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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

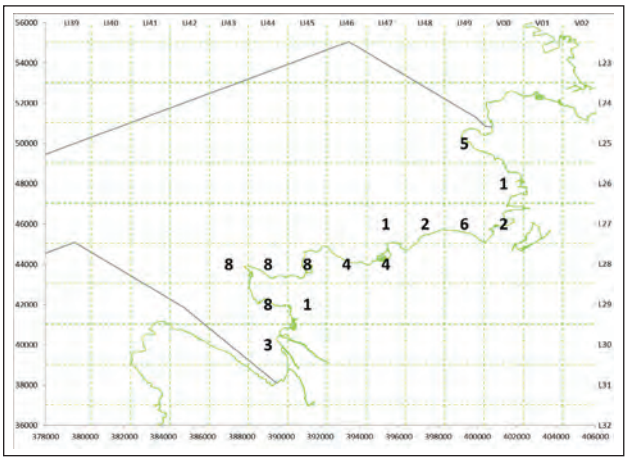

Fig. 1: UTM quadrants with numbers of cryptobenthic species present within.
Sl. 1: UTM kvadrati z označenim številom kriptobentoških vrst, ugotovljenih v njih.

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

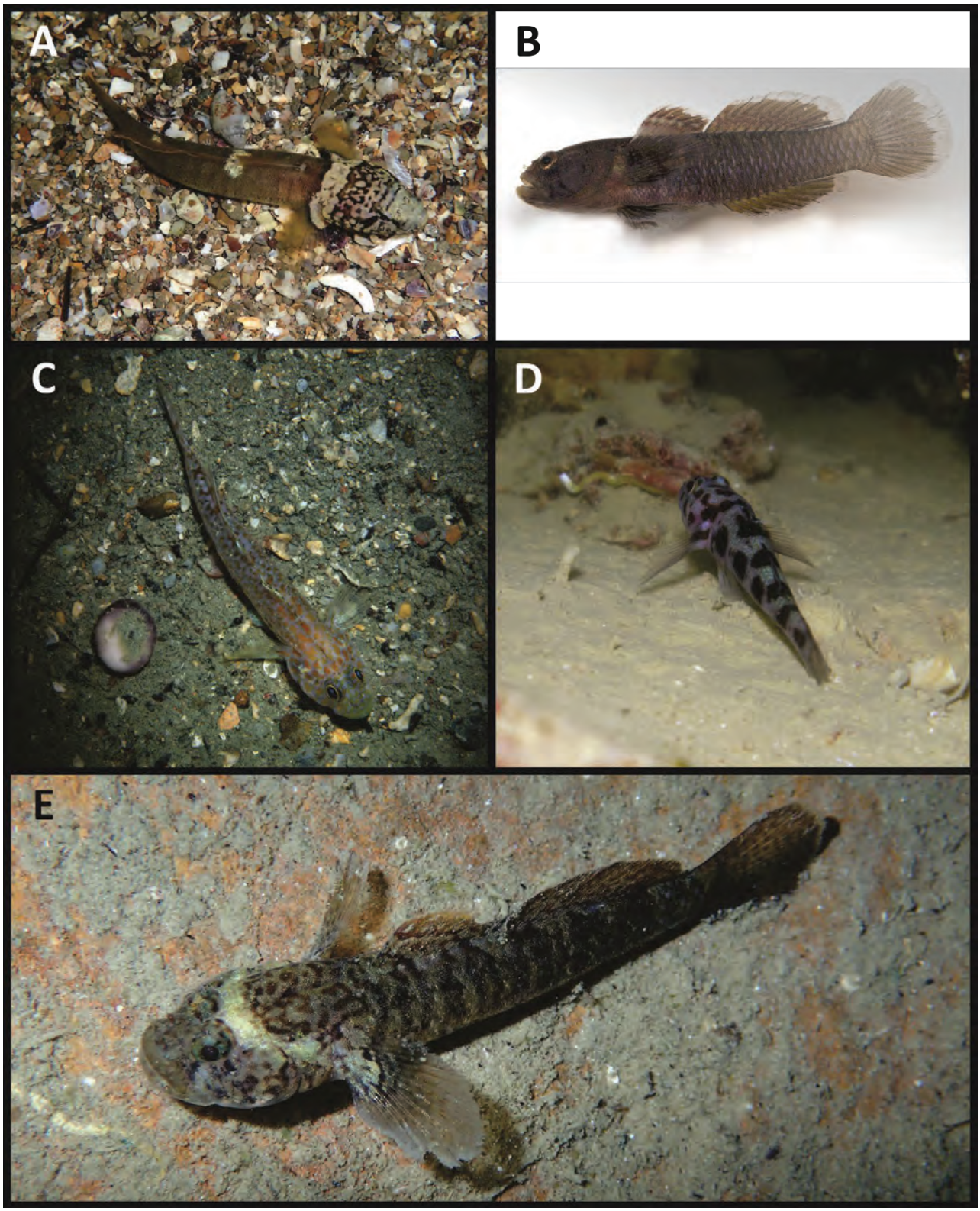

Fig. 2: Cryptobenthic gobies in the Slovenian Sea: A) *Chromogobius quadrivittatus*, ***B)*** *Millerigobius macrocephalus*, ***C)*** *Thorogobius macrolepis*, ***D)*** *Thorogobius ephippiatus* ***and E)*** *Zebrus zebrus*.
Sl. 2: Kriptobentoški glavači v slovenskem morju: A) *Chromogobius quadrivittatus*,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

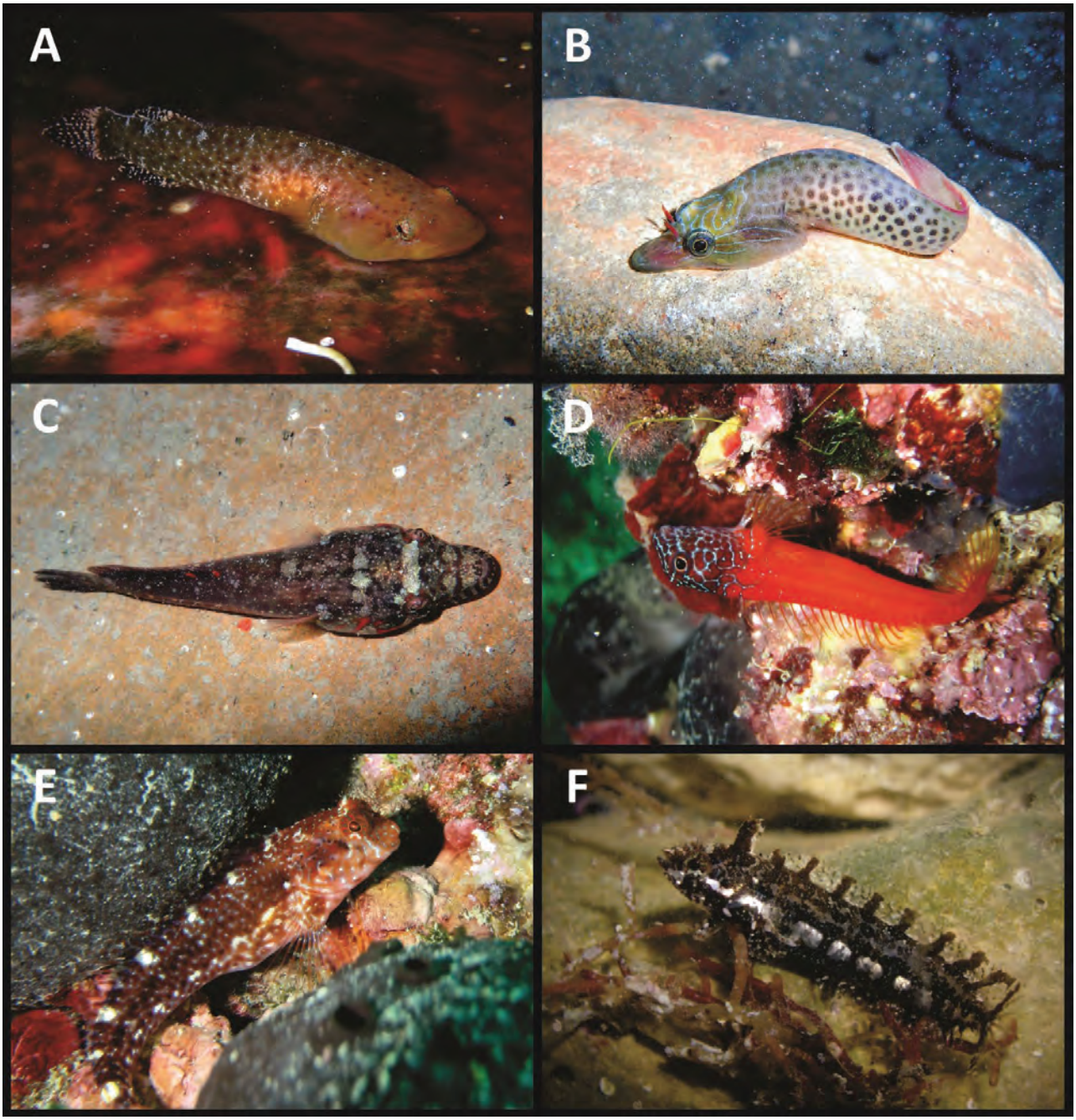

Fig. 3: Cryptobenthic fish species in the Slovenian Sea: A) *Apletodon incognitus*, ***B)*** *Lepadogaster lepadogaster*, ***C)*** *Lepadogaster candolii*, ***D)*** *Microlipophrys nigriceps*, ***E)*** *Parablennius zvonimiri* ***and F)*** *Clinitrachus argentatus*.
Sl. 3: Kriptobentoške vrste rib v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

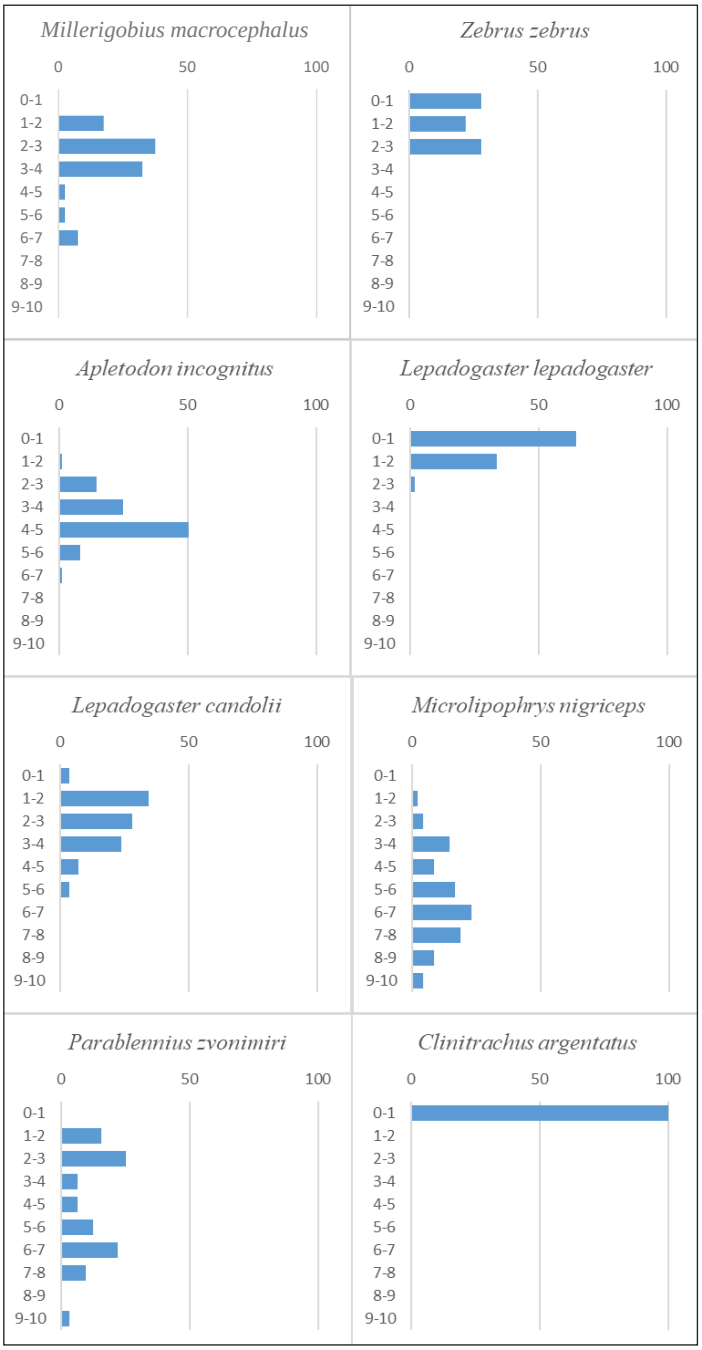

Fig. 4: Depth distribution of cryptobenthic fish species in the Slovenian Sea: *Millerigobius macrocephalus; Zebrus zebrus; Apletodon incognitus; Lepadogaster lepadogaster; Lepadogaster candolii; Microlipophrys nigriceps; Parablennius zvonimiri; Clinitrachus argentatus.* ***On abscissa axis are relative 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.

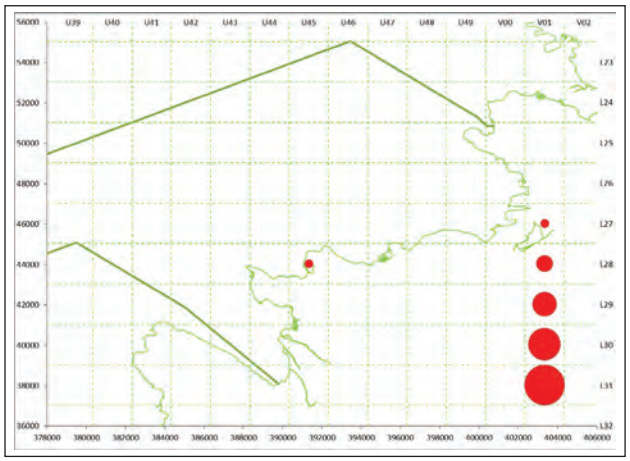

Fig. 5: Occurrence of *Chromogobius quadrivittatus* ***in the Slovenian Sea. The size of the dots is shown at the right of the map and is ranking from the smallest to the biggest, based on number of specimens found within quadrant: 1 specimen, 2-3 specimens, 4-5 specimens, 6-15 specimens, > 16 specimens.***
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).

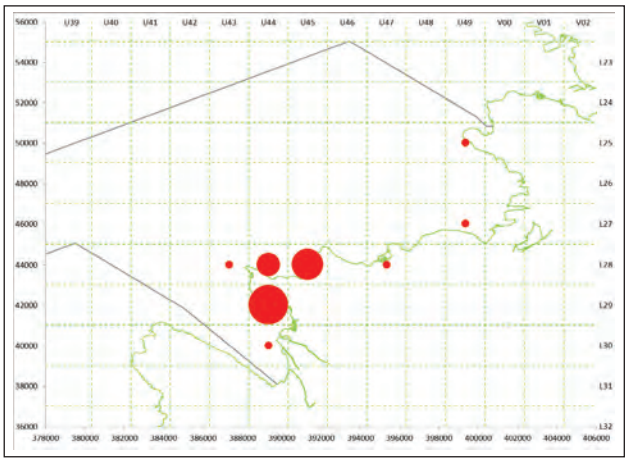

Fig. 6: Occurrence of *Millerigobius macrocephalus* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 6: Pojavljanje vrste *Millerigobius macrocephalus* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

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.

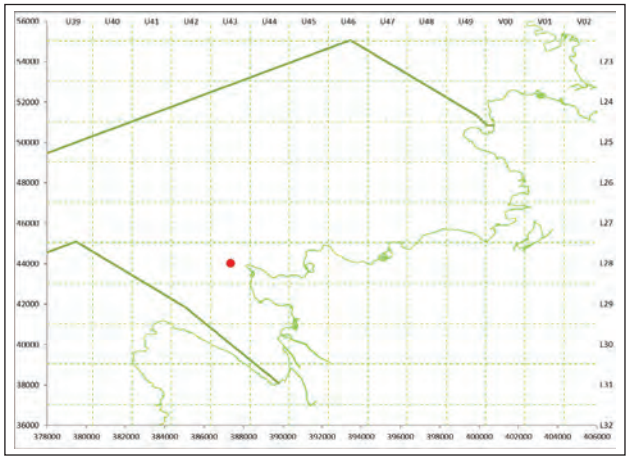

Fig. 7: Occurrence of *Thorogobius ephippiatus* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 7: Pojavljanje vrste *Thorogobius ephippiatus* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

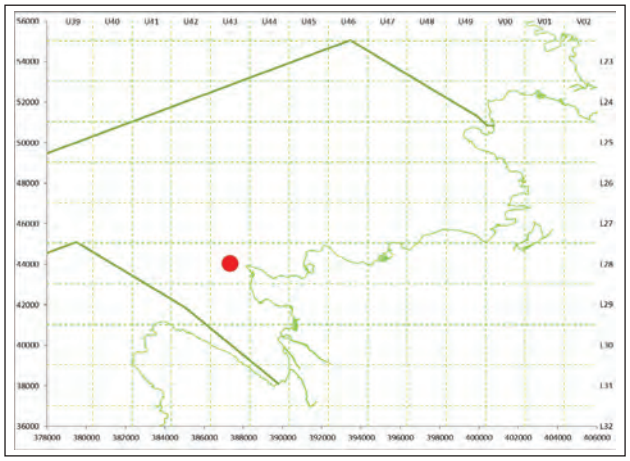

Fig. 8: Occurrence of** Thorogobius macrolepis **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 8: Pojavljanje vrste** Thorogobius macrolepis **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

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.

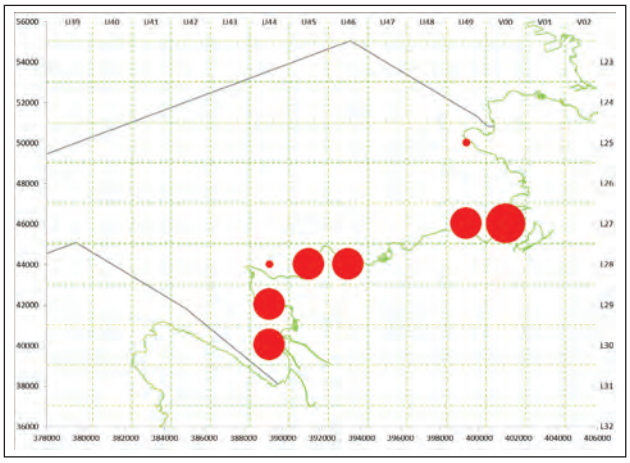

Fig. 9: Occurrence of** Zebrus zebrus **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 9: Pojavljanje vrste** Zebrus zebrus **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

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-

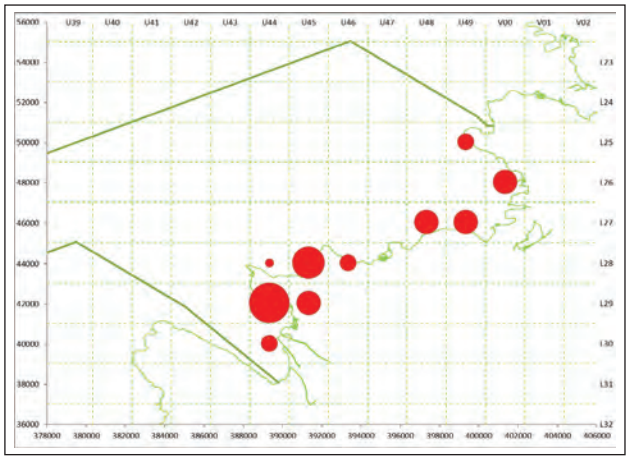

Fig. 10: Occurrence of** Apletodon incognitus **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 10: Pojavljanje vrste** Apletodon incognitus **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

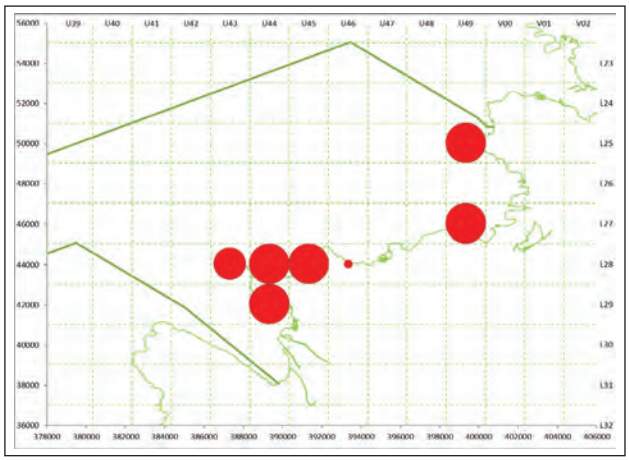

Fig. 11: Occurrence of** Lepadogaster candolii **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 11: Pojavljanje vrste** Lepadogaster candolii **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

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.

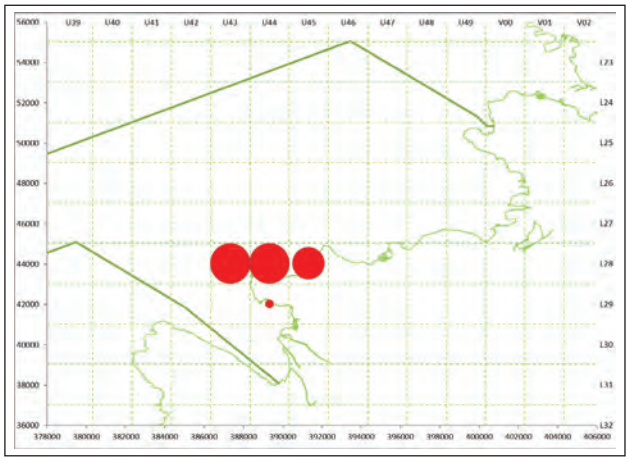

Fig. 13: Occurrence of *Microlipophrys nigriceps* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 13: Pojavljanje vrste *Microlipophrys nigriceps* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

Parablennius zvonimiri (Kolombatović, 1892)

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

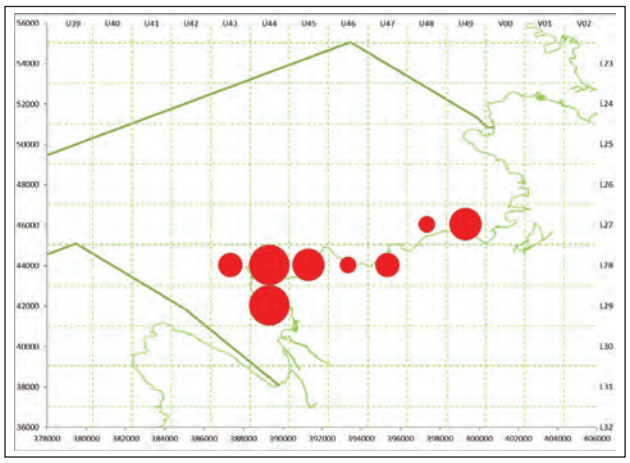

Fig. 12: Occurrence of *Lepadogaster lepadogaster* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 12: Pojavljanje vrste *Lepadogaster lepadogaster* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

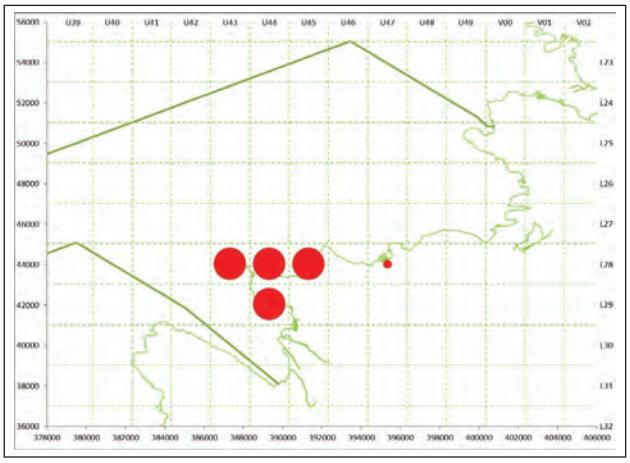

Fig. 14: Occurrence of *Parablennius zvonimiri* ***in the Slovenian Sea. For explanation of dot size see Fig. 5.***
Sl. 14: Pojavljanje vrste *Parablennius zvonimiri* ***v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.***

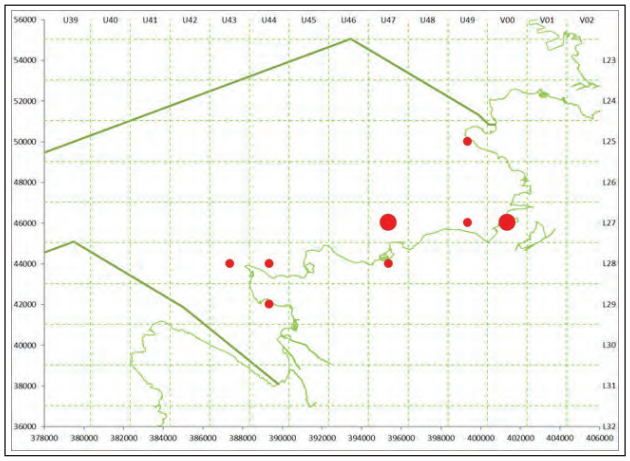

Fig. 15: Occurrence of** Clinitrachus argentatus **in the Slovenian Sea. For explanation of dot size see Fig. 5.
Sl. 15: Pojavljanje vrste** Clinitrachus argentatus **v slovenskem morju. Glej Sl. 5 za pojasnilo glede velikosti posameznih krogcev.

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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MORSKA KRIPTOBENTOŠKA FAVNA RIB SLOVENIJE (SEVERNI JADRAN)

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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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