandl *et al*., 2012) dealing with the occurrence of cryptobenthic fish species in the northern Adriatic, and new sampling techniques, other species are expected to be found in Slovenian waters in the future. This could be the case for two clingfish species, such as *Opeatogenys gracilis* (Canestrini, 1864) that is expected to be found in seagrass meadows, and *Gouania willdenowi* (Risso, 1810) that could be detected in a rocky environment on gravel beaches (gravel size 0.2 – 2 cm).

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We would like to express our gratitude to Žiga Dobrajc, to whom we dedicate this contribution. Special thanks go to Dr. Jurgen Herler, who helped us in studying coastal fish assemblages in Slovenian coastal waters in the summer of 2001. We are thankful to Milijan Šiško for his assistance and support in the preparation of the maps. Last but not least, we would like to thank Tihomir Makovec, Samo Alajbegović, Borut Furlan, Valter Žiža and Marjan Richter, who contributed important findings and thus to the knowledge of cryptobenthic fish assemblages.

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POVZETEK

Kriptobentoška ribja favna je ena izmed najmanj raziskanih ribjih skupin v Jadranskem morju. V slovenskih obalnih vodah je bilo do danes le nekaj objavljenih prispevkov, ki navajajo kriptobentoško ribjo skupnost. V pričujočem prispevku avtorji navajajo vse razpoložljive podatke o kriptobentoških ribjih vrstah s posebnim poudarkom na njihovo geografsko in globinsko razširjenost. Skupno je bilo zbranih 798 primerkov, ki pripadajo 11 različnim vrstam. Vrsti Thorogobius macrolepis *in* Chromogobius quadrivittatus *sta bili v slovenskih vodah odkriti šele pred kratkim. Večina rib je bila potrjenih z novimi vzorčevalnimi tehnikami, povezanimi z avtonomnim potapljanjem in z uporabo narkotičnega sredstva Quinaldine.*

Ključne besede: kriptični habitati, ribja skupnost, obalne vode, severni Jadran

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SPATIAL AND TEMPORAL DISTRIBUTION OF ANCHOVY (*ENGRAULIS ENCRASICOLUS*) AND SARDINE (*SARDINA PILCHARDUS*) EGGS IN SLOVENIAN TERRITORIAL WATERS (NORTHERN ADRIATIC)

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ABSTRACT

*Sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) have an important ecological role and are commercially the most important small pelagic species in the Adriatic. In the northern Adriatic Sea sardine and anchovy stocks are overexploited and in overexploitation. Understanding the ecology of these stocks through time is of crucial importance for their sustainable management. In the present work we recognized the most important sardine and anchovy spawning areas and periods in Slovenian territorial waters. Sampling was performed once a month for one year (August 2014–July 2015) at 10 sampling stations, evenly distributed around the Slovenian territorial waters following the Daily Egg Production Method (DEPM) protocol. Despite of low winter temperatures sardine eggs were recorded from September to April, with two spawning peaks, in November and February. The highest number of sardine and anchovy eggs were recorded in the north-western part of the Slovenian territorial waters and in the Koper Bay. Anchovy eggs were recorded from May to November, with the spawning peak in August.*

Key words: small pelagic, anchovy, sardine, spawning season, fish eggs, northern Adriatic Sea

DISTRIBUZIONE SPAZIALE E TEMPORALE DI UOVA DI ACCIUGA (*ENGRAULIS ENCRASICOLUS*) E SARDINA (*SARDINA PILCHARDUS*) IN ACQUE TERRITORIALI SLOVENE (ADRIATICO SETTENTRIONALE)

SINTESI

*La sardina (*Sardina pilchardus*) e l'acciuga (*Engraulis encrasicolus*) hanno un importante ruolo ecologico e sono le specie pelagiche commercialmente più importanti dell'Adriatico. Nell'Adriatico settentrionale le scorte di sardine e acciughe sono sovrasfruttate e in sovrasfruttamento. Comprendere l'ecologia di questi stock nel tempo è di cruciale importanza per la loro gestione sostenibile. Nel presente lavoro abbiamo riconosciuto le più importanti aree e periodi di deposizione delle sardine e delle acciughe nelle acque territoriali slovene. Il campionamento è stato eseguito una volta al mese per un anno (agosto 2014-luglio 2015) in 10 stazioni di campionamento, distribuite uniformemente nelle acque territoriali slovene, seguendo il protocollo del metodo di produzione giornaliera dell'uovo (DEPM). Nonostante le basse temperature invernali, le uova di sardine sono state ritrovate da settembre ad aprile, con due picchi di deposizione delle uova in novembre e febbraio. Il numero più elevato di uova di sardine e acciughe è stato registrato nella parte nord-occidentale delle acque territoriali slovene e nella baia di Capodistria. Le uova di acciuga sono state ritrovate da maggio a novembre, con il picco di deposizione delle uova nel mese di agosto.*

Parole chiave: piccolo pelagico, acciuga, sardina, stagione della deposizione delle uova, uova di pesce, Adriatico settentrionale

INTRODUCTION

Sardine (*Sardina pilchardus*; Walbaum, 1972) and anchovy (*Engraulis encrasicolus*; Linnaeus, 1758) dominate the pelagic environment in the northern and central Adriatic Sea and have a wide impact on its trophic web (Morello *et al.,* 2009). These small pelagic stocks also provide high economic yields for the fisheries sector of all countries around the Adriatic Sea. Coordinating and aligning interests and efforts among countries with such differences in economic and social importance of fisheries on the national level is complicated. For these reasons different management measures are difficult and slow to be implemented and meanwhile small pelagic stocks remain overexploited (COM, 2017). To understand and to be able to predict stock development through time, different stock assessment methods are continuously being developed and data are collected through scientific surveys as well as from the fisheries.

Daily Egg Production Method (DEPM) was developed in the late 1970s in California and has since been applied to several European anchovy stocks in the Mediterranean Sea (Alheit, 1993; Somarakis *et al.*, 2004; Mandić *et al.,* 2015). An important contribution that enabled application of the DEPM method to the Adriatic anchovy stock was that of REGNER (1985), who determined the developmental parameters of anchovy in the Adriatic Sea. Following from his research, the DEPM protocol for the small pelagic species of the Adriatic Sea has recently been developed in the framework of the AdriaMed project (Mandić *et al.*, 2014). According to the DEPM protocol, the full extent of the species' spawning area should be surveyed to enable valid stock assessment with this method Somarakis *et al.*, 2004.

Anchovy and sardine have mirror like reproductive strategies and oceanographic parameters – especially salinity and temperature – are of crucial importance in explaining the coexistence of the two species (Morello *et al.,* 2009). *Štirn et al.,* (1974) pointed out that this two species have more or less spatially competitive relationship. When considering geological timescale it seems that abundant population of anchovy, inhabiting energetically rich western waters of Northern Adriatic and high food plasticity in sardine, who probably had to adapt to remaining available habitats, points out one of the clues that there is a competitive relationship among adult fish for feeding areas (Morello *et al.,* 2009). *Štirn et al.,* (1974) noticed that in late spring, when sardine is still spawning and anchovy is migrating to the north and starting to spawn, areals of both species are not overlapping. This spatial separation in spring is visible also in distribution of their eggs (*Štirn et al.,* 1974). In winter, adult sardines migrate southwards from feeding areas such as Gulf of Trieste, Venice and Istrian coast, towards island Dugi Otok for spawning (Morello *et al.,* 2009; Škrivanič *et al.,* 1973). On the contrary, the main anchovy spawning activity takes place in warmer months in the offshore waters of island Dugi Otok towards the coastal Istrian waters (Morello *et al.,* 2009) and the coastal waters between the Gulf of Trieste and the Gargano peninsula, with the highest abundance of eggs in the Gulf of Trieste and off the mouth of the river Po (Morello *et al.,* 2009; Regner, 1996). Therefore, we expected Slovenian coastal territorial waters to be an important spawning ground for anchovy, but only of minor importance for sardine spawning.

Developmental time of anchovy and sardine eggs depends on temperature and is shortest during warmer water temperatures (Regner, 1987, 1996) minimizing exposure time of the most vulnerable, egg developmental stage. In such conditions egg sizes are smaller, since there is need to provide safety and nutrition to the embryo for much shorter time in such conditions (Riveiro *et al.,* 2004). In addition, smaller eggs have been observed later in the spawning season, when first year individuals tend to spawn (Regner, 1985). In view of this knowledge, we would expect sardine and anchovy eggs to be larger when their first spawning in the year occurs and when environmental conditions are not yet the most suitable. The eggs should be smallest during peak spawning and medium sized to large towards the end of the spawning period when environmental conditions are becoming less suitable.

In view of this knowledge, we would expect sardine and anchovy eggs to be larger when their first spawning in the year occurs and when environmental conditions are not yet the most suitable. The eggs should be smallest during peak spawning and medium sized to large towards the end of the spawning period when environmental conditions are becoming less suitable, which is also in line with results of anchovy egg developmental stage duration in Boka Kotarska Bay in Montenegro (Mandić. 2011).

As a partner of the AdriaMed project, Slovenia is contributing to development and application of the DEPM for the stock assessment of small pelagic fish in the Adriatic Sea (Pengal *et al.*, 2014). Therefore, the initial spatial study of egg distribution performed in August 2014 and supported by the AdriaMed project was extended by ZZRS (Fisheries Research Institute of Slovenia) to also gain insight into temporal distribution of spawning for both small pelagic species in Slovenian coastal territorial waters. Thus, this study provides results of the spatial and temporal distribution of spawning for sardine and anchovy in Slovenian territorial waters.

MATERIAL AND METHODS

Location and sampling

The studied area is situated in the southern part of the shallow Gulf of Trieste, which is the northernmost part of the Adriatic Sea (Fig. 1). Larger part of the gulf belongs to the infralittoral zone with typical flat muddy bottom, composed of clayey silt (Ogorelec *et al.,* 1991), while other the rest of the habitat types are limited to small dispersed areas (Lipej *et al.,* 2006). Slovenian territorial waters (studied area) is extremely shallow, with mean depth of 18.7 m (Ogrin, 2012). Because of its shallow nature with a mean depth of 35 m, northern Adriatic is extremely productive, but becomes hydrographically unstable and subjected to environmental variability during winter (Štirn, 1968).

In all the seasons there is a general inflow into the Gulf of Trieste at its south-eastern, deeper part, while the outflow appears along the gulf's axis near the sea surface and is driven by the dominant "bora" wind during winter. The surface layer of the Gulf of Trieste is dominated by seasonal winds and typical (anti)cyclonic circulations formed in different seasons, suggesting lower current speeds in the central part of the Gulf (Zavatarelli *et al.,* 2003; Malačič *et al.,* 2009). Stronger currents are typical near the capes such as Cape Madona in Piran (Ogrin, 2012).

Sampling was performed for twelve months from August 2014 to July 2015 on ten sampling stations, positioned app. 3 nautical miles apart in the Slovenian territorial waters. Due to adverse weather conditions sampling was impossible to perform in October and in January on stations 6 to 10. Sampling stations were reached by a boat of ZZRS and exact locations found with a handheld GPS unit.

The Daily egg production method (DEPM) protocol (Mandić *et al.,* 2014; Pengal *et al.,* 2014) was followed and sampling was conducted using WP2 net with mesh size of 200 µm and mouth diameter of 0,264 m^2. The net was towed from 5 m above the bottom to the surface with a hauling speed of 1 m/s. The samples were immediately preserved in 3 % solution of buffered formaldehyde and analysed at the Department of Biology at the Biotechnical Faculty of University of Ljubljana.

At each sampling station water temperature [°C], salinity, oxygen levels [mg/L] and dissolved oxygen [%] for each meter of the water column were measured by means of a Hatch CTD probe (Horvat, 2017). In August, November and December, salinity measurements were not collected at all sampling stations due to probe failure. Therefore, salinity of peak spawning for anchovy (August) was estimated using July data.

Mean monthly air and water temperatures for each month were also collected from Slovenian Environmental Agency (ARSO; Strojan, 2014a, b, c; Strojan, 2015 a, b ,c, d, e). Speed and direction of currents were gained from the stainless–steel buoy "Vida" (45° 32′ 55,68″ N, 13° 33′ 1,89″ E), where an AWAC current meter from Nortek As is mounted at the seafloor, at the depth of 22 m. Additionally, the direction of wind was collected from Vida (NIB, 2017) during sampling of each station. For sampling stations 1, 5, 6, 7, and 8 Chlorophyll–a concentrations [µg/L] were obtained from the Slovenian Environmental Agency for months August (2014)–January (2015) and June–July (2015) (Sever, 2016).

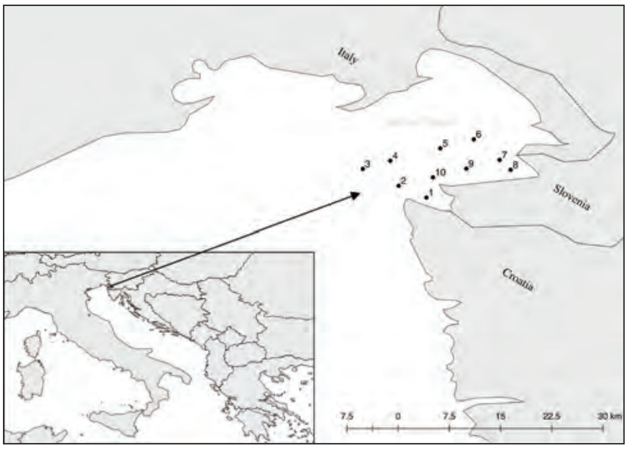

Fig. 1: Geographic position of ten sampling stations (1 – 10) in Slovenian territorial waters inside the Gulf of Trieste.
Sl. 1: Enakomerna razporeditev desetih vzorčnih postaj (1 – 10) v teritorialnih vodah Slovenije (Tržaški zaliv).

Analysis

Sardine and anchovy eggs were sorted from the samples and counted in the laboratory. Eggs were then measured with the program CellSense Standard under the microscope (Olympus Cx41) with 10 X 4 magnification. Eleven egg developmental stages and 5 developmental classes (A–E) were determined for sardine eggs following the proposal of the General Fisheries Council for the Mediterranean (karlovac, 1967; GFCM, 1975). Ten developmental stages were determined for anchovy eggs according to Regner's templates from AdriaMed Training Course (REGNER, 1985). Additional literature Ré *et al.,* (2009) and Mandić (2011) was referenced to determine the ages of sardine eggs. Regner's (1985) formula for developmental time and mean correction time were used to calculate the spawning interval.

Monthly abundance of sardine or anchovy eggs per m^2 were calculated for each sampling station using Tanaka's formula (Regner, 1985; Regner *et al.*, 1987). Since sardine and anchovy eggs were only found at a small number of stations (less than 50 %) in most months, the empty stations were omitted from the calculation of mean monthly abundance of eggs per station (as per Karlovac (1964) and Mandić (2011)). Finally, categorization by Karlovac (1964) was used to determine the spawning intensity category for the survey area. Information on length of adult sardine and anchovy fish that were caught in Slovenian territorial waters during our survey were retrieved from the database of the Fisheries Research Institute of Slovenia (ZZRS).

RESULTS

In total, 1646 eggs were collected, of which 68 were sardine, 951 anchovy and 627 were unidentified eggs belonging to other species. Of those, 3 sardine and no anchovy eggs were found during the incomplete January sampling and these eggs were omitted from the analysis (Fig. 2). Moreover, 34 anchovy and 3 sardine eggs were damaged so that it was impossible to determine their developmental stage or measure them. These eggs were used for the calculations of abundance, but not for the other analysis.

Abiotic parameters

The water depth at sampling stations ranged from 18 to 25 m. With the exceptions of May and August, there was no clear stratification of the water column during our sampling, data is in more detail presented in Horvat (2017). Temperature in the water column was gradually decreasing towards the bottom in the summer months without a clear thermocline (Fig. 3). On the contrary, salinity was lowest on the surface and gradually increasing towards the bottom, with an exceptionally strong pycnocline with a pronounced low surface salinity layer in November, when the sampling was performed after a rainfall event and freshwater lingered on the surface for a few days. The only month with the mean water column salinity below 38 was May.

Persistence of low oxygen levels in the bottom layer was detected throughout the summer months, from July to the end of September at most sampling stations. Oxygen content was high throughout the water column during the winter months.

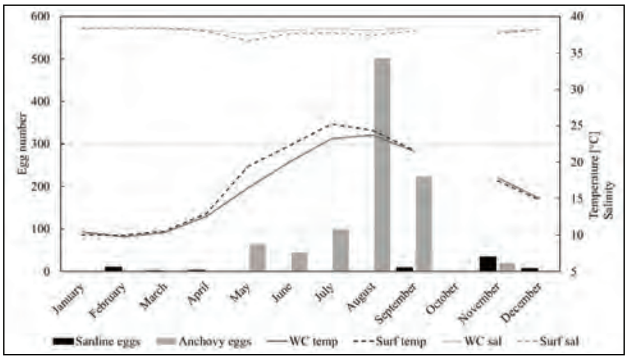

Fig. 2. Total number of sardine and anchovy eggs found in the samples from all stations by month with surface (Surf) and mean water column (WC) temperatures (temp) and salinities (sal).

Sl. 2: Skupno število iker sardele in sardona iz vseh vzorčnih postaj, predstavljeno po mesecih, vključno s temperaturo površinske vode (Surf) in povprečno temperaturo vodnega stolpca (WC) in slanostjo (sal).

Sardine

The highest abundance of sardine eggs and persistence were detected at stations 6 and 7 located towards the central part of Gulf of Trieste and the Koper Bay (Tab. 1). No sardine egg was found in the samples from station 3 in this survey and only individual eggs were identified at the neighbouring stations 2 and 4, which are located off the Savudrija cape. Low presence of sardine eggs was also determined for stations closest to the shore. Higher abundances were calculated for station 10, just off the Cape Madona, the deepest part of the Slovenian territorial waters.

The eggs occurred in the sampling area from September to April with the first spawning peak in November and a second, lower spawning peak detected in February (Fig. 4a). Medium sardine spawning intensity was determined for the earliest occurrence of sardine eggs in Slovenian territorial waters in late September with a mean of 11 eggs/m^2. In November, mean abundance of 19 eggs/m^2 was found in the sampling area, which indicates Slovenian territorial waters as an area of strong spawning intensity for sardine. Mean water column temperature at peak spawning was 17.84 °C and salinity 37.97. During the second abundance peak in February sardine eggs were found at five sampling stations (6–10) with on average 8 eggs/m^2 which corresponds to a low intensity spawning event. The lowest mean water column temperature (9.76 °C) and the highest salinity (38.39) during the survey were recorded for this sampling. The latest occurrence of sardine eggs in Slovenian

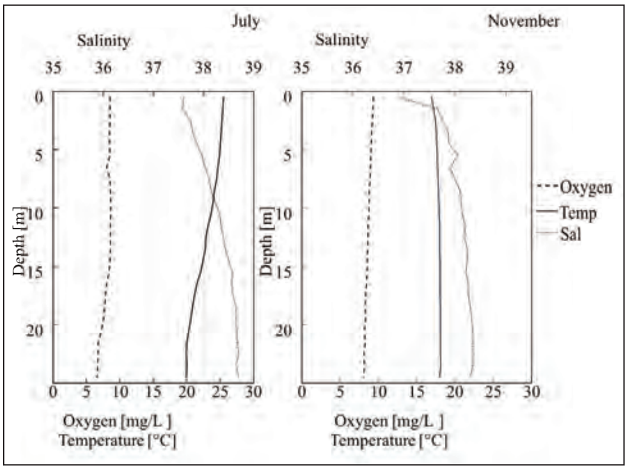

Fig. 3. Water temperature, salinity and oxygen profiles as a mean of all stations during peak spawning of anchovy (July; see Materials and methods) and sardine (November).

Sl. 3: Povprečne vrednosti vodnega stolpca vseh vzorčnih postaj za temperaturo, slanost in kisik tekom viška drsti sardona (julij; glej Material and methods) in sardele (november).

territorial waters was determined for April (on average 4 eggs/m^2).

The minimum egg developmental time (38.78 hours) for any station during our survey was calculated at station 8 in September and the maximum (137.01 hours) at station 6 in February. The shortest mean developmental time (39.21 hours) for sardine eggs was determined for September and the longest for February (128.25 hours; Fig. 4a), while in November it was the second shortest (51.80 hours).

Eggs stages B and C were detected in most samples, whereas stages A, D and E occurred only occasionally. Stage A was detected only in February, stages B and C from September to April and stage D in September and November. Stage E was never recorded.

Sardine eggs collected during this survey varied in size from 1.30 (in December) to 1.90 mm (in February; Fig. 4b). The smallest mean egg sizes were calculated for the autumn samples September (1.50 +/- 0.08 mm), November (1.55 +/- 0.09 mm) and December (1.54 +/- 0.02 mm). The largest mean egg sizes were detected in February (1.73 +/- 0.01 mm). Furthermore, the eggs containing the smallest oil drops were collected in September (mean of 0.15 +/- 0.03 mm) and the largest in February (mean 0.21 +/- 0.05 mm).

Anchovy

The highest abundance of anchovy eggs in the survey area were consistently detected at stations from 5 to 9, located towards the central part of the Gulf of Trieste and the Koper Bay (Tab. 1). The abundance decreased towards the mouth of the Gulf as well as towards the shore. Furthermore, stations 6–9 exhibited 100% persistence during the spawning season, with eggs being

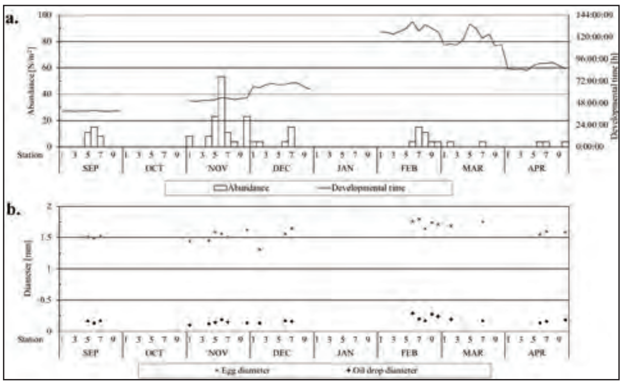

Fig. 4 Abundance of eggs, developmental time (a), mean egg diameter and mean oil drop diameter (b) by month and sampling station during the spawning period for sardine.

S. 4: Številčnost iker, razvojni čas (a), povprečni premer vseh iker in oljne kapljice (b) po vzorčnih postajah in mesecu drsti sardele.

Tab. 1: Mean abundance of sardine (Sar) and anchovy (Anc) eggs per station [N/m^2] during their presence in the survey area.

Tab. 1: Povprečna številčnost iker sardele (Sar) in sardona (Anc) na vzorčnih postajah [N/m^2] tekom njihove prisotnosti na območju raziskave.

Month/ Sampling station [N/m^2]	August		September		November		December		February		March		April		May		June		July		Mean abundance [N/m^2] on positive stations	
	Sar	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**	**Sar**	**Anc**
1	0	15	0	11	8	0	4	0	0	0	0	0	0	0	0	0	0	4	0	0	6	10
2	0	15	0	4	0	0	4	0	0	0	4	0	0	0	0	0	0	4	0	8	4	8
3	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	14
4	0	23	0	11	8	0	0	0	0	0	0	0	0	0	0	53	0	0	0	00	8	29
5	0	367	11	227	23	0	0	0	0	0	0	0	0	0	0	87	0	0	0	8	17	172
6	0	367	15	261	53	30	4	0	4	0	0	0	4	0	0	34	0	27	0	223	16	157
7	0	246	8	136	11	15	15	0	15	0	4	0	4	0	0	4	0	8	0	72	10	80
8	0	136	0	91	4	23	0	0	11	0	0	0	0	0	0	4	0	38	0	15	8	51
9	0	629	0	72	0	8	0	0	4	0	0	0	0	0	0	30	0	4	0	42	4	131
10	0	91	0	30	23	0	0	0	4	0	0	0	4	0	0	8	0	87	0	8	10	45

detected at these stations each month from May to November. We recorded the lowest abundances as well as persistency at station 3. Only during peak spawning in August anchovy eggs were present at all stations.

Anchovy eggs were detected in planktonic community of the Slovenian territorial waters between May and November, with the peak spawning recorded in August (Fig. 5a, Tab. 1). When the season's earliest anchovy eggs were identified in May at stations 3–10 (on average 30 eggs/m^2), mean water column temperature for these stations was 16.8 °C and salinity 37.57. The calculated abundance of anchovy eggs during peak spawning in August ranged from 8 eggs/m^2 at station 3 to 629 eggs/m^2 at station 9. However, the mean abundance of eggs for this period was 189.77 eggs/m^2. During peak spawning the mean water column temperature at positive stations was 23.75 °C and salinity around 38.09 (see Materials and Methods). Spawning intensity and persistence gradually decreased from September (94 eggs/m^2) to November, when the lowest egg abundances were detected (19 eggs/m^2) at stations 6–9.

Based on the temperature measurements, the mean developmental time for eggs was shortest in August (31 hours) and longest in May (72 hours). Most eggs from August samples were determined to be in stages IV and V (70.94 % of all eggs), which corresponds to highest spawning intensity between 1:00 and 2:30 o'clock in the night (Fig. 6). Furthermore, 93 % of eggs found in August samples were spawned between 21:00 in the evening and 8:00 in the morning.

The minimum length of anchovy eggs in the samples from Slovenian territorial waters was 1.07 mm and the maximum was 1.52 mm (Fig. 5b). The smallest mean egg sizes (length: 1.20 +/- 0.02 mm; Fig. 5b) were calculated for samples collected during the abundance peak in August. On the contrary, eggs were largest (length: 1.40 +/- 0.02 mm) towards the beginning and end of the spawning season.

DISCUSSION

As suggested by Regner (1985) temperature and salinity seem to be the most important factors determining spawning period and limiting spawning area of the small pelagic species in the Adriatic.

No significant correlation was found between abiotic (temperature, salinity, chl-a, ...) and biotic (egg abundance, size, occurrence,...) parameters, so the PCA

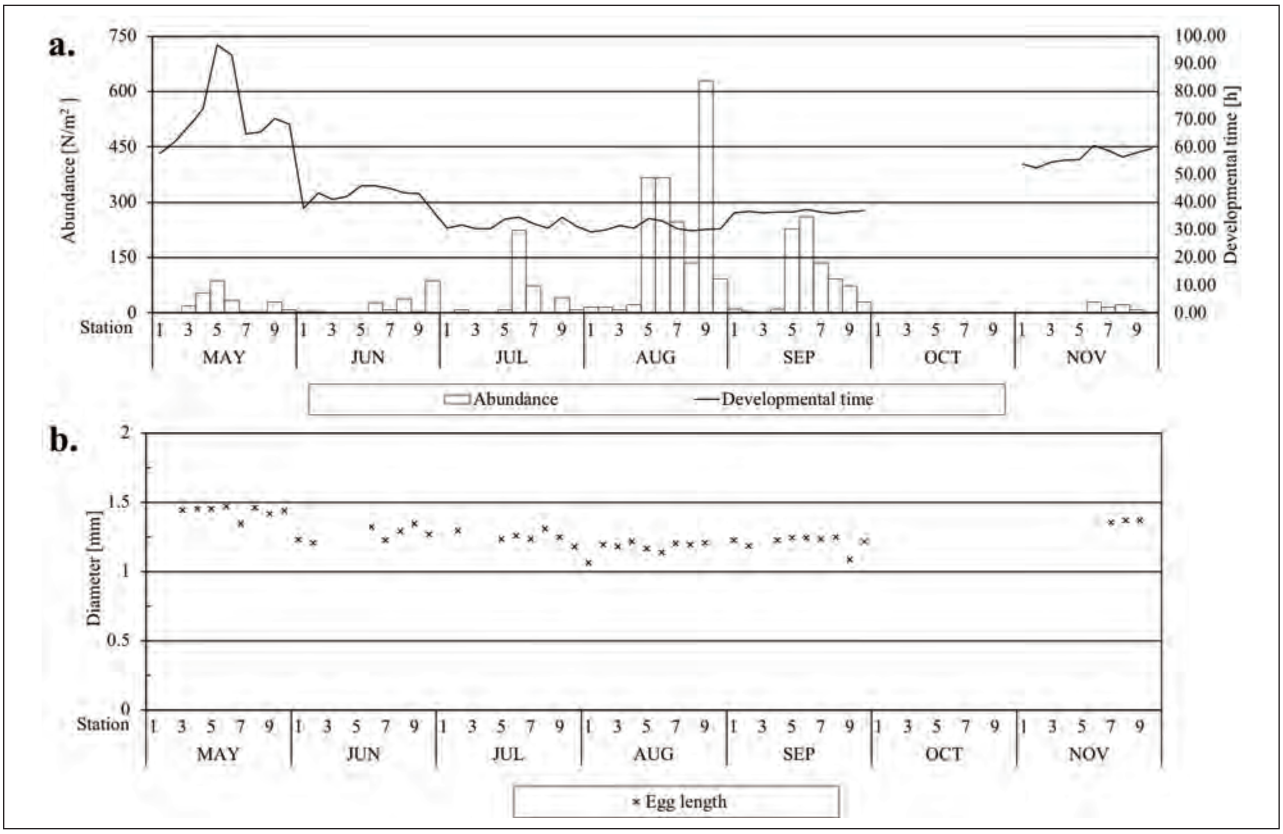

Fig. 5 Abundance of eggs, developmental time (a), mean egg length (b) by month for each sampling station during the spawning period for anchovy.
Sl. 5: Številčnost iker, razvojni čas (a), povprečna dolžina iker (b) po vzorčnih postajah in mesecu drsti sardona.

results are not presented in this article. The lack of correlation is attributable to the small surface, low depth and stable conditions of the Slovenian territorial waters, lacking the required diversity for such analysis.

Our findings confirm past findings (Štirn, 1968; Štirn *et al.,* 1974; Morello *et al.,* 2009) with anchovy spawning mainly during warmer months (Štirn, 1968; Štirn *et al.,* 1974; Morello *et al.,* 2009) in Slovenian territorial waters. In spring, the last sardine eggs were detected in April and the first anchovy eggs were found in May, completely separating spawning periods of the two species. In autumn, on the other hand, spawning periods were overlapping from September to November, when eggs of both species were found in the samples. The prolonged spawning of anchovy till November was recorded in 2014, which is a usual spawning period for central and southern Adriatic (Zavodnik, 1970; Regner, 1972; Morello *et al.,* 2009; Mandić, 2011) but not for the Northern Adriatic (Štirn, 1968; Štirn *et al.,* 1974; Morello *et al.,* 2009). We assume that one of the reasons might be the persistence of unusually high November mean sea water temperatures when comparing it to the mean November sea temperatures since 1981 at the Measurement station Koper (Strojan, 2014b). High abundances of anchovy eggs were still detected in the September samples, but low numbers collected in November were indicating the end of the spawning period. On the contrary, only individual sardine eggs were found in September samples and the first spawning peak was determined in November. The relatively low abundance of sardine eggs in September could be attributed to the numerous presence of anchovy who is more abundant and, thus, dominant in the area (Štirn, 1986). On the other hand, Slovenian territorial waters also represent the marginal area of sardine spawning range due to extreme environmental conditions during winter (Štirn, 1968, Gačić *et al.,* 1997; Shaltout *et al., 2014).*

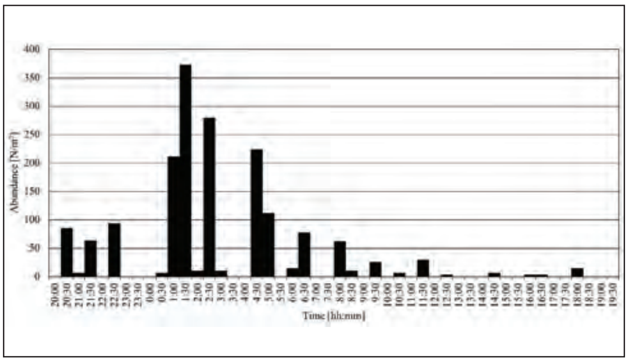

Fig. 6. Abundance of anchovy eggs (N/m²) by back-calculated spawning times during peak spawning in August.
Sl. 6: Številčnost iker sardona (N/m²) z "za nazaj" preračunanim časom drsti med viškom drsti v avgustu.

Sardine

The distribution of sardine eggs detected in this survey confirms the highest density of sardine eggs in the central open waters of the Gulf of Trieste. The abundance of eggs declines towards the entrance to the Gulf and towards the shores. Recent studies of currents in the Gulf of Trieste (Bogunović *et al.,* 2008) suggest that direction and speed of sea currents are the major reason for the described distribution of eggs. On the other hand, the average age for all sampled sardine eggs was approximately 16 hours at the time of sampling and considering the regular occurrence of strong winds and marine currents in the Gulf during winter time (Ogrin, 2012), the areas identified may not represent the actual spawning grounds.

The low absolute number of sardine eggs detected in this survey agree with other studies conducted in the northern Adriatic which found the spawning intensity in this area consistent with a periphery of the main sardine spawning grounds (Regner *et al.,* 1987; Štirn, 1968). Contrary to Štirn (1968), we can confirm sardine spawning in the Gulf of Trieste despite the low temperatures during winter. Sardine spawn with strong intensity in November as well as with medium intensity in September, December and February (Karlovac, 1964). Considering the trends observed, it is reasonable to conclude that spawning occurred also in October and January in Slovenian territorial waters. We predict that spawning intensity in October and January would also fall at least within the medium intensity category, if sampling was feasible during our survey.

Sardine eggs occurred in the survey area when mean water column temperature ranged from 9.20 to 22.00 °C and salinity range from 36.70 to 39.00. The first spawning peak in November was characterized by mean water column temperature of 17.77 °C and salinity around 37.80, calculated at stations where sardine eggs were found and salinity was around 37.80 (see Material and Methods).

According to previous research (Morello *et al.,* 2009; Regner *et al.,* 1987; Štirn, 1968), environmental conditions for peak spawning of sardine during this survey were the most suitable in January, when we also assumed the spawning peak would occur. Unfortunately, unsuitable weather conditions only allowed us to sample stations 1 to 5 and 10 in this month. Thus, the stations with otherwise highest abundances of eggs observed were not sampled and so the abundance is not comparable with other sampling months. Therefore, we allow the possibility that the highest sardine spawning peak in Slovenian territorial waters occurred in January.

The eggs recorded in this study were generally larger than those recorded by Mandić *et al.,* (2014) in Boka Kotorska Bay (Montenegro), suggesting that conditions for sardine spawning in the Gulf of Trieste are less suitable. Furthermore, the largest sardine eggs were found in

February and March, which can be partly explained by least favourable environmental conditions (low sea temperatures and salinity). Adults were not sampled during our survey and there is a lack of data from Data Collection Framework (DCF) for winter months, so we cannot confirm if length of fish also affected the size of eggs.

It was expected that egg stages D and E would be less frequent in all samples due to high mortality rates, since sampling was done in North Adriatic where, referring to Regner *et al.* (1987), mortality of sardine eggs and larvae is higher (coefficient of instantaneous mortality: 0.65) is higher than in the mean calculated on the entire Adriatic (coefficient of instantaneous mortality: 0.56). The exceptional occurrence of stage D eggs in November samples could indicate lower predator pressure during that time which is consistent with lower gelatinous plankton densities in northern Adriatic during autumn (Palmieri *et al.,* 2014; Malej *et al.,* 2004). Focused studies should be conducted to understand these dynamics.

Anchovy

The Gulf of Venice and the Gulf of Trieste are known to be the main spawning areas for anchovy in the Adriatic (Gamulin, 1983; Morello *et al.,* 2009). Similar to sardine, we found that anchovy eggs are the most abundant towards the central open waters of the Gulf of Trieste and decline in number towards the shores and entrance to the Gulf. On the contrary to what is shown by sardine, we can conclude and confirm (Štirn, 1968; Štirn *et al.,* 1974; Regner, 1985; Regner *et al.,* 1987; Dulčić, 1995) that these are the actual spawning grounds of anchovy, since the currents are very weak or absent during summer months (Malačič *et al.,* 2009) and the eggs are expected to linger where they were spawned.

During our survey anchovy spawned in Slovenian territorial waters between May and November. The first occurrence of eggs in May was characterized by the mean water column temperature of 16.44 °C and salinity 38.09. While exceptional presence of anchovy eggs until November has been reported in the central and southern Adriatic before (Regner, 1972), this study is the first to confirm occurrence of late, November spawning in the colder northern Adriatic. We assume the prolonged spawning coincided with higher water column temperatures (mean of 17.50 °C) in November during our survey, which were 2.6 °C higher than average (mean of 14.90 °C; Strojan, 2014b).

From abundance of anchovy eggs peak spawning intensity was determined for August, with mean water column temperature 23.75 °C and salinity from 37,40–38, confirming previous findings for northern Adriatic (Štirn, 1968; Regner, 1985). The anchovy spawning intensity gradually increased during the 3 spring months (May–July), exploded in August and finally decreased during the autumn months (Sep–Nov). In line with Regner (1985), this pattern closely followed the observed water column temperature changes. Furthermore, salinity measured during peak spawning in the Slovenian territorial waters is at the higher end of the previously observed range (28–38.5; Morello *et al.,* 2009; Štirn, 1968).

Moreover, Regner (1985; Morello *et al.,* 2009) observed that anchovy eggs from the open sea are larger than those from the coastal areas such as Gulf of Trieste and Lugovaj (1964; *as cited in* Regner, 1985) found that salinity also affects egg sizes, which are smaller and more elongated in lower salinities. We can confirm these hypothesis, since the eggs collected during this survey are one of the smallest (0.49–0.56 x 1.17–1.43 mm) recorded in the Adriatic Sea (Lugovaj, 1964; Regner, 1985; Zorica *et al.,* 2014; Mandič, 2011). Length measurements refer to formalin-preserved eggs, no correction of size was performed. In addition, the smaller egg sizes can also be attributed to the smaller size of individuals representing the northern Adriatic anchovy stock (Levi *et al.,* 1994). Adults were not sampled during our survey and there is a lack of DCF data during winter months, so we cannot confirm these relationships for Slovenian territorial waters.

The anchovy daily spawning interval determined in this survey is wider compared to previous studies and shifted towards the early morning hours (peak from 0:30 – 5:00 am; Fig. 6b). In the area of Chioggia (Venice Bay) Varagnolo (1964) reported spawning of anchovy to occur between 18:00–20:00, while Somarakis (2004) assumed anchovy spawn between 22:00 and 2:00 in the Eastern Mediterranean.

For the future surveys, we recommend that since the DEPM application presumes the coverage of entire spawning area, Slovenian territorial waters should be included in the future samplings to avoid underestimation of the SSB. In addition, due to the opposing spawning periods of sardine and anchovy, separate surveys should be performed to collect data, and protection of the spawning grounds for these two species should be managed separately.

CONCLUSIONS

For anchovy the main spawning season occurred in autumn in northern Adriatic, confirming Štirn's findings (1968). However, since predicted climate change could shift the sardine spawning area further north, affecting the current equilibrium with potentially considerable effects on small pelagic fisheries of northern Adriatic, the spawning of these two species should be closely monitored. Future studies should try to predict the impact of climate change on the spawning areas, the consequent change in competitive interaction among these two species and the potential fisheries implications for the Adriatic. Future DEPM studies should also include chlorophyll-a, phytoplankton and zooplankton measurements, since data are not available and is not a good indicator of production in the Slovenian territorial waters, since heavy maritime traffic causes suspension of the mud throughout the year, distorting this correlation.

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PROSTORSKO IN ČASOVNO POJAVLJANJE IKER SARDELE IN SARDONA V SLOVENSKEM TERITORIALNEM MORJU

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POVZETEK

Glavno obdobje drsti sardona v severnem Jadranu tekom naše raziskave je bilo jeseni, s čimer potrjujemo Štirnova (1968) odkritja. Zaradi pričakovanih klimatskih sprememb lahko pričakujemo, da se bo drst sardele pomaknila proti severnim območjem Jadrana, kar bi lahko vplivalo na trenutno ravnovesje staležev med malimi pelaškimi vrstami rib severnega Jadrana, zato predlagamo podrobnejše spremljanje drsti obeh vrst. V prihodnjih študijah bi bilo priporočljivo na podlagi različnih modelov predvideti kako se bodo spreminjala območja drsti, zaradi njunega kompetitivnega odnosa, in kakšen bo potencialni vpliv teh sprememb na njun ulov znotraj Jadrana. DEPM raziskave bi morale vključevati tudi beleženje zooplanktona, fitoplanktona in klorofila-a, saj se meritve s strani države ne opravljajo redno po celotnem območju teritorialnih voda Slovenije ter niso dober ali dovolj natančen pokazatelj primarne produkcije skozi leto, saj na meritve močno vpliva morski promet (tovorne ladje in križarke), ki povzroča dvig in mešanje sedimenta skozi vse leto.

Ključne besede: male pelaške ribe, sardon, sardela, drst, obdobje drsti, ikre, severno Jadransko morje

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OVERVIEW OF TROPHIC LEVELS RECORDED IN TELEOST SPECIES FROM NORTHERN TUNISIAN WATERS (CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

This paper reports about the observations made with regard to 21 teleost species comprising 1657 specimens from the northern Tunisian coast. These specimens were found in an area with sufficient prey species to allow them to live and develop, as confirmed by the size to total body weight relationship. The high values of vacuity index are probably due to both sampling and fishing methods. Crustaceans and teleosts are the prey most frequently consumed by these species. Additionally, the high trophic levels (TROPH) (± 3.00) indicated that these teleost species belong among carnivores. Of all the species examined, only one, Sarpa salpa *with TROPH = 2.00, was found to be herbivorous.*

Key words: Teleost species, trophic level, vacuity index, relation the total length *vs* the total body weight, competition for food, Tunisian coast

REVISIONE DEI LIVELLI TROFICI DI SPECIE DI TELEOSTEI IN ACQUE TUNISINE SETTENTRIONALI (MEDITERRANEO CENTRAE)

SINTESI

L'articolo riporta le osservazioni fatte su 21 specie di teleostei comprendenti 1657 esemplari provenienti dalla costa settentrionale tunisina. Gli esemplari sono stati trovati in un'area con una quantità di prede sufficiente per consentire loro di vivere e svilupparsi, come confermato dal rapporto tra le dimensioni corporee e il peso corporeo totale. Gli alti valori dell'indice di vacuità sono probabilmente dovuti sia al campionamento che ai metodi di pesca. Crostacei e teleostei sono le prede più frequentemente consumate da queste specie. Gli alti livelli trofici (TROPH) (± 3,00) hanno inoltre evidenziato che tali specie di teleostei sono carnivore. Di tutte le specie esaminate solo una, Sarpa salpa*, con TROPH = 2,00, è risultata erbivora.*

Parole chiave: teleostei, livello trofico, indice di vacuità, relazione tra lunghezza totale e peso corporeo totale, competizione alimentare, costa tunisina

INTRODUCTION

Fishery and aquaculture are believed to play an important role in Tunisian economy, which explains why studies related to these patterns have been the subject of several papers (see Bradaï, 2000; Rafrafi-Nouira, 2016). The entire Tunisian coast, including lagoons, has been continuously investigated since Vinciguerra (1882) to assess, in qualitative and quantitative terms, the status and the biodiversity of local ichthyofauna. Several studies focused on fish species occurring in northern areas (Castany, 1955; Ben Mustapha, 1966; Lubet & Azzouz, 1969; El Kamel-Moutalibi, 2014; Mnasri-Sioudi, 2014; Rafrafi-Nouira, 2016).

The aim of this paper is to point out the interrelationships between fish species caught off Ras Jebel and its closely related areas, and their potential preys. Thus, the trophic levels were determined for some species of commercial interest commonly observed in fish markets. Following Stergiou & Karpouzi (2002), estimation of trophic level plays a major role in monitoring fishery resources and their effect on ecosystems. Additionally, following Froese *et al.* (2011), the size *versus* total body weight relationship was calculated for each species to point out if they found sufficient food in the wild to live and develop.

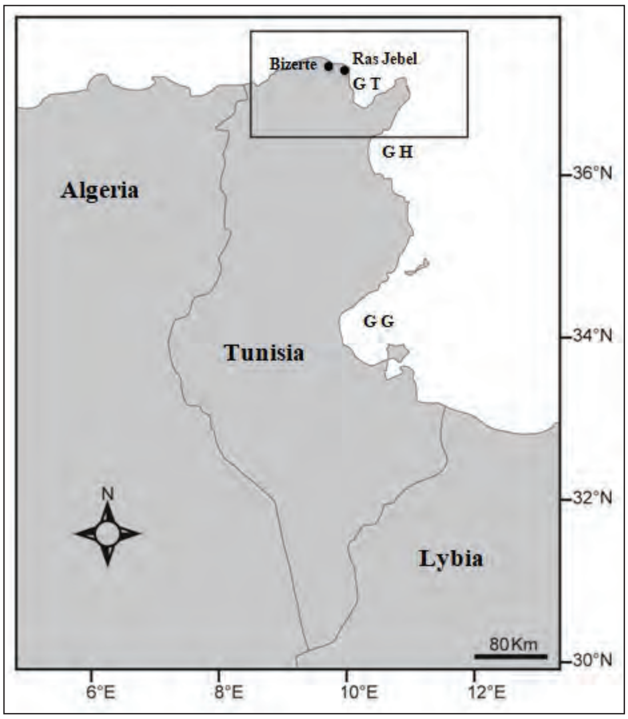

Fig. 1: Map of Tunisia indicating the capture area (rectangle) of 21 teleost species from the northern Tunisian coast. GT: Gulf of Tunis; GH: Gulf of Hammamet; GG: Gulf of Gabès.

Sl. 1: Zemljevid Tunizije z označeno lokaliteto (pravokotnik) ulova 21 vrst kostnic ob severni tunizijski obali. GT: Tuniški zaliv; GH: Hamameški zaliv; GG: Gabeški zaliv.

MATERIAL AND METHODS

Of the 124 fish species captured in northern Tunisian waters, 21 teleost species were targeted, comprising 1657 specimens sampled for this study between 2010 and 2015. According to the information provided by experienced local fishermen, the specimens were collected throughout the year off the northern and northeastern Tunisian coast, including the Gulf of Tunis (Fig. 1), by commercial fishing vessels using trawl over sandy and muddy bottoms, and gill nets and longlines on rocky bottoms, at depths ranging from 50 to 200 m. Each sampled specimen was identified using books and field guides, such as Whitehead *et al.* (1984-1986), Louisy (2002) and Quéro *et al.* (2003). All fresh specimens were delivered to the laboratory, where they were measured for total length (TL) to the nearest millimetre and weighed for total body weight (TBW) to the nearest gram.

For each specific sample the Shapiro–Wilk's test of normality was performed, with $P < 0.05$. The Chi-square test was used to determine significance ($P < 0.05$). The total length (TL) to total body weight (TBW) relation was used to complement the feeding studies following Froese *et al.* (2011). This relationship is $\mathrm{TBW} = a\mathrm{TL}^{b}$, and was converted into its linear regression, expressed in decimal logarithmic coordinates, and correlations were assessed by least-squares regression. Like so: $\log \mathrm{TBW} = \log a + b \log \mathrm{TL}$. Significance of constant b differences was assessed to the hypotheses of isometric growth if $b = 3$, positive allometry if $b > 3$, and negative isometry if $b > 3$ (Pauly, 1983). Comparison of means was carried out using ANOVA. These two latter tests were performed using the STAT VIEW 5.0 logistic model.

Once the fresh specimens were collected, their stomach contents were immediately removed by dissection, sorted and identified to the lowest taxonomic level (species level where possible), using taxonomic keys and field guides (Perrier 1964, 1975, Louisy, 2002). The prey items were counted and weighed to the nearest decigram after removal of surface water by blotting them with tissue paper. When prey items found in the stomachs were incomplete, the prey count was based on the number of different typical parts, such as beaks for cephalopods, claws and legs for crustaceans, carapaces for decapod crabs, shell and foot for bivalves, operculum and shell for gastropods, and the whole vertebral column and otoliths for teleost species. We assumed two or more prey species if the legs of crustaceans were different in size and shape, and a single prey species if they were very similar. The same methodology was used for determining vegetal preys. Preys not identified in the laboratory were preserved in 10% buffered formalin to be subsequently examined by specialists.

The analyses of food composition and feeding habits of these 21 species were based on the following indices suggested by Hureau (1970), Hyslop (1980) and Rosecchi & Nouaze (1987). The food composition and feeding habits of *C. conger* were studied using the following indices suggested by Hyslop (1980):

- Vacuity Index, VI = number of empty stomachs/ total number of stomachs x 100;
- Mean number of prey per stomachs: MN = total number of prey ingested/total number of full stomachs;
- Percentage of numerical abundance: %N = (number of prey item *i*/total number of prey) x 100;
- Percentage in weight: %W = (weight of prey item *i*/total weight of all prey) x 100;
- Percentage of frequency of occurrence: %F = (number of stomachs containing prey item *i*/total number of full stomachs) x 100.

The trophic level (TROPH) of each species area was calculated using TrophLab (Pauly *et al.*, 2000), a standalone Microsoft Access routine for estimating trophic levels, downloadable from FishBase (Froese & Pauly, 2014). Statistical differences ($P < 0.05$) in basic diet composition as a function of size and season were established by applying the Chi-square test (Sokhal & Rohlf, 1987).

The trophic level for any consumer species *i* is

$$\text{troph} = 1 + \sum_{j=1}^{G} DC_{ij} \cdot \text{troph}_j$$

where Troph*j* is the fractional trophic level of prey *j*, DC*ij* is the fraction of *j* in the diet of *i*, and G is the total number of prey species (Pauly *et al*., 1998; Pauly & Christensen, 2000; Pauly & Palomares, 2000):

All categories of preys identified in the present study were used to evaluate the trophic level of each teleostean species.

Following Stergiou & Karpouzi (2002), the trophic level values ranging from 2.0 to 4.5 and 3 categories of species were taken into consideration: pure herbivores = 2.0–2.1, omnivores with a preference for vegetable material = 2.1–2.9, omnivores with a preference for animal preys 2.9–3.7, carnivores feeding exclusively on animal preys =3.7–4.5.

RESULTS

All data recorded and calculated in the present paper are summarized in Table 1. The TL-TBW relationships revealed positive allometry in 13 species, low negative allometry in 3 species, and negative allometry in 5 species. The lowest negative allometry was recorded in *Dicentrarchus labrax* with *b*=1.23.

The vacuity index (VI) reached high values in 16 species, low values in 5 species, and in a single species, *Sarpa salpa*, it equalled 0.00. In this species, all the stomachs observed contained food or remains of food already described in materials and methods.

Overall, the two important zoological groups found in the guts were crustaceans and teleosts. Both groups were found together in 11 species, while teleosts were present in 20 species altogether. A single species, *S. salpa*, did not consume such preys, rather foraging for algae and seagrass. Among other groups also found in the stomach contents, cephalopods, annelids and sipunculids were the most frequent.

The trophic level (TROPH) reached high values - *i.e.*, close to or higher than 3.00 - in 16 species. Conversely, it displayed low values in 5 species: *Dentex dentex* (2.37), *Diplodus annularis* (2.57), *D. puntazzo* (2.24), *D. vulgaris* (2.73), which belong among omnivorous species, and in *S. salpa* (2.00), which is a pure herbivorous species. The TROPH of species caught in Tunisian waters is generally close to the data recorded by Stergiou and Karpouzi (2002), except in those concerning sparid species, which ranged between 3.80 and 4.50.

DISCUSSION

The size (TL) *versus* total body weight relationships exhibited positive allometry for most of the species studied in the present paper, indicating that they found in the wild sufficient prey to be able to live and develop in this area. The northern coast of Tunisia revealed high biodiversity, including potential prey species belonging to several zoological groups (Rafrafi-Nouira, 2016). All species presented herein are targeted by fishermen for local consumption or export, which enhances their commercial interest and increases their value for the local economy. Conversely, only 7 species displayed negative allometry, which phenomenon could be explained by sampling hazards, but competitive pressure for food, which reduces the availability of prey familiar to certain species, cannot be totally ruled out either.

Conversely, the vacuity index (VI) displayed high values in most species, which could be explained by the non-availability of prey in the wild despite the local biodiversity richness. Such a pattern could also be the result of sampling periods, and the availability of certain prey could vary according to the season (Rafrafi-Nouira, 2016). Sampling methods and use of fishing gears cannot be totally excluded either (Sallami *et al*., 2014; Rafrafi-Nouira *et al*., 2016). All specimens sampled off the northern Tunisian coast were caught by trawling and generally spent considerable time in nets prior to being landed, therefore certain prey was completely digested and the stomachs of predators were thus found empty when analysed. This hypothesis is corroborated by the digested remains of prey found in the stomach contents

Tab. 1: Parameters recorded in 21 teleost species collected from the northern coast of Tunisia. * Data from Sellami et al. (2015); ** Data from Rafrafi-Nouira et al. (2015); VI: vacuity index; C: crustaceans; T: teleosts; OG: other groups. TROPH 2: data from Stergiou & Karpouzi (2002).

Tab. 1: Izračunani parametri za 21 vrst kostnic, ujetih ob severni tunizijski obali. * Podatki iz vira Sellami et al. (2015); ** Podatki iz vira Rafrafi-Nouira et al. (2015); VI: indeks polnosti; C: raki; T: kostnice; OG: druge skupine. TROPH 2: podatki iz Stergiou & Karpouzi (2002).

Species	**Total length (TL) vs total body weight (TBW)**	**%VI**	**C**	**T**	**OG**	**TROPH 1**	**TROPH 2**
Gnathophis mystax (Delaroche, 1809) *	log TBW = – 5.88 + 3.09log TL, n = 48, r = 0.96	60.41	+	+	+	3.51	3.55
Belone belone (Linnaeus, 1758)	log TBW = – 5.79 + 2.94log TL, n =13, r = 0.97	69.23	-	+	-	4.50	-
Epinephelus marginatus (Lowe, 1834)	log TBW = – 5.14 + 3.11 log TL, n = 20, r = 0.99	65.00	+	+	+	3.51	4.13
Serranus scriba (Linnaeus, 1758)	log TBW = – 5.17 + 3.13 log TL, n = 76, r = 0.98	21.05	+	+	+	3.27	3.70
Dicentrarchus labrax (Linnaeus, 1758)	log TBW = – 0.58 + 1.23 log TL, n = 16, r = 0.91	75.00	+	+	-	4.20	-
Sciena umbra (Linnaeus, 1758)	log TBW = – 5.32 + 3.15 log TL, n = 63, r = 0.98	69.84	+	+	+	3.41	3.80
Dentex dentex (Linnaeus, 1758)	log TBW = – 4.34 + 2.75 log TL, n = 16, r = 0.97	81.25	+	+	+	2.37	4.50
Diplodus annularis (Linnaeus, 1758)	log TBW = – 3.88 + 2.58 log TL, n = 120, r = 0.96	70.45	+	+	-	2.57	3.40
Diplodus puntazzo (Cetti, 1777)	log TBW = – 4.77 + 2.98log TL, n = 31, r = 0.99	56.10	-	+	+	2.24	3.30
Diplodus sargus (Linnaeus, 1758)	log TBW = – 4.89 + 3.04log TL, n = 58, r = 0.98	23.07	+	+	+	3.09	3.38
Diplodus vulgaris (Linnaeus, 1758)	log TBW = – 4.89 + 3.02 log TL, n = 112, r = 0.96	94.00	-	+	+	2.73	3.70
Lithognathus mormyrus (Linnaeus, 1758)	log TBW = – 5.16 + 3.10 log TL, n = 43, r = 0.96	93.02	-	+	-	3.50	3.50
Oblada melanura (Linnaeus, 1758)	log TBW = – 5.18 + 3.11 log TL, n =32, r = 0.98	68.75	-	+	-	2.80	3.10
Sarpa salpa (Linnaeus, 1758)	log TBW =– 4.93 + 3.03 log TL, n =109, r = 0.93	0.00	-	-	+	2.00	2.50
Sparus aurata Linnaeus, 1758	log TBW = – 4.69 + 2.91 log TL, n = 80, r = 0.98	37.5	+	+	+	3.81	3.42
Labrus merula Linnaeus, 1758	log TBW = – 5.49 + 3.27 log TL, n =51, r = 0.99	80.40	+	+	-	3.20	3.47
Labrus viridis Linnaeus, 1758	log TBW = – 3.79 + 2.53 log TL, n = 65, r = 0.97	65.00	-	+	+	3.38	3.84
Symphodus melops (Linnaeus, 1758)	log TBW = –5.05 + 3.12 log TL, n = 68, r = 0.97	76.19	-	+	+	3.26	-
Symphodus tinca (Linnaeus, 1758)	log TBW = – 5.16 + 3.10 log TL, n =42, r = 0.97	68.96	-	+	+	3.32	3.26
Chelon labrosus (Risso, 1827)	log TBW = – 4.09 + 2.61 log TL, n =14, r = 0.89	95-94	-	+	-	3.50	-
Scorpaena porcus Linnaeus, 1758 **	log TBW = – 4.60 + 3.09 log TL, n =715, r = 0.96	41.11	+	+	+	3.48	3.82

which remained unidentifiable. Similar patterns were observed in previous studies about food and feeding habits of species from northern Tunisian waters (Mnasri *et al.*, 2012; El Kamel-Moutalibi *et al.*, 2013; Sallami *et al.*, 2014; Rafrafi-Nouira *et al.*, 2016).

Two zoological groups prevailed in the stomach contents: crustaceans and osteichthyans, thus confirming previous observations concerning other species inhabiting the same marine areas (Rafrafi-Nouira, 2016). Similarly, other preys were found, such as cephalopods, annelids, bivalves, and echinoderms, the number and weight of these animals depending on the species, and on the prey and predator sizes. Additionally, ontogenic changes were probably related to the biological environment and therefore prey availability.

The trophic levels of the 21 sampled species from northern Tunisian waters are similar to those estimated by Stergiou & Karpouzi (2002). Of these species, 17 could be considered top predators playing an important role in the regulation of the local marine ecosystem. Inter- and intraspecific competitive pressure for food cannot be completely avoided, which was probably the case with the sparid species, which occupied a lower TROPH level than other species, as sea grass and algae were recorded in their guts. Such findings could be considered as occasional or at least the result of a local abundance of marine plants that fishes would feed on in addition to other prey items. *S. salpa* is the best example of the effect of such abundance, as indicated by its low TROPH = 2.00 and VI = 0.00; namely, large amounts of algae and seagrass were found in the guts of the examined specimens throughout the year.

The study of food and feeding habits presented in this paper not only showed that viable populations of several animal species occurred in the area, but also enhanced the knowledge of local biodiversity. However, monitoring of fishery activities following recommendations and suggestions included in CIESM (2018) should be carried out to avoid drastic declines of populations, as was the case in other marine areas throughout the Mediterranean Sea.

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PREGLED TROFIČNIH NIVOJEV PRI RIBAH KOSTNICAH VZDOLŽ SEVERNOTUNIZIJSKIH VODA (OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

V prispevku avtorji poročajo o rezultatih, ki se nanašajo na 1657 primerkov rib kostnic, ujetih vzdolž severnotunizijske obale, ki pripadajo 21 vrstam. Primerki so bili ujeti v okolju, bogatem s plenom, kar je razvidno iz odnosa med velikostjo in telesno maso. Visoke vrednosti indeksa polnosti prebavila so verjetno posledica vzorčevalnih in ribiških metod. Najbolj pogosti skupini plena so raki in kostnice. Poleg tega visoki trofični nivo (TROPH) (± 3.00) potrjuje, da so obravnavane kostnice predvsem plenilke. Med vsemi obravnavanimi vrstami je le salpa rastlinojeda (TROPH = 2.00).

Ključne besede: kostnice, trofični nivo, indeks polnosti, odnos med telesno dolžino in maso, kompeticija za hrano, obala Tunizije

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SPONTANEOUS VEGETATION ON SLAG HEAPS IN SOUTHERN CROATIA

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ABSTRACT

A phytosociological investigation of spontaneous vegetation on seven-year-old ferro-manganese and silico-manganese slag heaps in southern Croatia showed a predominance of ruderals and weeds (Chenopodietea, Artemisietea vulgaris) *and taxa of dry open habitats* (Festuco-Brometea, Sedo-Scleranthetea). *The limited number and cover of woody taxa seem to indicate an early successional stage in the process of development of natural vegetation. However, we recommend removing the heaps from the area and initiating soil remediation according to Croatian law, EU standards and obligations.*

Key words: phytosociology, ruderal vegetation, industrial waste, Mediterranean climate, Dalmatia, eastern Adriatic

VEGETAZIONE SPONTANEA SU ACCUMULI DI SCORIE NELLA CROAZIA MERIDIONALE

SINTESI

Lo studio fitosociologico della vegetazione spontanea su accumuli di scorie di ferro-manganese e silico-manganese nel sud della Croazia, risalenti a sette anni addietro, ha messo in evidenza una predominanza di specie ruderali e infestanti (Chenopodietea, Artemisietea vulgaris) *e di taxa di habitat aridi e aperti* (Festuco-Brometea, Sedo-Scleranthetea). *Inoltre, un limitato numero di taxa arborei e arbustivi, con ridotta copertura, suggerisce l'insediarsi di un primo stadio della successione nel processo di sviluppo della vegetazione. Tuttavia si consiglia la rimozione degli accumuli di scorie dall'area e l'avvio della bonifica dei suoli, come previsto dalle leggi croate e secondo gli standard e gli obblighi dell'Unione Europea.*

Parole chiave: fitosociologia, vegetazione ruderale, rifiuti industriali, clima mediterraneo, Dalmazia, Adriatico orientale

INTRODUCTION

The Electrodes and Ferroalloys Factory (TEF) in the city of Šibenik, southern Croatia, is a former factory in which the production of pig iron, steel and ferrous alloys took place almost throughout the 20th century, ceasing in 1995. With the decommissioning of the facilities at the TEF site (total surface area of 22 hectares) various types of waste, such as ferro-manganese and silico-manganese slag, tar, phenolic residues, carborundum, graphite electrode scraps, etc. were left at the site. In the period from May 2010 to February 2011, a total of 140,000 tons of ferro-manganese and silico-manganese slag were moved to the village of Biljane Donje near the city of Zadar (Fig. 1). In recent times, only a smaller area with ca. 6,000 m^3 of the slag can still be found at the former TEF site in the city of Šibenik. Slag is typically dumped in heaps with no subsequent remediation.

Dumping sites for ash and slag waste represent a major challenge in terms of biological reclamation and introduction of vegetation. This is due to the disadvantageous properties of such waste, including the absence of soil organic matter (SOM), as well as nitrogen deficiency, high compaction, poor air-water ratio and high alkaline reaction (Kovář, 2004). The onset and development of vegetation at localities of such origin are important topics in restoration ecology (Rehounkova et al., 2011; Prach et al., 2014. and references therein). Such localities offer a unique opportunity for monitoring spontaneous processes of colonization/succession of organisms on these “artificial islands” and following biotic interactions in the process (Prach & Pyšek, 1994).

Fig. 1: Geographical position of the study areas in southern Croatia, eastern Adriatic.
Sl. 1.: Geografska lega raziskanega območja v južni Hrvaški, vzhodni Jadran.

In the NW Balkans, studies of spontaneous vegetation development in these habitats, based on phytosociological research, including description of particular plant associations, have been reported from Bosnia and Herzegovina (Lakušić *et al.*, 1977, 1978; Grgić & Lakušić, 1987) and Montenegro (Vukičević & Avdalović, 1982). In Croatia, such sites are still awaiting phytosociological investigation. The matter is addressed by the present study, which examines spontaneous vegetation on seven-year-old slag heaps in southern Croatia.

MATERIAL AND METHODS

Study area

The study was carried out in southern Croatia, in two areas: 1) the area of TEF situated in the city of Šibenik (43°44′43.1″ N, 15°52′56.9″ E), and 2) the landfill in the village of Biljane Donje, situated 20 kilometres east of the city of Zadar (44°05′47.9″ N, 15°28′55.5″ E) (Figs. 1 and 2). The slag heaps on the two sites originated from the production of ferroalloys in TEF, and have not been moved or replaced in the last seven years. The altitude of the sites is ca. 10 and 180 m a.s.l. in Šibenik and Biljane Donje, respectively. The heaps top out at about 1.5(–2) to 15 m above the level of the ground. The region has a typical Mediterranean climate: summers are warm and dry, winters mild and rainy, mean annual temperature 15.0–15.4 °C and mean annual precipitation 773–860 mm (data from the meteorological stations of the Croatian Meteorological and Hydrological Service in Šibenik and Zadar for the 1976–2006 period; Milović, 2008; Jasprica *et al.*, 2015). The vegetation surrounding the landfill in Šibenik is mainly composed of planted *Pinus halepensis* and urban ruderal plant communities (Milović, 2002). In Biljane Donje, the vegetation surrounding the landfill is a mosaic of preserved forest patches (mainly dominated by *Carpinus orientalis* and *Quercus pubescens*) and vineyards.

In general, the slag on the sites is alkaline (the pH of the substrate in initial successional stages is 8–9), with a low manganese content (MnO < 20 %) and about 30 % of Si produced by upgrading standard alloy through addition of silicon waste from the iron silicon industry at the end of the ferroalloy production process (Oliveira *et al.*, 2017).

Data collection

Fieldwork was carried out in May 2018. The Braun-Blanquet approach (Braun-Blanquet, 1964; Barkman *et al.*, 1964; Dierschke, 1994) was used for data collection, with category 2 subdivided into 2m, 2a and 2b. Five and four relevés were collected in Šibenik and Biljane Donje, respectively. The plots were selected randomly within each site and the entire surface of the landfills was covered. The size of relevé plots was 25 m^2. The

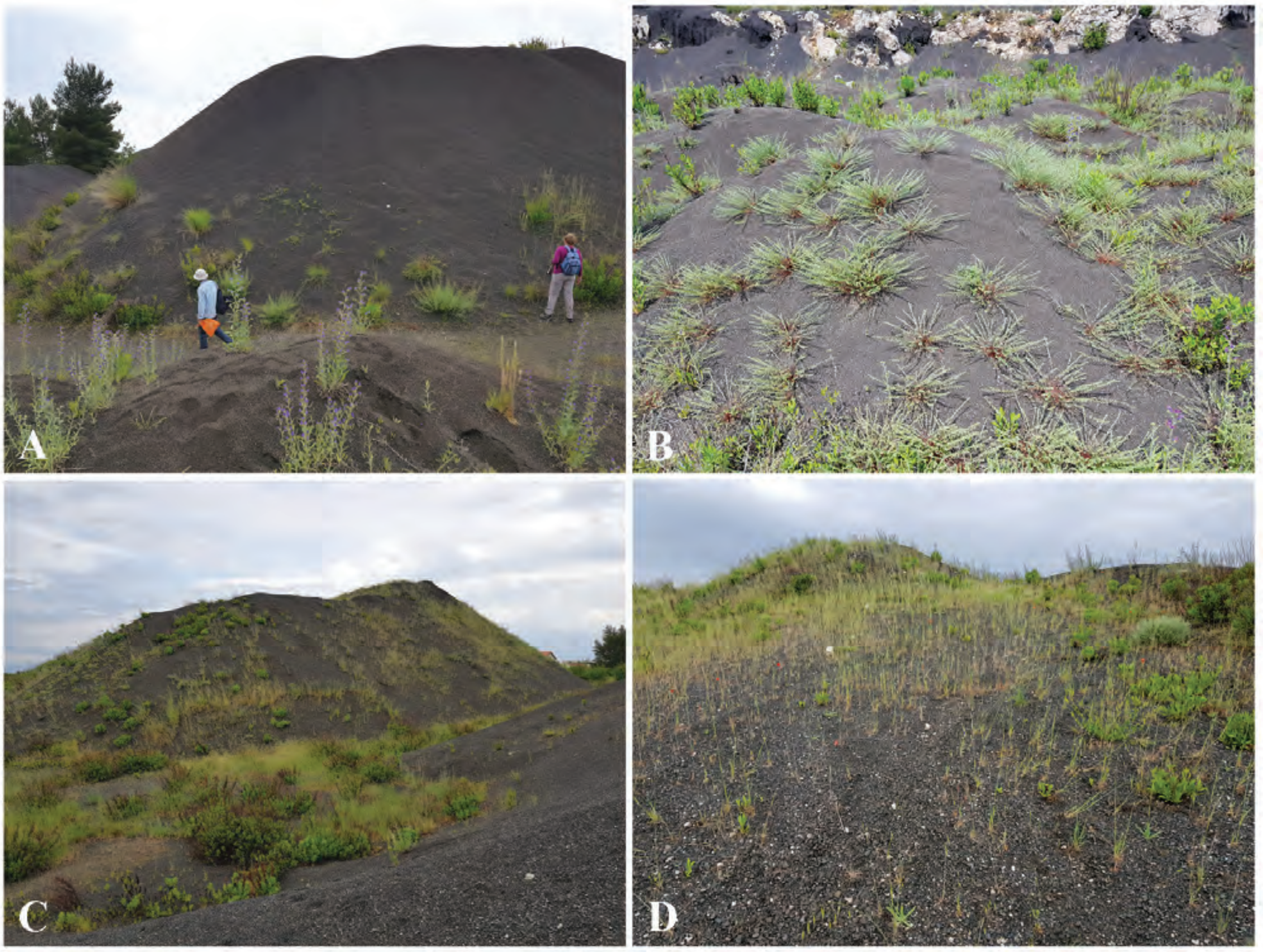

Fig. 2: Ferro-manganese and silico-manganese slag heaps in the area of the former Electrodes and Ferroalloys Factory in the city of Šibenik (A); details of vegetation with *Andrachne telephioides* ***and*** *Dittrichia viscosa* ***in Šibenik (B); heaps in the village of Biljane Donje, Zadar County (C), details of vegetation with*** *Avena barbata* ***and*** *Dittrichia viscosa* ***at the top of a heap in Biljane Donje (D) (Photo: N. Jasprica, May 5, 2018).***

Sl. 2: Feromanganska in silikomanganska jalovina v predelu nekdanje tovarne elektrod in železovih zlitin v Šibeniku (A); detajl vegetacije z vrstama *Andrachne telephioides* ***in*** *Dittrichia viscosa* ***v Šibeniku (B); jalovina v zaselku Biljane Donje v zadrskem okrožju (C), detajl vegetacije z vrstama*** *Avena barbata* ***and*** *Dittrichia viscosa* ***na vrhu jalovine v zaselku Biljane Donje (D) (Foto: N. Jasprica, 5 maj 2018)***

nomenclature of plant taxa follows the *Flora Croatica Database* (Nikolić, 2018). The biological forms were directly verified in the field, labelled with acronyms reported by Pignatti (1982) and based on the classification by Raunkiaer (1934). Regarding chorological forms, reference was made to Jasprica *et al.* (2017), as well as monographs used for taxonomic nomenclature.

Taxa were associated with vegetation units (classes). The system of characterizing species (mostly for those plants that are considered 'characteristic species' of the classes) was mostly derived from Mucina *et al.* (2016). The nomenclature of vegetation units followed Škvorc *et al.* (2017). Constant taxa were defined as those with a frequency 30 % within the vegetation unit. Dominant taxa were defined as those occurring in at least 10 % of the relevés of a vegetation unit with a cover value of 25 %.

RESULTS

There were 64 plant taxa in total (Tab. 1). The vegetation cover varied from 30 % to 80 %, while stands appeared on slopes ranging from 10° to 80°.

The landfills were dominated by Therophytes (57 %) and Hemicryptophytes (28 %). Phanerophytes and Chamaephytes occurred in equal percentages (5 % each).

Mediterranean floral elements (34 %), followed by a considerable share of Cosmopolitans (16 %) and

Tab. 1: Phytosociological table of vegetation on the ferro-manganese and silico-manganese slag heaps. Abbreviations: LF = life form, FE = floral element. Life forms: Ch - chamaephytes, G - geophytes, H - hemicryptophytes, P - phanerophytes, T - therophytes. Floral elements: MED - Mediterranean; SEU - South European; EA - Euroasian; WS - Cosmopolitan; CUAD - Cultivated and adventive plants; * - Illyrian-Adriatic endemic taxon.

Tab. 1: Fitosociološka preglednica vegetacije na feromanganski in slikomanganski jalovini. Okrajšave: LF = življenjska oblika, FE = floristični element. Življenjske oblike: Ch – hamefiti, G – geofiti, H – hemikriptofiti, P – fanerofiti, T – terofiti (enoletnice). Floristični elementi: MED – sredozemski, SEU – južnoevropski, EA – evrazijski, WS – kozmopoliti, CUAD – gojene in adventivne rastline, * - ilirsko-jadranski endemit.

Date and location of the relevés/ Datumi in lokalitete popisov: May 5, 2018. Rels. 1-5, Šibenik: Rel. 1. X = 5571400, Y = 4845052; Rel. 2. X = 5571390, Y = 4845085; Rel. 3. X = 5571443, Y = 4845104; Rel. 4. X = 5571441, Y = 4845092; Rel. 5. X = 5571431, Y = 4845006. Rels. 6-9. Biljane Donje, near Zadar: Rel. 6. X = 5538978, Y = 4883653; Rel. 7. X = 5538952, Y = 4883659; Rel. 8. X = 5538959, Y = 4883693; Rel. 9. X = 5538978, Y = 4883713.

		Relevé No.	1	2	3	4	5	6	7	8	9	
		Locality	Šibenik					Biljane Donje				
		Plot size (m^2)	25	25	25	25	25	25	25	25	25	
		Aspect	N	NE	.	NE	NE	N	S	W	W	
LF	FE	Slope (°)	10	55	.	70	80	70	70	40	80	
		Vegetation cover (%)	70	50	70	40	30	60	80	80	80	
		Total number of taxa	20	16	10	17	17	17	12	21	16	%
		Chenopodietea										
T	SEU	*Avena barbata* Pott ex Link	3	1	.	+	+	1	3	2a	2m	88
T	MED	*Echium plantagineum* L.	+	.	2a	.	.	+	3	+	+	66
H	MED	*Reseda alba* L.	.	+	.	.	.	+	1	+	+	55
T	MED	*Bromus madritensis* L.	1	.	.	+	+	.	.	.	.	33
T	MED	*Desmazeria rigida* (L.) Tutin	+	.	.	.	.	+	.	+	.	33
T	MED	*Aegilops neglecta* Req. ex Bertol.	.	+	.	.	+		.	+	.	33
H	MED	*Carduus pycnocephalus* L.	.	.	.	+	.	+	.	r	.	33
T	MED	*Lophochloa cristata* (L.) Hyl.	2a	.	.	.	.	.	.	+	.	22
T	MED	*Aegilops triuncialis* L.	+	.	.	.	.	.	.	+	.	22
T	MED	*Crepis sancta* (L.) Babc.	.	.	.	+	.	.	.	.	+	22
T	SEU	*Geranium purpureum* Vill.	.	.	.	.	2a	.	.	.	+	22
T	MED	*Medicago orbicularis* (L.) Bartal.	.	.	.	.	.	.	.	+	+	22
T	MED	*Sonchus asper* (L.) Hill ssp. *glaucescens* (Jord.) Ball	.	+	.	.	.	.	.	.	.	11

T	MED	*Urospermum picroides* (L.) Scop. ex F.W.Schmidt	.	.	.	.	.	.	.	.	r	11
		Festuco-Brometea										
H	EA	*Melica ciliata* L.	.	+	+	1	+	2b	+	.	.	66
T	EAF	*Arenaria leptoclados* (Reichenb.) Guss.	+	.	.	.	.	.	.	r	.	22
H	*	*Centaurea spinosociliata* Seenus	.	+	.	.	.	.	.	+	.	22
H	SEU	*Sanguisorba minor* Scop. ssp. *muricata* Briq.	.	.	+	+	.	.	.	.	.	22
H	SEU	*Lactuca viminea* (L.) J. et C. Presl	.	.	.	.	.	+	.	.	r	22
H	MED	*Tragopogon porrifolius* L.	.	.	.	.	.	+	.	.	.	11
T	MED	*Lomelosia brachiata* (Sm.) Greuter et Burdet (= *Trenastelma palaestinum*)	.	.	.	.	.	.	1	.	.	11
		Artemisietea vulgaris										
H	MED	*Dittrichia viscosa* (L.) Greuter	.	2a	2a	1	.	2b	1	2b	.	66
H	EA	*Chondrilla juncea* L.	.	.	.	+	+	.	.	+	+	44
H	WS	*Reseda lutea* L.	.	.	+	+	+	.	.	.	.	33
H	EA	*Picris hieracioides* L.	.	.	.	.	.	+	.	.	.	11
T	WS	*Galium aparine* L.	.	.	.	.	.	.	.	.	+	11
H	EA	*Cirsium vulgare* (Savi) Ten.	.	.	.	.	.	.	.	.	r	11
		Sedo-Scleranthetea										
T	WS	*Medicago minima* (L.) Barta	+	+	.	.	.	.	.	3	.	33
T	WS	*Cerastium pumilum* Curtis ssp. *glutinosum* (Fries) Jalas	+	.	.	.	.	.	.	+	.	22
T	EA	*Petrorhagia prolifera* (L.) P. W. Ball ex Heywood	.	+	.	.	.	.	.	+	.	22
T	MED	*Valantia muralis* L.	.	.	.	r	.	.	.	.	.	11

Ch	SEU	*Sedum ochroleucum* Chaix	.	.	.	.	+	.	.	.	.	11
Lygeo sparti-Stipetea tenacissimae												
H	MED	*Reichardia picroides* (L.) Roth.	.	.	.	.	r	+	.	.	r	33
T	SEU	*Vulpia ciliata* Dumort	2m	.	.	.	.	+	.	.	.	22
H	MED	*Piptatherum miliaceum* (L.) Coss.	.	3	.	+	.	.	.	.	.	22
H	MED	*Brachypodium retusum* (Pers.) P. Beauv.	.	+	.	.	.	.	.	.	.	11
Papaveretea rhoeadis												
T	CUAD	*Papaver rhoeas* L.	.	.	.	.	r	+	+	.	1	44
T	WS	*Senecio vulgaris* L.	.	.	.	.	.	r	.	r	+	33
T	EAF	*Veronica arvensis* L.	+	.	.	.	.	.	.	.	.	11
G	WS	*Convolvulus arvensis* L.	.	.	.	2a	.	.	.	.	.	11
Sisymbrietea												
T	EA	*Geranium rotundifolium* L.	+	+	.	.	.	.	.	.	.	22
T	MED	*Sisymbrium orientale* L.	+	+	.	.	.	.	.	.	.	22
T	WS	*Erodium cicutarium* (L.) L' Hér.	+	.	.	.	.	.	.	.	.	11
T	WS	*Xanthium strumarium* L.	.	.	.	.	.	.	r	.	.	11
Stipo-Trachynietea distachyae												
T	MED	*Linaria simplex* (Willd.) DC.	+	1	2m	1	+	2m	+	.	.	77
Ch	MED	*Andrachne telephioides* L.	.	.	4	+	r	.	r	+	4	66
T	MED	*Psilurus incurvus* (Gouan) Schinz et Thell	+	.	.	.	.	.	.	.	.	11
Quercetea ilicis												
P	MED	*Juniperus oxycedrus* L. ssp. *oxycedrus*	.	.	.	+	.	.	.	.	.	11
P	MED	*Pinus halepensis* Mill., juv.	.	.	.	.	+	.	.	.	.	11
G	MED	*Asparagus acutifolius* L.	.	.	.	.	.	.	r	.	.	11

		Helianthemetea guttati										
T	SEU	*Crupina crupinastrum* (Moris) Vis	.	.	+	.	+	.	.	.	.	22
T	MED	*Medicago coronata* (L.) Bartal.	+	.	.	.	.	.	.	.	.	11
T	MED	*Minuartia mediterranea* (Link.) K. Malý	+	.	.	.	.	.	.	.	.	11
		Thlaspietea rotundifoliae										
H	SEU	*Scrophularia canina* L. ssp. *bicolor* (Sibth. et Sm.) Greuter	.	.	.	1	.	.	.	.	.	11
T	MED	*Crucianella latifolia* L.	.	.	.	.	2m	.	.	.	.	11
		Digitario sanguinalis-Eragrostietea minoris										
T	MED	*Heliotropium europaeum* L.	.	+	+	+	.	+	+	+	+	77
		Koelerio-Corynephoretea canescentis										
T	EA	*Minuartia hybrida* (Vill.) Schischkin in Komarov	+	.	.	.	.	.	.	.	.	11
		Asplenietea trichomanis										
Ch	MED	*Aurinia sinuata* (L.) Griseb.	.	.	.	.	2a	.	.	.	.	11
		Rhamno-Prunetea										
P	WS	*Rosa canina* L.	.	.	.	.	r	.	.	.	.	11
		Molinio-Arrhenatheretea										
H	WS	*Plantago lanceolata* L.	.	.	.	.	.	.	.	+	.	11
		Others										
T	CUAD	*Conyza canadensis* (L.) Cronquist	+	+	.	.	.	.	.	.	.	22
		Fumaria sp.	.	.	+	.	.	.	.	.	.	11
		Daucus sp.	.	.	.	.	.	+	.	.	.	11
		Anthemis sp.	.	.	.	.	.	.	.	r	.	11

Euroasian plants (13 %), dominated on the landfills. Two non-indigenous species were noted: *Papaver rhoeas* and *Conyza canadensis*. The latter species is considered invasive in Croatia (Nikolić *et al.*, 2014). *Centaurea spinosociliata* was defined as an endemic taxon.

The highest number of taxa belonged to the *Chenopodietea* (14 taxa), followed by *Festuco-Brometea* (7), *Artemisietea vulgaris* (6) and *Sedo-Scleranthetea* (5). The number of taxa in the relevés ranged between 12 and 21 (average 16). The classes *Digitario sanguinalis-Eragrostietea minoris*, *Koelerio-Corynephoretea canescentis*, *Asplenietea trichomanis*, *Rhamno-Prunetea* and *Molinio-Arrhenatheretea* were represented by one taxon each, mostly with a low cover or frequency.

The dominant taxa were as follows: *Avena barbata*, *Echium plantagineum*, *Medicago minima*, *Piptatherum miliaceum* and *Andrachne telephioides*. Constant taxa were: *Avena barbata*, *Echium plantagineum*, *Reseda alba*, *Bromus madritensis*, *Melica ciliata*, *Dittrichia viscosa*, *Chondrilla juncea*, *Reseda lutea*, *Medicago* *minima*, *Reichardia picroides*, *Papaver rhoeas*, *Senecio vulgaris*, *Andrachne telephioides*, *Linaria simplex* and *Heliotropium europaeum*.

DISCUSSION

In the present study, spontaneous vegetation on seven-year-old slag heaps consisted of a relatively low number of taxa. Although we did not study vegetation dynamics, emergence of fast growing annual plant taxa and biennial hemicriptophytes was expected in the first few years, as established in similar studies (Řehounková *et al.*, 2011, and references therein). Transport of diaspores from the surrounding landscape, mainly through zoochory and anemochory, is among the factors governing the development of plant communities in the initial stages of succession (Vaňková & Kovář, 2004). Seeds of plants are sometimes also carried into the heaps by humans during the heaping process.

No bryophytes were found in our study, contrarily to the findings of Grgić & Lakušić (1987), who investigated succession processes on spoil heaps in Bosnia and Herzegovina. This may be generally attributed to the warm and dry Mediterranean climate and/or specific physical and chemical properties of steel slag in a slag heap.

In our case, ruderals and weeds (*Chenopodietea*, *Artemisietea vulgaris*) and taxa of the dry open habitats (*Festuco-Brometea*, *Sedo-Scleranthetea*) were dominant. In this study, contrary to the findings of Lakušić *et al.* (1977), who described some plant associations in the heaps (*Sedo-Scleranthetea*), no characteristic set of taxa was established. The most common taxa from the sites studied were also found in the urban ruderal communities of the surroundings, both in the cities of Šibenik and Zadar (Milović, 2002; Milović & Mitić, 2012) and their environs (Jasprica *et al.*, 2017). In general, but not studied here, the presence of the surrounding vegetation and variations in the species pool could also play a role in the different floristic composition and subsequent community transitions on the sites (Vukičević & Avdalović, 1982; Grgić & Lakušić, 1987; Otto *et al.*, 2006).

Both the low number and low cover of woody taxa appear to indicate an early successional stage in the process of the development of natural vegetation. Steel slag is highly reactive and when exposed to rainwater it is known to release ecotoxic metals into the surrounding water bodies and soils (Meng & Liu, 2000; Oliveira *et al.*, 2017). These biotopes may thus host only a fraction of the potential colonizers (Heckenroth *et al.*, 2016).

In summary, this study adds to the base of information on the structure of vegetation communities on industrial waste deposits in the Mediterranean climate. Nevertheless, given the relatively small area studied and low number of relevés, the results should be considered in the context of anthropogenic influences occurring as a generalized phenomenon throughout the Mediterranean Basin and elsewhere. Taking into account the origin, properties and locations of this waste material, we recommend removing the heaps from the area and undertaking soil remediation according to Croatian law, EU standards and obligations.

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SPONTANA VEGETACIJA NA JALOVINAH V JUŽNI HRVAŠKI

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POVZETEK

Fitosociološka raziskava spontane vegetacije na sedemletni feromanganski in silikomanganski jalovini v južni Hrvaški je pokazala prevladovanje ruderalnih rastlin in plevelov (Chenopodietea, Artemisietea vulgaris) *ter vrst odprtih habitatov* (Festuco-Brometea, Sedo-Scleranthetea). *Omejena pokrovnost gozdnih taksonov kaže na zgodnji stadij sukcesije v procesu razvoja naravne vegetacije. Avtorji priporočajo odstranjevanje jalovin z obravnavanega območja in pričetek remediacije prsti v skladu s hrvaško zakonodajo, evropskimi standardi in zahtevami.*

Ključne besede: fitosociologija, ruderalna vegetacija, industrijski odpadki, sredozemsko podnebje, Dalmacija, vzhodni Jadran

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LE LAMIACEAE DELLA FLORA ITALIANA: DISTRIBUZIONE REGIONALE E CONSIDERAZIONI FITOGEOGRAFICHE

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SINTESI

Con Lamiaceae si indica un'importante famiglia della flora italiana, ampiamente conosciuta e studiata. Il presente lavoro riporta l'elenco di tutte le entità segnalate in Italia, analizza la loro distribuzione geografica regionale, individua i principali pattern distributivi, presenta un'analisi fitogeografica e cerca di discutere le origini e movimenti migratori sulla base di dati bibliografici. Nel territorio nazionale sono segnalati 272 taxa infragenerici. La distribuzione regionale è alquanto discontinua: solo 15 taxa sono presenti in tutte le regioni; 8 in tutte le regioni continentali (comprendendo in alcuni casi anche la Sicilia o la Sardegna); gli altri si distribuiscono in una o poche regioni, anche in modo disgiunto. Prevale il contingente mediterraneo, seguito da quello endemico. Dalla letteratura consultata emerge che ci sono ancora incertezze e differenze di interpretazione riguardo le origini della famiglia, generi e specie e, dei movimenti migratori seguiti per colonizzare le regioni italiane.

Parole chiave: Lamiaceae, check-list, distribuzione regionale, biogeografia, origini

LAMIACEAE OF THE ITALIAN FLORA: REGIONAL DISTRIBUTION AND FITOGEOGRAPHIC CONSIDERATIONS

ABSTRACT

With Lamiaceae is indicted an important family of Italian flora, widely known and studied. The present work reports the list of all the entities reported in Italy, analyzes their regional geographical distribution, identifies the main distribution patterns, presents a phytogeographic analysis and tries to explain origins and migratory movements on the basis of bibliographic data. In the national territory 272 infrageneric taxa are reported. The regional distribution of the various taxa is somewhat discontinuous: only 15 taxa are present in all regions; 8 in all continental regions (including in some cases also Sicily or Sardinia), the others are distributed in one or a few regions, even in a disjointed way. The Mediterranean contingent prevails, followed by the endemic one. From the literature consulted it emerges that there are still uncertainties and opinions on the origins of the family, genera and species and the migratory movements that brought them to colonize the Italian regions.

Key words: Lamiaceae, check-list, regional distribution, biogeography, migrations, origins

INTRODUZIONE

La famiglia delle Lamiaceae Martinov comprende 245 generi con 7886 specie (The Plant List, ultimo accesso 1-12-2018) ed è caratterizzata da piante erbacee, lianose, arbustive e raramente arboree con fiori dalla forma bilabiata. Harley *et al.* (2004) la ripartisce in 7 subfamiglie:

- Ajugoideae Kost. che con circa 1100 specie è presente in tutti i continenti tranne l'Antartide;
- Lamioideae Harl. comprendente 57 generi e circa 1190 specie e, sebbene abbia una distribuzione cosmopolita, solo poche specie non vivono in Africa ed Eurasia;
- Nepetoideae (Dum.) Luerss. costituita da circa 112 generi e 3600 specie a distribuzione cosmopolita;
- Prostantheroideae Luerss., endemica dell'Australia, con 16 generi e circa 280 specie;
- Scutellarioideae Prantl con 5 generi e circa 380 specie a distribuzione subcosmopolita;
- Symphorematoideae Briq., endemica delle zone tropicali e subtropicali dell'Asia (India, Sri Lanka, sud-est asiatico e Malesia occidentale) che comprende 3 generi con circa 30 specie;
- Viticoideae Briq. che comprende da 6 a 10 generi e circa 400 specie distribuite in modo preponderante nelle zone tropicali e subtropicali del mondo.

Recentemente Li *et al.* (2016) e Li & Olmstead (2017) hanno descritto altre 5 subfamiglie: Cymarioideae, Peronematoideae, Premnoideae, Callicarpoideae e Tectonoideae.

Le Lamiaceae sono presenti in una vasta gamma di habitat e più diffuse nelle seguenti zone della terra: il Bacino del Mediterraneo, Asia (centrale, sud-occidentale, Cina e regione indomalesiana), l'Africa subsahariana e il Madagascar, l'Australia e il continente americano (Hedge 1992; Harley *et al.* 2004). Alcune piante sono coltivate e utilizzate dall'uomo a fini ornamentali, in cucina, profumeria, liquoreria, farmacia e nella medicina popolare.

È obiettivo del presente studio fornire una visione comprensiva sulla distribuzione delle specie appartenenti alla famiglia delle Lamiaceae presenti nel territorio italiano, e chiarire i fenomeni migratori che ne hanno determinato la diffusione.

MATERIALI E METODI

La nomenclatura e la distribuzione dei taxa presenti seguono: Celesti-Grapow *et al.* (2010), Bartolucci *et al.* (2018), *http://dryades.units.it/floritaly/* e successivi aggiornamenti riportati in bibliografia.

Per l'assegnazione dei tipi corologici (Tab. 1) si è seguito Pignatti (2018), tranne vari taxa cui è stato asse-

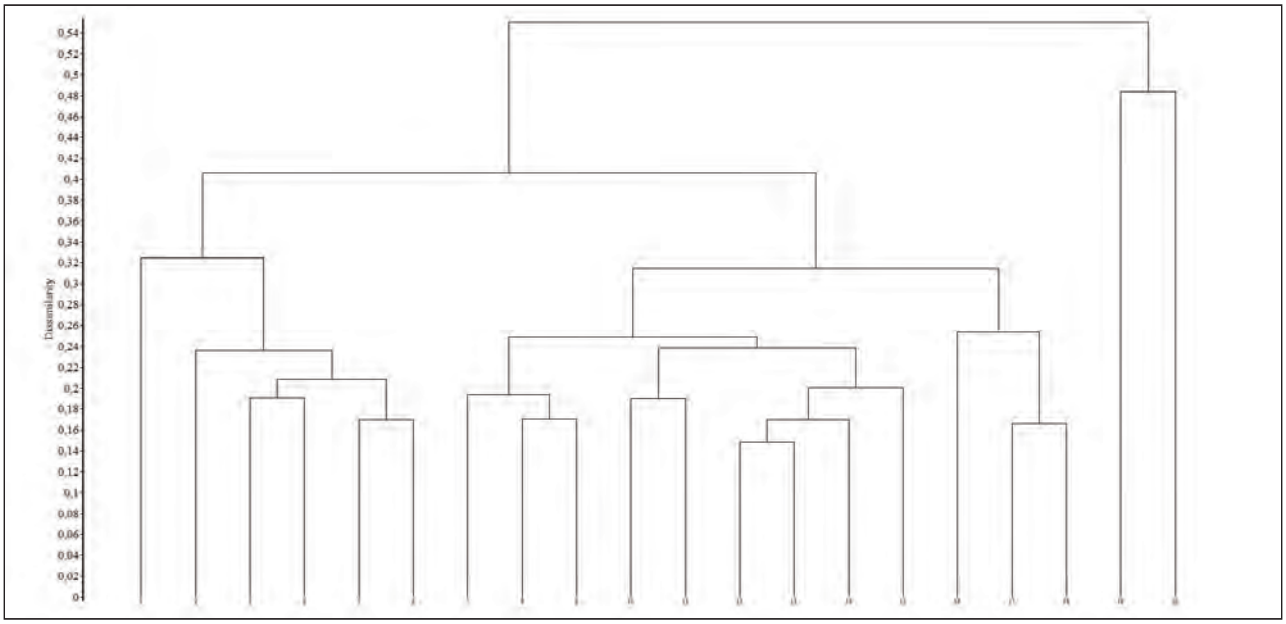

Fig. 1: Classificazione gerarchica delle regioni italiane in base alla somiglianza tra le distribuzioni dei singoli taxa di Lamiaceae. I numeri da 1 a 20 sono le regioni italiane: 1: Valle D'Aosta; 2: Piemonte; 3: Lombardia; 4: Trentino Alto-Adige; 5: Veneto; 6: Friuli Venezia-Giulia; 7: Liguria; 8: Emilia Romagna; 9: Toscana; 10: Marche; 11: Umbria; 12 Lazio; 13: Abruzzo; 14: Molise; 15: Campania; 16: Puglia; 17: Basilicata; 18: Calabria; 19: Sicilia; 20: Sardegna.
Sl. 1: Hierarhična ureditev italijanskih regij na podlagi podobnosti med posameznimi taksoni ustnatic (Lamiaceae). Številke od 1 do 20 so italijanske regije: 1: Dolina Aoste; 2: Piemont; 3: Lombardija; 4: Trentinsko – Zgornje Poadižje; 5: Benečija; 6: Furlanija-Julijska krajina; 7: Ligurija; 8: Emilija Romanja; 9: Toskana; 10: Marke; 11: Umbrija; 12 Lacij; 13: Abruci; 14: Molize; 15: Kampanija; 16: Apulija; 17: Bazilikata; 18: Kalabrija; 19: Sicilija; 20: Sardinija.

Tab. 1: Distribuzione regionale delle Lamiaceae della flora italiana. (1) da Bartolucci** et al.* ***(2018).
Tab. 1: Regionalna razširjenost ustnatic v italijanski flori. (1) povzeto po Bartolucci** et al.* ***(2018).

Regioni italiane	**Taxa totali**	**Totale taxa della flora regionale (1)**	**Percentuale Lamiaceae sulla flora regionale**	**Lamiaceae endemiche**	**Lamiaceae esclusive**
Valle d'Aosta	63	2333	2,7	-	-
Piemonte	100	3535	2,8	-	2
Lombardia	110	3429	3,2	-	3
Trentino Alto Adige	105	3504	3,0	2	5
Veneto	105	3338	3,1	2	1
Friuli Venezia Giulia	107	3147	3,4	1	5
Liguria	114	3080	3,7	2	4
Emilia Romagna	117	2843	4,1	1	2
Toscana	129	3400	3,8	3	3
Marche	105	2540	4,1	4	1
Umbria	95	2406	3,9	4	-
Lazio	121	3047	4,0	7	-
Abruzzo	135	3216	4,2	5	3
Molise	102	2327	4,4	5	-
Campania	128	2828	4,5	12	1
Puglia	114	2577	4,4	8	2
Basilicata	107	2607	4,1	9	-
Calabria	104	2799	3,7	12	1
Sicilia	108	2787	3,9	15	17
Sardegna	77	2441	3,1	10	15

gnato un nuovo corotipo sulla base delle informazioni desunte da: Aeschimann et al. (2004), Bartolucci *et al.* (2018), Euro+Med Data Base (2006), Poldini (1991) e Tutin *et al*. (1964-80).

Al corotipo Appennino-Balcanico sono stati assegnati i taxa presenti solo nel territorio delimitato dai seguenti confini fisici (Pezzetta, 2010): a) per la Penisola Italiana, le isole e l'arco appenninico dalla Liguria all'Aspromonte; b) per la Penisola Balcanica, Creta, le isole dell'Egeo e il territorio continentale a sud dell'asse fluviale che va dalle sorgenti della Sava alle foci del Danubio e dal Mar Nero all'Adriatico-Ionio. Al corotipo Subendemico sono stati assegnati i taxa contraddistinti da un areale che da qualche regione del territorio italiano sconfina in alcune zone dei Paesi vicini.

Al fine di avere maggiore chiarezza sui quadri distributivi, si è calcolato Il valore medio di presenza (Vm) nelle varie parti d'Italia (nord, centro, sud e isole), ottenuto sommando i dati regionali/il numero delle regioni.

Per quantificare la somiglianza tra le distribuzioni dei singoli taxa nelle regioni italiane è stata condotta una classificazione numerica delle regioni stesse, su dati di presenza-assenza, utilizzando il legame medio come algoritmo di clustering e l'indice di Soerensen come coefficiente di distanza (Fig. 1).

RISULTATI E DISCUSSIONE

L'elenco floristico comprende 272 taxa infragenerici, corrispondenti a circa il 3,3 % della flora italiana, che secondo Bartolucci *et al.* (2018) ammonta a 8195 taxa. Essi sono ripartiti in 40 generi, tra cui il più ricco è *Salvia* con 29 taxa, seguito da *Teucrium* con 23, *Clinopodium* con 21, *Thymus* con 19, *Lamium* con17, *Micromeria* e *Nepeta* con 12, *Mentha* con 11, *Ajuga* con 10, *Galeopsis* e *Scutellaria* con 9 e poi tutti gli altri con valori inferiori.

I taxa spontanei, non avventizi si ripartiscono in 5 subfamiglie che, tenendo conto delle classificazioni proposte da Harley *et al*. (2004), Li *et al.* (2016) e Li & Olmstead (2017), comprendono i seguenti generi:

1. Viticoideae: *Vitex*;
2. Ajugoideae: *Ajuga*, *Teucrium* e *Clerodendrum*;
3. Scutellarioideae: *Scutellaria*;
4. Lamioideae: *Acanthoprasium*, *Ballota*, *Betonica*, *Chaiturus*, *Galeopsis*, *Lamium*, *Leonurus*, *Marrubium*, *Melittis*, *Molucella*, *Phlomis* e *Stachys*;

5. Nepetoideae: *Clinopodium*, *Dracocephalum*, *Glechoma*, *Hyssopus*, *Lavandula*, *Lycopus*, *Melissa*, *Micromeria*, *Mentha*, *Nepeta*, *Ocimum*, *Origanum*, *Perilla*, *Prunella*, *Salvia*, *Satureja*, *Thymbra*, *Thymus* e *Ziziphora*.

Solo 15 specie sono presenti in tutte le regioni italiane: *Ajuga reptans*, *Lamium amplexicuale*, *L. purpureum*, *Lycopus europaeus*. *Marrubium vulgare*, *Mentha aquatica* subsp. *aquatica*, *M. pulegium* subsp. *pulegium*, *M. spicata*, *Nepeta cataria*, *Prunella laciniata*, *P. vulgaris* subsp. *vulgaris*, *Salvia rosmarinus*, *Stachys annua* subsp. *annua*, *Teucrium chamaedrys* subsp. *chamaedrys* e *T. montanum*.

I seguenti taxa sono presenti in tutte le regioni peninsulari e in qualche caso anche in Sicilia o Sardegna: *Betonica officinalis*, *Clinopodium nepeta* subsp. *nepeta*, *C. nepeta* subsp. *sylvaticum*, *C. vulgare* subsp. *vulgare*, *Galeopsis angustifolia*, *Lamium maculatum*, *Mentha longifolia* e *Stachys sylvatica*. Le altre entità hanno una distribuzione variabile che può comprendere una o più regioni.

La maggior presenza di taxa si registra nell'Italia settentrionale con 173 unità che corrispondono a circa il 63,6 % del totale delle lamiacee italiane. Nell'Italia Centrale (dalla Toscana all'Abruzzo) sono presenti 162 taxa (59,5 %) e nell'Italia meridionale 158 (58,1 %) e in Sicilia e Sardegna 125 (45,9 %).

Il valore medio di presenza (Vm) è più alto nell'Italia Centrale con 117,2. Nell'Italia Meridionale è di 111, nell'Italia settentrionale è di 102,6 e nelle isole 92,5.

La regione più ricca (Tab. 1) è l'Abruzzo con 135 taxa ed è seguita da: Toscana (130); Campania (128); Lazio (122), Emilia Romagna (117); Liguria e Puglia (114); Lombardia (110); Sicilia (108); Friuli Venezia Giulia e Basilicata (107); Veneto (106); Marche e Trentino Alto Adige (105); Calabria (104); Molise (102); Piemonte (100); Umbria (95); Sardegna (77); Valle d'Aosta che chiude con 63 taxa.

La classificazione (Fig. 1) mostra una maggiore affinità tra le regioni dello stesso settore geografico (Nord, Centro, Sud e isole). La Sicilia e la Sardegna, che dimostrano la maggiore affinità in assoluto, sono nettamente separate dagli altri gruppi, un risultato riconducibile alle loro particolari vicende paleogeografiche. In vari settori e/o regioni, sono segnalate entità assenti in altri o che raggiungono un limite di distribuzione assoluto o circoscritto al territorio nazionale.

Nell'Italia nord-occidentale (Liguria) è presente la seguente entità stenoendemica assente in altre regioni e unica rappresentante del genere in Italia: *Acanthoprasium frutescens*. In una o più regione alpina centro-orientale (dalla Lombardia al Friuli Venezia Giulia) sono presenti in modo le seguenti entità assenti altrove: *Salvia pratensis* subsp. *saccardiana, Stachys talbotii* e *Teucrium siculum* subsp. *euganeum*. Nell'Italia Centrale è presente la seguente entità assente in altre regioni: *Mentha requienii* subsp. *bistaminata*. Nell' Italia Meridionale sono presenti le seguenti specie non segnalate in altri settori della penisola: *Lavandula austroapennina*, *Phlomis tenorei*, *Salvia ceratophylloides*, *Stachys recta* subsp. *tenoreana* e *Thymus picentinus*.

I seguenti taxa sono presenti solo in Sardegna: *Clinopodium sandalioticum*, *C. sardoum*, *Glechoma sardoa*, *Mentha requienii* subsp. *requienii*, *Micromeria cordata*, *Nepeta foliosa* e *Salvia desoleana*. In Sicilia, invece sono presenti i seguenti taxa non segnalati in altre regioni: *Clinopodium alpinum* subsp. *nebrodense*, *C. minae*, *C. raimondoi*, *Scutellaria rubicunda*, *Stachys germanica* subsp. *dasyanthes*, *Thymus praecox* subsp. *parvulus* e *T. richardii*.

Le seguenti specie sono segnalate solo in una delle seguenti regioni italiane:

- **Piemonte**: *Galeopsis sulphurea* e *Scutellaria minor*;
- **Lombardia**: *Plectranthus scutellarioides*, *Salvia reflexa* e *Stachys guillonii* subsp. *hyssopifolia*;
- **Trentino Alto Adige**: *Dracocephalum moldavica*, *Salvia amplexicaulis*, *Stachys talbotii*, *Teucrium hircanicum* e *T. polium* subsp. *purpurascens*;
- **Veneto**: *Teucrium siculum* subsp. *euganeum*;
- **Friuli Venezia Giulia**: *Ballota nigra* subsp. *velutina*, *Clinopodium acinos* subsp. *villosum*, *C. einseleanum*, *C. thymifolium*, *Salvia napifolia* e *Thymus illyricus*;
- **Liguria:** *Acanthoprasium frutescens*, *Stachys rossii*, *Teucrium chamaedrys* subsp. *pectinatum* e *Prunella hyssopifolia*;
- **Emilia Romagna**: *Dracocephalum parviflorum* e *Scutellaria albida*. subsp. *albida*;
- **Toscana**: *Mentha requienii* subsp. *bistaminata, Salvia officinalis* subsp. *gallica* e *Stachys salisii*;
- **Marche**: *Nepeta italica*;
- **Abruzzo**: *Clinopodium graveolens*, *Mentha cervina* e *Thymus zygiformis*;
- **Campani**a: *Stachys recta* subsp. *tenoreana;*
- **Puglia**: *Clinopodium serpyllifolium* subsp. *fruticosum* e *Stachys cretica;*
- **Calabria**: *Salvia ceratophylloides;*
- **Sicilia**: *Ajuga chamaepitys* subsp. *suffrutescens*, *Clinopodium alpinum* subsp. *nebrodense*, *C. minae*, *C. raimondoi*, *Origanum onites*, *Salvia canariensis*, *S. leucantha*, *S. microphylla*, *S. pinnata*, *Scutellaria rubicunda*, *Stachys germanica* subsp. *dasyanthes*, *S. perfoliata*, *Teucrium creticum*, *T. luteum*, *T. massiliense*, *Thymus praecox* subsp. *parvulus* e *T. richardii*;
- **Sardegna**: *Clinopodium sandalioticum*, *C. sardoum*, *Glechoma sardoa*, *Lamium garganicum* subsp. *corsicum*, *Mentha requienii* subsp. *requienii*, *Micromeria cordata*, *M. filiformis* subsp. *filiformis*, *Nepeta foliosa*, *Salvia desoleana*, *Satureja thymbra*, *Stachys brachyclada*, *S. corsica*, *S. germanica* subsp. *dasyanthes*, *Teucrium subspinosum* e *Thymus herba-barona*.

I dati riportati dimostrano che le regioni insulari e quelle continentali di confine sono più ricche di lamiacee endemiche ed assenti in altre regioni. Diverse entità nella penisola italiana sono a un limite assoluto del loro areale. Infatti:

- raggiungono in Italia il limite settentrionale assoluto di distribuzione: *Micromeria microphylla, Nepeta italica, Satureja montana* subsp. *variegata, Stachys arenaria* subsp. *arenaria, S. marrubiifolia, S. recta* subsp. *subcrenata, Thymus carstiensis, T. illyricus* e *T. zygiformis*;
- raggiungono in Italia il limite meridionale assoluto di distribuzione geografica: *Clinopodium alpinum* subsp. *alpinum, C. nepeta* subsp. *nepeta, Dracocephalum moldavica, Galeopsis angustifolia* subsp. *angustifolia, G. ladanum, Lamium garganicum* subsp. *corsicum, Stachys corsica* e *Thymus oenipontanus*;
- raggiungono in Italia il limite orientale assoluto di distribuzione: *Ajuga chamaepitys* subsp. *suffrutescens, Galeopsis reuteri, Lamium flexuosum, Lavandula angustifolia, L. latifolia, Melittis melissophyllum* subsp. *albida, Mentha requienii* subsp. *bistaminata, M. suaveolens* subsp. *insularis, Micromeria marginata, Nepeta apulei, N. tuberosa*. subsp. *tuberosa, Prunella hyssopifolia, Stachys arenaria* subsp. *arenaria, S. brachyclada, S. guillonii* subsp. *hyssopifolia, S. heraclea, S. marrubiifolia, S. rossii, Teucrium chamaedrys* subsp. *pectinatum, T. lucidum, T. subspinosum, Thymus striatus* subsp. *acicularis* e *T. vulgaris* subsp. *vulgaris*;
- raggiungono in Italia il limite occidentale assoluto di distribuzione: *Ajuga orientalis, Ballota nigra* subsp. *velutina, B. pseudodictamnus* subsp. *pseudodictamnus, Clinopodium suaveolens, C. thymifolium, Dracocephalum moldavica, Lamium bifidum* subsp. *balcanicum,* L. *flexuosum,* L. *garganicum* subsp. *striatum, Lycopus exaltatus, Marrubium incanum, M. peregrinum, Mentha microphylla, Micromeria graeca* subsp. *fruticulosa, M. microphylla, M. thymifolia, Nepeta italica, N. nepetella* subsp. *nepetella, Origanum onites, Phlomis fruticosa, Salvia officinalis* subsp. *officinalis, S. virgata, Satureja subspicata* subsp. *liburnica, S. montana* subsp. *variegata, Scutellaria altissima, Stachys cretica, S. perfoliata, S. recta* subsp. *subcrenata, S. thirkei, S. tymphaea* e *Thymus carstiensis*.

Altre entità in qualche regione raggiungono un limite distribuzionale non assoluto ma che riguarda solo il territorio peninsulare. In particolare, raggiungono il limite meridionale di distribuzione in:

- **Emilia Romagna**: *Clerodendrum bungej* e *Leonurus quinquelobatus*;
- **Toscana**: *Ballota nigra* subsp. *nigra, Betonica hirsuta, Horminum pyrenaicum* e *Teucrium scorodonia*;
- **Marche**: *Thymus pulegioides*,
- **Lazio**: *Nepeta nepetella subsp. nepetella, Perilla frutescens* e *Teucrium botrys*;
- **Abruzzo:** *Ajuga pyramidalis, Clerodendrum trichotomum, Lamium galeobdolon* subsp. *flavidum, Satureja subspicata* subsp. *liburnica, Stachys thirkei, Teucrium scordium* subsp. *scordium* e *Thymus oenipontanus*;
- **Molise**: *Betonica alopecuros* subsp. *divulsa* e *Salvia nemorosa* subsp. *nemorosa*;
- **Campania**: *Chaiturus marrubiastrum, Clinopodium acinos* subsp. *acinos, C. nepeta* subsp. *ascendens, Galeopsis pubescens, Hyssopus officinalis* subsp. *officinalis, Lycopus exaltatus, Nepeta nuda* subsp. *nuda, Origanum vulgare* subsp. *prismaticum, Salvia pratensis* subsp. *pratensis, Scutellaria altissima, Stachys marrubiifolia, S. montana* subsp. *montana* e *S. recta* subsp. *recta*;
- **Puglia**: *Ajuga genevensis, Clinopodium alpinum* subsp. *alpinum, C. suaveolens, Galeopsis speciosa, Marrubium peregrinum, Scutellaria hastifolia, Stachys palustris* e *Thymus vulgaris* subsp. *vulgaris*;
- **Basilicata**: *Ballota nigra* subsp. *meridionalis, Lamium album subsp. album, L. garganicum* subsp. *striatum, Melittis melissophyllum* subsp. *melissophyllum, Salvia verticillata* subsp. *verticillata, S. virgata, Stachys recta* subsp. *subcrenata, Thymus moesiacus* e *T. striatus* subsp. *acicularis;*
- **Calabria**: *Betonica officinalis, Clinopodium vulgare* subsp. *vulgare, Galeopsis angustifolia* subsp. *angustifolia, G. ladanum, Glechoma hederacea, Hyssopus officinalis* subsp. *aristatus, Lamium bifidum* subsp. *bifidum, L. galeobdolon* subsp. *montanum, L. garganicum* subsp. *garganicum, L. garganicum* subsp. *laevigatum, L. maculatum, Lavandula austroapennina, Melissa officinalis* subsp. *officinalis, Mentha longifolia, Salvia glutinosa, S. haematodes, Satureja montana* subsp. *montana, Scutellaria alpina* subsp. *alpina, S. galericulata, Stachys arenaria* subsp. *arenaria, S. germanica* subsp. *germanica, S. germanica* subsp. *salviifolia, S. heraclea, S. recta* subsp. *grandiflora, S. tymphaea, Thymus praecox* subsp. *polytrichus* e *Ziziphora capitata* subsp. *capitata*;
- **Sicilia**: *Ajuga chamaepitys.* subsp. *chamaepitys, A. iva* subsp. *iva, A. orientalis, A. reptans, A. tenorei, Ballota hispanica, B. nigra* subsp. *uncinata, B. pseudodictamnus* subsp. *pseudodictamnus, Clinopodium alpinum* subsp. *meridionale, C. nepeta* subsp. *nepeta, C. nepeta* subsp. *spruneri,* C. *C. nepeta* subsp. *sylvaticum, C. vulgare* L. subsp. *arundanum, Lamium amplexicaule, L. garganicum* subsp. *laevigatum, L. hybridum, L. purpureum, Lavandula latifolia, L. multifida, L. stoechas, Marrubium alysson, M. incanum, Melissa officinalis* subsp. *altissima, Melittis melissophyllum* subsp. *albida, Mentha aquatica* subsp. *aquatica, M. microphylla, M. pulegium.* subsp. *pulegium, M. spicata, Micromeria graeca* subsp. *garganica, M. graeca* subsp. *fruticulosa, M. graeca* subsp. *graeca, M. juliana, Mi. microphylla, M. nervosa, Moluccella spinosa, Nepeta cataria, Origanum majorana, O. vulgare*

subsp. *vulgare*, *Phlomis fruticosa*, *P. herba-venti* subsp. *herba-venti*, *Prunella laciniata*, *P. vulgaris* subsp. *vulgaris*, *Salvia argentea*, *S. clandestina*, *S. microphylla*, *S. officinalis* subsp. *officinalis*, *S. rosmarinus*, S. *sclarea* subsp. *sclarea*, *S. verbenaca*, *Stachys annua* subsp. *annua*, *S. byzantina*, *S. italica*, *S. major*, S. *ocymastrum*, *S. romana*, *S. sylvatica*, *Teucrium campanulatum*, *T. chamaedrys* subsp. *chamaedrys*, *T. flavum*. subsp. *flavum*, *T. fruticans*. subsp. *fruticans*, T. *scordium*. subsp. *scordioides*, *T. siculum* subsp. *siculum*, T. *spinosum*, *Thymbra capitata*, *Thymus longicaulis* subsp. *longicaulis*. *T. spinulosus* e *Vitex agnus-castus*.

Raggiungono il limite settentrionale di distribuzione nelle seguenti Regioni:

- **Valle d'Osta**: *Salvia aethiopis*;
- **Piemonte**: *Galeopsis reuteri*, *Hyssopus officinalis* subsp. *officinalis*, *Lamium garganicum* subsp. *laevigatum*, *Lycopus exaltatus*, *Nepeta nepetella* subsp. *nepetella*, *N. nuda* subsp. *nuda*, *Salvia clandestina*, *S. nemorosa* subsp. *nemorosa*, *Satureja montana*. subsp. *montana* e *Scutellaria columnae* subsp. *columnae*;
- **Lombardia**: *Ballota nigra* subsp. *uncinata*, *Galeopsis segetum*, *Lamium bifidum* subsp. *bifidum*, *L. hybridum*, *Salvia rosmarinus*, *S. verbenaca*, *Stachys arvensis*, *S. montana*, *S. recta*. subsp. *grandiflora* e *S. montana* subsp. *montana*;
- **Trentino Alto Adige**: *Ajuga chamaepitys* subsp. *chamaepitys*, *A. genevensis, A. reptans*, *A. pyramidalis*, *Ballota nigra* subsp. *meridionalis*, *B. nigra* subsp. *nigra*, *Betonica hirsuta*, *B. officinalis*, *Galeopsis angustifolia* subsp. *angustifolia*, *G. bifida,* G. *ladanum*, *G. pubescens*, *G. speciosa*, *G. tetrahit*, *Glechoma hederacea*, *G. hirsuta*, *Horminum pyreniacum*, *Hyssopus officinalis* subsp. *aristatus*, *Lamium album* subsp. *album*, *L. amplexicaule*, *L. maculatum*, *L. orvala*, *L. purpureum*, *Lavandula latifolia*, *Leonurus cardiaca*, *Lycopus europaeus*, *Marrubium vulgare*, *Melittis melissophyllum* subsp. *melissophyllum*, *Mentha aquatica*, *M. arvensis*, *M. longifolia*, *M. pulegium* subsp. *pulegium*, *Melissa officinalis* subsp. *officinalis*, *Origanum vulgare* subsp. *prismaticum*, *Prunella laciniata*, *P. vulgaris* subsp. *vulgaris*, *Salvia glutinosa*, *S. haematodes*, *S. officinalis* subsp. *officinalis, S. pratensis*. subsp. *pratensis*, *S. verticillata*. subsp. *verticillata*, *S. viridis*, *Satureja hortensis*, *Stachys alpina* subsp. *alpina*, *S. annua* subsp. annua, *S. germanica*. subsp. *germanica*, *S. germanica* subsp. *salviifolia*, *S. montana* subsp. *montana*, *S. palustris*, *S. sylvatica*, *Scutellaria alpina* subsp. *alpina*, *S. galericulata*, *Thymus oenipontanus*, *T. praecox* subsp. *polytrichus*, *T. pulegioides*, *T. pseudochamaedrys*, *Teucrium botrys*, *T***.** *chamaedrys* subsp. *chamaedrys*, *T. montanum* e *T. scordium* subsp. *scordium*;
- **Veneto**: *Micromeria juliana* e *Phlomis fruticosa*;
- **Friuli Venezia Giulia**: *Clinopodium vulgare* subsp. *arundanum*, *Satureja montana*. subsp. *variegata*, *Stachys maritima* e *Thymus longicaulis* subsp. *longicaulis*;
- **Liguria**: *Ajuga iva* subsp. *iva*, *A. orientalis*, *Lavandula stoechas* subsp. *stoechas*, *Micromeria graeca* subsp. *graeca*, *Stachys ocymastrum* e *Teucrium fruticans* subsp. *fruticans*;
- **Emilia Romagna**: *Clinopodium alpinum* subsp. *meridionale*, *C. nepeta* subsp. *spruneri*, *Melissa officinalis* subsp. *altissima*, *Salvia virgata*, *Stachys heraclea*, *S. thirkei*, *S. tymphaea*, *Thymus moesiacus*, *T. striatus* subsp. *acicularis* e *Ziziphora capitata* subsp. *capitata*;
- **Toscana**: *Mentha suaveolens* subsp. *insularis*, *Salvia microphylla*, *Stachys marrubiifolia*, *S. major*, *Teucrium marum*, *T. siculum* subsp. *siculum* e *Thymbra capitata*;
- **Marche**: *Betonica alopecuros* subsp. *divulsa*, *Lamium flexuosum* e *Teucrium flavum* subsp. *glaucum*;
- **Lazio**: *Salvia fruticosa* subsp. *thomasi* e *Thymus spinulosus*;
- **Abruzzo**: *Ajuga chamaepitys* subsp. *chia*, *A. tenorei*, *Ballota hispanica* e *Clinopodium suaveolens*.

Tab. 2: Distribuzione delle Lamiaceae della flora italiana per tipo di habitat.
Tab. 2: Razširjenost ustnatic v italijanski flori glede na tip habitata.

Tipo di habitat	Numero taxa
Margini di boschi	5
Cespuglieti e Siepi	25
Prati e Campi coltivati	25
Boschi di varie tipologie	28
Incolti e Ruderi	71
Radure di boschi	11
Macchie e boscaglie	14
Garighe	19
Ambienti umidi	40
Prati aridi	80
Pascoli alpini e subalpini	15
Ghiaioni, Macereti e Pietraie	30
Rupi e sue fessure	61
Dune	5
Pascoli sassosi	39
Muri	7

- **Molise**: *Melittis melissophyllum* subsp. *albida* e *Micromeria graeca* subsp. *garganica*;
- **Campania**: *Lavandula austroapennina*, *Micromeria graeca* subsp. *consentina*, *M. graeca* subsp. *longiflora* e *Stachys arenaria* subsp. *arenaria*;
- **Puglia**: *Lamium garganicum* subsp. *garganicum*, *Marrubium alysson*, *Micromeria nervosa*, *Moluccella spinosa*, *Teucrium campanulatum* e *T. spinosum*.

Per gli altri taxa non è stato possibile affermare con certezza i limiti di distribuzione.

Le Lamiaceae della flora italiana crescono in habitat molto diversi (Tab. 2). Oltre 100 taxa si rinvengono nei prati e pascoli di vario tipo (aridi, umidi, sassosi, etc.) e generalmente in ambienti aperti e soleggiati tra cui le garighe e i consorzi terofitici effimeri. Non mancano tuttavia le specie che prediligono gli habitat riparati e freschi dei boschi di varie tipologie, delle macchie e dei cespuglieti. Oltre 60 taxa si rinvengono tra le rupi, pietraie e ghiaioni di vario tipo, ambiti inospitali ove solo pochi organismi specializzati riescono a sopravvivere.

Dalla Tabella 3 emerge che sono presenti in tutte le fasce altitudinali comprese tra il livello del mare e oltre 2400 metri, con molte entità presenti in più fasce. La maggior ricchezza si ha nella fascia che va da 100 a 900 m con 210 taxa (77,2 %). Ad altitudini maggiori e minori diminuiscono: nelle fasce tra 900-1800 m., 1800-2400 m. e oltre 2400 metri sono presenti rispettivamente 151, 47 e 11 taxa e in quella tra 0 e 100 metri ne sono presenti 172.

La Tabella 4 riporta i risultati dell'analisi fitogeografica, con la ripartizione percentuale dei vari elementi corologici. I taxa si ripartiscono in 7 contingenti floristici tra cui domina il mediterraneo con 82 taxa. Seguono i contingenti: europeo (53), endemico (49), eurasiatico (46), avventizio (31), nordico (7) e atlantico (4). Al contingente endemico appartengono entità con distribuzione molto ristretta: i taxa endemici in senso stretto (stenoendemici) presenti solo in una o più regioni italiane e i taxa subendemici. Esso dimostra innanzitutto che il territorio nazionale anche per le lamiacee è un ambito di speciazioni floristiche. Inoltre: è più rappresentato in Sicilia e Sardegna con 30 taxa di cui alcuni presenti anche in altre regioni centro-meridionali; è presente con 19 taxa nell'Italia meridionale, 10 nell'Italia Centrale e 9 nell'Italia settentrionale. Per quanto riguarda gli altri contingenti floristici si ossserva quanto segue:

- il contingente mediterraneo è più rappresentato in Sicilia e Sardegna con 56 taxa e mostra un trend decrescente dalle regioni meridionali a quelle settentrionali;
- i contingenti avventizio, eurasiatico ed europeo hanno un trend decrescente da nord a sud;
- il contingente nordico è rappresentato da un pari di numero di taxa da nord a sud, mentre si riduce in Sicilia e Sardegna:
- il contingente mediterraneo-atlantico registra la maggior ricchezza nell'Italia settentrionale, seguono Sicilia e Sardegna e poi con valori identici l'Italia centrale e meridionale.

Tab. 3: Distribuzione delle Lamiaceae in base all'altitudine.
Tab. 3: Razširjenost ustnatic glede na nadmorsko višino.

Altitudine in metri	Numero taxa
0-100	172
100-900	215
900-1800	151
1800-2400	47
Oltre 2400	11

Le origini della famiglia

Dove e quando le Lamiaceae si originarono e in quale epoca raggiunsero la penisola italiana? Nelle ere geologiche passate, vegetali provenienti da tutte le direzioni raggiunsero i territori emersi che oggi costituiscono l'Italia sfruttando le connessioni territoriali esistenti e/o in presenza di una barriera, con la dispersione a lunga distanza che affida la diffusione degli organi riproduttivi al vento, agli animali, agli uccelli, alle correnti marine e all'uomo. La ricostruzione delle ere geologiche in cui le migrazioni avvennero non è facile: ancora oggi nonostante i progressi delle conoscenze biogeografiche permangono molti lati oscuri. Vari spunti sono stati forniti dalle ricerche di biologia molecolare e sistematica filogenetica con cui è stato possibile: 1) ricostruire gli alberi genealogici di vari taxa; 2) individuare i centri d'origine, i territori in cui sono presenti i taxa più antichi, i processi di speciazione e le rotte migratorie seguite per colonizzare varie parti del globo. Di solito, per la stima dei periodi temporali dei processi e meccanismi evolutivi si utilizza il cosiddetto orologio molecolare, che prende in considerazione i tempi medi di evoluzione di alcune sostanze proteiche. Esso si basa sul fatto che le mutazioni genetiche avvengono con frequenze generalmente costanti: tenendo conto del numero di variazioni riscontrate, è possibile stimare il tempo trascorso dal momento in cui ebbero inizio (Zuckerkandl & Pauling, 1962). In anni recenti, l'uso di nuovi algoritmi ed elaboratori più potenti ha consentito alla filogenetica molecolare di fare enormi progressi: ora è possibile elaborare ipotesi complesse sulle relazioni filogenetiche, i modelli biogeografici di dispersione, espansione, vicarianza e transizioni evolutive riguardanti gruppi che vanno da specie strettamente correlate a intere famiglie di piante.

Un gruppo di organismi più o meno affini si diversificò e assunse i propri caratteri distintivi, da un antenato

Tab. 4: Corotipi delle Lamiaceae della flora italiana.
Tab. 4: Horotipi ustnatic v italijanski flori.

Elementi geografici	Numero taxa	%
Endemico e Subendemico	**49**	**18,0**
Endemico	37	
Subendemico	12	
Mediterraneo	**82**	**30,1**
Eurimediterraneo	20	
Stenomediterraneo	26	
Mediterraneo-Occidentale	19	
Mediterraneo-Orientale	7	
Mediterraneo Montano	1	
Sud-Mediterraneo	1	
Nord-Est-Mediterraneo	3	
Sud-Est-Mediterraneo	1	
Sud-Ovest-Mediterraneo	3	
Nord-Ovest-Mediterraneo	2	
Eurasiatico	**46**	**16,9**
Eurasiatico *s.s.*	15	
Europeo-Caucasico	11	
Eurosiberiano	3	
Sud-Europeo-Sud-Siberiano.	5	
Pontico	3	
Paleotemperato	4	
Mediterraneo-Turaniano	4	
Mediterraneo-Pontico	1	
Nordico	**7**	**2,6**
Circumboreale	7	
Europeo	**53**	**19,5**
Europeo *s.s.*	1	
Centro-Europeo	3	
Orofita Sud-Ovest-Europeo	3	
Orof. Sud-Europeo	7	
Orofita Sud-Est- Europeo	6	
Illirico	2	
Sud-Est-Europeo	9	
Ovest-Europeo	2	
Appennino-Balcanico	17	
Est-Alpino-Dinarico	2	
Sud-Europeo	1	
Atlantico	**4**	**1,5**
Mediterraneo-Atlantico	1	
Subatlantico	3	
Avventizio	**31**	**11,4**
Avventizio	31	
Totale	**272**	**100**

comune presente in una o più aree geografiche definite "centri di origine". Da tali ambiti l'antico progenitore si diffuse colonizzando territori in cui talvolta s'innescano mutazioni genetiche che portano alla formazione di nuovi taxa. Di conseguenza, oltre al centro d'origine primario si possono avere altri secondari e post-secondari ove sono avvenuti e avvengono i processi di diversificazione biologica. Spesso si fa coincidere il centro di origine con il territorio in cui una famiglia di organismi viventi raggiunge la maggiore diversità, sono presenti entità con caratteristiche più ancestrali o si sono trovati reperti fossili più antichi.

Nel caso delle Lamiaceae, i reperti fossili conosciuti non consentono di individuare il centro d'origine e l'antenato da cui discendono, ma si rivelano utili per affermare che suoi taxa popolavano certe regioni terrestri durante precise ere geologiche. Alcuni di essi sono i seguenti: frutti di resti di *Gmelina tertiara* Bande di fine del Cretaceo inizio Paleocene (circa 67-64 Ma), rinvenuti in India (Wheeler *et al*., 2017); polline di *Nepetoideae* di 49 Ma e semi di *Melissa* della prima metà dell'Oligocene rinvenuti in Germania; polline di *Ocimumpollenites indicus* risalente alla prima metà dell'Eocene (circa 49 Ma) rinvenuto nella regione indiana del Rajasthan (Kar, 1996); *Ajuginucula smithii* Reid et Chandler e *Melissa parva* Reid et Chandler del medio Oligocene (circa 28,4 milioni di anni fa) rinvenuti a Bembridge Inghilterra (Martínez-Millán, 2010); resti di *Teucrium sibiricum* L. del Tardo Oligocene (28,4-23 Ma) rinvenuto nella Siberia occidentale (Dorofeev, 1963); frutti di *Lycopus cf. antiquus* Reid 1920 del Miocene rinvenuti a Nowy Sacz (Polonia) (Łańcucka-Środoniowa); resti di *Origanum vulgare* risalenti al Medio Miocene (16-13,8 Ma), rinvenuti in Germania (Mai, 2001); resti di *Stachys laticarpa* e *Lamium* sp. del Medio Miocene (13,8-11,6 Ma) rinvenuti in Germania (Roy & Lindqvist, 2015); frutti di *Teucrium* della metà del Miocene rinvenuti a Fasterholt e Søby (Danimarca) (Friis, 1985); semi di *Glechoma hederacea*, *Lycopus* sp., *L. cholmechensis* Wieliczk., *Mentha pliocenica* Dorof., *Stachys* cf. *pliocenica* Dorof., *Teucrium pripiatense* (Dorof.) Wieliczk. e *T. tatjanae* Nikit. di fine Pliocene inizio Pleistocene rinvenuti in Bielorussia (Velichkevih & Zastawniak, 2003); semi di *Ajuga antiqua* C. Reid & E. Reid del Pliocene-Pleistocene rinvenuti in Italia (Martinetto, 2015); semi dl *Teucrium pripiatense* del Pliocene rinvenuti in Germania (Mai, 2007). In conclusione i dati riportati, consentono di affermare che: i fossili più antichi risalgono a circa 67-64 Ma e sono stati rinvenuti in India, all'epoca un subcontinente isolato che si allontanava dalla costa orientale dell'Africa e si avvicinava all'Asia; in parte dei territori che oggi costituiscono l'Europa centro-settentrionale, le Lamiaceae erano presenti a partire da 49 Ma; la subfamiglia Nepetoidae è la più antica. Tenendo conto di tali dati si può sostenere che in India o più in generale nel continente asiatico è situato il centro d'origine delle Lamiaceae?

Ad avviso di Harley *et al*. (2004) la famiglia si originò durante il Cretaceo. Wu & Li (1982) sostengono che la famiglia è originaria della Cina meridionale o dell'Indomalesia e le subfamiglie più primitive sono le Prostanthcroideae e le Ajugoideae. Hedge (1992) invece sostiene che l'Asia centrale e Sud-Occidentale possono essere considerati centri di origine primaria da cui le lamiacee si diffusero verso altri territori ove i processi di diversificazione continuarono, tra i quali: il Bacino del Mediterraneo, l'Africa australe, l'America occidentale, le isole oceaniche e altre zone del continente asiatico. Nell'Asia sud-occidentale sono presenti 66 generi e circa 1100 specie (Hedge, 1992). Nel suo ambito l'Iran con 46 generi e 406 specie (Jamzad, 2013) e la Turchia con 47 generi e 782 specie (Celep & Dirmenci, 2017), hanno il maggior numero di taxa. Per Manafzadeh *et al.* (2014) la regione irano-turanica è un importante hot spot di diversità biologica-evolutiva delle xerofite da cui i generi *Salvia*, *Nepeta*, *Thymus* e *Scutellaria* si originarono e diffusero.

Ipotesi su periodi e rotte migratorie

Al fine di elaborare ipotesi attendibili sui periodi e rotte migratorie seguite dalle lamiacee per raggiungere la penisola italiana, si prenderanno in considerazione vari eventi paleogeografici che dal Terziario all'Olocene, si sono susseguiti contribuendo alla formazione dell'attuale assetto floristico-vegetazionale.

Le migrazioni del Terziario

Durante il Terziario, da circa 65 Ma a 2 Ma, iniziarono gli eventi che portarono alla formazione della penisola italiana e gli sconvolgimenti paleogeografici furono accompagnati da: la comparsa di famiglie di piante e animali, colonizzazione di nuovi territori ed estinzioni. La diffusione e formazione delle lamiacee nella penisola italiana durante il Cenozoico avvenne in tre diversi periodi: uno più antico che coinvolse generi a distribuzione paleotirrenica e paleoegeica; uno intermedio nel Messiniano; l'ultimo più recente nel Pliocene.

Nella prima fase più antica di inizio Oligocene, circa 34 Ma, la zona dove in seguito sorgerà l'Italia era occupata da un mare tropicale circondato a Ovest dal blocco iberico-provenzale cui era unita la microzolla sardo-corsa, a Nord ed Est da terre che costituivano la Dinaride e a Sud dall'Apulide o Egeide, un subcontinente comprendente territori emersi appartenenti alla Puglia attuale, la penisola balcanica e l'Anatolia. All'epoca l'arco calabro-peloritano, la Sardegna e la Corsica costituivano un unico blocco collegato alla placca europea in un'area corrispondente all'attuale Provenza-Linguadoca. Anche le Baleari e parte del Nord-Africa erano legate alla placca europea in un ambito territoriale compreso tra la Spagna meridionale e la Catalogna e facevano parte di un lungo corrugamento detto massiccio ercinico che andava dalla Spagna sino a Vienna (Bosellino, 2005). Durante il Tardo Oligocene il territorio iniziò a frammentarsi, si formarono varie microplacche tra cui quella corso-sardo-calabra che si staccò, subì una rotazione e lentamente si portò nella posizione attuale. L'arco calabro-peloritano dopo aver accompagnato alla deriva di Corsica e Sardegna, continuò a spostarsi verso sud- est (Bosellino, 2005, op. cit.). Secondo Furon (1959), invece, tra l'Oligocene e l'Eocene esisteva un subcontinente chiamato Thyrrenis o Massiccio Iberico-Tirrenico che incorporava oltre ai territori suddetti anche l'Arcipelago toscano e varie paleoisole ora unite all'Italia centrale: il Promontorio del Circeo, il Monte Argentario e le Colline Metallifere. Le connessioni territoriali tra il blocco sardo-corso, l'arcipelago toscano, l'area ligure-provenzale, le Baleari e la penisola iberica favorirono le migrazioni floristiche. In seguito le piante presenti nell'area, con il lungo isolamento geografico si diversificarono in nuove specie. A tali cause sono da attribuire le vicarianze foristiche tra le regioni peninsulari da un lato e, Nord-Africa e/o Europa occidentale dall'altro. La distribuzione di *Micromeria filiformisis s.l.* e *Prunella hyssopifolia* potrebbe riflettere quest'evento paleogeografico. Altre prove di antichi legami con la penisola iberica sono fornite dal gruppo di *Thymus richardii* che comprende: *T. richardii* Pers. subsp. *richardii* presente a Minorca e in alcune zone dell'ex Jugoslavia; *T. richardii* subsp. *nitidus* (Guss.) Jalas endemico dell'isola di Marettimo; *T. richardii* subsp. *ebusitanus* (Font Quer) Jalas presente a Ibiza e *T. richardii* subsp. *vigoi* Riera, Gilames & Rosselló della penisola iberica. Anche *Nepeta foloisa*, affine a N. *multibracteata* Desf. (Valsecchi & Corrias, 1973) potrebbe tetstimoniare tali antichi legami.

Durante il Miocene: 1) l'isolamento geografico dell'arco calabro-peloritano favorí la formazione di vari endemismi condivisi tra Calabria e Sicilia tra cui *Scutellaria columnae* subsp. *gussonei*; 2) con la deriva delle microzolle terziarie, diverse entità mediterraneo-occidentali raggiunsero i territori emersi della Sicilia da cui si espansero verso altre regioni dell'Italia Meridionale.

Altre migrazioni floristiche avvennero attraverso l'Egeide, il subcontinente che univa l'Asia minore con la Grecia, il Gargano, Salento e altri territori emersi. Secondo Gridelli (1950) nel Miocene il Gargano era collegato alla Dalmazia, il Salento alla Grecia-Albania e tra le due zone esisteva un tratto di mare definito solco transegeico. Le ricerche successive (De Giuli *et al*., 1987; Rögl, 1999, Patacca *et al*., 2008), sia pur con sfumature diverse, confermano l'esistenza di ponti territoriali diretti tra varie parti emerse della Puglia e la penisola balcanica tra fine Oligocene-inizio Miocene e durante il Langhiano. Francini Corti (1966) definì paleoegeiche le specie che varcarono l'Adriatico miocenico. Tra esse: *Phlomis fruticosa*, *Salvia triloba* (sin. *Salvia fruticosa*) e *Satureja cuneifolia*. Probabilmente anche altre lamiacee di origini orientali varcarono l'Adriatico miocenico, tra cui gli antenati di *Lamium garganicum*, *Micromeria graeca* e *Stachys italica* che proseguirono la rotta migratoria lungo l'Appennino meridionale e raggiunsero la Sicilia.

L'epoca successiva in cui avvennero nuove ondate migratorie, speciazioni, vicarianze, etc. è il Messiniano tra 7 e 5 Ma. Nel suo corso si sollevò la soglia di Gibilterra, s'interruppero i collegamenti con l'oceano Atlantico, il Bacino del Mediterraneo si prosciugò a causa della forte evaporazione e si aprirono collegamenti territoriali che favorirono le migrazioni foristiche (Bocquet *et al.*, 1978). In questo periodo si suppone esistessero ponti terrestri che univano: il Nord-Africa e la Sicilia con, da un lato Sardegna, Corsica, Liguria e Toscana e dall'altro con Calabria, l'Appennino e quest'ultimo con la penisola balcanica. Il clima caldo-arido che s'instaurò favorì la diffusione di piante steppiche, xerofile e alofite. Ad avviso di Pignatti (1994) all'epoca, piante d'origine orientale con spiccate caratteristiche xerotermofle, capaci di attecchire su suoli molto salati, raggiunsero i territori emersi della penisola italiana, percorrendo un lungo corridoio che univa il Nord-Africa con la penisola iberica, l'arco pirenaico-alpino-appenninico o il sistema sardo-corso. Bonanni (2018) sostiene che all'epoca si diffusero e differenziarono vari arbusti tra cui quelli appartenenti ai seguenti generi di lamiacee: *Clinopodium*, *Hyssopus*, *Lavandula*, *Melissa*, *Mentha*, *Ocimum*, *Origanum*, *Phlomis*, *Satureja* e *Thymus*.

La disgiunzione degli areali di *Mentha suaveolens* subsp. *insularis*, *Teucrium marum*, *T. massiliense*, *T. subspinosum* e *Thymus herba-barona* potrebbe essere la conseguenza sia delle derive mioceniche sia delle migrazioni foristiche del Messiniano.

Nel periodo in esame è ipotizzabile che dal Nord-Africa raggiungessero la Sicilia, la Sardegna e altre regioni peninsulari diversi taxa e loro antenati di origini mediterranee sud-occidentali tra cui: *Ajuga chamaepitys* subsp. *suffrutescens, Clinopodium alpinum* subsp. *meridionale*, *Lavandula multifda*, *L. stoechas*, *Nepeta apulei*, N. *tuberosa* subsp. *tuberosa*, *Stachys arenaria*, *S. brachyclada*, *S. glutinosa, Teucrium fruticans, T. lucidum* e l'antenato del gruppo di *Teucrium siculum*. Si può ipotizzare che alcune specie del gruppo appartengano alla corrente migratoria floristica sud-occidentale che secondo La Valva (1992), durante il Cenozoico collegava la penisola iberica con l'Africa settentrionale, l'Algeria, la Sicilia e l'Appennino meridionale. È possibile che all'epoca sia esistito anche un collegamento diretto o attraverso il Nord-Africa della Sicilia con la penisola anatolica, le isole egee e/o la Grecia centrale che permise la migrazione di *Ajuga orientalis*, *Mentha microphylla*, *Origanum onites*, *Salvia fruticosa s.l., Stachys perfoliata*, *Teucrium creticum* e dell'antenato di *Scutellaria rubicunda*.

Al Messiniano o altra epoca imprecisata del Terziario potrebbero risalire le affinità floristiche esistenti tra le Alpi centro-occidentali e il Mediterraneo Orientale che documentano: la discendenza da antenati comuni che popolavano l'Europa meridionale e il Bacino del Mediterraneo; entità orientali migrate in direzione occidentali seguendo direttrici sconosciute. A questa categoria di taxa appartengono: *Micromeria marginata* affine a *M, croatica* (Pers.) Schott presente nella penisola balcanica e il genere *Acanthoprasium* costituito da due specie presenti rispettivamente nelle Alpi Marittime e a Cipro, Ad avviso di Martini (1984) i taxa di *Acanthoprasium* si originarono da un antenato comune che nel Miocene occupava le terre emerse del Mediterraneo; la trasgressione marina post- messiniana portò all'isolamento delle popolazioni e alla loro diversificazione.

Durante il periodo successivo del Pliocene che iniziò circa 5,3 Ma e si concluse attorno a 2,5 Ma, si riapri lo stretto di Gibilterra, il Bacino del Mediterraneo si riempi, si ebbe la progressiva formazione della penisola italiana che emerse prima come arcipelago e poi come sistema montuoso unitario, un lembo del continente Sud-Egeide si separò dalla penisola balcanica per unirsi all'Appennino meridionale e la temperatura media della terra iniziò a scendere producendo un clima più secco che contribuì a trasformare la vegetazione esistente. Le foreste tropicali di laurisilve si diradarono e in varie parti furono sostituite dai boschi a sclerofille più adatti al clima arido che si era formato. Di conseguenza altre ondate migratorie e processi di diversificazione portarono alla formazione di nuovi assetti vegetazionali. In questo periodo varie entità centro-europee e nordiche iniziarono il processo di colonizzazione lungo la penisola italiana. La scomparsa dei ponti terrestri del Messiniano, causò l'isolamento geografico degli organismi viventi cui segui la diversificazione di piante d'origine mediterranea e di diversi taxa endemici tra cui molti appenninici. Pignatti (1994) considera *Ajuga tenorei* un'entità appartenente al gruppo delle specie endemiche appenniniche altomontane che si formò verso la fine del Terziario quando la catena emerse dal mare e fu colonizzata da piante provenienti da est e ovest. I reperti fossili analizzati da Martinetto (1995) confermano che durante il Pliocene, il genere *Ajuga* aveva colonizzato l'Italia e avvalorano l'ipotesi di Pignatti. Tra la fine del Miocene e l'inizio del Pliocene, ad avviso di Favarger & Robert (1994) dalla branca meridionale della flora arcto-terziaria si originarono vari taxa tra *Horminum pyrenaicum* e *Stachys alopecurus*.

Potrebbe essere iniziato durante il Pliocene anche il processo di diversificazione che portò alla formazione di *Stachys salisii,* da Borzatti De Loewenstern & Mannocci (2008) considerata un'entità apoendemica originatasi per poliploidizzazione da un taxon diploide diffuso nelle zone vicine del complesso sardo-corso e dell'Arcipelago Toscano. *Stachys salisii* e l'entità simile *S. corsica* hanno notevoli affinità con taxa di origine orientale. Il loro antenato probabilmente nel Messiniano raggiunse i territori emersi della penisola italiana e durante il Pliocene iniziò a diversificarsi.

Le migrazioni pleistoceniche

Nel Pleistocene ci fu un'alternanza di periodi glaciali freddi e fasi calde che influenzarono profondamente la biodiversità del Mediterraneo. Durante le fasi fredde: la temperatura media delle zone temperate era di circa 10° inferiore a quella attuale; lungo la penisola italiana, il limite delle nevi perenni toccava 1300 metri d'altitudine; il livello marino si abbassò; si connessero tra loro territori ora separati dal mare: la Sicilia con la Calabria, la Sardegna con la Corsica, varie isole dell'Arcipelago toscano con la terraferma e vaste zone appartenenti alle due penisole circumadriatiche. A causa di ciò si produssero estinzioni di specie terziarie, accantonamenti, formazione di nuove specie, disgiunzioni e nuove ondate migratorie. Nei paesaggi frammentati delle zone continentali e delle isole mediterranee s'innescò la speciazione allopatrica tramite selezione e/o deriva genica (Thompson, 2005). Le migrazioni floristiche mettendo in contatto piante di diverse origini, favorirono l'allopoliploidia ossia l'ibridazione tra specie seguita da poliploidia. Gli ibridi superando la condizione di sterilità, iniziarono a riprodursi e si diffusero conquistando nuovi territori. A tal proposito, secondo Ietswaart (1980), tra fine Pliocene e il Pleistocene vari taxa del genere *Origanum*, migrarono, vennero in contatto, s'ibridarono e formarono nuove specie.

La sopravvivenza di molti organismi viventi d'origine terziaria avvenne in aree definite centri di rifugio. Ad avviso di Médail & Diadema (2009) nel Bacino del Mediterraneo ne sono individuabili 52 di cui 32 nel settore occidentale, 19 in quello orientale e 8 nel territorio italiano (Alpi Marittime, Sardegna, Alpi Apuane, Gargano, Campania, Appennino Meridionale, Calabria e Sicilia). Secondo Ozenda (1994) le zone di rifugio in Italia erano costituite dalla punta del Salento, la Sardegna, la Sicilia e la fascia costiera tirrenica dal Lazio alla Calabria. Nello stesso periodo la larghezza del Canale di Sicilia si ridusse a circa 40-50 Km rispetto agli attuali 145 Km e probabilmente questo fatto favorì la dispersione a lunga distanza di piante provenienti dal continente africano.

Secondo Tomaselli & Gualmini (2000) durante l'era glaciale, attraverso il raccordo fisco tra l'Appennino settentrionale e le Alpi Occidentali, esistevano relazioni fitogeografche che permisero le migrazioni foristiche di taxa orofili ovest-europei, alpino-occidentali e alpino-appenninici da Nord-Ovest a Sud-Est nei periodi freddi e in direzione opposta in quelli caldi. Altri studi (Negri, 1928; Corti, 1956) hanno dimostrato che in più fasi del Quaternario varie entità atlantico-occidentali, attraversando i valichi a bassa quota delle Alpi Marittime e dell'Appennino settentrionale raggiunsero il Piemonte e poi proseguirono verso altre regioni. A questa categoria potrebbe appartenere *Teucrium scorodonia*.

All'epoca la linea di costa tra le penisole italiana e balcanica si trovava qualche centinaio di chilometri più a sud di quella attuale e poteva congiungere le città di Ancona e Zara. Nel territorio più a sud, varie isole dalmate erano inglobate alla terraferma, le opposte sponde circumadriatiche erano più vicine ed esistevano territori emersi. Si presume che la maggiore vicinanza delle sponde e i ponti terrestri che si erano instaurati, favorirono i movimenti migratori che portarono in Italia specie appennino-balcaniche e generalmente orientali. Una specie che usufruì di tali connessioni fu *Salvia officinalis*. Ad avviso di Radosavljević *et al.* (2015), la regione costiera dell'Adriatico orientale, oltre che centro d'origine del taxon, durante il Wurm fu anche un'area di rifugio da cui ripartirono i ripopolamenti dei territori vicini. A loro avviso anche l'Appennino meridionale in cui le popolazioni di *Salvia officinalis* sono caratterizzate un numero notevole di alleli, poteva costituire un'area di rifugio. Probabilmente le popolazioni di *Salvia officinalis* e di altre specie tra cui *Hyssopus officinalis* subsp. *aristatus*, *Marrubium incanum, Stachys recta* subsp. *subcrenata*, *S. recta* subsp. *grandiflora* e *Thymus praecox* subsp. *polytrichus* raggiunsero la penisola italiana seguendo più rotte migratorie: la via carsica nord-adriatica e un ponte terrestre più a sud.

Le seguenti entità appennino-balcaniche presenti solo nelle regioni centro-meridionali, invece, potrebbero essere migrate in direzione occidentale percorrendo un'unica rotta migratoria: *Lamium bifidum subsp. balcanicum*, *L. garganicum* s.l., *Micromeria graeca* s.l., *Stachys thirkei*, *S. tymphaea*, *Thymus striatus s.l.* e *T. zygiformis*.

Durante qualche fase calda del Pleistocene o nell'Olocene, attraverso il collegamento tra il Carso triestino e la penisola balcanica raggiunsero il Friuli Venezia Giulia: *Ballota nigra* subsp. *velutina*, *Clinopodium acinos* subsp. *villosum*, *C. einseleanum*, *C. thymifolium*, *Micromeria juliana*, *Salvia napifolia, Satureja montana.* subsp. *variegata*, *S. subspicata* subsp. *liburnica* e *Thymus illyricus*.

Ai periodi interglaciali freddi del Pleistocene è da attribuire la migrazione nella penisola della componente microtermica nordica ed eurasiatica della flora italiana cui appartengono le seguenti lamiacee: *Clinopodium vulgare*, *Galeopsis bifida*, *Glechoma hederacea*, *Lycopus exaltatus*, *Mentha arvensis*, *Prunella vulgaris*, *Scutellaria galericulata*, *Stachys palustris* e *S. sylvatica*. Durante gli interglaciali caldi, invece, raggiunsero la penisola entità tipiche degli ambienti steppici.

Le migrazioni oloceniche

L'Olocene iniziò circa 11700 anni fa e fu caratterizzato da un vistoso aumento della temperatura e del livello marino, l'arretramento delle linee costiere e dei ghiacciai alpini, l'espansione dei relitti terziari sopravvissuti in stazioni di rifugi, la diffusiome di entità di diverse origini geografiche e la formazione di nuovi taxa. In questo periodo l'uomo iniziò la domesticazione di piante e animali, svolgendo un importante ruolo nella trasformazione del paesaggio.

Dopo l'era glaciale, due distinte ondate migratorie interessarono le regioni dell'Italia settentrionale. La prima che si sviluppò in più fasi seguendo una direttrice est-ovest attraverso un corridoio padano o il margine inferiore delle Alpi, portò diverse piante pontiche, mediterraneo-orientali ed est-europee sino alle regioni occidentali della penisola. È probabile che alcune specie proseguissero i movimenti migratori anche in direzione sud. La seconda ondata che era stata preceduta da altre simili nel Pleistocene, attraverso i bassi valichi delle Alpi Marittime e dell'Appennino permise l'ingresso nelle regioni peninsulari di elementi atlantici, mediterraneo-ocidentali e ovest-europei. Nello stesso periodo dai rifugi dell'Italia meridionale partirono ondate migratorie in direzione settentrionale. Circa 10000 anni fa, secondo Pignatti (2018) *Dracocephalum austriacum* raggiunse le Alpi. Ad avviso di Poldini (1989) dopo il Wurm, il Carso litoraneo fu ripopolato da entità illiriche provenienti dall'immediato retroterra balcanico.

La diffusione diretta o indiretta delle piante nell'Olocene fu favorita anche dall'uomo che in diverse regioni peninsulari era presente circa 50000 anni fa. In generale l'uomo con l'attività agricola, il pascolo, gli incendi, la costruzione d'infrastrutture di trasporto e di edifici da un lato provoca la rarefazione di piante autoctone e dall'altro favorisce l'introduzione di piante estranee che si adattano facilmente agli ambienti artificiali ricavati dai disboscamenti effettuati. Molte piante potrebbero essere state diffuse anche con il commercio marittimo, tra cui *Satureja thymbra* che ad avviso di Pignatti (2018) potrebbe essere stata introdotta in Italia dai Fenici. Nel Bacino del Mediterraneo in cui le lamiacee hanno il più importante centro di diversità, si sono sviluppate antiche civiltà e gli uomini per millenni hanno modificato gli habitat, influenzando la distribuzione delle piante, i loro modelli evolutivi, flussi genici, processi differenziazione e la dispersione dei semi (Thompson, 2005). Secondo Pignatti (1994), l'impatto umano sulla flora ha provocato un aumento del grado di ploidia in diverse specie e variazioni morfologiche, tra cui quelle osservate nel genere *Acinos* (ora inserito in *Clinopodium*).

Molte lamiacee coltivate da oltre 5000 anni si sono spontaneizzate, conquistando nuovi territori. Esistono papiri egizi del 2800 a.C. che indicano gli usi medicamentosi di erbe come il basilico, la lavanda, la maggiorana, la menta e la salvia che all'epoca potevano essere coltivate e si diffusero a causa dell'uomo.

Si può presumere che le seguenti lamiacee coltivate da almeno 2000 anni, si siano spontaneizzate: *Ballota pseudodictamnus*, *Leonurus cardiaca*, *Stachys rosmarinus* e specie appartenenti ai generi *Lavandula*, *Melissa*, *Mentha*, *Ocimum*, *Origanum*, *Salvia*, *Satureja* e *Thymus*. In periodi più recenti, in alcuni casi negli ultimi 2-3 secoli, la flora italiana si è arricchita di altri taxa coltivati e naturalizzati appartenenti ai generi: *Caryopteris*, *Clerodendrum*, *Dracocephalum*, *Elsholtzia*, *Lamium*, *Lavandula*, *Leonurus*, *Lycopus*, *Nepeta*, *Perilla*, *Physostegia*, *Plectranthus*, *Salvia*, *Scutellaria*, *Stachys* e *Teucrium*.

Modalità di dispersione

Durante la loro evoluzione le lamiacee hanno adottato accorgimenti anatomico-strutturali che facilitano la dispersione e il trasporto. Alcuni taxa hanno semi che per le loro ridotte misure o per particolari caratteristiche anatomiche, possono essere facilmente trasportati dalle correnti aeree. Altri sono diffusi dagli animali con due diversi modi: 1) hanno semi carnosi che sono mangiati e poi dispersi con gli escrementi; 2) sono costituiti da superfici vischiose, meccanismi di aggancio con setole e uncini o sono inclusi in parti spinose che facilitano l'adesione al corpo (Bouman & Meeuse1992).

I semi di alcune specie dei generi *Ajuga, Lamium*, *Stachys* e *Teucrium*, dopo il distacco dalla pianta, in un primo tempo possono essere trasportati dal vento a brevi distanze e poi sono dispersi dalle formiche.

Alcuni taxa della tribù *Menthae* hanno adottato i seguenti accorgimenti morfologici che facilitano la dispersione a lunga distanza: ali, peli apicali e squame sui semi, calici gonfiati e altri accorgimenti anatomici (tumbleweed che prevede il trasporto dell'intera pianta) per la dispersione con il vento, spine per la dispersione epizocora, "sacche" di flottazione e la myxospermia, osservabile anche nella maggior parte delle *Nepetoideae*, che consiste nella secrezione di sostanze mucillaginose da parte semi o frutti per facilitare l'attaccamento al corpo degli animali e il trasporto con le correnti idriche. In generale, la diffusione biogeografica della tribù *Mentheae* avvenne sfruttando i ponti terrstri mentre sono più rari attraverso le barriere terrestri o idriche (Drew & Systma, 2012).

USTNATICE (LAMIACEAE) V ITALIJANSKI FLORI: REGIONALNA RAZŠIRJENOST IN FITOGEOGRAFSKI POMISLEKI

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POVZETEK

Družina ustnatic (Lamiaceae) je pomembna in dobro raziskana v italijanski flori. V pričujočem delu avtor poroča o seznamu vseh vrst v Italiji, analizira njihivo regionalno geografsko razširjenost, prepoznava glavne vzorce razširjenosti, predstavlja rezultate fitogeografske analize in poskuša razpravljati o izvoru in selitvenih premikih na temelju bibliografskih podatkov. Na italijanskem ozemlju se pojavlja 272 infrageneričnih taksonov. Regionalna razširjenost je bolj ali manj nesklenjena: samo 15 taksonov je prisotnih v vseh regijah (upoštevaje v nekaterih primerih tudi Sicilijo in Sardinijo); drugi so razširjeni v eni ali nekaj regijah, tudi v obliki disjunkcij. Prevladujejo sredozemske vrste, sledijo jim endemiti. Na podlagi pregledane literature je razvidno, da še vedno obstajajo nejasnosti in razlike glede interpretacije izvora družine, rodov in vrst ter selitvenih premikov pri naseljevanju italijanskih regij.

Ključne besede: Lamiaceae, popis vrst, regionalna razširjenost, biogeografija, izvor

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OCCURRENCE OF GIANT TUN, *TONNA GALEA* (LINNAEUS, 1758) (GASTROPODA: TONNIDAE) IN THE MARINE WATERS OFF SLOVENIA (NORTHERN ADRIATIC SEA)

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ABSTRACT

On 1st December 2018 a fisherman caught a specimen of the giant tun Tonna galea *(Linnaeus, 1758) in the bottom trammel net for flounders, approximately 1 Nm outside the town of Izola. The net was placed on a muddy bottom at 20 m of depth. This is the second record of* T. galea *in the Slovenian waters (Gulf of Trieste, northern Adriatic Sea). Another specimen (the first one) was previously reported in October 2015 in the waters off Piran. By including* T. galea *in the checklist of Slovenian marine malacofauna, at least 370 gastropod species were up to date recorded in the Slovenian part of the Adriatic Sea.*

Key words: Giant tun, *Tonna galea*, marine malacofauna, Gulf of Trieste, northern Adriatic Sea

PRESENZA DI DOGLIO, *TONNA GALEA* (LINNAEUS, 1758) (GASTROPODA: TONNIDAE), IN ACQUE MARINE AL LARGO DELLA SLOVENIA (ADRIATICO SETTENTRIONALE)

SINTESI

Il 1° dicembre 2018 un esemplare del gigantesco *doglio* Tonna galea *(Linnaeus, 1758)* è stato *catturato con una rete da posta, il tramaglio, a circa 1 Nm dalla cittadina di Izola. La rete è stata posizionata su fondo fangoso a 20 m di profondità. Questo è il secondo ritrovamento di* T. galea *nelle acque slovene (Golfo di Trieste, Adriatico settentrionale). Un altro esemplare (il primo) è stato segnalato a ottobre 2015 nelle acque di Pirano. Includendo* T. galea *nella lista della malacofauna marina slovena, almeno 370 specie di gasteropodi sono state registrate nella parte slovena dell'Adriatico.*

Parole chiave: Doglio, *Tonna galea*, malacofauna marina, Golfo di Trieste, Adriatico settentrionale

INTRODUCTION

Tonna galea (Linnaeus, 1758) is a large gastropod, widespread in the Atlantic and Pacific Oceans and in the Mediterranean Sea (de Simone, 1995). It is the second largest Mediterranean gastropod, which could reach more than 29 cm in size (Katsanevakis *et al., 2008)*. It mainly inhabits sandy and muddy sediments and seagrass meadows (Katsanevakis *et al*., 2008). It is a carnivore which preys on sea cucumbers such as *Holothuria tubulosa, H. forskali, H. poli* and *H. sanctori* (Toscano *et al*., 1992; Francour, 1997), other echinoderms and mollusks. The basic life history of this species deserved only scarce scientific interest and many aspects of its biology and ecology still remains unknown (Doxa *et al*., 2011). Nowadays, this giant gastropod is endangered mostly by artisanal fishermen and collectors (Tunesi *et al*., 2006). It is a rare and protected species according to Annex II of the Bern convention (Council of Europe, 1979) and the Protocol of the Barcelona convention (Annex II) (European Community, 1999; UL RS, 2002). However, it is still sporadically collected in many Greek areas by divers (Katsanevakis *et al*., 2008) as a food delicacy or for shell collectors (Tunesi *et al*., 2006; Russo & Perini, 2016). The aim of this paper is to present data on the occurrence of this giant gastropod in the Slovenian part of the Adriatic Sea.

MATERIAL AND METHODS

Two individual giant tuns were found in recent years in the Slovenian part of the Adriatic Sea. The first was recorded on 24th October 2015 close (200 m distance northward) to the diffuser of the pipeline of the sewage outfall near Piran and the second on 1st December 2018 one Nm outside the town of Izola (45° 33′ 20.9″ N; 013° 38′ 19.6″ E). Both individuals were caught accidentally as by-catch in the bottom trammel net. In the first case the giant tun was kept in the Aquarium Piran still alive and then moved to the Shell museum Piran where it is now part of the exhibited collection. A note on this record was mentioned in the Piran municipal bulletin by Simič (2015).

In the second case, the specimen was caught in a trammel net for flounders, placed on muddy bottom at 20 m of depth overnight. The specimen was deposited still alive in the Piran Aquarium into a 3.400 l aquarium tank with sandy bottom (Fig. 1). The giant tun was photographed and the shell measured with a calliper to the nearest millimetre (Fig. 2). The specimen is housed in the collection of the Aquarium Piran.

Fig. 1: Specimen of Tonna galea, caught in the waters off Izola (Slovenia), kept in the Piran Aquarium (Photo: M. Rogelja).
Sl. 1: Primerek velikega sodca, ujetega v vodah okoli Izole (Slovenija) v piranskem akvariju (Foto: M. Rogelja).

RESULTS AND DISCUSSION

The species was easily recognized through external morphological characters such as shell, which is spiral in shape and globose, resembling a barrel. The colour is pale brown and homogenous. Shell aperture is large with its outside border damaged. The surface of the shell is covered with wide spiral ribs (Cossignani & Ardovini, 2011). Head and the muscular foot are rather large and beige coloured with irregular dark brown spots. The shell measured 155 mm and the oral aperture is 145 mm wide. The giant tun collected in 2015 measured 190 mm.

Published data on the occurrence of *Tonna galea* are very scarce in the Adriatic Sea. Stefano Chiereghin considered this species as very rare in the northern Adriatic already two centuries ago (Chiereghin, 2001). According to Coen (1933, 1937; in: Russo & Perini, 2016) *T. galea,* a species which used to be rather common, seems to face the threat of extinction.

More recently the giant tun was recorded in Montenegro (Petović *et al.,* 2017), in Croatia (*e.g*. Zavodnik *et al.,* 2006) and in Italy (Cossignani *et al*., 1992). Even more rare is considered in its northern part. In fact, the majority of available faunistic surveys on mollusks or invertebrates did not mention this species for areas of northern Adriatic Sea (*e.g*. Zavodnik & Kovačić, 2000; Zavodnik *et al*., 2005; Kučić, 2016). In the eastern northern Adriatic, there are only few published records on this species. A specimen of *T. galea*, collected in August 1965 in waters off the island of Lošinj, is housed in the collection of the Natural History Museum of Rijeka (Croatia) (http://www.prirodoslovni.com/inventarna/). Another one was mentioned by Zavodnik *et al.* (2006) for the island of Pag. Other available data are known from local newspapers or social media. Those are dealing on cases of illegal hunting of giant tuns in the waters off Novigrad (Klobučar Opačak, 2013) and of finding of a specimen, stranded on a beach in Rovinj (Orlović Radić, 2016) which was after released back into the sea. In their comprehensive survey of mollusks in the Gulf of Trieste, Vio & De Min (1996) mentioned an empty shell caught by a fisherman in waters off Savudrija (Istria peninsula), but without any precise data. In the western part of the north Adriatic Sea *T. galea* was recently found in waters of Caorle (Venezia), when a juvenile specimen was caught by fishermen in a depth range from 25 to 30 m (Russo & Perini, 2016). Unfortunately, authors did not provide any information about the date of capture.

According to De Min & Vio (1996), at least 232 species of gastropods were recorded in the waters of Slovenia. However, authors focused their research mostly on shelled gastropods, so many seaslugs were not mentioned in their text. In a recently published monography on marine opisthobranchs in Slovenia, Lipej *et al*. (2018) reported 141 species. By analysing both checklists and by including *T. galea* in the list, at least 370 gastropod species were up to date recorded in the Slovenian part of the Adriatic Sea.

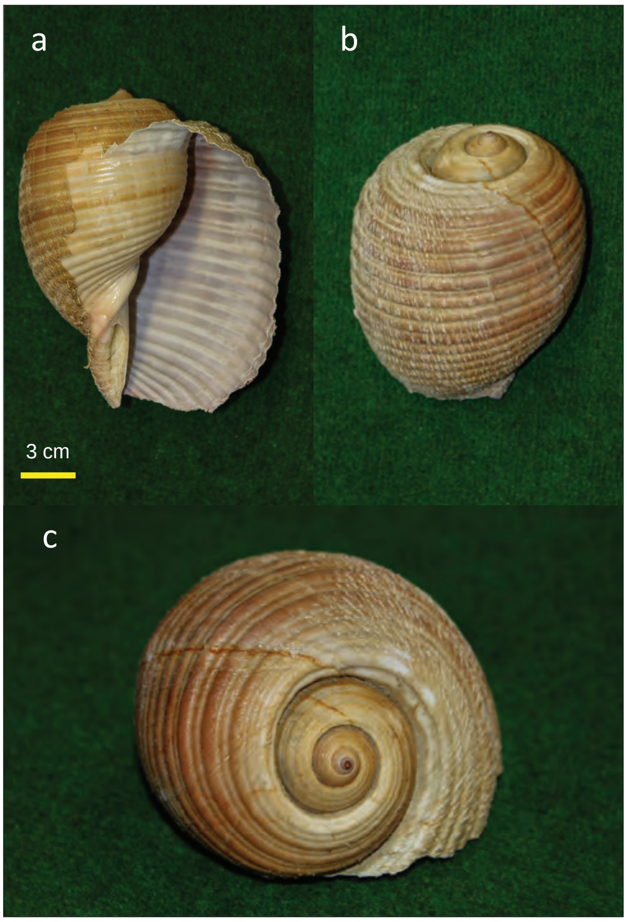

Fig. 2: Shell of the studied specimen of Tonna galea, caught in the waters off Slovenia (Photo: M. Rogelja).
Sl. 2: Lupina ujetega primerka velikega sodca, ujetega v vodah okoli Izole (Slovenija) v piranskem akvariju (Foto: M. Rogelja).

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POJAVLJANJE VELIKEGA SODCA, *TONNA GALEA* (LINNAEUS, 1758) (GASTROPODA: TONNIDAE) V MORSKIH VODAH SLOVENIJE (SEVERNI JADRAN)

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POVZETEK

*Prvega decembra je lokalni ribič približno 1 Nm pred Izolo v ribiško mrežo ujel primerek velikega sodca (*Tonna galea*). Mreža je bila postavljena v globini 20 m nad muljastim dnom. To je drugi zabeležen primer pojavljanja velikega sodca v slovenskih vodah (Tržaški zaliv, severni Jadran). Pred tem je bil en primerek te vrste (prvi zapis o pojavljanju) ujet v vodah blizu Pirana oktobra 2015. Upoštevaje nov podatek je seznam morskih polžev v slovenskem delu Jadranskega morja bogatejši še za eno vrsto in zdaj šteje najmanj 370 vrst.*

Ključne besede: veliki sodec, morska malakofavna, drugi zapis o pojavljanju, Tržaški zaliv, Jadransko morje

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SPATIAL DISTRIBUTION OF THREE SPECIES OF *PALAEMON* SHRIMP (CRUSTACEA: DECAPODA: CARIDEA) IN BADAŠEVICA RIVER (SW SLOVENIA)

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ABSTRACT

We investigated the presence, spatial distribution and possible co-existence of Palaemon *species from Badaševica river and its draining channels. We used inverted bottles with a bait to trap the shrimp and recorded three species (*P. elegans, P. adspersus, P. antennarius*) from six out of seven surveyed localities. The localities mostly differed in distance from the coastline (0–3.6 km) and salinity (3.9–36.2), while high variation was recorded in other hydrological, physio-chemical and biochemical parameters among the localities and species.* P. elegans *was present only at the river mouth at salinity of 33.2, while* P. antennarius *was predominantly found at localities in a distance more than 2 kilometres inland.* P. adspersus *was most common and prevailed at localities with denser vegetation. Although* P. adspersus *and* P. elegans *were both found at a single locality, their microhabitat clearly differed (*P. elegans *was recorded exclusively at the river mouth,* P. adspersus *ca. 50 metres inland). A single specimen of* P. antennarius *was trapped together with* P. adspersus *but in general their spatial and ecological segregation was well expressed. Presence of ovigerous females in brackish environment was confirmed* for P. adspersus *and* P. antennarius. *Males outnumbered females in all three species.*

Key words: brackish environment, spatial segregation, co-occurrence, Palaemonidae, salinity

DISTRIBUZIONE SPAZIALE DI TRE SPECIE DI GAMBERI DEL GENERE *PALAEMON* (CRUSTACEA: DECAPODA: CARIDEA) NEL FIUME CORNALUNGA (SLOVENIA SUD-OCCIDENTALE)

SINTESI

Gli autori hanno studiato la presenza, la distribuzione spaziale e la possibile coesistenza di specie del genere Palaemon *nel fiume Cornalunga e nei suoi canali di drenaggio. Con l'uso di bottiglie rovesce con un'esca, hanno intrappolato tre specie di gamberetti (*P. elegans, P. adspersus, P. antennarius*) in sei delle sette località campionate. Le località sono posizionate a distanze differenti dalla costa (0-3,6 km), con diverse salinità (3,9-36,2) e ampie differenze pure negli altri parametri idrologici, fisico-chimici e biochimici tra località e specie.* P. elegans *è presente solo alla foce del fiume (salinità pari a 33.2), mentre* P. antennarius *è presente prevalentemente in località a una distanza maggiore ai 2 km verso l'entroterra.* P. adspersus *è più comune, trovato prevalentemente in località con vegetazione più densa. Sebbene* P. adspersus e P. elegans *sono stati trovati in una sola località, il loro microhabitat differisce chiaramente (*P. elegans *presente esclusivamente alla foce del fiume, metre* P. adspersus *a circa 50 metri di distanza verso l'entroterra). Un singolo esemplare di* P. antennarius è stato trovato *intrappolato insieme a* P. adspersus*, ma in generale la loro segregazione spaziale ed ecologica* è *ben espressa. La presenza di femmine ovigere in ambiente salmastro è stata confermata per* P. adspersus e P. antennarius. *Per tutte le specie i maschi campionati superavano in numero le femmine.*

Parole chiave: ambiente salmastro, segregazione spaziale, co-occorrenza, Palaemonidae, salinità

INTRODUCTION

Palaemonidae are diagnosed by the size of their second chelipeds that are always larger (in some species slightly and in other extremely) than the first chelipeds (Bauer, 2004; De Grave *et al.*, 2008; Christodoulou *et al.*, 2016). The genus *Palaemon* consists of 87 species (De Grave & Ashelby, 2013; Carvalho *et al.*, 2014; Tzomos & Koukouras, 2015), however there are only two genera and 14 species in the Palearctic region (De Grave *et al.*, 2008; Tzomos & Koukouras, 2015). In Slovenia, five species of Palaemonidae shrimps are reported (Manning & Stevčić, 1982; Christodoulou *et al.*, 2016), although this family is one of the most speciose within the Caridea (de Grave *et al.,* 2008; Christodoulou *et al.*, 2016) following the Atyidae (43 genera) with 14 genera in total (Christodoulou *et al.*, 2016).

Among them, three species were known to penetrate rivers and channels, but only *Palaemon anntenarius* H. Milne Edwards, 1837 is treated as a predominantly freshwater species inhabiting lakes and rivers. Nevertheless, it can sometimes be found also in coastal brackish waters such as lagoons and estuaries in the Mediterranean basin (Holthuis, 1961; d'Udekem d'Acoz, 1999; Falciai & Palmerini, 2002; Gottstein-Matočec & Kerovec, 2002). This species is on the list of protected species in Slovenia (Decree on protected wild animal species: Anonymous, 2004). *Palaemon adspersus* Rathke, 1837 and *Palaemon elegans* Rathke, 1837 are predominantly marine species but can be found in anchialine waters, and they can sometimes co-occur (Manning & Stevčić, 1982). In Slovenia, they were found together in few localities in the areas of tidal flats, where another *Palaemon* species, *P. xiphias* (Risso, 1816) can also occur (Manning & Stevčić, 1982). *Palaemon serratus* (Pennant, 1777), a fifth palaemonid species from Slovenia, is frequently reported from the coastal marine environments (Turk & Richter, 2007).

In total, there are only three small rivers with direct outflow into the Adriatic Sea in Slovenia: Dragonja at the border with Croatia in the south, Rižana outflowing into the port of Koper in the north, and Badaševica that is flowing through the artificial channel throughout its lower flow, while in its upper part it flows through agricultural landscape. Spring of Badaševica that was our focal river is at 196 m above sea level and reach the Bay of Koper after 9.5 kilometres with a gradient of only 2.07 %. In its lower part, gradient is even lower, only 0.14 % during the last 2.2 kilometres before the outflow. Owing to its torrential nature, floods were frequent in its lower part, therefore the river channel was highly changed and redirected; the river banks were walled or covered with stone blocks and many draining channels were constructed since 1950s (Plut, 1979). Badaševica had its old channel outflowing in the San Canziano bay, however an artificial new main and some side (draining) channels were constructed south of it and the river has now its main outflow in the Bay of Koper (Plut, 1979). All three main rivers of the Slovenian part of Adriatic basin potentially contribute to the pollution of the gulf of Trieste (Turk, 2016). At their estuaries, freshwater and marine systems are interacting, and anchialinae water is present. According to salinity, habitat categories can be divided in freshwater (i.e. limnetic: 0–0.5) and saline (oligohaline: 0.5–5; mesohaline: 5–15; polyhaline: 18–30; mixohaline: 30–40) environments (Jones & Hallin, 2010).

In the present study we provide the information on spatial distribution of three species of *Palaemon* within

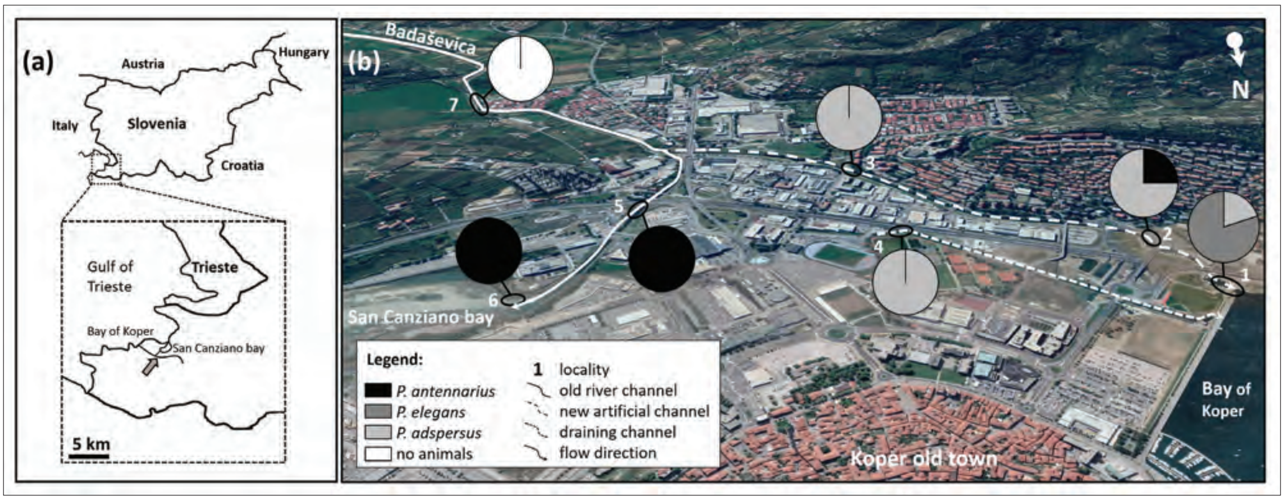

Fig. 1: Geographical position of Badaševica river (arrow) in Slovenia (a) and sampling localities with proportions of sampled Palaemon ***species (b) (map adjusted and redrawn from Google Earth).***
Sl. 1: Geografski položaj reke Badaševice (puščica) v Sloveniji (a) in vzorčna mesta s prikazanimi razmerji ujetih vrst iz rodu Palaemon ***(b) (prirejeno po Google Earth).***

Tab. 1: Sampling localities (S) with hydrological, biological, physio-chemical and biochemical parameters (min–max value) in Badaševica river.
Tab. 1: Vzorčna mesta (S) z razponom hidroloških, bioloških, fizikalno-kemijskih in biokemijskih parametrov v reki Badaševici.

S	Geographic coordinates	Distance of traps from the sea [m]	Channel type	Substrate	Vegetation	Tidal influence	T [°C]	Oxygen [mg/L]	Oxygen [%]	pH	Conductivity [mS/cm]	Salinity	Nitrates [mg/L]	Chl a [μg/L]
1	45°32′32.8″N 13°43′11.4″E	0–80	new artificial channel	silt, mud, rocks, walled	exposed, some different algae	strong	11.1–25.9	7.08–11.75	86.3–116.8	8.05–8.09	16.1–50.2	13.2–33.2	42.3–195.5	0.40–8.10
2	45°32′25.5″N 13°43′14.9″E	250–300	new artificial channel	silt, mud, rocks, walled	some filamentous algae	strong	11.2–25.7	7.16–12.19	87.0–124.0	8.05–8.14	13.1–50.5	10.5–32.6	35.4–196.5	0.61–25.33
3	45°32′09.4″N 13°43′45.8″E	1130–1150	new artificial channel	rocks (artificial), walled (incl. bottom)	some filamentous algae	medium	12.1–25.6	7.09–12.46	86.0–127.4	8.06–8.33	4.16–50.4	3.0–36.2	14.2–193.0	1.90–33.66
4	45°32′23.1″N 13°43′45.3″E	780–820	draining channel	silt, mud	some phylamentous algae, *Phragmites*	low	11.4–25.7	9.31–11.34	102.1–130.6	7.62–8.06	16.46–42.0	6.3–12.7	40.3–130.5	1.41–33.91
5	45°32′16.2″N 13°44′12.1″E	2110–2160 (B*) 3520–3570 (SC*)	old channel	silt, mud	dense filamentous algae	low	13.5–27.1	7.81–15.34	85.3–145.8	8.15–8.20	25.20–47.4	9.5–13.7	59.1–173.5	3.14–34.61
6	45°32′28.7″N 13°44′20.3″E	2500–2550 (B) 3050–3100 (SC)	old channel	silt, mud	filamentous and other algae	low	17.8–28.9	15.34–21.72	175.4–227.2	8.33–8.70	27.1–45.6	15.7–33.9	68.6–151.0	4.41–16.78
7	45°31′48.0″N 13°44′40.0″E	2550–2610	old channel	silt, mud, concrete, small rocks, walled	algae in periphyton	none	10.0–28.4	6.16–11.80	78.5–125.3	7.80–8.30	0.63–38.4	3.9–22.7	0.94–138.5	3.66–41.71

*B – distance measured through new Badaševica channel to open sea; SC – distance measured through San Canziano bay to open sea a single river system (Badaševica in SW Slovenia) and discuss possible environmental factors influencing their spatial distribution.

MATERIAL AND METHODS

Specimens were collected with trapping at seven localities (Fig. 1) of Badaševica river and its draining channels from the outflow (locality 1) to artificial barrier 2.6 km inland (locality 7) (Fig. 1, Tab. 1). Locality 7 was situated below a two metres high artificial dam, hence no traps were set upstream from the dam. Three plastic bottles (volume 1.5 l) with inverted opening were used per locality and the distance from the sea of each trap was measured (Tab. 1). Crushed mussels (*Mytillus galloprovincialis*) and chicken meat were used as bait and trapping lasted for four days during four sampling sessions in spring 2017. Samples were collected once per month in middle March, April, May and June. Sampling localities were georeferenced using a GPS and physicochemical water quality parameters (dissolved oxygen (mg*L^{-1}), oxygen saturation (%), water temperature (°C), conductivity (mS*cm^{-1}), and pH) were measured using a Portable multiparameter Aquaprobe AP-200 with a GPS Aquameter (Aquaread AP 2000). At each locality, sediment type and tidal influence (strong, medium, low, none) were assessed by naked eye (Tab. 1). Samples of water were transferred into the laboratory and chlorophyll a (μg*L^{-1}) was measured shortly afterwards. Salinity was calculated from water temperature and conductivity. Distance from the sea was measured from orto-photo maps for each sampling locality as a range of distances between the three traps.

Specimens were identified using the Olympus SZX7 stereomicroscope with a built-in camera. The identification key of González-Ortegón & Cuesta (2006) was used for species identification. Presence of ovigerous females and male-female ratio were checked. Nomenclature follows De Grave & Ashelby (2013).

RESULTS

Main observations and measurements on the hydrological and physio-chemical parameters at seven sampling localities are compiled in Tab. 1. Altogether, three species were sampled during the study from localities 1–6, while no animals were recorded at locality 7 (Fig. 1, Tab. 2). Most animals were collected in April and May with 52.6 % and 31.6 % of the total sample size, respectively, while in March and June only 7.9 % of the total sample size in each of those months was collected. *Palaemon adspersus* was most commonly sampled (69.7 % of sampled animals) and was found at four localities (1–4; see Tab. 2).

At locality 4, where only *P. adspersus* was recorded, animals counted for 50.0 % of the total sample size. The ranges of chemical parameters measured at each sampling day and locality overlap among the three species, however, oxygen levels (concentration and saturation) were bit higher at locality 6 (and sometimes at locality 5) than at the other localities. Moreover, the distance from the sea and salinity greatly differ among the localities (Tab. 1). With time (i.e. consecutive sampling periods), *P. adspersus* was recorded progressively further from the coastline (Tab. 2). While it was recorded from localities 1, 2 and 4 (50–820 metres from the coastline) in March, it was found at localities 2, 3 and 4 (250–1150 metres inland) in April, and only at localities 3 and 4 (780–1150 metres inland) during May and June. *P. elegans* (5.3 % of total sample) was found only in one (outermost) of the three traps at the river mouth (locality 1) where salinity at the sampling day was 33.2, which is almost as high as salinity reported for the northern Adriatic Sea (approx. 38–39, *e.g.* Grbec *et al.*, 2007). *P. adspersus* was recorded together with *P. elegans* at locality 1, however it was found there in another trap that was set 50 m from the river mouth, at salinity of 13.2. In total, *P. adspersus* was found 50–1150 m inland, at salinity range 3.2–36.2. *P. antennarius* (25.0 % of total sample size) was found at longest distance from the sea, i. e. at two localities (5, 6) that are situated more than 2 kilometres from the coastline, with salinity range 19.0–30.9. Nevertheless, a single specimen of *P. antennarius* was found also at locality 2 (ca. 300 metres from the coastline) together with *P. adspersus* at salinity 10.5. As in *P. adspersus*, recordings of *P. antennarius* progressed further inland with time (Tab. 2). While the species was recorded at locality 2 in March, it was later recorded only from localities 5 (April, May; ca. 2.1 kilometres from the coastline) and 6 (June; ca. 2.5 kilometres from the coastline).

During April and May, presence of ovigerous females was confirmed for *P. adspersus* (2 and 5 females at localities 2 and 4, respectively) and *P. antennarius* (4 females at locality 5) but not for *P. elegans*. Males outnumbered females in all three species (100 % of males in *P. elegans*, 75.0 % in *P. antennarius* and 78.4 % in *P. adspersus*).

DISCUSSION

We report on a presence and spatial segregation of three *Palaemon* species (*P. adspersus*, *P. elegans*, *P. antennarius*) in Badaševica river and channels nearby. Nevertheless, *P. adspersus* and *P. elegans* are frequently reported from the same environments (Berglund & Bengtsson 1981; Łapínska & Szaniawska 2006; Janas 2013). In estuaries with a low tidal influence both can inhabit meadows of *Zostera marina*, however, Berglund (1980; 1982) reports that in a latter case *P. adspersus* is more abundant, possibly due to larger body size in comparison to *P. elegans*. Moreover, a spatial co-occurence of three species of *Palaemon*, *P. antennarius*, *P. adspersus* and *P. varians* with an ecological niche separation within *Phragmites australis* was reported by Dolmen *et al.* (2004). In this case, *P. adspersus* and *P. elegans* occurred

Tab. 2: A list of species per each sampling locality (S), sampling date (month, in roman numerals) and number of sampled shrimps together with physio-chemical and biochemical parameters measured at each successful sampling.
Tab. 2:. Seznam vrst po vzorčnih mestih (S) s podatki o datumu vzorčenja (mesec, označeno z rimskimi številkami) in številu zbranih kozic ter vrednostmi fizikalno-kemijskih in biokemijskih parametrov ob vsakem uspešnem vzorčenju.

S	**Species**	**Month**	**No.**	**T [ºC]**	**Oxygen [mg/L]**	**Oxygen [%]**	**pH**	**Conductivity [mS/cm]**	**Salinity**	**NO$_3$ [mg/L]**	**Chlorophyll a [µg/L]**
1	*P. adspersus*	III	1	11.1	10.44	94	8.09	16.08	13.2	42.3	8.10
	P. elegans	V	4	20.5	9.17	101.3	8.08	45.7	33.2	144.5	3.67
2	*P. adspersus*	III	1	11.2	10.23	92.1	8.14	13.1	10.5	35.4	25.33
		IV	2	16.2	12.19	124	8.13	35.9	27.8	104.5	4.42
	P. antennarius	III	1	11.2	10.23	92.1	8.14	13.1	10.5	35.4	25.33
3	*P. adspersus*	IV	4	16.4	12.46	127.4	8.33	4.97	3.2	26.1	18.92
		V	5	20.4	10.50	111.2	8.13	49.8	36.2	123.5	1.90
		VI	1	25.6	7.09	86.0	8.06	50.4	32.6	193.0	2.88
4	*P. adspersus*	III	3	11.4	11.34	102.9	8.06	16.5	13.4	40.3	18.03
		IV	26	16.8	9.91	102.1	7.95	27.3	20.3	77.1	33.91
		V	8	24.4	9.31	110.6	7.99	42.0	27.3	96.7	1.41
		VI	1	25.7	10.76	130.6	7.62	34.2	21.1	131.5	5.88
5	*P. antennarius*	IV	8	19.6	7.82	85.3	8.17	42.5	30.9	120.5	34.61
		V	7	25.9	8.68	106.0	8.15	31.2	19.0	79.2	3.14
6	*P. antennarius*	VI	4	28.9	15.72	202.2	8.33	39.8	23.3	151.0	15.11

in a microhabitat with lower and *P. varians* with higher density of *P. australis* (Dolmen *et al.*, 2004). On the other hand, where a tidal influence is strong, *P. adspersus* and *P. elegans* in most cases select different microhabitats (Dolmen *et al.*, 2004). In our case, selection of different microhabitats of the two species would be in line with observations of a strong tidal influence at our localities; whereas *P. elegans* was found only at the final point of the riverine mouth, *P. adspersus* occupied brackish part of the river up to approx. one kilometre from the coastline. Both species usually prefer well aerated systems with salinity higher than 15 (mostly polyhaline and mixohaline environments) (Barnes, 1994; Dolmen *et al.*, 2004).

Despite that there are records of occurrence of *P. elegans* below 6.5 of salinity from the Baltic sea (mesohaline to oligohaline waters; Dolmen *et al.*, 2004; Łapínska & Szaniawska, 2006), both species are euryhaline, however in Badaševica only *P. adspersus* was found in a wide range of salinity (oligohaline to mixohaline). During our study, *P. elegans* was found only in mixohaline water. Berglund & Bengtsson (1981) reported that *P. elegans* is more prone to hypoxy than *P. adspersus*. In our case, oxygen levels were similar for a locality with *P. elegans* and for localities with *P. adspersus*. Therefore, we cannot see the oxygen as a factor influencing spatial segregation of the two species in our case. Both species are mainly nocturnal (Berglund 1980; Hagerman & Ostrup, 1980; Guerao & Abello, 1996; Janas & Baranska, 2008), however pronounced nocturnal activity is usually less stressed in *P. adspersus* (Berglund, 1980; Hagerman & Ostrup, 1980). Since *P. elegans* is not a habitat specialist, more prone to hypoxia, more active and quicker in feeding than *P. adspersus*, it can occupy sites that are not preferential for stronger and larger *P. adspersus* (Berglund & Bengtsson, 1981). Especially when found in marine environments, *P. adspersus* prefers meadows of marine flowering plants (e.g. *Posidonia*, *Zostera*, *Cymodocea*) (Manent & Abella-Gutiérrez, 2006), while *P. elegans* can be abundant also at sandy and unprotected bottom (Berglund & Bengtsson, 1981). This could be in line with our case as the environment at the site with *P. elegans* was open and unprotected. Moreover, we recorded *P. adspersus* only at localities where dense vegetation was present. It should be noted that *P. adspersus* was by far most abundant at the end of a draining channel at locality 4 (73.1 % of a *P. adspersus* sample) with densest vegetation. Since it has been reported that *P. adspersus* rather avoid open spaces since it can be quickly detected by the predators owing to its large size, this locality seemingly offers this species an optimal habitat and reproduction site, and is probably lacking shrimp predators. Moreover, at the localities closest to the coastline (1, 2), shrimps were found only at the beginning of the sampling period (at locality 1, a single specimen in March, and at locality 2, a single and two specimens in March and April, respectively). No additional animals were found there during the continuation of the sampling period (May, June), and a species reached a peak of abundance in April at locality 4 (50.0 % of a *P. adspersus* sample).

P. anntenarius represented 25.0 % of the total sample size and was found in two localities where neither of the above mentioned species occurred. *P. antennarius* is reported to be oligohaline species that inhabits freshwater to brackish environments with muddy bottom. Most commonly it is mentioned as a true freshwater species (Dalla Via, 1987; Gottstein-Matočec *et al.*, 2006; Anastasiadou *et al.*, 2009, 2014; Christodoulou *et al.*, 2016). During our study it was found in mesohaline and polyhaline waters and always above 15 of salinity, however, this is not contradicting its euryhaline nature as Dalla Via (1987) reports that it can be found at a wide range of salinity from 5 to 30. This species can adapt to quick salinity changes by metabolic adjustment if the changes in salinity are short-termed, while at higher salinities (>19) oxygen uptake strongly increases. Populations that inhabit brackish environments with higher salinity can adapt up to approximately 25 of salinity but in the same time brackish populations cannot easily adapt to low salinities (Dalla Via, 1987). This is in line with our results as this species was found at the range of salinity above 10.5 (but even higher than reported in literature, up to 30.9) and most abundant at the two localities (5, 6) with highest oxygen levels. Gottstein-Matočec *et al.*, 2006 reported that *P. antennarius* shows higher reproductive success in environments with stable salinity, however during the reproductive period brackish waters were preferred (Dalla Via, 1987; Gottstein-Matočec *et al.*, 2006) over waters with lower salinity in delta of Neretva (SE Croatia). Sheltered bays with stable environment (low tidal influence, stable salinity, warm temperature, abundance of food) and muddy bottom can therefore be optimal for the reproduction of the species, such as probably at localities 5 and 6 in our case where it was recorded after the beginning of its breeding season in April. Nevertheless, a single specimen of *P. antennarius* was found before the breeding season in March also at locality 2 in the main channel of the Badaševica river, in this case together with *P. adspersus*. We failed to find the data on a sympatric occurrence of those two species in the literature, so we think this co-occurence was coincidetial. However, we cannot exclude the option that *P. antennarius* can occasionally be present in the main channel of the river, possibly due to drift or active spreading of the species.

Sex ratio in our samples strongly deviates towards males and this contradicts the reports for all three species where females are usually more abundant (Gottstein-Matočec *et al.*, 2006; Łapínska & Szaniawska, 2006; Manent & Abelle-Gutiérrez, 2006). *P. adspersus* for which a reproductive period lasts from March to August (Guerao & Ribera, 1995; Manent & Abella-Gutiérrez, 2006) females were frequently noticed to lay eggs in shallow coastal marine waters (Barnes, 1994; Guerao & Ribera, 1999; Glamuzina *et al.,* 2014). Nevertheless, we noticed some ovigerous females in the river channel itself (28.6 % of all ovigerous females at locality 2), however, it is possible that some of them move towards the sea for egg laying which could cause their deficit upstream. Since most of ovigerous *P. adspersus* females (71.4 %) were found at locality 4 it is also possible that ovigerous females seek for protected and well-hidden places where they remain for the most of time. Hence, their trapping probability could be lower than for males and estimated sex ratio is then biased towards males. In *P. antennarius*, reproductive period lasts from April until August with a maximum in June (Gottstein-Matočec *et al.*, 2006). This is in line with our data for Slovenian mesohaline and polyhaline environments, while no conclusions can be made on unusual sex ratio in *P. antennarius* (but see above for *P. adspersus*) and *P. elegans*. For the latter, a small sample size may prevent a more accurate conclusion.

CONCLUSIONS

In this study we reported on a well expressed spatial and ecological segregation among three species of *Palaemon* in a brackish environment of a river Badaševica. The following conclusions can be made:

1. *P. elegans* and *P. adspersus* select different habitats near the river outflow that is under a strong tidal influence (*P. elegans* occupies more exposed rocky bottom at higher salinity at the final point of the outflow, and *P. adspersus* is present at a microsite with lower salinity in a better protected river channel only few tens of meters inland);
2. *P. antennarius* and *P. adspersus* seem to be ecologically and spatially well separated as the vast majority of *P. adspersus* was found in a drainage channel and upper the river channel with dense vegetation (mostly macrophytes), and *P. antennarius* was found predominantly at sites more than 2 kilometres inland with low tidal influence in a well aerated water;
3. Presence of ovigerous females was confirmed for *P. adspersus* and *P. antennarius*.

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PROSTORSKA RAZPOREDITEV TREH VRST KOZIC IZ RODU *PALAEMON* (CRUSTACEA: DECAPODA: CARIDEA) V BADAŠEVICI (JZ SLOVENIJA)

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POVZETEK

Preiskovali smo prisotnost, prostorsko razporeditev in možnost sobivanja vrst iz rodu Palaemon *v reki Badaševici in njenih odvodnih kanalih. Za pasti smo uporabili plastenke z navznoter obrnjenim ustjem. Zabeležili smo tri vrste (*P. elegans, P. adspersus, P. antennarius*) s šestih od sedem preiskovanih vzorčnih mest. Vzorčna mesta so se najbolj razlikovala po oddaljenosti od morja (0–3.6 km) in slanosti (3.9–36.2), pri ostalih beleženih hidroloških, fizikalno-kemijskih in biokemisjkih parametrih pa smo zabeležili veliko stopnjo variabilnosti tako med vzorčnimi mesti kot vrstami kozic.* P. elegans *smo zabeležili le na ustju reke pri slanosti 33.2,* P. antennarius *pa smo skoraj izključno našli le na vzorčnih mestih, ki so od morja oddaljena več kot 2 km.* P. adspersus *je bila najštevilnejše zastopana vrsta in se je pojavljala v velikem številu predvsem na lokacijah z gosto vegetacijo. Čeprav smo* P. adspersus *in* P. elegans *našli na istem vzorčnem mestu ob izlivu reke v morje, smo opazili, da se izbira njunega mikrohabitata razlikuje (*P. elegans *smo našli neposredno na izlivu reke v morje,* P. adspersus *pa smo zabeležili prb. 50 m po toku navzgor).* P. antennarius *smo le enkrat (en osebek) našli na eni od vzorčnih mest skupaj s* P. adspersus*, a je bila sicer prostorska in ekološka ločitev med vrstami jasno vidna. Prisotnost ovigerih samic smo potrdili za vrsti* P. adspersus *in* P. antennarius. *Samci so bili pri vseh treh vrstah številnejši od samic.*

Ključne besede: somorno okolje, prostorska ločitev, sobivanje, Palaemonidae, slanost

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MISCELLANEA

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ABIOTIC PARAMETERS IN TUNIS SOUTHERN LAGOON AFTER AN ENVIRONMENTAL RESTORATION AND STATUS OF MACROBENTHIC BIOCENOSIS (NORTHERN TUNISIA, CENTRAL MEDITERRANEAN SEA)

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ABSTRACT

Tunis Southern Lagoon was previously polluted by anthropogenic activities which needed a thorough environmental restoration, achieved during September 2001. The aim of the work is to reveal the positive changes of the abiotic parameters and their role on the biodiversity of the lagoon. Ecological measures carried out during a 24-months period (from October 2014 to September 2016) at 3 fixed stations, showed an improvement in water quality, confirming the positive impact of the restoration project. An overview of the macrobenthic biocenosis evolution is also discussed in the present work.

Key words: Eutrophication, restoration, improvement, water quality, biodiversity

PARAMETRI ABIOTICI NELLA LAGUNA MERIDIONALE DI TUNISI DOPO IL RESTAURO AMBIENTALE E STATO DELLA BIOCENOSI MACROBENTONICA (TUNISIA SETTENTRIONALE, MEDITERRANEO CENTRALE)

SINTESI

In passato la Laguna meridionale di Tunisi è stata contaminata da varie attività antropogeniche e pertanto necessitava di un accurato restauro ambientale, effettuato nel settembre 2001. L'articolo vuole evidenziare i cambiamenti positivi dei parametri abiotici e il loro ruolo sulla biodiversità della laguna. Le misure ecologiche effettuate nel corso di un periodo di 24 mesi (da ottobre 2014 a settembre 2016) in 3 stazioni fisse, hanno mostrato un miglioramento della qualità dell'acqua, confermando l'impatto positivo del progetto di restauro. Nel presente lavoro viene anche presentata una revisione dell'evoluzione della biocenosi macrobentonica.

Parole chiave: eutrofizzazione, restauro, miglioramento, qualità dell'acqua, biodiversità

INTRODUCTION

In the last decades, Tunis Southern Lagoon was polluted by local anthropic activities which induced dystrophic crises together with destruction of benthic communities (Ben Souissi, 2002; Chakroun, 2004), due to the fact that this lagoon poorly communicated with the sea. Water renewal was low, and a hyper-eutrophication and contamination by toxic heavy metals occurred in this brackish restricted area. An environmental rehabilitation of the lagoon was decided by Tunisian authorities to limit eutrophication and contamination by toxic industrial discharges. The project also aims to improve biodiversity and gradually restore fishery activities in the lagoon (Ben Souissi *et al*. 2015). The project of restoration was conducted between April 1998 and July 2001 by the Society for Research and Promotion of Tunis (SEPTS) and the consortium (LAC SUD 2000) (Vandenbroek and Ben Charrada 2001). The environmental restoration focused the enlargement the depth of the canal joining the lagoon to the sea and installing a hydraulic system allowing frequent renewal of the waters of the lagoon and the elimination of areas of water stagnation. The main objective of this study consists to analyze the new ecological status of this ecosystem based on 2 years of measurements locally carried out. An overview on its macrobenthic flora and the fishing interest fauna is discussed in this paper to point out the impact of ecological restoration on the biological environment.

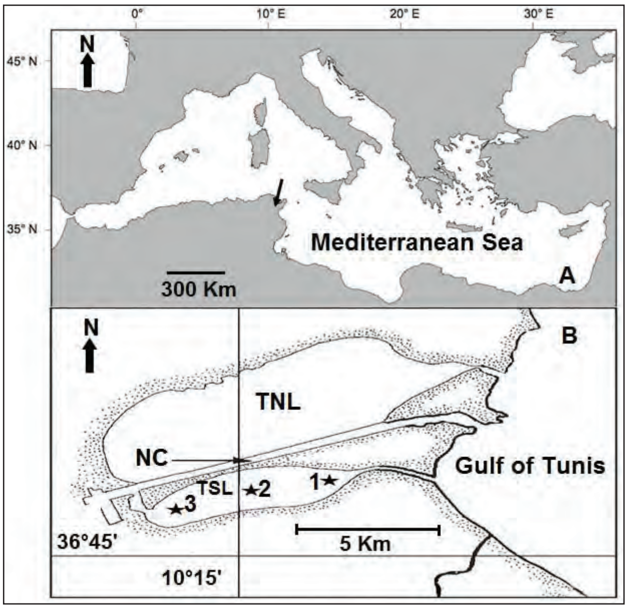

Fig. 1: A. Map of Tunisia pointing out the site of Tunis Southern Lagoon (TSL) located in the north. B. Tunis Northern Lagoon (TNL) separated from Tunis Southern Lagoon by a navigation channel (NC).1-3 sampling stations in TSL.

Sl. 1: A. Zemljevid Tunizije z označeno južno tuniško laguno (TSL) na severu. B. Severna tuniška laguna je od južne omejena s plovnim kanalom (NC). 1-3 Vzorčevalne postaje v TSL.

MATERIAL AND METHODS

The Lagoon of Tunis is separated in two areas by a navigation canal (Fig. 1). Tunis Southern Lagoon extends over an area of 720 ha with an almost regular depth of about 2.4 m. It appears as an ellipse stretching in a SW-NE direction, between 36°46′47″and 36°48′00″N and 10°12′22″ and 10°16′41″E. Its shores have been excavated and protected by large rocky blocks. Three sampling stations are located in the lagoon and indicated by; Station 1 located to the east of the lagoon near the bay of Tunis, station 2 in the middle and station 3 in the west (Fig. 1). To access to these stations, a flat bottom boat suitable for navigation in the lagoon was used, the analyses consist of monthly measurements carried out *in situ* and in the laboratory during a 24 months from October 2014 to September 2016.

Temperature, salinity, pH, and dissolved oxygen were monthly measured at approximately 10 cm below the surface using a salinometer (WTW.LF 197), a pH meter (WTW. pH 197) and oximeter (WTW.OXI 197) calibrated beforehand. Turbidity was measured using a Secchi disk. In the laboratory, chemical analyzes of total nitrogen and phosphorus were analyzed in the laboratory by means of a photometric method which uses, as reagents, kits tests previously prepared by the supplier of the equipment. The basic tool of the photometric method is a photometer Photolab S12 type WTW equipped with a thermoreactor CR3000 type WTW. The chlorophyll-a was determined using the spectrophotometric method of Lorenzen (1967) and following Parsons *et al*. (1984), the analysis of the latter must be initiated rapidly (within 3 hours after sampling). The main results of two years of measurements are presented below. Data on macrobenthic fauna and flora were based on a compilation of published articles, thesis, surveys and our own observations in the last decade.

RESULTS

Temperature - The total average of 2 years of measurements is 20. 3 °C, the minima recorded vary between 9.8 and 11.8 °C and the maxima between 26.6 and 28 °C (Fig. 2). Temperatures recorded in station 1, near the Gulf of Tunis, show a slightly higher thermal gradient (1°C) compared to the other stations. This gradient is explained by the discharges of electric central near the water inlet to the lagoon, which discharge about 60 m^3s^{-1} of hot water. This difference is more appreciable in winter than in summer.

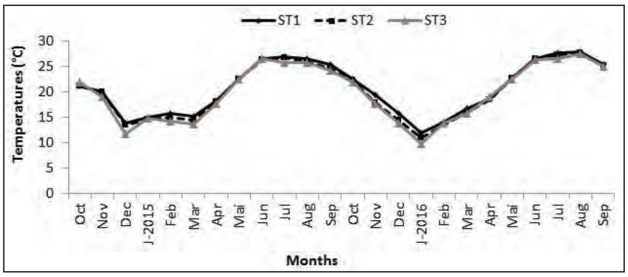

Fig. 2: Water temperatures in the Tunis southern lagoon (from October 2014 to September 2016)
Sl. 2: Temperatura vode v južni tuniški laguni (od oktobra 2014 do septembra 2016).

Salinity - The salinity in the lagoon is homogeneous. The mean value recorded during our study period is 37.5. The lowest exceptional salinities were 31.3 and 34.1 recorded respectively in September 2015 and February 2016 (Fig. 3). These values are recorded as a result of rainfall that caused storm water to enter the lagoon from the banks. The maximum salinity has reached a value of 39 recorded in July 2016 due to high temperatures that enhanced evaporation in the lagoon. With the exception of these values, salinity has varied with an annual gradient that usually does not exceed 1. This is mainly due to the rapid renewal of the lagoon water, which makes the effect of evaporation relatively low.

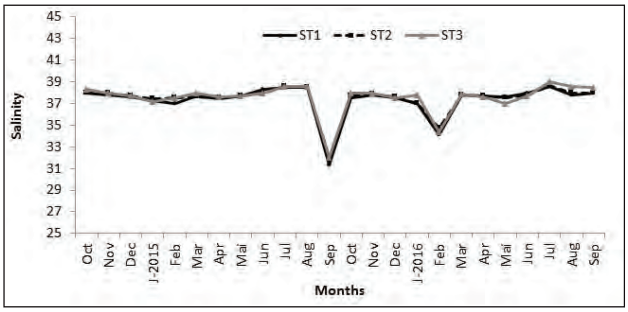

Fig. 3: Water salinity in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 3: Slanost v južni tuniški laguni (od oktobra 2014 do septembra 2016).

pH - The mean pH recorded in the southern lagoon over the period from October 2014 to September 2016 is 8.3, the maximum value is 9 while the minimum is 7.85 (Fig. 4). The relatively low values recorded in summer 2015 are mainly due to the exceptional warmth occurred during this period, which accelerate the fermentation and mortality of macroalgae inducing a relatively low pH. During the period of algal growth, the release of CO2 tends to increase this parameter.

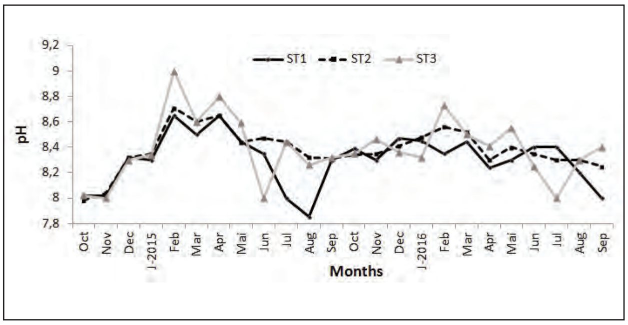

Fig. 4: Water pH in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 4: pH vode v južni tuniški laguni (od oktobra 2014 do septembra 2016).

Transparency - The average transparency of the water in the lagoon is about 2.0 m (Fig. 5). The lowest transparency values are recorded in station 1, which is largely influenced by the water in coming from the Gulf of Tunis. From station 2, the visibility conditions change and the influence of the gulf decreases considerably, the transparency is therefore better. The western part of the lagoon (ST3) represents the most transparent zone because it is less influenced by the gulf; moreover, it is constantly invaded by caulerpes, having roots sunk in the sediment, with a tendency to fix the materials on the bottom.

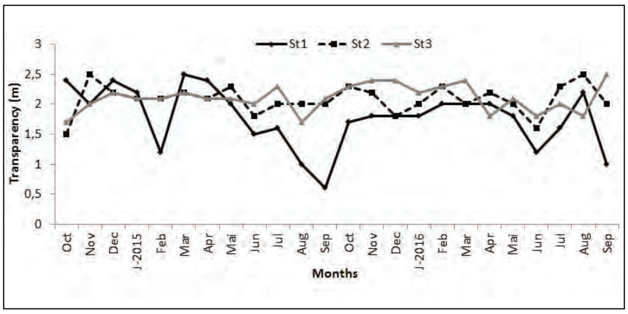

Fig. 5: Monthly fluctuations of Transparency (m) in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 5: Mesečna nihanja prozornosti (m) v južni tuniški laguni (od oktobra 2014 do septembra 2016).

Dissolved Oxygen - The dissolved oxygen contents range from 70 to 130%. The average of the two years of measurements in the lagoon is 90% (Fig. 6). The maximum values observed are due to the production of oxygen by photosynthesis of macroalgae and the minimum values observed are probably due to the mineralization of organic matter resulting from the mass mortality of nitrophilic algae.

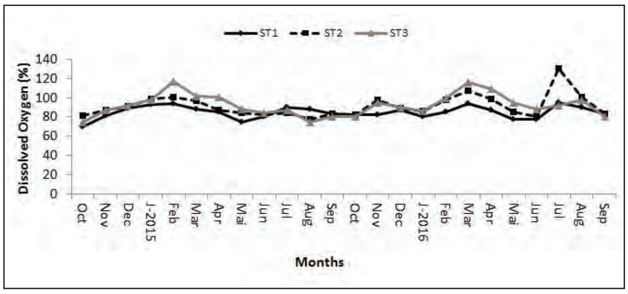

Fig. 6: Monthly fluctuations of dissolved Oxygen (%) in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 6: Mesečna nihanja koncentracij raztopljenega kisika (%) v južni tuniški laguni (od oktobra 2014 do septembra 2016).

Total Nitrogen - The average total nitrogen concentration over the two years is 674 µg/l. An extreme value of 1378 µg/l was recorded in November 2015 (Fig. 7). This rate coincided with the massive mortality of macroalgae in this month since the organic form of nitrogen constitutes about 89% of total nitrogen.

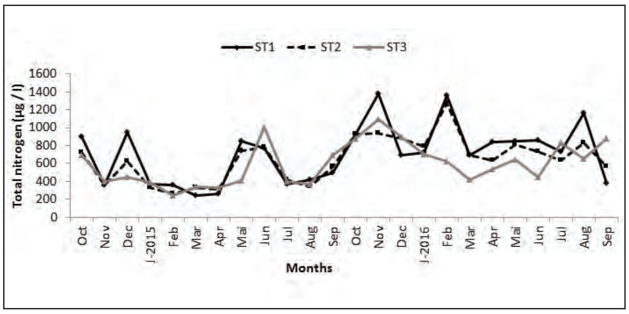

Fig. 7: Monthly fluctuations of total nitrogen (µg/l) in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 7: Mesečna nihanja koncentracij celokupnega dušika (µg/l) v južni tuniški laguni (od oktobra 2014 do septembra 2016).

Total phosphorus - The total phosphorus content range from 9 to 93 µg/l with an average of 32.7 µg/l (Fig. 8). The peaks are due either to the mortality of the macroalgae or to the action of the floods and rains that preceded the periods of these peaks and which brought large quantities of phosphate nutrients into the lagoon.

Chlorophyll-a - The Chlorophyll-a allow us to assess the degree of eutrophication of the water, in the Tunis southern lagoon, chlorophyll-a concentration varies from 0.28 to 14.88 µg/l (Fig. 9). The average of the two years relatively low at 2.5 µg/l.

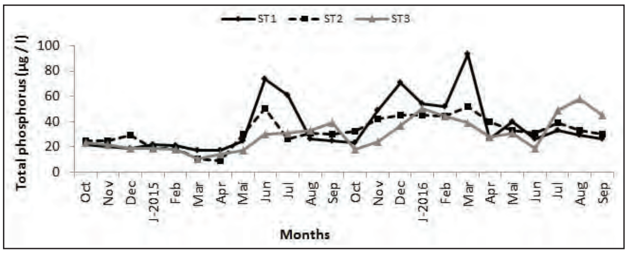

Fig. 8: Monthly fluctuations of total phosphorus (µg/l) in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 8: Mesečna nihanja koncentracij celokupnega fosforja (µg/l) v južni tuniški laguni (od oktobra 2014 do septembra 2016).

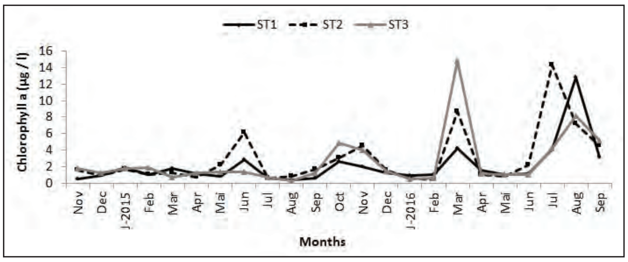

Fig. 9: Monthly fluctuations of Chlorophyll a (µg/l) in the Tunis southern lagoon (from October 2014 to September 2016).
Sl. 9: Mesečna nihanja koncentracij klorofila a (µg/l) v južni tuniški laguni (od oktobra 2014 do septembra 2016).

DISCUSSION

Prior the lagoon's ecological rehabilitation, the average monthly salinity ranged between 31 and 48.9 (Ben Souissi 2002), between 37 and 38.3, after environmental restoration. This comparison indicated that the euryhalin character of the lagoon is changed into "marinization" *sensu* Zaouali and Baeten (1983). High levels of dissolved oxygen in water trend towards an eutrophication, and to date since the end of environmental restoration, no dystrophic crisis was observed; the dissolved oxygen levels oscillate around the saturation point (Hermi & Aissa (2002); Chakroun, 2004). Monthly pH averages were saw-tooth fluctuations between 8.11 and 9.49 and may even reach very alkaline pH values as a result of spills of various chemical pollutants (Ben Souissi 2002). This parameter currently has a spatiotemporal stability since the minimum value did not drop below 8 and the maximum value did not exceed 8.4.

Based on the key parameters of eutrophication indicators: total phosphorus and chlorophyll-a, expressed as annual averages, the eutrophication status of the Tunis Southern Lagoon waters can be outlined. The report of these concentrations on the abacus following the model proposed by the OCDE (1982) showed that the waters of the Tunis southern lagoon are mesotrophic with a probability of 54% *versus* the hypereutrophic state observed before the restoration with a probability of 70% (Jouini *et al.,* 2005).

The restoration of the lagoon displayed a high increase of biodiversity, with occurrence of species of phanerogams and seaweed of marine origin. Among new established vegetation in the lagoon were found the endemic caulerpe *Caulerpa prolifera* (Forsskål) J.V.Lamouroux, 1809, and the brown algae *Cystoseira barbata* (Stackhouse) C.Agardh, 1820 indicator of a healthy ecosystem (Ben Souissi *et al*., 2015). Prior to restoration, the benthic macroflora was exhibited a very low biodiversity characteristic from eutrophic euryhalin and eurytherm facies dominated by *Ulva rigida* C.Agardh, 1823, typical of lagoon environments (Ben Souissi, 2002; Shili *et al*., 2002).

The lagoon azoic during its restoration was progressively invaded by several species, among them were found immigrants from Indo-Pacific origin established since autumn 2001 in the area with the start-up of locks and the restoration of communication with the sea (Gulf of Tunis) and the lagoon itself (Ben Souissi *et al.,* 2003).

The current malacological fauna of the lagoon is comprised 50 species of molluscs, 2 Polyplacophora, 28 gastropods (especially nudibranchs), 17 bivalves and 3 cephalopods *versus* only 29 species recorded before restoration (Eteres *et al*. 2011). Of these 50 species, 5 are allochthonous having an Indo-Pacific origin. The best instance is *Fulvia fragilis* (Forsskål & Niebuhr, 1775), which colonized and invaded the entire lagoon, with presence of juveniles and specimens up to 60 mm in width (Rifi *et al*., 2011; 2013).

Therefore, new activities have been developed such as the collection of mussel on artificial rocky banks of the lagoon and fishery of cephalopod species such as common cuttlefish *Sepia officinalis* Linnaeus, 1758 and musky octopus *Eledone moschata* (Lamarck, 1758).

A diversity of carcinological fauna was displayed in the lagoon comprising 44 crustacean species (19 decapods, 11 isopods, 10 amphipods, 3 barnacles and a single stomatopod) were recorded *versus* 29 before the ecological rehabilitation of the lagoon. Of these 44 species, 31 are autochthonous and 13 allochthonous (Ounifi Ben Amor *et al*. 2017). The presence of some species seems not to be transient since several of them were well established in the area (Ounifi Ben Amor *et al*., 2015; 2016a; 2016b).

The ichthyofauna is also much diversified and concomitantly allowed the resumption of fishing activities in area. Eight species of elasmobranch and more than 70 teleost species are recorded in the lagoon (Méjri *et al*., 2004; Ben Souissi *et al*., 2005). A survey carried out in 2014 among fishermen operating regularly in the lagoon shows that the local ichthyofauna included more than 90 species (Ben Souissi *et al*. 2015).

The physicochemical and trophic analyzes carried out before and after the restoration of Tunis southern lagoon, display a high water quality, stability and an improvement in edaphic environment of the lagoon. This homogenization observed after the ecological restoration is the consequence of an important exchange between the lagoon and the Gulf of Tunis. Such exchange and the absence of water stagnation in some areas have led to a marked disappearance of nitrophilous algae *versus* the reappearance of marine species. The successful settlement of these latter in Tunis southern lagoon revealed the evident improvement of the lagoon waters.

ABIOTSKI PARAMETRI V TUNIŠKI JUŽNI LAGUNI PO OKOLJSKI OBNOVI IN STATUS MAKROBENTOŠKIH BIOCENOZ (SEVERNA TUNIZIJA, OSREDNJE SREDOZEMSKO MORJE)

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POVZETEK

Južna tuniška laguna se je soočala z onesnaženjem zaradi antropogenih dejavnosti, zato je prišlo septembra 2001 do okoljske obnove. Namen tega prispevka je obelodaniti pozitivne spremembe v abiotskih dejavnikih in njihovo vlogo glede biodiverzitete v laguni. Ekološke meritve, ki so potekale v 24-mesečnem obdobju (od oktobra 2014 do septembra 2016) na 3 stalnih postajah, so pokazale izboljšanje kvalitete vode in s tem potrdile pozitivni učinek projekta obnove. Avtorji v delu razpravljajo tudi o makrobentoških biocenozah.

Ključne besede: evtrofikacija, obnova, izboljšanje, kvaliteta vode, biodiverziteta

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DELO NAŠIH ZAVODOV IN DRUŠTEV

ATTIVITÀ DEI NOSTRI ISTITUTI E SOCIETÀ

ACTIVITIES BY OUR INSTITUTIONS AND ASSOCIATIONS

PROTECTING ADRIATIC BIODIVERSITY IN KOTOR: THE CONGRESS ADRIBIOPRO 2019

An international conference on the protection of the biodiversity of the Adriatic Sea was held from 7th to 10th April 2019 in the town of Kotor, a small coastal pearl listed as a UNESCO World Heritage Site. The conference was organized by the Institute of Marine Biology of the University of Montenegro. It was the final event of the project "Marine Biodiversity Conservation Center 'Boka Aquarium' – MonteAqua", aiming to gather all relevant national and regional stakeholders, as well as to secure closer regional cooperation in the Adriatic region. During the four days filled with various activities, participants from 16 countries delivered 92 presentations covering 9 different topics: marine biodiversity conservation, conservation of coastal and marine areas, preventing marine pollution, rare and endangered species in the Adriatic Sea, invasive and alien marine species, roles of aquaria, sustainable use of marine resources, marine biotechnology, and freshwater biodiversity conservation.

The event opened with an exhibition by the talented underwater photographers Ivana Orlović Kranjc and Janez Kranjc titled "Hidden Beauty of the Sea". The photographs portraying the rich and colourful underwater world of the Adriatic Sea were a lovely introduction into two days of interesting presentations and panel discussions.

In her introductory speech, Professor Đurđica Perović, Vice Rector of the University of Montenegro, stated that the results of the conference would be used in shaping future marine science priorities and policies in Montenegro and other Adriatic countries. With the main focus of the conference being biodiversity and its protection, a lot of emphasis was put on some current issues that pester the global oceans, such as unsustainable use of resources, marine pollution and non-indigenous species, as well as certain local problems characteristic of the Adriatic Sea. On a more operational note, the participants pointed out some deficits, such as the lack of experts in taxonomy, especially in the younger generation, as well as the growing need for cooperation among Adriatic countries.

Many excellent contributions were presented, abstracts of which can be viewed at the website of the 'Aquarium Boka' Marine Biodiversity Conservation Center (http://www.aquariumboka.ucg.ac.me/wp-content/uploads/2019/04/AdriBioPro2019-BookAbstracts-20190408.pdf). Among eminent researchers, Academician Professor Dr. Gordan

Fig. 1: Panel discussion with esteemed marine biologists on the topic: Why Adriatic biodiversity matters (photo: Institute of marine biology Kotor).

Fig. 2: The participants of the first AdriBioPro conference (photo: Institute of marine biology Kotor).

Karaman, an expert in amphipod taxonomy, presented his lifelong study of these crustaceans, which yielded descriptions of several new species from the Bay of Kotor. A special focus was put on the issue of mass mortality of the Mediterranean endemic bivalve *Pinna nobilis* caused by a protozoan parasite. An international group of researchers presented their experience and lessons learned from this occurrence and the measures taken so far to counteract it. The word of the conference had reached as far as Lebanon; in fact, the marine scientists from this country presented an interesting study of the Lebanese population of the endangered, yet still heavily exploited common guitarfish.

Many interesting speeches were given, priorities and policies were discussed, but like in many similar occasions, even more valuable connections and collaborations were probably made during the array of social activities. The conference dinner held on the Wednesday evening was one of them. We had a unique opportunity to see a glimpse of rich Montenegrin cultural heritage through the performance of local folklore dancers, while enjoying Montenegrin food and wine. In my opinion, the conference was a success and more such occasions would be appreciated in the Adriatic region in the future.

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MARINE BIOLOGY STATION PIRAN
50 1969 2019

IN MEMORIAM

IN MEMORIAM OF FABIO PERCO (1946–2019)

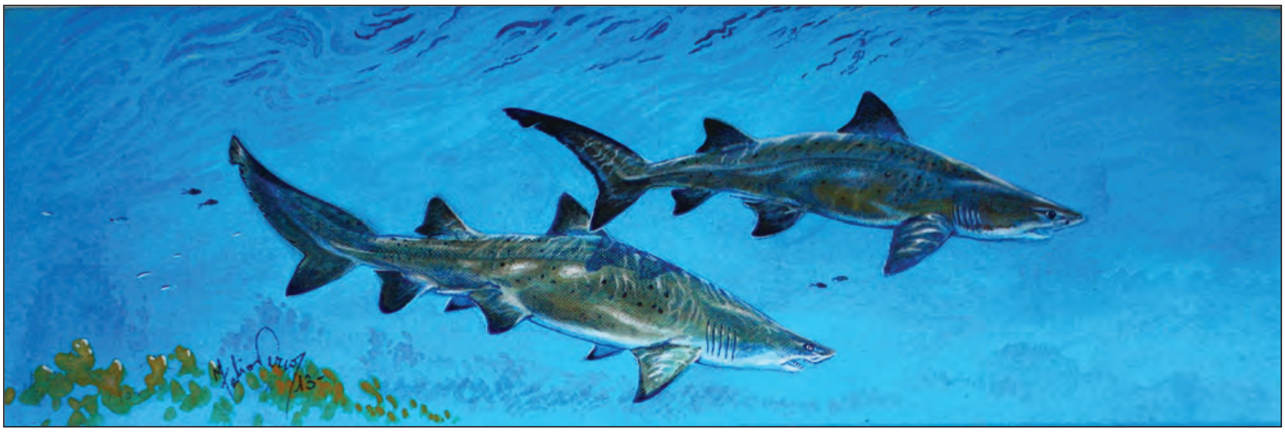
In the middle of February 2019, more than 300 people paid their last respects to Dr Fabio Perco at the cemetery of Santa Anna in Trieste. Fabio was an esteemed biologist, an outstanding ornithologist and a very warm person, who left a profound mark on the creation, protection, management and popularisation of many Italian natural sites of immense importance, such as the northern Adriatic lagoons, the coastal limestone cliffs and Trieste's karstic environment. He was actively involved in the creation of the Škocjan Inlet Nature Reserve on the Slovenian coast. In short, I can surely say he dedicated his entire life to nature conservation.

Carcharhinus limbatus ***(drawing Fabio Perco).***

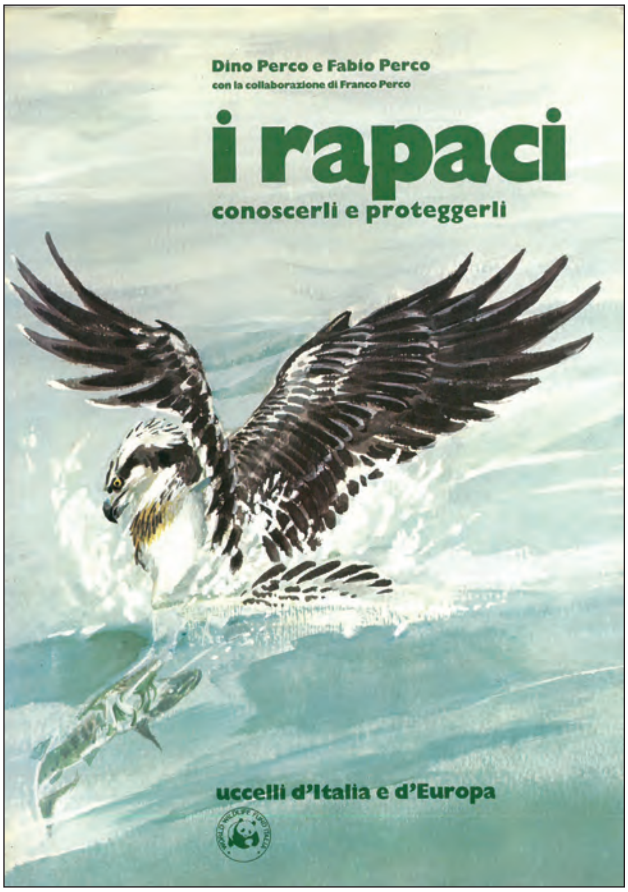
Fabio was a truly gifted artist, who was certainly bestowed his artistic talent at birth, for his father Dino was an excellent illustrator, as were Fabio's brothers and daughters. Fabio was a master wildlife painter, able to produce exquisite illustrations of birds and other animals. The birds in his paintings are realistic and authentic, always depicted in their natural habitats, but with a fairy tale touch. Some of his masterpieces of lagoon avifauna are on display at the centre of the Škocjanski Zatok Nature Reserve in Koper. His magnificent art was undoubtedly inspired by his love for nature, especially the animal kingdom.

He planned and brought to realisation many nature conservation projects. His efforts were crucial in the creation of several coastal protected areas, such as the Regional Nature Reserve "Isola della Cona". This popular ornithological and naturalist site has won numerous awards at national and international levels. Fabio was also a promotor for the establishment of a centre for white storks at the Oasis of Quadris near Fagagna del Friuli and in charge of the establishment of a lakeside feeding station for vultures at Cornino near Udine. Unfortunately, he did not manage to bring to life another brilliant project of his, whose goal was to reintroduce the white-tailed eagle (*Haliaetus albicilla*) into the province of Friuli Venezia Giulia.

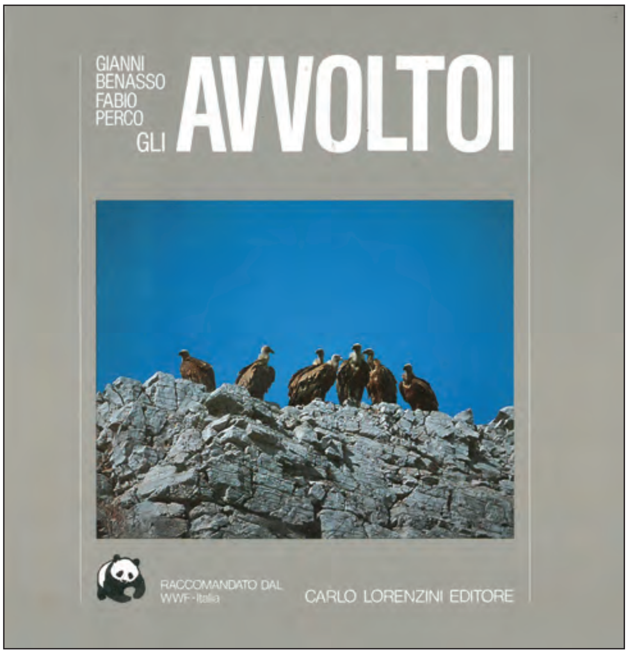
Fabio was also a gifted writer, publishing articles on a variety of topics dealing with ornithology, nature conservation and protected areas, especially the wetlands. He was a dedicated man who gathered his inspiration from his family, so it is not surprising that he published many books in co-authorship with his close relatives. He dedicated a lot of his time to researching birds of prey and owls. In fact, Fabio studied natural sciences at the University of Trieste, obtaining his Master of Science title with a thesis on the goshawk (*Accipiter gentilis*) in the Trieste Karst. My favourite book by Fabio is a monograph about owls and birds of prey entitled *I rapaci, conoscerli e proteggerli* (WWF Italia, 1976), which he co-wrote with his father Dino and his brother Franco, also a skilled illustrator and writer. He also produced a book on the fauna of the impressive limestone cliffs of Duino together with his daughter Nicoletta (*Fauna della Riserva naturale Falesie di Duino*, 2011), with illustrations created by his daughter Elena. Among the many



Carcharias taurus **and** *Odontaspis ferox* ***(drawing Fabio Perco).***



other monographs that Fabio penned, the amazing study dealing with vultures, which he published with Gianni Benassi (*Gli avvoltoi*, 1985), and the one on the griffon



vulture (*Il grifone in Italia e nel mondo*, 1996) co-authored with Fulvio Genero and Bruno Dentesani (1996), deserve special mention.

I regret to have known Fabio for only a few years; still, I can say that our meetings were very fruitful for me. I learned so much from him, heard so many stories and enjoyed every single moment that I spent with him in his karstic realm of Sgonico. The possibility and privilege to exchange opinions with such an erudite and discussing topics of terrestrial and marine biology, nature conservation, history and etymology, is something I will never forget. He was a skilled narrator who could present a topic in a very interesting and detailed manner.

But above all, I will remember Fabio as a genuinely warm person, a good friend with a great sense of humour, and an eternal discoverer of the secrets of nature. We will remain surrounded by his legacy in the wetlands of either side of the Gulf of Trieste...

Lovrenc Lipej

Fabio Perco (photo: Nataša Šalaja).

NAVODILA AVTORJEM

1. Revija ANNALES (*Anali za istrske in mediteranske študije* Series, Historia Naturalis) objavlja **izvirne znanstvene** in **pregledne članke** z naravoslovnimi vsebinami, ki obravnavajo posebnosti različnih podpodročij sredozemskega naravoslovja: morska biologija in ekologija, ihtiologija, geologija s paleontologijo, krasoslovje, oljkarstvo, biodiverziteta Slovenije, varstvo narave, onesnaževanje in varstvo okolja, fizična geografija Istre in Mediterana idr. Vključujejo pa tudi **krajše** znanstvene prispevke o zaključenih raziskovanjih., ki se nanašajo na omenjeno področje.

2. Sprejemamo članke v angleškem, slovenskem in italijanskem jeziku. Avtorji morajo zagotoviti jezikovno neoporečnost besedil, uredništvo pa ima pravico članke dodatno jezikovno lektorirati.

3. Članki naj obsegajo do 48.000 znakov brez presledkov oz. 2 avtorski poli besedila. Članek je mogoče oddati na e-naslov annales@mbss.org (zaželjeno) ali na elektronskem nosilcu (CD) po pošti na naslov uredništva.

Avtor ob oddaji članka zagotavlja, da članek še ni bil objavljen in se obvezuje, da ga ne bo objavil drugje.

4. Naslovna stran članka naj vsebuje naslov članka, ime in priimek avtorja (avtorjev), ime in naslov inštitucije, kjer je (so) avtor(ji) zaposlen(i) oz. domači naslov in naslovom elektronske pošte (samo prvi oz. korespondenčni avtor).

5. Članek mora vsebovati **povzetek** in **izvleček.** Izvleček je krajši (cca. 10 vrstic) od povzetka (cca. 30 vrstic).

V *izvlečku* na kratko opišemo namen, metode dela in rezultate. Izvleček naj ne vsebuje komentarjev in priporočil.

Povzetek vsebuje opis namena in metod dela ter povzame analizo oziroma interpretacijo rezultatov. V povzetku ne sme biti ničesar, česar glavno besedilo ne vsebuje. V povzetku se avtor ne sklicuje na slike, tabele in reference, ki so v članku.

6. Avtorji naj pod izvleček članka pripišejo ustrezne **ključne besede** (največ 6). Zaželjeni so tudi angleški (ali slovenski) prevodi izvlečka, povzetka, ključnih besed, podnapisov k slikovnemu in tabelarnemu gradivu. V nasprotnem primeru bo za prevode poskrbelo uredništvo.

7. Glavni del besedila naj vključuje sledeča poglavja: Uvod, Material in metode, Rezultati, Razprava ali Rezultati in razprava, Zaključki (ali Sklepi), Zahvala (če avtor želi), Literatura. Dele besedila je možno oblikovati v podpoglavja (npr. Pregled dosedanjih objav v Uvodu, Opis območja raziskav v Material in metode). Podpisi k slikam so priloženi posebej za poglavjem Literatura.

8. Tabele avtor priravi posebej na ločenih straneh v programu Word, tako kot rokopis, jih zaporedno oštevilči in opremi z naslovom – kratkim opisom. V glavnem delu besedila se sklicuje na tabele tako, da jih na ustreznem mestu označi z npr. "(Tab. 1)".

9. Slikovno gradivo (grafi, zemljevidi, fotografije, table) avtor posreduje v ločenih datotekah (jpeg, tiff) z najmanj 300 dpi resolucije pri želeni velikosti. Največja velikost slikovnega gradiva je 17x20 cm. Vsa potrebna dovoljenja za objavo slikovnega gradiva (v skladu z Zakonom o avtorski in sorodnih pravicah) priskrbi avtor sam in jih predloži uredništvu pred objavo članka. Slike je potrebno tudi podnasloviti in zaporedno oštevilčiti (glej točko 7). V glavnem delu besedila se avtor sklicuje na slike tako, da jih na ustreznem mestu označi z npr. "(Sl. 1)".

10. Bibliografske opombe, s čimer mislimo na **citat** – torej sklicevanje na druge publikacije, sestavljajo naslednji podatki v oklepaju: *avtor* in *leto izida*; npr. (Novak, 2007). Če sta dva avtorja, se izpišeta oba (Novak & Kranjc, 2001), če so trije ali več pa se izpiše samo prvi, ki mu sledi okrajšava *et al.* (Novak *et al.*, 1999). Več citatov je med seboj ločenih s podpičjem in si sledijo kronološko - z naraščajočo letnico izdaje, npr. (Novak *et al.*, 1999; Adamič, 2001; Kranjc & Zupan, 2007). Osebno informacijo (ustno, pisno) izpišemo prav tako v oklepaju z navedbo kratice imena in priimka posredovalca informacije, za vejico pa dodamo "osebno sporočilo", npr. (J. Novak, *osebno sporočilo*).

11. Celotni **bibliografski podatki** so navedeni v poglavju Literatura v abecednem vrstnem redu. Pri tem avtor navede izključno dela, ki jih je v članku citiral. Če ima isti avtor več bibliografskih podatkov, se najprej kronološko izpišejo tisti, kjer je edini avtor, sledijo dela v soavtorstavu še z enim avtorjem in dela v soavtorstvu z več avtorji. Imena revij, v katerih so izšla citirana dela, se izpišejo okrajašano (splošno priznane okrajšave revij). Članki, ki še niso bili publicirani, se lahko citirajo le, če so bili dokončno sprejeti v tisk, pri čemer se na koncu bibliografskega podatka doda beseda "v tisku". Člankov, ki so šele bili poslani v recenzijo, se ne sme citirati.

Primeri navajanje različnih tipov bibliografskih podatkov:

članki v revijah:

Klock, J.-H., A. Wieland, R. Seifert & W. Michaelis (2007): Extracellular polymeric substances (EPS) from cyanobacterial mats: characterisation and isolation method optimisation. Mar. Biol., 152, 1077-1085.

Knjige in druge neserijske publikacije (poročila, diplomska dela, doktorske disertacije):

Wheeler, A. (1969): The fishes of the British Isles and North-West Europe. McMillan, London, 613 p.

Poglavje v knjigi:

McEachran, J. D. & C. Capapé (1984): Myliobatidae. In: Whitehead, P. J. P., M. L. Bauchot, J.-C. Hureau, J. Nielsen & E. Tortonese (eds.): Fishes of the North-eastern Atlantic and the Mediterranean, Vol. 1. Unesco, Paris, pp. 205-209.

12. Drugo: latinski izrazi kot npr. *in vivo*, *in situ*, *e.g.*, *i.e.*, ter rodovna (*Myliobatis* sp.) in vrstna (*Myliobatis aquila*) imena se izpišejo v fontu italic. Kadarkoli je možno, se uporabljajo enote iz sistema SI (Système international d'unités).

13. Prvi odtis člankov uredništvo pošlje avtorjem v **korekturo.** Avtorji so dolžni popravljeno gradivo vrniti v enem tednu. Besedilo popravljamo s korekturnimi znamenji, ki jih najdemo na koncu Slovenskega pravopisa (2001), Ljubljana, ZRC SAZU, 24–25.

Širjenje obsega besedila ob korekturah ni dovoljeno. Druge korekture opravi uredništvo.

14. Za dodatna pojasnila v zvezi z objavo člankov je uredništvo na voljo.

UREDNIŠTVO

ISTRUZIONI PER GLI AUTORI

1. La rivista ANNALES (*Annali per gli studi istriani e mediterranei*, Series Historia Naturalis) pubblica **articoli scientifici originali** e **compendii** dai contenuti scientifici relativi ai vari settori della storia naturale e pertinenti l'area geografica del Mediterraneo: biologia marina, ecologia, ittiologia, geologia, paleontologia, carsologia, olivicoltura, biodiversità della Slovenia, tutela della natura, inquinamento e tutela dell'ambiente, geografia fisica dell'Istria e del Mediterraneo ecc. La rivista pubblica anche articoli scientifici **brevi** relativi a ricerche concluse pertinenti a tali settori.

2. La Redazione accetta articoli in lingua inglese, slovena e italiana. Gli autori devono garantire l'ineccepibilità linguistica dei testi, la Redazione si riserva il diritto di una revisione linguistica.

3. Gli articoli devono essere di lunghezza non superiore alle 48.000 battute senza spazi, ovvero 2 fogli d'autore. Possono venir recapitati all'indirizzo di posta elettronica annales@mbss.org (preferibilmente) oppure su supporto elettronico (CD) per posta ordinaria all'indirizzo della Redazione.

L'autore garantirà l'originalità dell'articolo e si impegnerà a non pubblicarlo altrove.

4. Ogni articolo deve essere corredato da: **titolo**, nome e cognome dell'autore (autori), denominazione ed indirizzo dell'ente di appartenenza o, in alternativa, l'indirizzo di casa, nonché l'indirizzo di posta elettronica (solo del primo autore o dell'autore di corrispondenza).

5. I contributi devono essere corredati da un **riassunto** e da una **sintesi**. Quest'ultima sarà più breve (cca. 10 righe) del riassunto (cca 30 righe).

Nella *sintesi* si descriveranno brevemente lo scopo, i metodi e i risultati delle ricerche. La sintesi non deve contenere commenti e segnalazioni.

Il *riassunto* riporterà in maniera sintetica lo scopo, i metodi delle ricerche e l'analisi ossia l'interpretazione dei risultati. Il riassunto non deve riferirsi alle tabelle, figure e alla bibliografia contenuta nell'articolo.

6. Gli autori sono tenuti ad indicare le **parole chiave** adeguate (massimo 6). Sono auspicabili anche le traduzioni in inglese (o sloveno) della sintesi, del riassunto, delle parole chiave, delle didascalie e delle tabelle. In caso contrario, vi provvederà la Redazione.

7. Il testo principale deve essere strutturato nei seguenti capitoli: Introduzione, Materiali e metodi, Risultati, Discussione o Risultati e discussione, Conclusioni, Ringraziamenti (se necessari), Bibliografia. Il testo può essere strutturato in sottocapitoli (ad es. sottocapitolo Rassegna delle pubblicazioni nell'Introduzione; sottocapitolo Descrizione dell'area di ricerca nel capitolo Materiali e metodi). Le didascalie devono essere presentate separatamente, a seguito del capitolo Bibliografia.

8. Le tabelle saranno preparate in forma elettronica come il manoscritto (formato Word) e allegate in fogli separati alla fine del testo. Gli autori sono pregati di contrassegnare ogni tabella con un numero e il titolo ossia una breve descrizione. Nel testo la tabella viene richiamata come segue: (Tab. 1).

9. Il materiale grafico (grafici, carte geografiche, fotografie, tavole) va preparato in formato elettronico (jpeg o tiff) e consegnato in file separati, con una definizione di 300 dpi alla grandezza desiderata, purché non ecceda i 17x20 cm. Prima della pubblicazione, l'autore provvederà a fornire alla Redazione tutte le autorizzazioni richieste per la riproduzione del materiale grafico (in virtù della Legge sui diritti d'autore). Tutto il materiale grafico deve essere accompagnato da didascalie (vedi punto 7) e numerato.. Nel testo i grafici vengono richiamati come segue: (ad es. Fig. 1).

10. I riferimenti bibliografici (citazioni) richiamano un'altra pubblicazione (articolo). La nota bibliografica, riportata nel testo, deve contenere i seguenti dati tra parentesi: *cognome dell'autore*, *anno di pubblicazione*, ad es. (Novak, 2007). Se gli autori sono due, verranno indicati entrambi (Novak & Kranjc, 2001), nel caso di tre o più autori verrà indicato soltanto il primo, seguito dall'abbreviazione *et al.* (Novak *et al.,* 1999). Vari riferimenti bibliografici in una stessa nota vanno divisi dal punto e virgola e segnalati in ordine cronologico, ad. es. (Novak *et al.*, 1999; Adamič, 2001; Kranjc & Zupan, 2007). La testimonianza (orale, scritta) verrà indicata tra parentesi con l'abbreviazione del nome e con il cognome di chi l'ha trasmessa, seguiti dalla virgola e la dicitura "informazione personale", ad es. (J. Novak, *informazione personale*).

11. La bibliografia completa va inserita in ordine alfabetico nel capitolo Bibliografia. L'autore indicherà esclusivamente i lavori e le edizioni citati nell'articolo. Se si citano più lavori dello stesso autore, verranno indicati prima in ordine cronologico i lavori in cui l'autore appare solo, poi quelli in cui l'autore compare assieme ad un secondo coautore, seguiti infine da quelli in cui egli compare tra più coautori. I nomi delle riviste in cui sono pubblicati i lavori citati saranno indicati nella forma abbreviata (abbreviazioni ufficialmente riconosciute). Gli articoli inediti si possono citare soltanto se sono in corso di pubblicazione, facendo loro seguire la dicitura "in corso di pubblicazione". Gli articoli, non ancora recensiti non possono essere citati.

Esempio di lavoro bibliografico:

Articoli in riviste:

Klock, J.-H., A. Wieland, R. Seifert & W. Michaelis (2007): Extracellular polymeric substances (EPS) from cyanobacterial mats: characterisation and isolation method optimisation. Mar. Biol., 152, 1077-1085.

Libri ed altre pubblicazioni non periodiche (relazioni, tesi di laurea, dissertazioni di dottorato):

Wheeler, A. (1969): The fishes of the British Isles and North-West Europe. McMillan, London, 613 p.

Capitoli di libro:

McEachran, J. D. & C. Capapé (1984): Myliobatidae. In: Whitehead, P. J. P., M. L. Bauchot, J.-C. Hureau, J. Nielsen & E. Tortonese (eds.): Fishes of the North-eastern Atlantic and the Mediterranean, Vol. 1. Unesco, Paris, pp. 205-209.

12. Altro: Le espressioni latine come ad es. *in vivo*, *in situ*, *e.g.*, *i.e.*, i nomi dei generi famiglie (*Myliobatis* sp.) e delle specie (*Myliobatis aquila*) si scrivono con il carattere italic. Quando possibile saranno utilizzate le unità del sistema SI (*Système international d'unités*).

13. Gli autori ricevono le **prime bozze** di stampa per la revisione. Le bozze corrette vanno quindi rispedite entro una settimana alla Redazione. In questa fase, i testi corretti con segni adeguati (indicazioni in merito si trovano alla fine della pubblicazione "Slovenski pravopis" (2001), Ljubljana, ZRC SAZU, 24-25, non possono essere più ampliati. La revisione delle bozze è svolta dalla Redazione.

14. La Redazione rimane a disposizione per eventuali chiarimenti.

LA REDAZIONE

INSTRUCTIONS TO AUTHORS

1. The journal ANNALES (*Annals for Istrian and Mediterranean Studies,* Series Historia Naturalis) publishes **original scientific** and **review articles** in the field of natural studies related to the specifics of various subfields of Mediterranean natural studies: marine biology and ecology, ichthyology, geology with paleontology, karst studies, olive growing, biodiversity of Slovenia, nature protection, pollution and environmental protection, physical geography of Istria and the Mediterranean, etc. It also publishes **short** scientific papers on completed research projects related to the above-mentioned subfields.

2. The articles submitted can be written in the English, Slovene or Italian language. The authors should ensure that their contributions meet acceptable standards of language, while the editorial board has the right to have them language edited.

3. The articles should be no longer than 48,000 characters (spaces excluded) or 32 typewritten double-spaced pages. They can be submitted via e-mail annales@mbss.org (preferably) or regular mail, with the electronic data carrier (CD) sent to the address of the editorial board.

Submission of the article implies that it reports original unpublished work and that it will not be published elsewhere.

4. The **title page** should include the title of the article, the name and surname of the author(s), their affiliation (institutional name and address) or home address, and e-mail address (of the first author or the corresponding author only).

5. The article should contain the **summary** and the **abstract,** with the former (c. 30 lines) being longer than the latter (c. 10 lines).

The *abstract* contains a brief description of the aim of the article, methods of work and results. It should contain no comments and recommendations.

The *summary* contains the description of the aim of the article and methods of work and a brief analysis or interpretation of results. It can contain only the information that appears in the text as well. It should contain no reference to figures, table and citations published in the main text.

6. Beneath the abstract, the author(s) should supply appropriate **keywords** (max 6) and, if possible, the English (or Slovene) translation of the abstract, summary, keywords, and captions to figures and tables. If unprovided, the translation will be provided by the editorial board.

7. The **main text** should include the following chapters: Introduction, Material and Methods, Results, Discussion or Results and Discussion, Conclusion, Acknowledgement (not obligatory), References. Individual parts of the text can form a sub-chapter (e.g. Survey of Previous Studies under Introduction; Description of Research Area under Material and Methods). Captions to figures should appear on a separate page beneath References.

8. Each **table** should be submitted on a separate page in Word programme (just like the main text). It should be numbered consecutively and supplied with the title – brief description. When referring to the tables in the main text, use the following style: (Tab. 1).

9. Illustrative matter (diagrams, maps, photographs, plates) should be submitted as separate files (in jpeg or tiff format) and saved at a minimum resolution of 300 dpi per size preferred, with the maximum possible publication size being 17x20 cm. Prior to publication, the author(s) should obtain all necessary authorizations (as stipulated by the Copyright and Related Rights Act) for the publication of the illustrative matter and submit them to the editorial board. All figures should be captioned and numbered consecutively (cf. Item 7). When referring to the figures in the main text, use the following style: (Fig. 1).

10. **Bibliographic notes** or **citations** – i.e. references to other articles or publications – should contain the following data: *author* and *year of publication,* e.g. (Novak, 2007). If there are two authors, include both surnames (Novak & Kranjc, 2001); if there are more than two authors, include the surname of the first author followed by a comma and the abbreviation *et al.* (Novak *et al.*, 1999). If there is more than one reference, separate them by a semicolon and list them in ascending chronological order, e.g. (Novak *et al.*, 1999; Adamič, 2001; Kranjc & Zupan, 2007). When citing information obtained through personal communication (oral, written), provide the initial letter of the name and full surname of the informant followed by a comma and the phrase *personal communication,* e.g. (J. Novak, *personal communication*).

11. The entire list of **bibliographic data** should be published under References in alphabetical order. The author(s) should list only the works cited in the article. If you are listing several works by the same author with some of them written in co-authorship, first list those written by the author him/herself, then those written in co-authorship with another author, and finally those written in co-authorship with more than one author, with the entries listed in chronological order. The names of journals in which the works cited were published should be abbreviated (cf. list of official journal abbreviations). Unpublished articles can be cited only if they have been approved for publication, which should be indicated by adding the phrase *in press* to the end of the relevant bibliography entry.

Some examples of how to cite different types of bibliographical data:

Articles published in serial publications:

Klock, J.-H., A. Wieland, R. Seifert & W. Michaelis (2007): Extracellular polymeric substances (EPS) from cyanobacterial mats: characterisation and isolation method optimisation. Mar. Biol., 152, 1077-1085.

Books and other non-serial publications (reports, diploma theses, doctoral dissertation):

Wheeler, A. (1969): The fishes of the British Isles and North-West Europe. McMillan, London, 613 p.

Chapters published in a book:

McEachran, J. D. & C. Capapé (1984): Myliobatidae. In: Whitehead, P. J. P., M. L. Bauchot, J.-C. Hureau, J. Nielsen & E. Tortonese (eds.): Fishes of the North-eastern Atlantic and the Mediterranean, Vol. 1. Unesco, Paris, pp. 205-209.

12. Miscellaneous: Latin phrases such as *in vivo*, *in situ*, *e.g.*, *i.e.*, and names of genera (*Myliobatis* sp.) and species (*Myliobatis aquila*) should be written in italics. Whenever possible, use the SI units (Système international d'unités).

13. The authors are sent the **first page proofs**. They should be returned to the editorial board within a week. When reading the proofs, the authors should use the correction signs listed at the end of the book Slovenski pravopis (2001), Ljubljana, ZRC SAZU, 24–25.

It is not allowed to lengthen the text during proof-reading. Second proof-reading is done by the editorial board.

14. For additional information regarding article publication contact the editorial board.

EDITORIAL BOARD

KAZALO K SLIKAM NA OVITKU

SLIKA NA NASLOVNICI:
Kriptobentoške vrste rib so slabo raziskana skupina manjših rib, ki so vseskozi skrite v skrivališčih. Med njimi so tudi mnoge vrste rib prisesnic. Na fotografiji je veliki prisesnik (*Lepadogaster lepadogaster*), ki je razmeroma pogosta vrsta bibavičnega pasu. (Foto: D. Trkov)
Sl. 1: Nekateri prisesniki si za domovanje izberejo zelo nenavadna bivališča, kot so mrtve ostrige, ostanki leščurjev ali pa oklepi mrtvih rakovic. To velja za vrsto prisesnika *Apletodon incognitus*, o kateri je še vedno zelo malo znanega. (Foto: D. Trkov)
Sl. 2: Afriški kostorog (*Stephanolepis diaspros*) je lesepska selivka, ki se je marsikje v vzhodnem Sredozemskem morju že uveljavila. Vzdolž tunizijske obale poročajo o množičnem pojavljanju. (Foto: L. Lipej)
Sl. 3: Morski sodec (*Tonna galea*) je drugi največji morski polž v Sredozemskem morju. Pred kratkim so to redko in ogroženo vrsto prvič našli tudi v slovenskem delu Jadranskega morja. (Foto: M. Rogelja)
Sl. 4: Velikega prisesnika (*Lepadogaster candolii*) najdemo pod večjimi ploščatimi kamni v zgornjem infralitoralu. Pojavlja se globlje od pikastega prisesnika, poleg tega pa ga najdemo pod kamni na morskih travnikih. (Foto: D. Trkov)
Sl. 5: Navadni sklat (*Squatina squatina*) je ena izmed najbolj ogroženih vrst morskih psov v Sredozemskem morju, marsikje pa je celo že izginil. Novejša opazovanja in sprejeti naravovarstveni ukrepi dajejo upanje, da mu bo vseeno uspelo preživeti. (Foto: L. Kastelic)
Sl. 6: Kozica *Palaemon elegans* je pogosta vrsta v slovenskem delu Jadrana. V raziskavi prostorske razporeditve in sobivanja različnih kozic v reki Badaševici in pritokih se je pojavljala le v ustju reke. (Foto: B. Mavrič)

INDEX TO IMAGES ON THE COVER

FRONT COVER:
Cryptobenthic fish fauna is an under-researched group of small-sized fish living hidden in their shelters virtually all the time. Among them there are many clingfish species. The shore clingfish (*Lepadogaster lepadogaster*) on the photograph is a rather common intertidal species. (Photo: D. Trkov)
Fig. 1: Certain clingfish choose very peculiar shelters, such as dead oysters, remains of noble shells or even carapaces of dead crabs. One of these is *Apletodon incognitus*, a still poorly investigated species. *(Photo: D. Trkov)*
Fig. 2: The reticulated leatherjacket (*Stephanolepis diaspros*) is a Lessepsian migrant already established in some areas of the eastern Mediterranean Sea. This species is reported to be present in high numbers along the Tunisian coast. (Photo: L. Lipej)
Fig. 3: The giant tun (*Tonna galea*) is the second largest Mediterranean gastropod. Recently, this rare and endangered species has also been reported from the Slovenian part of the Adriatic Sea. (Photo: M. Rogelja)
Fig. 4: The Connemara clingfish (*Lepadogaster candolii*) inhabits spaces under big flat stones in the upper infralittoral stage. It occurs deeper than shore clingfish and can also be found in seagrass meadows. (Photo: D. Trkov).
Fig. 5: The angel shark (*Squatina squatina*) is among the most endangered shark species in the Mediterranean, known to be already absent from certain areas. New records and adopted nature conservation measures are giving some hope for its survival. (Photo: L. Kastelic)
Fig. 6: The rockpool shrimp *Palaemon elegans* is a common species in the Slovenian part of the Adriatic Sea. In a research studying the distribution and coexistence of different shrimp species in the Badaševica River and its tributaries, this species was only present at the river mouth. (Photo: B. Mavrič)

Inštitut
IRRIS