ISBN 978-961-93486-4-2

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Piran, 2016

Title: BIOGENIC FORMATIONS IN THE SLOVENIAN SEA

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Publisher: National Institute of Biology, Marine Biology Station Piran

For publisher: prof. dr. Tamara LAH TURNŠEK

Print: SCHWARZ PRINT d.o.o.

Circulation: 500

Place and year of publishing: Piran, 2016

This document has been printed within the framework of Project on Mapping of key marine habitats in the Mediterranean and promoting their conservation through the establishment of Specially Protected Areas of Mediterranean Importance (SPAMIs)" (MedKeyHabitats Project).

The Medkeyhabitats Project is implemented with the financial support of MAVA foundation.

CIP - Kataložni zapis o publikaciji

Narodna in univerzitetna knjižnica, Ljubljana

551.26(262.3-17)

574.1(262.3-17)

LIPEJ, Lovrenc

Biogenic formations in the Slovenian sea / Lovrenc Lipej, Martina Orlando-Bonaca, Borut Mavrič ; [photographs Emiliano Gordini ... [et al.] ; illustrations Tihomir Makovec, Milijan Šiško]. - Piran : Nacionalni inštitut za biologijo, Morska biološka postaja, 2016

ISBN 978-961-93486-4-2

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284112896

To Žiga and Samo...

and all those who have dedicated their lives to the wonderful world below the surface.

Content

Preface

Khalil ATTIA
RAC/SPA Director

The Mediterranean Sea is characterized by its rich biodiversity and high rate of endemism. The Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea, adopted by the Contracting Parties to the Barcelona Convention in 2008 and recently updated by CoP19 (Athens, February 2016), aims at protecting the coralligenous assemblages in the Mediterranean.

The enhancing of scientific research, with the collaboration between the Mediterranean countries by transferring of technologies and working tools and spreading knowledge related to coralligenous assemblages diversity, contributes in this way, to the implementation of the Action Plan.

This publication is the product of scientists' research work, exchange of experience and communication of data to preserve the region common natural heritage.

The Regional Activity Centre for Specially Protected Areas (SPA/RAC) will continue to coordinate regional efforts and to promote inter-country cooperation towards protecting the Mediterranean's coralligenous assemblages.

Preface

Prof. Dr. Tamara Lah Turnšek
Directress of the National Institute of Biology

Even though Slovenia is a small country, it has an impressively high biodiversity and beautiful nature. These were described as early as the 17th century by Janez Vajkard Valvasor and later on by many naturalists and researches. Slovenia's tiny part of the Adriatic Sea has induced curiosity that has led to the accumulation of a wealth of knowledge about this marine environment. Many researchers have dedicated their whole life to it, like the great biologists Miroslav Zei, Jože Štirn and others. The generations of scientists from the Marine Biology Station of the National Institute of Biology have, and will be describing this sea, this big organism, which lives and breathes with us, feeds us, but also punishes us, is stubborn, and is kind – and will endure for a long time after we are gone…

Our task here and now is to preserve our sea. That is why, first of all, we have to understand it precisely – down to the atoms and molecules, to the cells and their aggregates and further dig into the secrets of marine symbioses. We can start with this wonderful book by Lovrenc Lipej, Martina Orlando-Bonaca and Borut Mavrič from the Marine Biology Station at Fornače in Piran. They visited the bottom of the sandy Adriatic Sea and described the geologic forms of underwater structures – or biogenic formations, well known to generations of fishermen. They shed light on and described this ecosystem, whose presence we could only suspect, with miraculous colours. We could hardly imagine how rich, interesting and special the world of biogenic formations created by life forms really is.

Although divers, biologists, geologists, physicists and chemists have discovered a lot of interesting and special knowledge about marine biodiversity, further research in this direction will undoubtedly reveal new facts. In particular, those related to the understanding of natural partnerships - symbioses and associations, and the fluctuations and balances between living and nonliving nature, which amazes us time and again. We can admire the mysterious forms of life on this planet, no matter where they appear on the planet, no matter at which altitude or depth or geographical coordinates. But the biogenic formations are here, we can reach them by putting on our mask and *flippers – or only from the sofa, if we open the book. The more interesting they are, the more we are willing to dive deeper into the explanations of live underwater sculptures, as expressed by talented biologists, the researchers of the Marine Biology Station of our Institute.*

About the book

Authors

It is well known that the northern Adriatic Sea is particular. This northernmost area of the Mediterranean Sea is outstanding from different points of view, due to the numerous particular characteristics such as the trezze, as they are called in Trieste or tegnùe, as they are known in Venice. Similar formations are also present in the Slovenian part of the Adriatic Sea, which are known for their immense biodiversity. Paradoxically, fishermen from both sides of the border have been aware of such biogenic formations for centuries, while researchers discovered these valuable elements of biodiversity only recently. These small and peculiar geomorphologic formations, densely overgrown with fauna and flora, creep out of the sedimentary bottom in the form of small hills and attract a variety of economically important fish species and other animals. The fact that researchers from Slovenia and Italy have the possibility to study such hidden treasures of biodiversity in the Gulf of Trieste and the broader northern Adriatic is even more inspiring.

Up to date, the presence of trezze and similar structures has not been confirmed in the Slovenian part of the Adriatic; however, there are other kinds of structures of biogenic origin (biogenic formations). One such biogenic formation is located in front of Cape Ronek, not far from the Nature Reserve of Strunjan, whereas the second one is located close to the Nature Monument of Debeli rtič. Both biogenic formations are large-sized, since they are almost 200 m long and both are made of dead Mediterranean stony coral (Cladocora caespitosa) corallites. Underwater sampling revealed an immense biodiversity, hosted by both giant platforms; a high density of stony coral colonies and the giant brain sponge (Geodia cydonium), a huge diversity of benthic invertebrates and many coralline algae. Taking into account the diverse fish fauna, the importance of biogenic structures is even more significant.

Although SCUBA diving researchers have discovered many new, less known and rare species associated with biogenic formations, we are certain that future research will substantially enlarge the checklist of species. In addition, further research will improve our understanding of ecological relationships, patterns and processes related to biogenic formations, and also ellucidate the impact of anthropogenic activities on such benthic communities.

This book provides a general overview of the biodiversity of biogenic formations in Slovenia. It is not an ultimate survey of fauna and flora. The aim is to inspire researchers of marine life in the northern Adriatic and other Mediterranean areas, scientists from other fields of life sciences and SCUBA divers, to study biogenic formations and coralligenous biocoenoses in an attempt to reveal their hidden treasures and mysteries. Having this in mind, we would like to express our sincere thanks to the RAC/SPA Centre in Tunis for their immense support in publishing this document.

INTRODUCTION

At the top of the Adriatic Sea

Marine and terrestrial habitats differ in many ways. One major difference is the fact that there is not a single animal species on land that is attached to the substrate. A number of external parasites might be the only exception. On the contrary, many animal species in the sea there live their entire life or at least part of it attached to the seabed or other living organisms. Some of these sessile animals are known to create new habitats. The first examples we most probably think of are corals and the big coral reefs that they form in tropical waters, but habitats and animal groups that form new living environments are much more numerous. In fact, other species create many underwater reefs (Figure 1).

Figure 1: Biogenic formations are thriving with life and sustain large numbers of different species.

The Slovenian Sea

The Adriatic Sea is divided into three large geographical units, namely, the northern, central and southern Adriatic (Figure 2). The northern Adriatic is a relatively shallow ecosystem, considering that its depth does not exceed 50 m. The Gulf of Trieste is a shallow marine ecosystem where characteristics of the coastal and open waters of the northern Adriatic are combined. The Slovenian part of the Adriatic Sea covers the southern part of the Gulf of Trieste. With few exceptions, the depth does not exceed 25 m. Due to its shallowness and freshwater inputs, the waters of the gulf experience considerable temperature and salinity variations. The tidal amplitudes are also remarkable. The water in the gulf circulates in an anticlockwise direction. The circulation is influenced by winds, while the eastern current originating from the Istrian coast has a great impact on the hydrodynamics of the Gulf. The Gulf of Trieste is known for its intensive fisheries and tourism.

The coastline of the Slovenian Sea (Figure 3) and the Gulf of Trieste is also experiencing intensive urbanisation, which affects marine and coastal biodiversity. The Slovenian coast is approximately 46 kilometres long. It is characterized by flysch cliffs, which are still present in their natural state, and flat sedimentary coast in the mouths of valleys and rivers. In the central part of the Slovenian Sea, sand is predominant, consisting of 80% fine sand of biological origin (Ogorelec *et al.,* 1991). The sediment inside the bays of Koper and Piran consists of silt and clay.

Despite the fact that the coastline is heavily urbanised and industrialized, the Slovenian Sea plays an important role in terms of biodiversity. The numerous habitat types include some rare, peculiar and endangered ones, including coralligenous biocoenosis, associations with different *Cystoseira* species and seagrass meadows. The richness of species inhabiting the Slovenian part of the Adriatic Sea or occasionally present there is immense. According to some studies, at least 1800 species have been recorded in the area. In order to ensure conservation of the most important elements of biodiversity, a number of protected areas – marine and coastal – have been established starting in the 1990.

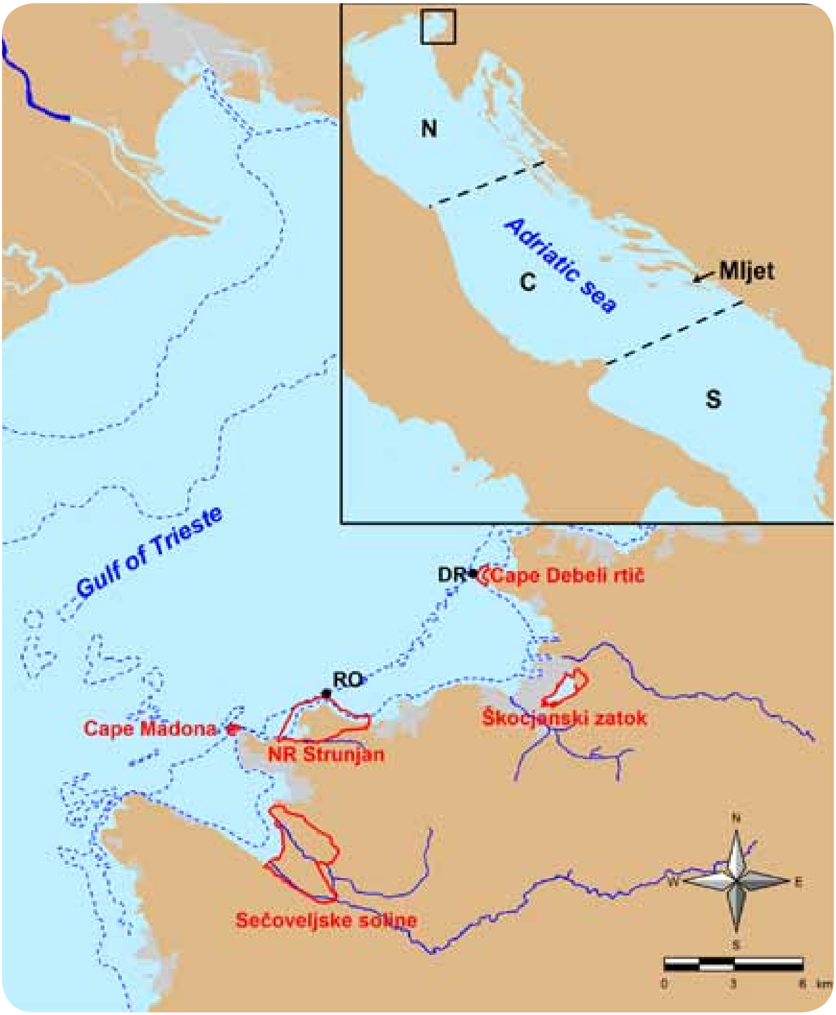


Figure 2: Map of the Slovenian part of the Adriatic Sea with marine and coastal protected areas highlighted in red. The two black dots represent the two biogenic formations: RO - Ronek and DR - Debeli rtič. The smaller map represent the division of Adriatic Sea in three parts: N - northern Adriatic, C - central Adriatic and S - southern Adriatic Sea.

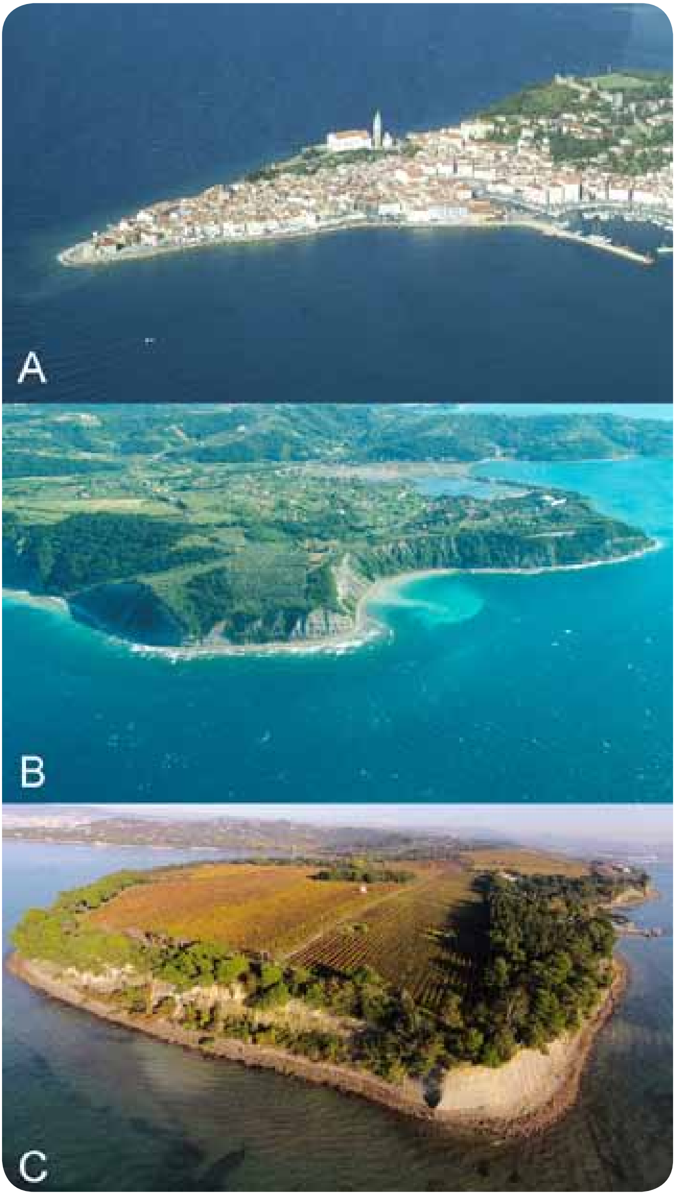


Figure 3: Panoramic vew of of the three marine protected areas in Slovenia, the Nature Monument Cape Madona (A), the Nature Reserve Strunjan (B) and the Nature Monument Debeli Rtič (C). See figure 2 for locations.

The northern Adriatic coralligenous

The shallow northern Adriatic Sea is dominated by muddy and sandy bottoms, which are nutrient-rich and for a long time it was believed that these are the only bottoms existing in this area. Researchers in the 1960s have shown that the monotony of sedimentary bottoms is often interrupted by the presence of numerous rocky habitats. In fact, the first to mention the rocky outliers in this part of the Adriatic Sea was Giuseppe Olivi more than 200 years ago (1792). Moreover, northern Adriatic fishermen have been familiar with this kind of environments for centuries because they are rich fishing points; they are called *tegnùe* along the Venetian coast (Casellato *et al.*, 2006), while in the Gulf of Trieste they are known as *trezze*. These rocky outcrops attract a diverse number of bottom invertebrates and fish. Around 250 such rocky outcrops (Figure 4) have been counted in the Italian part of the Gulf of Trieste.

Figure 4: Biogenic formation in front of Grado (Italy).

Moreover, similar formations are found in Slovenia; they are less numerous, but on the other hand much bigger. These biogenic formations have many special features that are specific to a coralligenous biocoenosis, which is a biological community formed primarily by coralline algae. Unlike other benthic marine environments, the coralligenous biocoenosis, abbreviated as coralligenous, received considerably less attention. In 1969, professor Štirn and his colleagues wrote a paper regarding the coralligenous environment in the Slovenian part of the Adriatic Sea (Figures 5, 6, 7), but this was the only document available until recently (Štirn *et al.*, 1969). In the last decade, particularly after a scientific meeting on the coralligenous environment, which took place in Piran in March 2011, the researchers suggested that the northern Adriatic forms of coralligenous environment, such as *trezze, tegnùe,* the precoralligenous in the infralittoral belt and biogenic formations of Mediterranean stony coral, should be recognized as specific elements within the Mediterranean coralligenous biocoenosis.

Figure 5: Melobesian coralligenous from the Slovenian Sea.

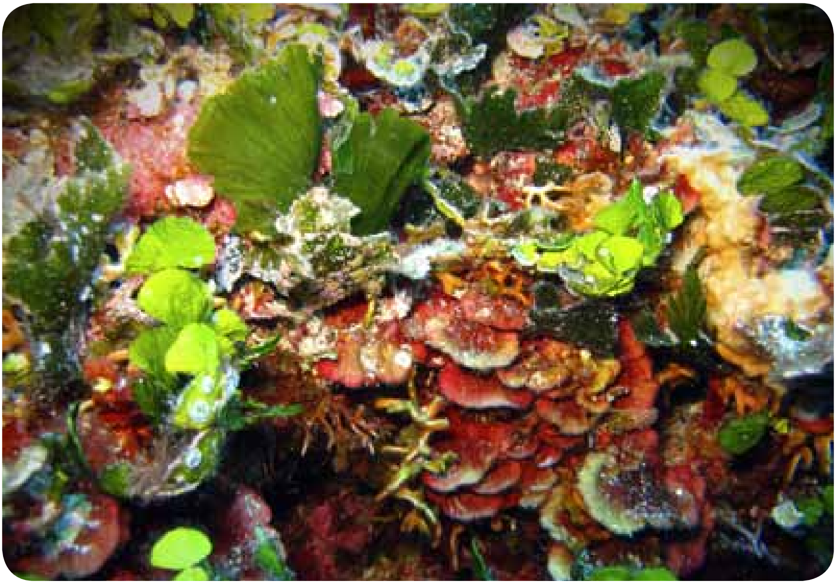
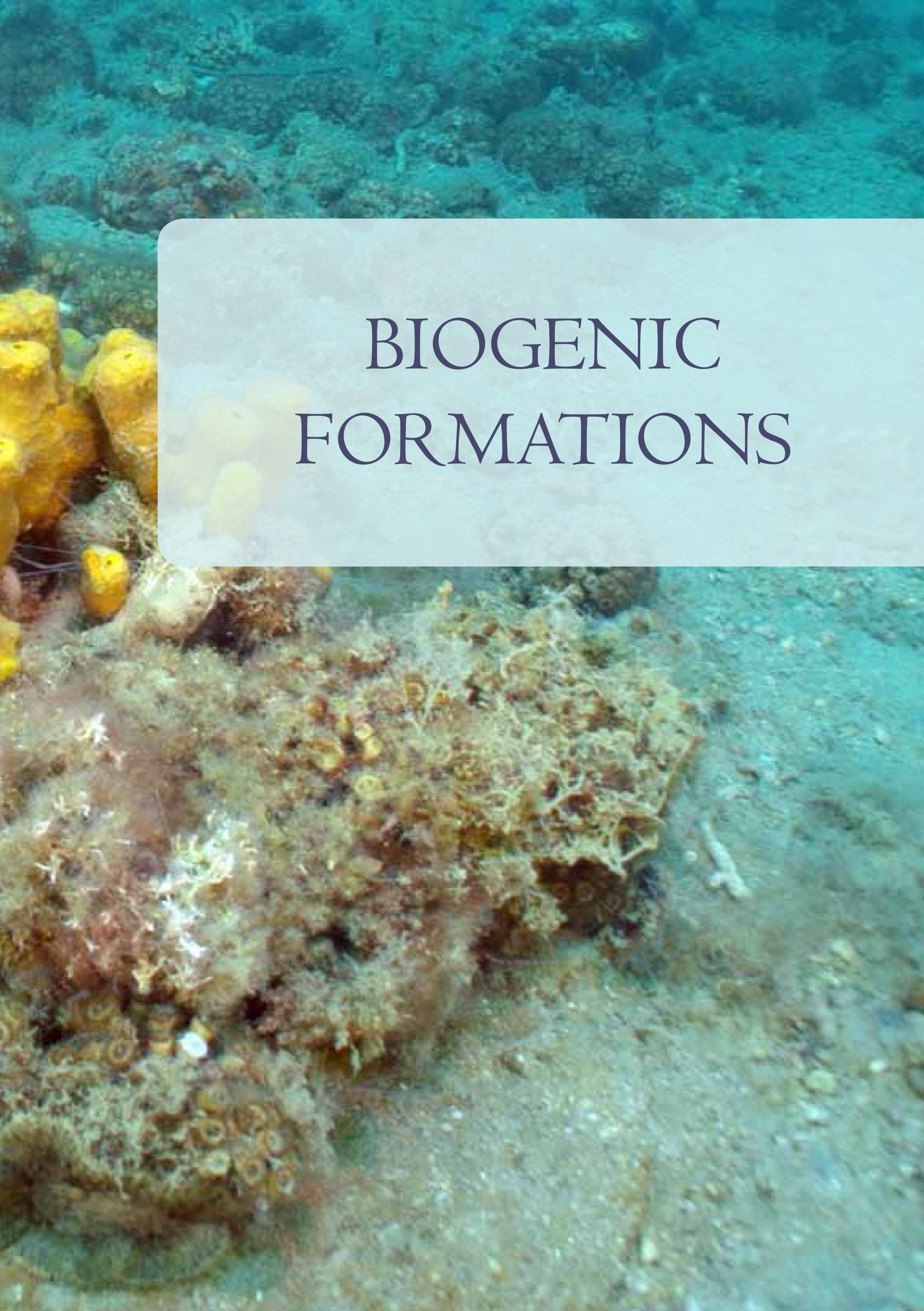


Figure 6: Precoralligenous from the Slovenian Sea.

Figure 7: Facies of Mediterranenan stony coral from the Slovenian Sea.

BIOGENIC FORMATIONS



What are biogenic formations?

The expression biogenic formation denotes any formations that are the result of limestone loading by some marine organisms during their lifetime. Such organisms are called ***bioconstructors*** since, by creating calcareous structures, they offer settlement possibilities to many diverse organisms. The most well known bioconstructors are corals (Anthozoa) that create coral reefs in tropical and partially sub-tropical environments. In addition to corals, other invertebrates, such as hydrozoans (Hydrozoa) and marine tube worms (Polychaeta Sedentaria), create reefs. Several other groups of invertebrates and algae construct smaller forms of very diverse biogenic formations, which may cover surfaces of only a few dm^2. In this publication, the overview of biogenic formations includes not only newly built structures but also those formed by the dead skeletal remains of different organisms. Many bottom invertebrates have a skeleton or a shell made of limestone, which may form hard bottom islands in a predominantly sedimentary environment.

An overview of the biogenic formations that have so far been identified in the Slovenian Sea and in the surrounding area is presented in Table 1. The word ***biocoenosis*** in its broad sense denotes a community of living organisms inhabiting a particular living environment. An ***association*** is a lower bionomic unit, a plant community, which defines a special floristic composition (characteristic or differential species). Associations can have several ***facies***, which are even smaller bionomic units, characterized by the local prevalence of certain ecological factors that lead to a dense development of one or a number of species.

Table 1: Basic data on currently identified and potential biogenic formations in the Slovenian part of the Adriatic Sea and their bionomic definition. Types of biogenic formations follow each other in relation to their increasing surface. The asterisk indicates a potential bionomic definition in accordance with the initiative for the definition of the coralligenous biocoenosis in the northern Adriatic Sea, presented by participants of the northern Adriatic benthologists workshop held in Piran in 2011.

Type of biogenic formation	Dominant elements	Distribution	Coastal belt	Depth (m)	Area (m^2)	Peculiarity	Bionomic definition
Clusters	Filter feeding epifauna	Western part of Piran bay	Circalittoral	20 – 30	< 0.10	Secondary hard bottom formed by seashells	Biocoenosis of the coastal detritic bottom
Reefs of tube worms	*Ficopomatus enigmaticus*	Coastal wetlands	Infralittoral	1 – 3	< 5	Monospecific reef	Euryhaline and eurythermal biocoenosis; Facies with *F. enigmaticus*
Rocky outcrops called "trezze"	Coralline algae	IItalian part of the Gulf of Trieste; western part of Piran bay	Circalittoral	20 – 30	< 10	Secondary hard bottom	Biocoenosis of the coastal detritic bottom *Coralligenous biocoenosis
Areas with Medi-terranean stony coral	*Cladocora caespitosa*	Cape Madona and Piranček	Infralittoral	8 – 11 7 – 10	< 100	Rocky bottom	Biocoenosis of photophilic algae; Facies with *C. caespitosa*
Precoralligenous	Coralline algae	Cape Debeli rtič; Izola; Strunjan NR; area from Pacug to Bernardin	Infralittoral	6 – 14 (4 – 16)	< 1000	Initial stage, rocky bottom	Biocoenosis of photophilic algae; Association with *Fla-bellia petiolata* and *Peysson-nelia squamaria* * Coralligenous biocoenosis
Mediterranean stony coral reefs	*Cladocora caespitosa*	Cape Debeli rtič; Cape Ronek	Circalittoral	12 – 20	> 10000	Composed by dead corallites	Biocoenosis of the muddy detritic bottom * Coralligenous biocoenosis

Bionomic definition or where to find biogenic formations?

Where are biogenic formations located? In the Adriatic Sea, they are located from the shallowest areas to the greatest depths. In order to define the environment in which biogenic formations occur, the first thing to do is define coastal belts, namely the vertical distribution of living environments in the sea. Thus, there is a succession of different belts, starting with the one adjacent to the coast and ending with the greatest depth zone. In the Slovenian part of the Adriatic Sea, the succession is as follows: the spray zone or supralittoral belt, the intertidal zone or mediolittoral belt, the infralittoral and the circalittoral belts.

The spray zone is defined by the presence of the spray generated from the breakage of waves on rocks. The extension of the supralittoral belt is closely related to the exposure of the coastline. In an exposed environment, due to strong hydrodynamic forces, the spray is more diffused in a vertical direction than it is in an environment protected from waves. The spray zone has characteristic faunistic (Figure 8) and floristic elements.

Figure 8: Very inhospitable ecological conditions rule in the spray zone, which are only tolerated by rare organisms, including the small periwinkle snail (Melaraphe neritoides).

Within this transition belt between the land and the sea, very harsh living conditions rule, since organisms are always out of the water (emersion), but moisturized by marine spray. Only a few species can withstand such ecological conditions; however, they may occur in large numbers. The main ecological factors in the spray zone are abiotic factors. Besides the already mentioned wave motion (hydrodynamics), temperature, salinity and the associated moisture and evaporation are also important.

The intertidal zone is characterized by alternating phases of high and low tides (Figure 9). During the high tide, intertidal organisms are submerged (immersion) and can carry out their life functions. At low tide, when above water and exposed to the atmosphere, they try to withstand the harsh living conditions. Like in the spray zone, living conditions in the intertidal zone are also considered to be very unfavourable and limiting.

Figure 9: The intertidal zone under water (left) and emerged (right).

The infralittoral belt is characterised by stable, favourable living conditions, and therefore organisms do not face several extremely harsh circumstances related to emersion. This belt (Figure 10) extends to the lower growth limit of photophilic algae on rocky bottoms and the lower limit of seagrasses on sedimentary bottoms (mostly 8-11 m of depth in the Slovenian Sea).

Figure 10: The infralittoral belt on rocky bottoms is overgrown with algae, while on sedimentary bottoms with seagrasses.

In ***the circalittoral belt,*** among macrophytes only sciaphilic algal species are present, living in very low light conditions. Environmental factors such as light availability, turbulence, sedimentation and substrate type, considerably influence the survival of organisms. In the Slovenian part of the Adriatic Sea, the circalittoral belt occurs mainly on sedimentary bottoms (Figure 11).

Figure 11: Circalittoral sedimentary bottom.

Nowadays, sampling with autonomous diving equipment (SCUBA) is of crucial importance for exploring biogenic formations. Štirn *et al.* (1969) in their paper on the knowledge of the Adriatic coralligenous environment, which was also one of the first studies of this type in the Adriatic Sea, had already noted the importance of using diving equipment.

As already mentioned, at a joint meeting held in Piran in March 2011, northern Adriatic researchers from Italy, Croatia and Slovenia took the initiative to distinguish a number of coralligenous forms (like *trezze, tegnùe,* precoralligenous and Mediterranean stony coral biogenic formations) within the coralligenous Mediterranean biocoenosis.

Since the bionomic definition of the coralligenous biocoenosis in the northern Adriatic Sea has not yet been clarified, in this monograph we wish to avoid defining biogenic formations in terms of biocoenoses. Thus, every type of biogenic formation is considered as a complete unit, regardless of its (previous) bionomic definition.

Clusters

The western part of the Slovenian Sea is characterized by an area in the form of a large tongue which is distinctly different from other areas (Figure 12). On the muddy sea bottom of this area, clusters of benthic organisms appear that settled on the remains of bivalve shells and other skeletal residues. Such an environment is also called shell detritic bottom. The marine currents carry shells to depressions or mounds, on which various benthic invertebrates immediately begin to settle. Apart from bivalve shells, sea snail shells, marine worm tubes, skeletal remains of sea urchins, both regular (Echinoidea Regularia) and irregular (Irregularia), and some coralline algae can also be found. Here and there, sea currents carry small stones as well. Still, this environment apparently acts as a muddy desert, which is dotted with small oases of clusters, built on the skeletal residues.

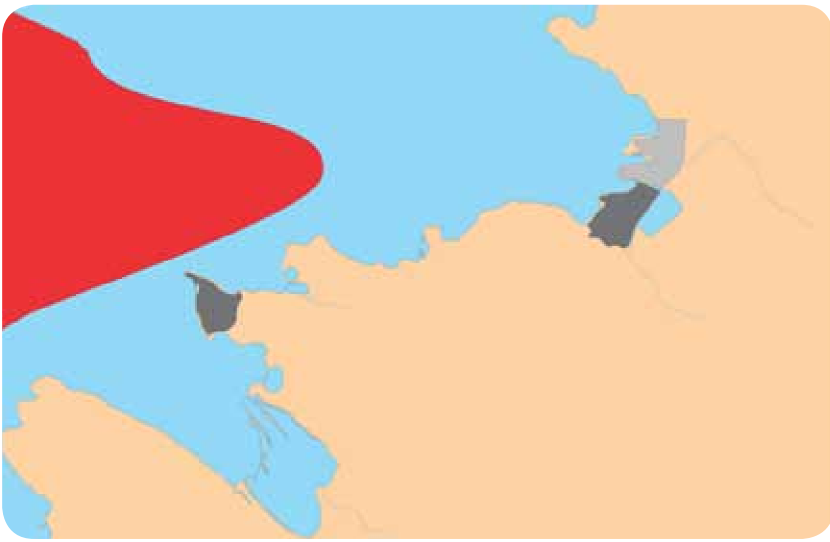


Figure 12: Indicative distribution of coastal detritic bottom biocoenoses in the Slovenian Sea.

From a bionomic point of view, the shell detritic bottom corresponds to the coastal detritic bottom biocoenosis (Table 1; Lipej *et al.*, 2006). The secondary hard bottom, formed by the accumulation of bivalve shells and skeletal remains of other organisms, is an important factor that allows the colonization of a diverse group of invertebrates (Figure 13). Typical species are marine sponges (e.g. *Suberites domuncula*), the egg cockle *Laevicardium oblongum,* the hermit crab *Paguristes oculatus,* and the green sea urchin (*Psammechinus microtuberculatus*). Clusters are defined by representatives of the epifauna (fauna living on the surface of the substrate or on other living organisms), which differ from the epifauna that is characteristic of the muddy bottom surface.

Figure 13: Clusters of benthic organisms in coastal detritic bottom biocoenoses.

Reefs of tube worms (polychaetes)

The Škocjanski zatok Nature Reserve (Figure 14) is a coastal wetland in the vicinity of the port and town of Koper. Since its establishment in the late nineteen fifties, it has faced major changes. Investigations in the lagoon part of the inlet have revealed interesting results in terms of marine and brackish fauna and flora. Moreover, some non-native species of marine organisms were discovered, including the tube worm *Ficopomatus enigmaticus*.

Figure 14: Panorama of the Škocjanski zatok Nature Reserve.

Using its tubes, *F. enigmaticus* (Figure 15) creates large clusters of specimens, a kind of conglomerate, which in exceptional cases forms reefs with a surface greater than 1 m^2. Thus, in the area of the Škocjan inlet where storm-water overflow drains into the lagoon, there are many reefs of this type (Figure 16). Since this species is highly resistant to major changes in salinity, it inhabits coastal wetlands around the Adriatic and the Mediterranean Seas. Although it is a non-native species originating from the northern coast of South America, no negative effects on the new environment have been noted until now. Actually, this tube worm has found its new niche in a changing environment, with high fluctuations in salinity and temperature, where only the most ecologically hard-wearing organisms can adapt. Since, in terms of number of species, lagoons are less diverse habitats compared to the marine environment as a whole, such reefs are very important. They increase spatial heterogeneity, which is a key factor for the settlement of other organisms, although significantly less than in a typical marine environment.

Figure 15: Ficopomatus enigmaticus *– single specimens with the branchial crown visible in the aperture of the hard tube.*

Figure 16: Ficopomatus enigmaticus *- reefs composed of hard tubes.*

Trezze and tegnùe

Biogenic formations in the Italian part of the northern Adriatic Sea are peculiar, since such geological structures are not present in other parts of the Mediterranean Sea. Apparently, they resemble coral reefs, ascending a few meters in height from the seabed. Such formations have been known for centuries as *tegnùe* along the Venetian coast, and as *trezze* (Figure 17) in the Gulf of Trieste.

Figure 17: Trezza, a biogenic formation offshore Grado.

Currently, the origin of underwater reefs in Italian northern Adriatic waters is explained in different ways. According to their formation process, two types of rock substrate are defined:

- **clastic sedimentary rocks ("beachrocks")** originating from the cementation of carbonate sediments (sands) or organogenic detritus (mollusc thanatocoenosis). They have the form of horizontal slabs that rise from the sea bottom with a slight slope; therefore, they are often covered by sediment (Andreoli *et al.,* 2010).

- **sedimentary rocks in chemical storage** whose formation is associated with the emission of methane gas (CH_4) from the seabed. In seawater, methane oxidises, providing a source of carbon dioxide that, in the presence of calcium, is converted into carbonate ($CaCO_3$), thus activating the cementation of sediments. This process takes place in layers that are covered by sediments. The rocks are then revealed due to erosion of covering sediments (Andreoli *et al.,* 2010).

During the creation of new living niches on these reefs, two processes are crucial, bioconstruction and bioerosion, both presented in the chapter on bioconstructors. In the first process, some species of benthic organisms precipitate calcite, which is the main mineral component of limestone, while in the second process certain invertebrates bore holes in the rocky substrate.

It is not yet clear whether geomorphological features like trezze (on the Italian side of the Gulf of Trieste) are also present in the Slovenian Sea. So far, studies carried out on circalittoral biocoenoses (Orlando-Bonaca *et al.,* 2012) have been very limited and such formations have not been discovered. However, dredging close to the Italian border in Piran bay showed that there are many hard habitats (covering a few m^2), with diverse epifaunal elements, on the sea bottom.

Areas with Mediterranean stony coral

Mediterranean stony coral (*Cladocora caespitosa*) is a representative of temperate anthozoans living in the Mediterranean Sea, and is known to create real coral reefs. The species occurs in the Mediterranean Sea from the Messinian Salinity Crisis in the Miocene (6 million years ago). It occurs from shallow waters to almost 50 m of depth, while in the Slovenian part of the Adriatic Sea down to 20 m. The depth distribution is limited by light conditions, since zooxanthellae, endosymbiotic dinoflagellates, are characteristic of this species, and they need light for photosynthesis.

Mediterranean stony coral (Figure 18) is a good ecological indicator, since it is found everywhere in the Mediterranean Sea, and it is a slowly growing sessile invertebrate, reflecting the consequences of past events in its environment. Unfortunately, in recent decades, in many parts of the Mediterranean Sea, mass deaths of this coral species have been reported (Figure 19).

Figure 18: A colony of Mediterranean stony coral.

Figure 19: Normal (top left), bleached (top right) polyps, and a completely dead colony (below) of Mediterranean stony coral.

Mediterranean stony coral occurs practically everywhere in the Slovenian Sea. In some places, live colonies form a special facies, which is typical of Piran's cape (Cape Madona). In this area, a very high density of living coral colonies per unit area has been recorded. The locality of Pirunček (nearby Piran) is even more interesting from that point of view, since the density of colonies in this facies is among the highest in the Slovenian Sea (Table 2, Figure 20). One third of all colonies measures more than 20 cm in length, indicating favourable conditions for their growth in this environment.

Moreover, in the waters off Piranček, large-sized colonies of Mediterranean stony coral have been found. The biggest colony found had a diameter of 68 cm.

Table 2: Density of Mediterranean stony coral colonies in various areas in the Slovenian Sea.

Locality	**Density (n/100m²)**
Biogenic formation at Debeli rtič	3 (2-4)
Cape Debeli rtič	83 (70-96)
Cape Strunjan	85 (66-105)
Cape Ronek	108
Piranček	160 (128-192)
Pacug	186
Bernardin	285 (263-306)
Biogenic formation at Ronek	652 (498-806)

Figure 20: Facies of Mediterranean stony coral near the locality of Piranček in Piran.

Precoralligenous and coralligenous

In their benthic bionomy of the Adriatic Sea, Pérès & Gamulin-Brida (1973) defined the initial stage of the coralligenous biocoenosis as precoralligenous, where green sciaphilic algae, such as *Halimeda tuna* and *Flabellia petiolata,* are dominant. The precoralligenous can gradually develop into a mature stage (climax) of the coralligenous biocoenosis or it can never reach this final stage. In the coralligenous, highly sciaphilic communities with coralline algae, sponges, corals and bryozoans are dominant. Pérès & Gamulin-Brida (1973) argued that the precoralligenous occurs in different kinds of biotope: a) in the upper parts of steep walls, b) in shaded areas of deeper meadows of the Neptune grass (*Posidonia oceanica*) and in dense meadows of this species in shallower waters, c) in shaded surfaces under bushy seaweeds like *Cystoseira adriatica*, d) in rock-shelters, cavern roofs, caves within shallower coastal belts, and d) on half-shaded surfaces of mediolittoral formations of red incrusting algae. In some Adriatic and Mediterranean areas, calcified thalli of some species (such as *Lithophyllum byssoides* and *L. tortuosum*) grow and merge among them to form magnificent mediolittoral horizontal shelves. These biogenic formations, called "trottoir" (pavement in French) because they resemble paving slabs, measure more than 50 cm in width and stick to the rocky surface in the basal part only, where growth began.

According to Štirn and colleagues (1969), the precoralligenous starts between 8 and 12 m of depth and prospers down to the transition into soft bottom (Table 3). The Melobesian coralligenous may develop between 10 and 16 m of depth, but also as an outlier (or enclave) in the mediolittoral belt. Štirn and colleagues divided the coralligenous into several types according to vertical distribution (Table 3). They distinguished the upper precoralligenous, the lower precoralligenous, the Melobesian coralligenous, the facies with *Parazoanthus axinellae* (Figure 21), the coralligenous in the strict sense, and the lower coralligenous.

Figure 21: The anthozoan Parazoanthus axinellae.

Table 3: Distribution of the coralligenous according to Štirn and colleagues (1969).

	Depth range (m)	Typical algae (genera)	Typical animals (genera)
Upper precoralligenous	8-12	*Codium, Sargassum*	*Chondrilla, Ircinia, Sphaerechinus, Echinaster*
Lower precoralligenous	10-14	*Flabellia, Halimeda*	*Chondrosia, Protula, Halocynthia, Myriozoum*
Melobesian coralligenous	10-16	*Lithophyllum, Peyssonnelia, Mesophyllum*	*Petrosia, Spondylus, Arca, Retepora, Ircinia*
Facies - *Parazoanthus*	12-16	-	*Axinella, Halichondria, Aplysina cavernicola, Dysidea*
Coralligenous *sensu stricto*	15-55	-	*Eunicella, Leptopsammia, Hippodiplosia, Cellaria,*
Lower coralligenous	30-50	-	*Paramuricea, Corallium*

Of the above mentioned coralligenous types, the upper and lower precoralligenous, and the Melobesian coralligenous can be found in the Slovenian Sea (according to Štirn *et al.,* 1969). Despite the confusion as regards the definition of coralligenous biocenoses in the Mediterranean bionomy, in our opinion these three types of coralligenous biogenic formations in the infralittoral belt could be considered under the common name of precoralligenous. In the Slovenian Sea, the upper precoralligenous on rocky bottom can be found from 4 m of depth, following the biocoenosis of photophilic algae, in relation to light availability. It occurs where light conditions are too weak for the survival of brown seaweeds of the genus *Cystoseira.* The boundary between the upper and lower precoralligenous in the Slovenian Sea is, considering the above mentioned study, very difficult to determine, since coastal belts quickly succeed each other in a relatively short distance from the coastline.

On the contrary, the Melobesian coralligenous (according to Štirn *et al.,* 1969) can be recognized quickly by the characteristic shape and colour. Red coralline algae grow over several rocks and/or boulders like a kind of glue, and form amorphous formations, which are rich in tunnels and caves. Among calcified red algae, the best known are those from the genera *Peyssonnelia, Jania, Corallina, Lithothamnion, Lithophyllum,* and *Mesophyllum.* They can also be found in shallower waters in the form of enclaves (small bionomic categories that indicate the occurrence of one biocoenosis inside another), hidden in shady biotopes, such as rock-shelters, caves or large crevices. Precoralligenous formations can be encountered in the infralittoral belt in all places where there is a rocky bottom, but significant differences in communities can be found, mainly linked to the size of rocks and boulders. In such an environment, some characteristic species like the thorny oyster (*Spondylus gaederopus*) and the stony sponge (*Petrosia ficiformis*) can be encountered (Figure 22).

Some authors have included the association Flabellio-Peyssonnelietum squamariae Molinier 1958 (part of the precoralligenous), in the biocoenosis of photophilic algae (Bakran-Petricioli, 2006; Giaccone, 2007), which grows in the infralittoral belt.

Figure 22: The stony sponge (Petrosia ficiformis)*.*

The presence of the coralligenous (see Table 1) in the Slovenian Sea has not been confirmed yet, but it is known from other parts of the Adriatic Sea. When talking about the coralligenous, we have in mind the coralligenous biocoenosis, which is placed among circalittoral biological communities. The coralligenous ("coralligène") was firstly named by Marion (1883) at the end of the 19th century as an area located among seagrass meadows of the Neptune grass (*P. oceanica*) and coastal muddy bottoms, known by fishermen from Marseilles as *"broundo"*. The name was selected because red coral (*Corallium rubrum*) grew in this area, in a depth range from 30 to 70 m (Figure 23).

The first division of the coralligenous was given by Laborel (1960). He distinguished formations in caves and rock-shelters, formations on walls, formations at the foot of walls, formations on flat surfaces and coralligenous platforms. Pérès and Picard (1964) have simplified this division and proposed two categories, namely the coralligenous on coastal rocky bottom and the coralligenous on platforms or flat rising grounds (outliers). They proposed the definition of coralligenous as the climax stage in the succession, and the precoralligenous as an initial stage of the coralligenous biocoenosis.

*Figure 23: The red coral (*Corallium rubrum*).*

The coralligenous is associated with corals only in respect of the name, since it is formed by coralline algae that create limestone formations as corals do. In such communities, corals may also be present, but not necessarily. Corals are anthozoan (Anthozoa) representatives, typical benthic cnidarians, characterized by the generation of polyps. They can be solitary or colonial. Colonial corals can generate large biogenic formations called coral reefs. They are typical mainly of tropical seas between 20° and 30° latitude, but there are also temperate coral reefs. A real coral reef of Mediterranean stony coral (*C. caespitosa)* is known from Lake Veliko jezero on Mljet Island in southern Dalmatia (Figure 24).

Coralline algae that create the coralligenous probably get this name because they look like miniature corals. These algae are characterised by the fact that calcium carbonate ($CaCO_3$) accumulates in their cells, which protects the algae from herbivores. Coralline algae live in low light conditions, which are too harsh for other species, like green algae.

Figure 24: A Mediterranean stony coral reef on Mljet Island.

Coralline algae

The precoralligenous and the coralligenous are primarily associated with the presence of coralline algae (Figure 25), which are considered *bioconstructors* of the secondary (organogenic) hard bottom. These species are also called "*bioengineers*" as they create new niches for many invertebrates and other algae. Coralline algae are, therefore, very important for the creation, development and maintenance of complex structures, which give a typical appearance to the colourful underwater landscape, as long as organisms are alive, and also a recognizable shape of fossil protuberances when only the limestone parts of dead organisms remain (Andreoli *et al.*, 2010).

Figure 25: Coralline algae with a distinctive purple colour appearance.

The capacity of coralline algae to build a habitat is associated with the mechanism of mineralization of the cell wall with calcium and, to a lesser extent, magnesium carbonate. In red algae (Rhodophyta) from the family Corallinaceae, the carbonate is present in the crystalline calcite form mainly, while in red algae from the family Peyssonneliaceae and in green algae (Chlorophyta) from the family Halimedaceae it precipitates as aragonite. In various experiments, scientists have found that mineralization is not a consequence of photosynthesis, since it is also observed in parasitic and heterotrophic species. The occurrence of calcification helps to balance the carbon dioxide deficit in water, which is due to photosynthesis, and thus contributes to the maintenance of the alkaline potential in sea water (Andreoli *et al.*, 2010).

In the Mediterranean Sea, the coralligenous biocoenosis comprises at least 315 algal species (Boudouresque, 1973; Ballesteros, 2006). Among them, some species have the function of bioconstructors (coralline algae), others bore holes into hard structures (particularly certain green algae and cyanobacteria), and some are accompanying species, which include a number of exotic and invasive taxa.

Different genera and species that build biogenic formations do not always live and work at the same time or in the same place. Their importance in the dynamic process of the creation of biogenic formations also differs, due to the complex synergy of biotic factors with abiotic (temperature, light, hydrodynamics) and edaphic factors (salinity, nutrients, type of substrate).

The results of a Mediterranean study, which was conducted by Canals and Ballesteros (1997), have shown that in an infralittoral community, where the green alga *Halimeda tuna* and the red alga *Mesophyllum alternans* were dominant, the production of limestone was approximately 465 g of $CaCO_3$ per m^2 per year. In the circalittoral community, where the dominant species was *Lithophyllum stictaeforme,* the increase of limestone was 170 g of $CaCO_3$ per m^2 per year. The highest limestone accumulation rates (between 0.006 and 0.83 mm per year) were measured in the circalittoral belt in an environment characterized by the phenomenon of uprising water masses (upwelling).

Approximately twenty species of coralline calcareous algae are located in the precoralligenous and coralligenous. However, calcareous algae that with their growth contribute substantially to the construction of organogenic formations are not more than a dozen (Giaccone *et al.,* 2009). Among the most important bioconstructors of the coralligenous in the Mediterranean Sea, the following red algae of the families Corallinaceae and Peyssonneliaceae are considered: *Lithophyllum incrustans, L. stictaeforme, Titanoderma pustulatum, Lithothamnion philippii, M. alternans, Neogoniolithon brassica-florida, Peyssonnelia polymorpha, P. rosa-marina, Spongites fruticulosa, Sporolithon ptychoides,* and the green alga *H. tuna* of the family Halimedaceae. Among them, *L. stictaeforme* and *M. alternans* are the most active in the construction of biogenic formations (at least from the lower Pliocene).

Mediterranean stony coral reefs

Currently, two major biogenic formations are known for the Slovenian Sea, which were repeatedly sampled within the project TRECORALA. These biogenic formations are located off Cape Ronek and off Cape Debeli rtič. Both have substantially larger dimensions than trezze and are linked to the presence of Mediterranean stony coral (*C. caespitosa*), since they are formed by dead corallites of this species. In some cases, such as in Lake Veliko jezero on Mljet Island, biogenic formations are also created by living colonies of Mediterranean stony coral, with an extremely high density per unit area, or by extremely large colonies and interconnected colonies. In the Mediterranean Sea, several localities with biogenic formations created by Mediterranean stony coral are known (Figure 26).

Figure 26: Biogenic formations associated with Mediterranean stony coral are known from various areas in the Mediterranean Sea. Legend: 1 - Columbretes (Spain), 2 – Port Cros (France), 3 - La Spezia (Italy) 4 - Ronek (Slovenia), 5 – Debeli rtič (Slovenia), 6 - Rovinj (Croatia), 7 - Prvić (Croatia), 8 - Pag (Croatia), 9 - Mljet (Croatia), 10 - Atalanta Gulf (Greece), and 11 - Tunisia. Adapted from Kersting & Linares (2012).

Biogenic formation at Cape Ronek

Off Cape Ronek, in the waters off Strunjan Nature Reserve, a large biogenic formation extends, starting at a distance of 430 m from the coastline (Figure 27). Its shape is elliptical, with the longest axis in the west-east direction, and the shortest in the north-south direction. The highest point of the bioformation is at 12.4 m depth, and it extends down to 21 m, where it shifts into a muddy bottom. It is completely composed of dead, broken corallites of Mediterranean stony coral. This solitary structure is surrounded on all sides by a muddy bottom, significantly less rich in biodiversity.

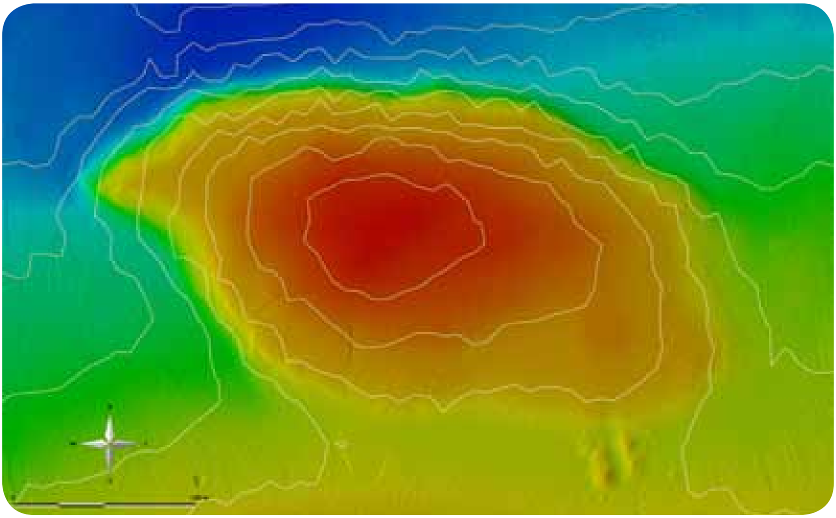


Figure 27: Image of biogenic formation near Cape Ronek generated from multi-beam echosounder data.

The bioformation near Cape Ronek is not covered by a surface layer of mud, which is however present on the similar formation off Cape Debeli rtič. Therefore, the bottom current in this environment is assumed to be a very powerful element, actively influencing the structure of animal life, as well. At the biogenic formation near Cape Ronek, the density of living colonies of Mediterranean stony coral is considerably higher than in other areas of the Slovenian Sea (Table 2), but the colony diameter is much smaller. Along eight different transects, stretching from the highest and central part of the biogenic platform, the density of the colonies ranged between 312 and 806 per 100 m^2. Mediterranean stony coral is also the dominant faunal element of this biogenic formation. Beside this species, the tubular sea cucumber (*Holothuria tubulosa*), the violet sea urchin (*Sphaerechinus granularis*), the smooth brittle star (*Ophioderma longicauda*), the brain sponge (*Geodia cydonium*) and the yellow tube sponge (*Aplysina aerophoba*) (Table 4) are common bottom fauna species.

Table 4: Density of dominant elements of benthic macrofauna (number of individuals/100m^2) along eight different transects (oriented according to the cardinal directions) on the biogenic formation near Cape Ronek.

Species/cardinal directions	N	NE	E	SE	S	SW	W	NW
Cladocora caespitosa	670	312	806	478	498	728	700	324
Holothuria tubulosa	60	32	78	60	62	84	32	46
Sphaerechinus granularis	26	14	60	66	44	44	50	2
Ophiodema longicauda	6	4	40	34	40	70	76	14
Aplysina aerophoba	8	18	0	4	6	10	12	48
Geodia cydonium	10	22	0	4	0	0	0	52
Didemnum sp.	2	2	0	0	0	0	0	34
Chondrilla nucula	0	0	6	0	8	0	6	16
Cereus pedunculatus	0	4	4	0	18	0	2	0
Hexaplex trunculus	4	0	4	0	60	0	10	0

In addition to the typical bottom composed of broken dead corallites and a high density of living colonies of Mediterranean stony coral, clusters of bottom organisms are also typical of the biogenic formation near Cape Ronek (Figure 28). Many smaller bottom invertebrates accumulate on the sea bottom among coral colonies and the two large-sized sponge species, G. *cydonium* and *A. aerophoba.* In such clusters, smaller species of sponges such as *Haliclona mediterranea,* colonial tunicates of the genus *Didemnum,* ascidians such as *Polycitor adriaticus,* species of the genus *Microcosmus,* *Phallusia fumigata* and the white solitary tunicate (*P.mammilata*), the bryozoan *Schizobrachiella sanguinea*, and many tube worms, such as *Serpula vermicularis, Protula tubularia* and *Pomatoceros triqueter* are found.

Figure 28: Panoramic view of the biogenic formation near Cape Ronek.

Coralline algae

Recent sampling of some habitat types in the Slovenian circalittoral belt, such as the coastal detritic bottom biocoenosis and the biogenic formation at Cape Ronek, have led to the conclusion that, at depths between 14 and 20 m, at least 11 species of coralline algae occur (Figure 29). Some were already known in Slovenian marine waters (*Titanoderma pustulatum, Lithophyllum racemus, Neogoniolithon mamillosum, Phymatolithon lenormandii, Pneophyllum confervicola* and *Pneophyllum fragile*); while some other red algae (*Hydrolithon boreale, Lithothamnion minervae, Lithothamnion philippii, Lithothamnion sonderi* and *Neogoniolithon brassica-florida)* were found for the first time in the Slovenian Sea (Falace *et al.,* 2011).

On the biogenic formation near Cape Ronek, the bottom is covered here and there by calcareous red algae, such as *L. racemus, L. minervae, L. philippii, L. sonderi, P. lenormandii, P. confervicola* and *P. fragile* (Falace *et al.,* 2011). Their thalli form different bottom shapes: live encrusting bases, dead attached colonies of calcified thalli, live rhodoliths and fossil rhodoliths. The term "rhodolith" includes all biogenic excrescences where calcareous red algae represent at least 50% of the nodule, which consists of the coralline alga together with the substrate/core (Bressan & Babbini, 2003). The fact that the thallus of the alga is alive on all sides of the rhodolith proves that the structure is occasionally rolled by marine currents or representatives of the mobile fauna. Both *L. philippi* and *L. minervae* occur in the encrusting and rhodolithic forms. Off Cape Ronek, rhodoliths *L. minervae* and *L. racemus* (which appears only in a sub-spherical form) are mostly dead, fossilized. Live *L. minervae* and *L. racemus* rhodoliths are more common in spring months, while encrusting forms of thalli in autumn months. Encrusting and flat thalli of *L. minervae, L. philippii, L. sonderi* and *P. fragile* occur on the biogenic formation primarily as epibionts on dead corallites of Mediterranean stony coral (Falace *et al.,* 2011).

Figure 29: A coralline alga among corallites of Mediterranean stony coral.

Fauna

Colonies of Mediterranean stony coral (Figure 30) in the Slovenian Sea measure from a few cm up to more than 60 cm in diameter. They consist of radially growing and branched individual corallites composed of calcium carbonate, with a lot of space. There are various weaving galleries and crevices, filled with water and/or trapped sediment. Therefore, structures formed by this species represent an important opportunity for the settlement of a variety of small invertebrates. In such an environment, they are well hidden and safe from predators. Colonies of Mediterranean stony coral provide three different microhabitat types to other organisms (Figure 31): a hard substrate for *epilithic* organisms (on the surface of the colony) and *endolithic* organisms (within the colony), intermediary spaces for *vagile* animals, and sediment for *infauna* (animals that dig and burrow in soft bottom). The great complexity of microhabitats allows the settlement of a large number of animals in a small area or volume. Such places are also known for the important role they play in nutrient circulation since, due to complexity (and related increased active surface and abundance of organisms), turbulence at the bottom is reduced and the sedimentation rate and nutrient retention both increase.

Figure 30: A colony of Mediterranean stony coral is a complex microhabitat.

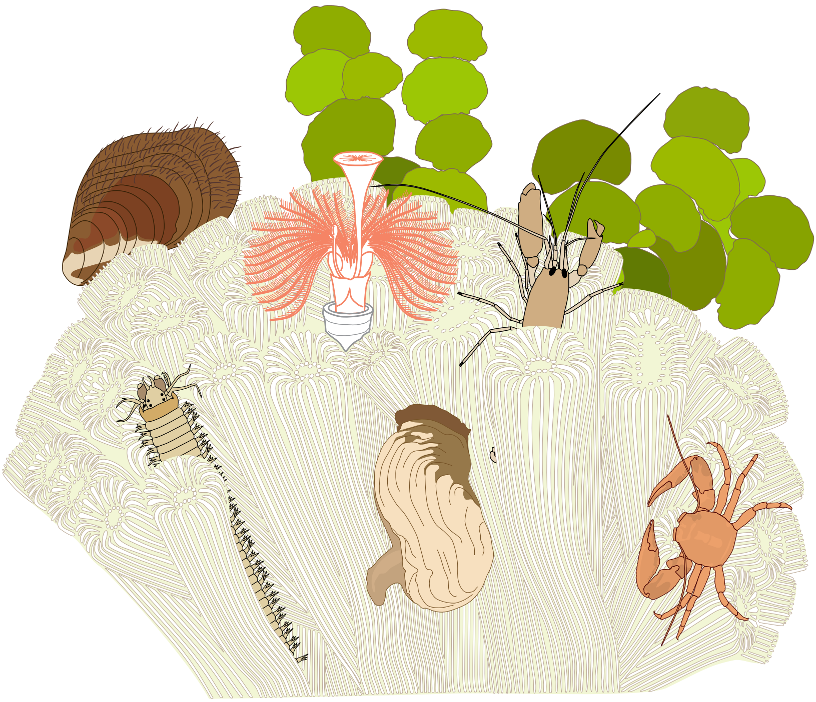


Figure 31: Drawing of a colony of Mediterranean stony coral with some characteristic or dominant representatives, which find their residence or hideout inside and/or on the colony.

Among the animal groups that inhabit Mediterranean stony coral colonies in the Slovenian Sea, molluscs dominate in terms of abundance, followed by polychaets and crustaceans (Figure 32). Most animals are endolithic, but many of them are also free living or sessile (Figure 33). In terms of diet, suspensivores dominate (they feed on tiny organisms and debris that are lifted from the sea bottom by water movements). Among them, endolithic bivalves (*Rocellaria dubia* and *Hiatella arctica*) prevail and are also among the first colonizers of Mediterranean stony coral colonies. Bivalves such as *Arca noae, Striarca lactea, Modiolus barbatus* and *Chama gryphoides*, which are epilithic species found on the surface of colonies, are also very frequent. Among polychaets, filter feeders, tube worms (e.g. *Serpula* *concharum*) and predatory species (e.g. *Eunice siciliensis, Lysidice ninetta*) dominate, while among crabs *Pisidia longimana, Athanas nitescens* and *Eualus cranchii* are the most frequent. A large portion of animals includes juvenile specimens, to which the structure of coral colonies offers protection from predators in the early, sensitive period of their life. In the case of bivalves, more than 50% of specimens are juveniles, while some species of crab are only present in the form of young specimens (e.g. *Pillumnus hirtellus*). The ratio among animal groups in relation to species diversity differs slightly. In terms of species richness, polychaets dominate, followed by molluscs and crustaceans. The highest species richness is recorded among vagile organisms, while in relation to the diet it is the highest among predators and suspensivores (Pitacco *et al.* 2014).

Figure 32: A colony of Mediterranean stony coral overgrown with epifauna (the yellow tube sponge prevails in this colony). Arms of brittle stars twisting between corallites.

The structure of colonies and their complexity changes with the growth of corals. Thus, the external surface area of colonies increases with growth, thus increasing the number of intermediate spaces among corallites. Consequently, the composition of the fauna that live in colonies changes, as well. Both the number of species and abundance increase. Species richness in colonies of Mediterranean stony coral follow the Arrhenius equation (1921), which states that the number of species increases with the increasing surface area. The number of invertebrate species living in colonies of Mediterranean stony coral increases with the size/diameter of each colony.

Figure 33: Polycitor adriaticus *on the biogenic formation near Cape Ronek.*

Biogenic formation at Cape Debeli rtič

Flysch slopes decorating the Debeli rtič Natural Monument sweep very gently, and only near the lighthouse, mounted on a rocky platform, descend deeper than 5 m of depth. The underwater rocky shore formed by large sandstone boulders, covered with flourishing algal vegetation, near the lighthouse continues firstly on a sedimentary bottom formed by coarse sand, and then into a particular biogenic formation, which is just like the one at Cape Ronek composed of dead Mediterranean stony coral corallites.

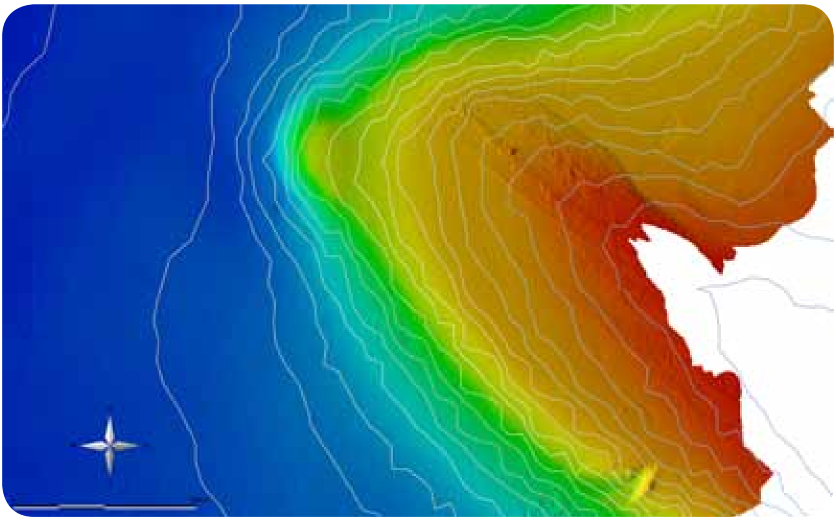


Figure 34: Image of biogenic formation at Cape Debeli rtič generated from multi-beam echosounder data.

The biogenic formation at Cape Debeli rtič (Figures 34 and 35) is more or less of triangular shape with a rounded plateau, which looks like a knob. On the reef there is a steep step where the coastal sandy-rocky bottom sweeps into muddy sediment, which happens very quickly in comparison with the near surroundings. The biogenic formation is covered here and there by a thin layer of mud and, therefore, accurate assessment of its borders is very difficult. It starts at about 10 m of depth and sweeps down to 17.5 m of depth. Unlike the biogenic formation at Cape Ronek, there are only a few living colonies of Mediterranean stony coral in this area (Table 2). The number of brain sponges, tubular sea cucumbers, and violet sea urchins is also considerably lower. On the contrary, daisy anemones (*Cereus pedunculatus*) are very abundant (Table 5). Some endemic species are present on this biogenic formation, such as the sea slug *Dondice banyulensis* (Figure 36).

Table 5: Density of dominant elements of the benthic macrofauna (number of individuals/100m^2) along three different transects of the biogenic formation near Cape Debeli rtič.

Dominant elements	I	II	III
Holothuria tubulosa	36	22	14
Cereus pedunculatus	19	40	36
Phallusia fumigata	14	2	4
Cladocora caespitosa	2	0	4
Aplysina aerophoba	4	0	6
Sphaerechinus granularis	2	2	4

Figure 35: Panoramic view of the biogenic formation near Cape Debeli rtič.

Figure 36: The nudibranch sea slug Dondice banyulensis, *a Mediterranean endemic species.*

SETTLEMENT ON BIOGENIC FORMATIONS

Colonisation of hard structures

Beside coralline algae, many other sessile organisms colonize hard structures thus creating biogenic formations. Similar patterns of colonisation are known for coralligenous and other natural or anthropogenic substrates in the environments dominated by sedimentary (muddy or sandy) bottoms. On the sedimentary bottom, benthic animals live on the surface or in the sediment. The former are known as epifauna and the later as endofauna or infauna. The sedimentary bottom is a rather inappropriate living environment for benthic invertebrates, since they are often suffocated by intense resuspension, which negatively affects their normal living functions. Beside resuspension, they are also affected by currents. From this point of view, any type of hard substrate available in such conditions surrounded by the dominant sandy or muddy environment is an attractive colonizing opportunity for many sessile organisms (Figure 37). Even a small cluster of bivalve shells, small stones or a small colony of Mediterranean stony coral attracts the planktonic larvae of benthic animals for settlement purposes.

Figure 37: A small cluster of organisms in a muddy desert-like environment.

Colonisation by planktonic larvae

An intense struggle for survival occurs in the Slovenian part of the Adriatic Sea, in the Gulf of Trieste and in the broader northern Adriatic Sea. The planktonic larvae of many benthic invertebrates (Figure 38) are colonizing all available hard structures, on which they can attach themselves. They are defined as meroplankton, including all animals, which are planktonic in the early phases of their lives only (eggs and larvae). After those periods they develop into adult benthic invertebrates.

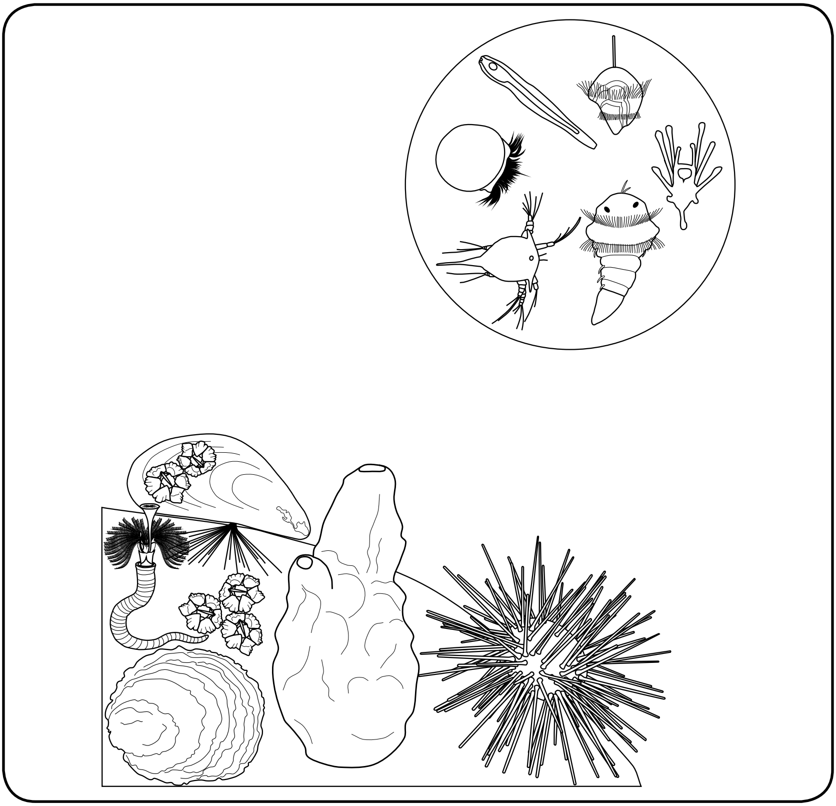


Figure 38: Zooplanktonic larvae seeking a suitable living environment to settle down and develop into adult benthic animals.

The most typical benthic animals, which have planktonic larvae, are sponges (Porifera), hydrozoans (Hydrozoa), cirriped crustaceans (Cirripedia), gastropods (Gastropoda), bivalves (Bivalvia), decapods (Decapoda), echinoderms (Echinodermata), ascidians (Tunicata Ascidiacea) and many others.

Sometimes, a suitable colonizing environment is created when sea currents deposit fragments of shell in small pits. An accumulation of such remains offers the planktonic larvae of benthic animals an opportunity to colonize the clusters. In certain areas, such as under mariculture facilities for mussels, the accumulation of shells, dropped by mariculturers while gathering or cleaning mussels, leads to the formation of small islets of hard bottom in the muddy or sandy environment. Such islets, which could be considered as a secondary hard bottom, are rapidly being colonized by planktonic larvae and subsequently benthic animals. The accumulation of shells or other organic remains is thus rapidly overgrown with benthic animals. Similar fouling processes are ongoing on different artificial structures such as piers (Figure 39), wavebreakers and other coastal objects.

Figure 39: Columns of Koper harbour pier, completely overgrown with epifauna.

The community of filtrators

The bottoms of the Gulf of Trieste and the broader area of the northern Adriatic Sea are characterized by benthic communities, dominated by filtrator organisms. In fact, many benthic animals feed on food particles, filtered from the water column. They are well adapted for efficient filtration of bacteria, phytoplankton and zooplankton organisms, different flakes, dissolved organic matter, but also heavy metals and many other pollutants (Stachowitsch, 1998).

Table 6: Filtration efficiency for certain benthic invertebrates (A – Stachowitsch, 1998; B – Lisberg & Petersen, 2000; C – Milanese et al.*, 2003).*

	Filtration efficiency	**Filtration efficiency per day (20 active hours)**
Large ascidians	5-17 dm^3/h (A)	100-340 dm^3
Large sized bivalves	2 dm^3/h (A)	40 dm^3
Bryozoans	0.11 $dm^3/h\ cm^2$ (B)	214 dm^3/m^2
Sponge *Chondrilla nucula*	14 $dm^3/h\ m^2$ (C)	280 dm^3/m^2

Filtrators have different filtration efficiency (Table 6). Among them the most efficient are certain ascidians (Tunicata), which are able to filtrate as much as 17 l sea water per hour. A densely overgrown community of benthic animals (for example on artificial reefs) could filter a great amount of seawater in a short period of time and act as a natural eutrophication controler (*sensu* Officer *et al.*, 1982).

After the colonisation of planktonic larvae on a hard object (for example a rock) and subsequent metamorphosis into adult benthic animals, an encrusting substrate, made by animals with calcified skeletons, is slowly created. In a harsh struggle for space, new animals continuously colonize such encrusting formations. With time, the rock becomes completely overgrown with the benthic invertebrate community.

With the colonisation of hard objects (Figure 40), the abundance and richness of the animal community increases. Some of them deposit limestone, while others dig holes in the substrate. In this way, encrusting coatings and limestone clusters of different shapes are created and at the same time cracks, crevices, burrows and cavities are excavated by some organisms. The spatial heterogeneity, defined as the number of structural elements on the substrate surface, is thus increased, as well. An area with higher spatial heterogeneity is characterized by higher abundance and species richness.

Figure 40: The majority of filtrators are sessile.

Attraction of other organisms

In the same way, artificial reefs become overgrown with epifauna, as well. The densely overgrown benthic algal and invertebrate communities create an organic coating and at the very same time filter particles from the water column. The process of colonisation is continuous, and thus newcomers arrive constantly and make the food web even increasingly complex. Densely overgrown hard substrate is attractive to other species also due to immense spatial heterogeneity (Figure 41). The artificial and natural reefs, together with biogenic formations, are interesting for other species due to: (i) living habitat, (ii) feeding ground, (iii) proper reproductive ground, (iv) shelter to escape from predators and (v) nursery area, where juveniles can develop safely.

Since such reefs and similar formations also attract many predators from different feeding guilds according to the principle "something for everyone", abundance and species richness increases. Reef dwellers are characterized by many antipredator strategies such as, for example, camouflage and different types of mimicry.

Figure 41: Dense epifaunal communities attract many other organisms.

Creation of new niches

The next factor, which is important for an understanding of the colonisation of biogenic formations, consists in various organisms that create new possibilities – new niches for other organisms. In that respect, we discriminate between bioconstructors, which actually create biogenic formations or offer possibilities for colonisation to numerous organisms, and bioeroders, which excavate burrows in the substrate or erode it (Figure 42).

Figure 42: The contemporary processes of bioconstruction and bioerosion are creating new niches.

Bioconstruction

Bioconstruction is defined as the formation of biogenic structures with the integration and accumulation of calcified skeletons of marine organisms. Cocito (2004) discriminates between three categories of functional units:

- **Constructors** are erect and well-branched skeletonised marine organisms and form the majority of biogenic formations. They usually have large-sized and strong skeletons, which are able to withstand the force of current and waves. Amongst the best known are the Mediterranean stony coral (*C. caespitosa*) and coralline algae. Other bioconstructors include ciriped crustaceans, vermetid gastropods (family Vermetidae), oysters (Figure 43) and other bivalves and bryozoans (Figure 44).

- **Binders** are encrusting organisms, which expand and unite the components of the framework (the product of erect organisms) and the settling sediment. They have small-sized skeletons with prevalent lateral growth (Di Geronimo *et al.,* 2002). Such organisms include cyanobacteria and diatoms, which produce biofilms, encrusting sponges and encrusting calcified algae.

- **Bafflers** are usually small, erect non-skeletal or poorly skeletonized organisms, which reduce current velocity on the framework surface, enhancing deposition of sediment and cavity filling. They have small-sized skeletons, which are poorly mineralized or not mineralized at all. Bafflers include certain erect bryozoans, some sponges, certain algal species and other organisms.

*Figure 43: Oysters (*Ostrea edulis*) are the major bioconstructors of the fouling community formed on the pier-coloums in the Port of Koper.*

*Figure 44: Branched structure formed by a bryozoan (*Schizobrachiella sanguinea*).*

Bioerosion

Other organisms are related to the process of bioerosion. Certain researchers discriminate between three types of bioeroding organisms. The first group includes organisms that browse on the substrate created by coralline or other algae. Such bioeroders include certain sea urchins. The other two groups are represented by microeroders or microborers and macroeroders or macroborers, respectively.

Browsing

Formations created by coralline and other algae are browsed by certain species of sea urchins (Figure 45). The common sea urchin (*Paracentrotus lividus*) erodes such substrate in order to form small pits, but only when grazing on erect algae. The violet sea urchin (*S. granularis*) grazes on the living thalluses of coralline algae. It is the main biological agent that substantally erodes the formations of coralline algae along the French Mediterranean coast (Sartoretto & Francour, 1997).

It was estimated that 19 g $CaCO_3$ urchin^{-1} year^{-1} are eroded by the common sea urchin and as much as 295 g $CaCO_3$ urchin^{-1} year^{-1} by the violet sea urchin in the Mediterranean Sea (Sartoretto & Francour, 1997). Considering that primary production of coralline algae in the Balearic Islands was estimated to be between 100 and 150 g $CaCO_3$ m^{-2} year^{-1} (Canals *et al.*, 1988), bioerosion by the violet sea urchin is significant.

At the biogenic formation off Cape Ronek, the Violet sea urchin is one of the most abundant macroinvertebrates. The density of sea urchins ranged from a few specimens to 66 specimens per 100 m^2. These densities are comparable to those of French researchers (Sartoretto & Francour, 1997), which ranged from 28 to 88 specimens per 100 m^2. It is therefore possible that Violet sea urchins play the same role as bioeroders at the biogenic formation off Cape Ronek.

Figure 45: The violet sea urchin (Sphaerechinus granularis) *(left) and the common sea urchin* (Paracentrotus lividus) *(right).*

Excavation of burrows

Many different organisms are involved in the process of bioerosion by excavating burrows (Figure 46). Microeroders are mainly cyanobacteria, green algae and marine fungi. Macroeroders, which dig burrows of much bigger dimensions, include sponges, bivalves, sea urchins, various polychaets and even fishes.

Figure 46: The date mussel (Lithophaga lithophaga)*. A bivalve with closed (left) and open valves with protruding extending foot (right).*

The date mussel (*Lithophaga lithophaga*) is the most well known bioeroder in the Slovenian part of the Adriatic Sea; it burrows by mechanical and chemical erosion. Empty date mussel burrows are very important since they are inhabited by a rich community of marine animals such as various species of cnidarians, decapods, bryozoans, molluscs and certain fish species. The date mussel occurs everywhere along the Slovenian coastline, and is particularly abundant in the waters off the Strunjan Nature Reserve.

Less known macroeroders include sponges of the genus *Cliona* (Figure 47) and also certain bivalve species such as *Rocellaria dubia* (Figure 48), *Hiatella arctica, Petricola petricola Teredo navalis* (Figure 49), and *Pholas dactylus*. Burrows of *R. dubia* can be found in almost every rock and boulder. The burrows are visible on the surface in the shape of number 8, with the smaller upper and larger lower burrow. The common piddock (*P. dactylus*), which is an edible bivalve, inhabits sandstone boulders and is especially abundant in areas with sandstone terraces. Another important macroeroder is the sipunculid *Aspidosiphon muelleri.* Recently, research findings were published on the damage caused by this macroeroder on the objects of the Baiae submarine archaeological park located close to Naples (Antonelli *et al.*, 2015).

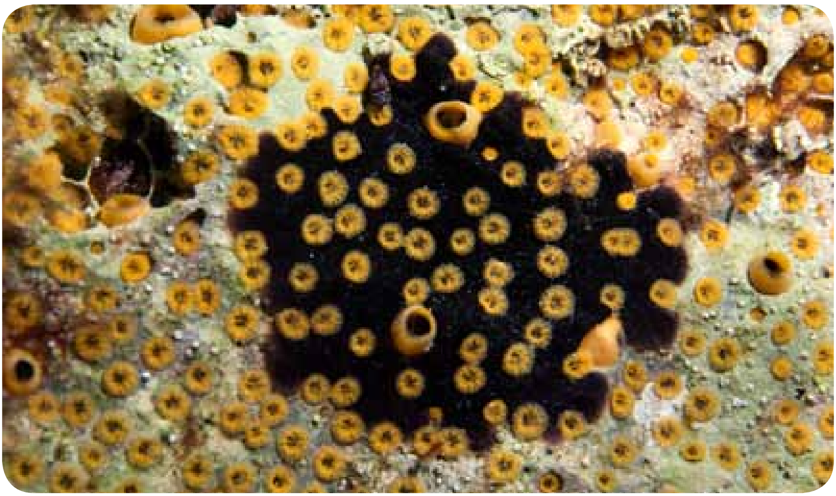
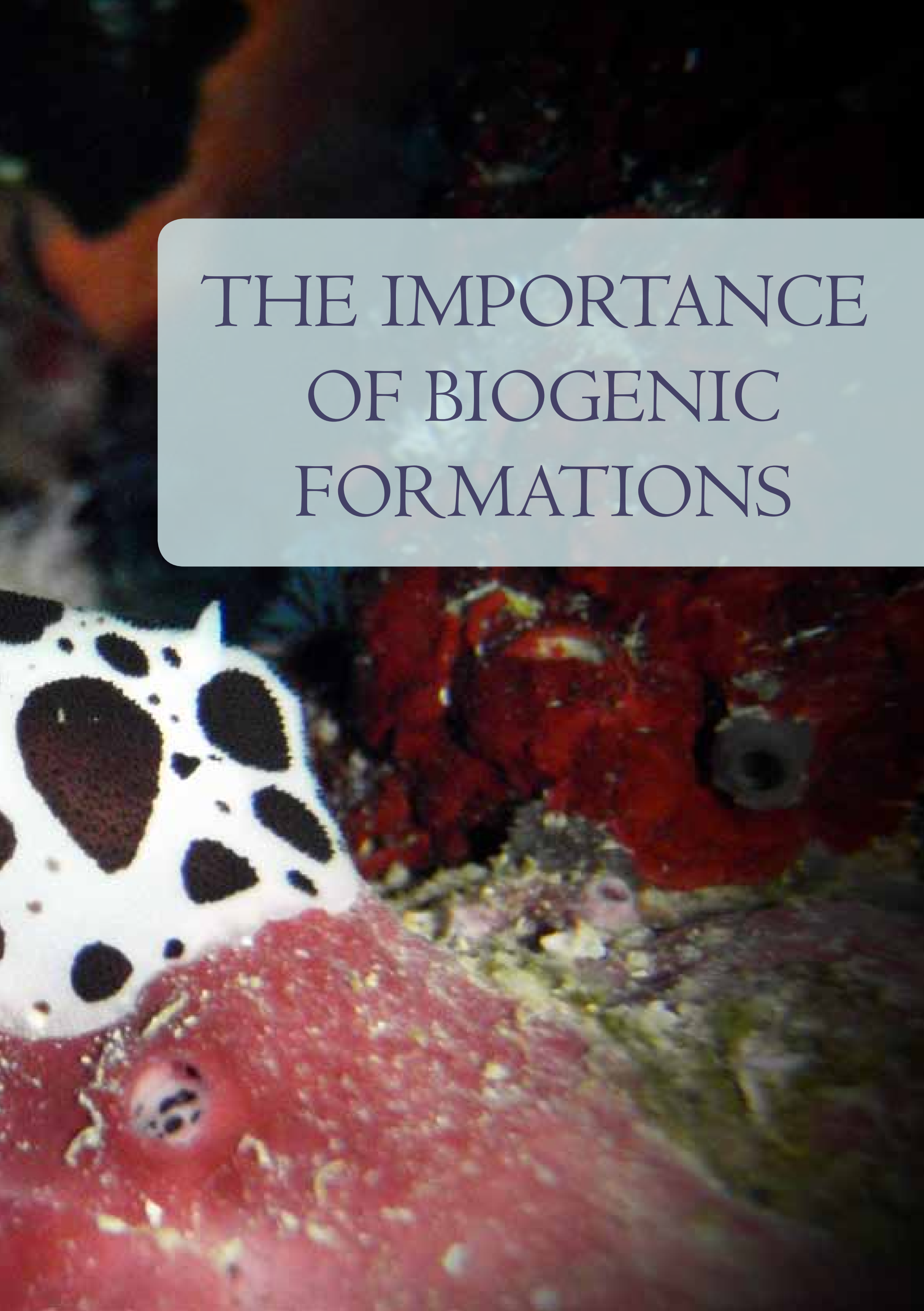


Figure 47: Siphons of the sponge Cliona sp.*, visible on the surface of a stone.*

Figure 48: Limy chimneys of the flask-shell (Rocellaria dubia) *rising above the surface.*

Figure 49: The naval shipworm (Teredo navalis) *is an eroder specialised to bore through a submerged wood.*

THE IMPORTANCE OF BIOGENIC FORMATIONS



Biogenic formations are only second in importance to Neptune grass (*P. oceanica*) meadows as a biodiversity hotspot in the Mediterranean Sea (Boudoresque, 2004).

Natural Educational Resource

Due to their immense richness, high productivity and many ecological processes, coralligenous and other biogenic formations are also considered a very interesting environment from the educational point of view. Benthic organisms and coastal fish species were forced to develop different mechanisms due to the harsh stuggle for space. In such environments, it is possible to get aquainted with many different options of coexistence, from mutualism, comensalism, inquilinism to parasitism. The numerous different variations of antipredator strategies are interesting, as well. Because of this, coralligenous and biogenic formations are an exceptional environment for recognizing many processes and living strategies of marine organisms, which are manifested by the adaptations of benthic organisms and fishes.

Anti-predator strategies

A community of species involved in bioconstruction attracts many other species, which are related to them. In the precoralligenous, for example, the green algal species *Halimeda tuna* attracts certain opisthobranch sea slugs such as *Boselia mimetica,* which grazes on it. In the broad group of Opisthobranchia there are certain smaller groups such as the Nudibranchia, a group of beautiful species with vivid colouration and diversity of shapes. Nudibranchs are characterized by the fact that they are closely related to their prey species, especially in the case of hydrozoan polyps and sponges.

Certain species have developed living strategies for finding their prey, while others are able to escape from predators or defend themselves from predators. The latter, the so-called antipredator strategies, are especially frequent in the coralligenous environment. Some species simply escape from predators or hide in different types of shelter (which are presented in the chapter on cryptobenthic and endolithic species). Other species have developed special adaptations in order to camouflage themselves and prevent detection (Figure 50). Finally, some species, although detectable by predators, have developed specific mechanisms that protect them from predators.

Figure 50: The opisthobranch sea slug Ercolania coerulea *is almost invisible when grazing on its favourite prey –* Valonia *algae.*

Camouflage

Camouflage is a particular antipredator strategy. Some benthic invertebrates and fishes camouflage themselves in their environment in order to be invisible to predators. They remain motionless on rocks and boulders on the sea bottom, confident of deceiving their predators with their camouflage outfits. Such species have to choose the proper environment, in which their colour or shape makes the animal difficult to be seen. However, some species are able to change their colour pattern continuously and match it with the colour or shapes of their environment. This is characteristic of cuttle fish (*Sepia officinalis*), which can match the environment while swimming. In the case of benthic fish species, flatfish are masters of deceit. Some of them can even camouflage themselves on the pen shell (Figure 51).

Figure 51: Blochs topknot (Zeugopterus regius) *camouflaged on the pen shell* (Pinna nobilis)*.*

Some invertebrates, especially some crabs, are known to attach different benthic sessile invertebrates and algae to their carapaces in order to camouflage themselves. Like flatfish, they remain motionless on the sea bottom in their masking outfit, which protects them from predators. The choice by crabs of which invertebrate species to place on their carapace, depends on two factors. Firstly, the invertebrates used for masking should be very common in the living environment of the crab and secondly, they should be inedible. The sponge crab (*Dromia personata*), which is one of the largest crab species in the Slovenian part of the Adriatic Sea, cuts up some benthic invertebrates to create a masking hat. Sponge crabs use their last pair of legs to hold a sponge or other chosen invertebrate in place as camouflage.The most frequently chosen invertebrate is the colonial ascidian *Aplidum conicum* (Figure 53), but there are also cases of hats created with sponges *Aplysina aerophoba, Chondrosia reniformis, Chondrilla nucula* and *Cacospongia scalaris.* Smaller crabs seem to especially photogenic; they cut their hat out of the vivid red sponge *Phorbas fictitious.* Such camouflaged crabs are invisible to predators and divers, as well. Decorator crabs of the genus *Pisa* (Figure 52) are real masters of disguise. These crabs cover their carapaces with various invertebrates that are common in their environment.

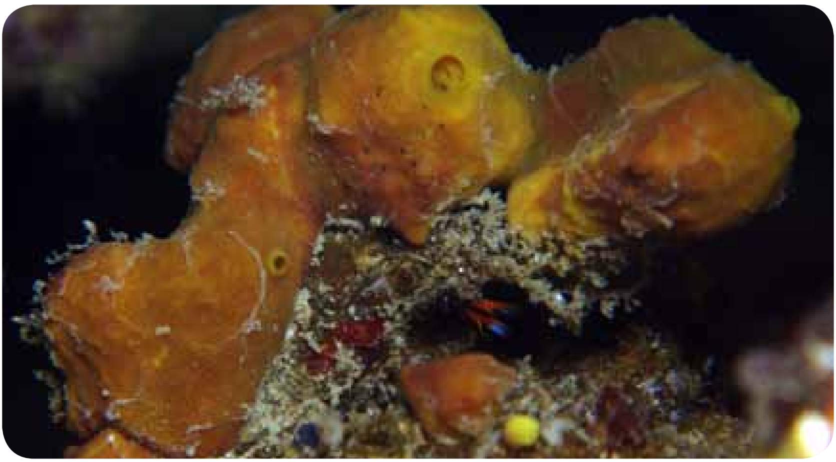


Figure 52: Hiding under hats made of other organisms makes the decorator crab from the genus Pisa *invisible.*

Figure 53: Masking hats of the sponge crab (Dromia personata) *made of different invertebrates: a* – Aplidium conicum, *b* – Cacospongia scalaris, *c-* Chondrilla nucula, *d* – Aplysina aerophoba *and e* – Phorbas fictitious.

Mimicry

Mimicry is also considered a successful antipredator strategy. Compared to camouflage, where the animal tries to blend itself in the environment, in the case of mimicry the animal is clearly visible to predators (Figure 54). There are many types of mimicry in nature, especially in the case of insects. In the marine realm, the *Batesian* and *Müllerian mimicries* are the best known. In Müllerian mimicry, two or more distasteful or toxic animals imitate each other's aposematic colour patterns or body shapes in order to warn the predator about their inpalability or toxicity. In the case of Batesian mimicry, certain palatable and non toxic animals try to mimic the colour patterns of really distasteful and toxic animals. In the first case, the animals warn their predators, while in the second case they try to deceive their predators. The key factor in both cases is the fact that the predator, due to its bad first experience with an unpalatable or toxic animal, avoids any further meetings with such kind of prey. The importance of mimicry is therefore based on the predator's bad experience; the predator is able to recognize the warning colouration of the prey rapidly.

Figure 54: Cratena peregrina *is "grazing" on colonial hydrozoans of the genus* Eudendrium*.*

Müllerian mimicry

Müllerian mimicry was discovered and named by the German zoologist and naturalist Fritz J. Müller (1821–1897). There are numerous examples of this type of mimicry in coralligenous biocoenoses and biogenic formations. From this point of view, sea slugs (Opisthobranchia) offer many instructive examples (Figure 55). In the majority of marine gastropods (and in other molluscs, as well) the shell is the primary defensive organ against predators. Some of them possess thick shells, others numerous spikes and projections, while some have large or rounded shells, which prevent the predator from swallowing the animal. The great majority of seas lugs, however, do not have a shell. They are characterized by their vivid colouration, which warns predators about their impalability or toxicity. The vivid colouration evolved as an antipredator strategy, since sea slugs have poor eyesight while their potential predators, for example, fishes, are able to see well. Certain opisthobranchs such as nudibranchs obtain their toxins from their food items or produce them as secondary metabolites. Many species that feed on colonial hydrozoan polyps use the ingested cnidae for their own protection against predators. Such cnidae are known as klepto-cnidae (stolen cnidae).

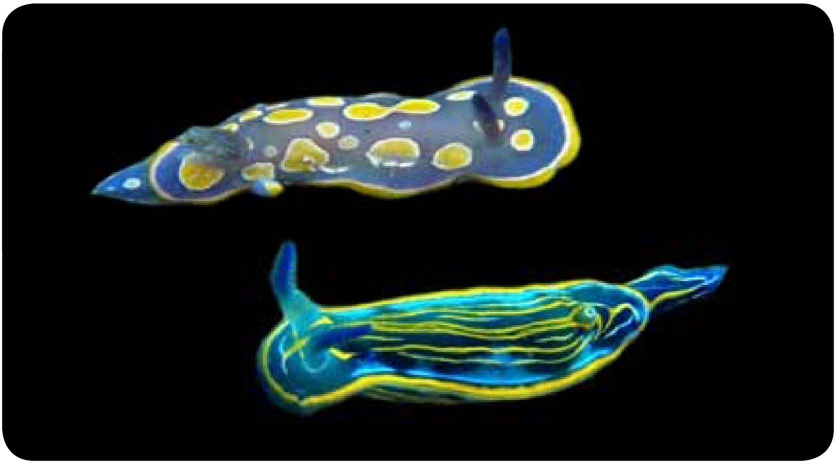


Figure 55: Felimida luteorosa *(above) in* Felimare villafranca *(below).*

Batesian mimicry

In Batesian mimicry, harmless animals imitate the colours and patterns of harmful and unpalatable species. In this case, the harmful animal represents the model, while the animal that imitates such model, is called mim or imitator. This form of mimicry was named after the English naturalist Henry Walter Bates, who studied butterflies in the rainforests of Amazonia. Cases of Batesian mimicry are much more common in the tropical environment; however, they are also found in local marine areas. The goby *Gobius vittatus* is an example of Batesian mimicry; this goby imitates the colour pattern of the blenny *Parablennius rouxi,* which is distastesful.

The orange flatworm (*Yungia aurantiaca*) resembles, in colour and shape, the nudibranch *Platydoris argo* that is avoided by predators (Figure 56). Both species inhabit the sedimentary bottom of the Gulf of Trieste down to 20 m of depth. The nudibranch has a very hard integument and, thus, predators are not attracted to this species. Due to this fact, the orange flatworm imitates the nudibranch to deceive predators that have already experienced an unpleasant meeting with the nudibranch.

Figure 56: Platydoris argo *(left) and* Yungia aurantiaca *(right).*

Other antipredator strategies

There are many cases of mutualism on biogenic formations. Mutualism is a type of symbiosis, in which both partners benefit from the relationship. Many hermit crabs inhabit the empty shells of muricid snails (*Bolinus brandaris, Hexaplex trunculus*) and some other gastropod species (Figure 57), covered with sea anemones such as *Calliactis parasitica* and *Adamsia palliata.* Both of them ensure that predators avoid preying on hermit crabs. Even some unpalatable sponges such as *Suberites domuncula* and other species, and certain colonial ascidians such as *Botryllus schlosseri* are efficient against predators.

There are also many cases of commensalism. In this type of symbiosis, one partner benefits from living with the other one, while the latter does not benefit at all and is not harmed. Some shrimp species such as T*ypton spongicola* and *Alpheus dentipes* live in the burrows of the sponge *Cliona viridis.*

Figure 57: The colonial hydrozoan Epizoanthus *sp. covers the shell inhabited by the hermit crab* Paguristes eremita.

Other strategies

The use of invertebrates and algae for camouflage is very important in the coralligenous environment. However, there are also species that have developed strategies against overgrowth. Such strategies are generally known for algae and corals, especially in tropical seas, which struggle for light and thus efficient photosynthesis.

Algae and corals try to prevent shading or overgrowth by their competitors for space. In similar ways, some benthic invertebrates develop strategies against overgrowth (antifouling). The solitary ascidian *Halocynthia papillosa,* which colonizes biogenic formations, is never overgrown by any organisms due to an efficient antifouling strategy (Figure 58).

Figure 58: An ascidian species Halocynthia papillosa*.*

CRYPTOBENTHIC HABITATS

What are cryptobenthic habitats and cryptobenhic fauna?

An important part of biogenic formations is represented by cryptobenthic habitats. These are all types of habitats, which offer shelters or reproductive grounds for certain species of organisms. There is a lack of knowledge on cryptobenthic habitats and cryptobenthic animals. Cryptobenthic animals are those animal species that more or less hide under stones and rocks, in cracks and crevices, in holes, burrows and cavities all their lives (Table 7). Such species are hard to detect and consequently are also less known. Many of them are characteristically sciaphilous or photophobic, which means that they occur in shaded, dim microhabitats on rocks and boulders or hiding in the above mentioned natural holes such as burrows, crevices or cavities. They are completely dependent on their shelters and they only leave them occasionally.

Cryptobenthic habitats can be found from shallow waters down to circalittoral biocoenoses. The number of specimens and species depends on spatial heterogeneity (see the chapter on colonisation). The greater the number of different structural elements available for building a habitat type, the greater the number of potential microhabitat types and thus the higher species richness is.

During the last decade, several new species of invertebrates were discovered for the first time in Slovenia; some of them were also less known in other areas of the Adriatic Sea. Such species include, for example, the crab *Herbstia condylliata,* which is a typical element of the coralligenous biocoenosis. Perhaps the best known in this regard are the cryptobenthic fishes, which can be defined in different ways. Some researchers include several blennies in the cryptobenthic fishes group; blennies do not actually hide but only escape in holes to avoid predators. Others consider cryptobenthic fishes as being those that are always hidden in their shelters. To lure them out of their shelters and to sample them, special narcotics used in ichthyological sampling are necessary. Such species, for instance, include the the large-headed goby (*Millerigobius macrocephalus*), the zebra goby (*Zebrus zebrus*) and clingfish species *Apletodon incognitus* (Figure 59).

Figure 59: A clingfish species Apletodon incognitus.

Cryptobenthic species are an important part of the costal fish community. According to Harmelin (1987), the coastal fish community can be divided into many groups (Figure 60). There are more or less related to the sea bottom (nectobenthic, epibenthic and cryptobenthic) with the exception of the nectonic fish group that is not dependent on the sea bottom. Many studies have demonstrated that when using non-destructive techniques (so-called visual census), more than half of all fish species in a certain area can be overlooked. In one study, 226 fish species were recorded by using the ichthyocid rotenon, and only 36% of them were confirmed by visual censuses (Smith-Vaniz *et al.*, 2006).

In the Slovenian part of the Adriatic Sea, only certain fish groups, such as blennies and their relatives (Blennioidea), can be considered as well-studied (see, for example, Lipej & Richter, 1999; Lipej & Orlando-Bonaca, 2006; Orlando-Bonaca, 2006; Orlando-Bonaca & Lipej, 2007, 2008a, 2008b; Lipej *et al.*, 2008). Other published papers have dealt with the coastal fish community (Lipej *et al.*, 2003; 2005; Orlando-Bonaca & Lipej, 2005; Orlando-Bonaca *et al.*,2008; Lipej *et al.*, 2007; 2012).

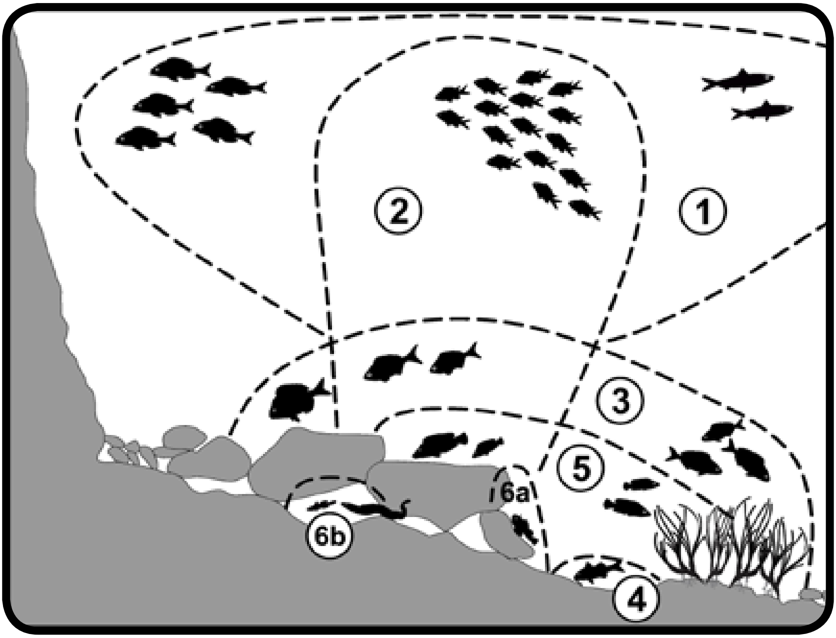


Figure 60: Spatial organisation of the coastal fish community. Ecological groups: 1 – non-resident nectonic fish species, 2 – sedentary nectonic fish species, 3– nectobenthic fish species with moderate vertical and lateral movements, 4– nectrobenthic fish species with lateral movements but without vertical displacements, 5– sedentary nectobenthic fish species with negligible vertical and lateral movements and 6– sedentary nectobenthic fish species with negligible movements; 6a – epibenthic fish species, 6b – cryptobenthic fish species (modified from Harmelin, 1987).

Cryptobenthic fish species

Cryptobenthic fish species (A) can be divided into different groups (Tables 7 and 8) according to their preference for certain cryptic habitats. Some species in fact occurr in such habitats only exceptionally, others occasionally, while some species regularly inhabit cryptic habitats (Kovačić *et al.*, 2012).

Table 7: Division of benthic fishes according to their preference for different cryptic habitats.

CODE	SPECIES	DEFINITION	ADDITIONAL DESCRIPTION
A	**CRYPTOBENTHIC**		
A1	**REAL CRYPTOBENTHIC**	Always hidden in burrows & cavities, under stones, in bivalve shells	A special technique is required for sampling (narcotics)
A2	**LARGE SIZED CRYPTOBENTHIC**	They may leave the cavity; however, they fiercely defend it	A special technique is required for sampling (selective sampling)
B	**ENDOLITHIC**		
B1	**OBLIGATE ENDOLITHIC**	Always occurring in holes	Holes are excavated by endolithic bivalves and sponges
B2	**FACULTATIVE ENDOLITHIC**	May use holes for shelter and as nesting grounds, but not necessarily	They inhabit natural and artificially made holes
C	**FALSE CRYPTOBENTHIC**	Nectobenthic, occasionally found in burrows, cavities or under stones	They are not dependent on the availability of holes and cavities
D	**EPIBENTHIC**		
D1	**REAL EPIBENTHIC**	Species on the surface of stones, rocks, boulders, close to cavities	They are related to the sea bottom, but not to cryptic habitats
D2	**CAMOUFLAGED EPIBENTHIC**	Species with a colour pattern that blends into the environment	They are related to the sea bottom, but not to cryptic habitats
D3	**EPIPSAMMAL**	Burying themselves in sediment	They are related to the sea bottom, but not to cryptic habitats

Real cryptobenthic species

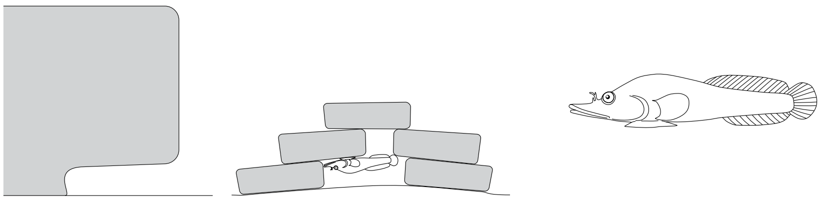


Figure 61: Real cryptobenthic species and their microhabitat.

Real cryptobenthic species are those that always stay hidden in crevices, cracks, cavities, dead bivalves, remains of crab carapace and similar (Figure 61). Their shelter is similar to the holes occupied by endolithic fish species; however, they are not strictly dependent on the size or diametre of their shelters. Typical representatives are various species of clingfish (Gobiesocidae) and gobies (Gobiidae) (Fig. 62). They are difficult to detect in their environment without the use of narcotics.

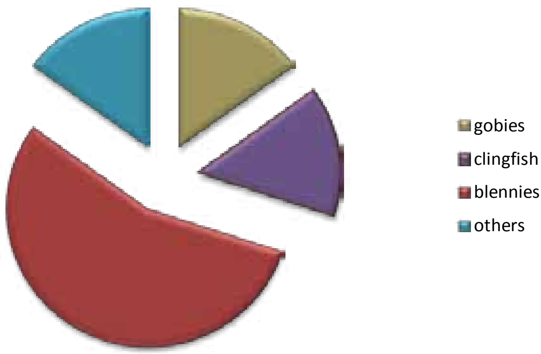


Figure 62: Taxonomic identity of cryptobenthic fish species in the Slovenian Sea (including real cryptobenthic species, large-sized cryptobenthic species and endolithic fish species).

Table 8: Cryptobenthic and endolithic fish species in the Slovenian part of the Adriatic sea:

A – under sandstone terraces,
B – cavities, crevices and cracks in rocks,
C – cavities, overgrown with precoralligenous epiflora and epifauna,
D and E – species inhabiting the burrows of date mussels and in endolithic bivalves and sponges,
F – empty shells of bivalves and crab carapaces,
G – under stones and rocks,
H – artificial cavities (bottles, cans, bricks and others).

Inf – *infralittoral,* Med – *mediolittoral.*

	A	B	C	D	E	F	G	H
Species/Depth belt	Inf	Inf	Inf	Med	Inf	both	both	both
Aidablennius sphynx				√				
Coryphoblennius galerita				√				
Microlipophrys nigriceps			√		√			
Microlipophrys dalmatinus				√	√			
Lipophrys canevae				√				
Parablennius zvonimiri			√		√	√		
Parablennius incognitus			√	√	√	√		√
Parablennius rouxi			√		√			√
Parablennius tentacularis			√		√	√		√
Lipophrys trigloides				√				
Salaria pavo				√			√	
Millerigobius macrocephalus		√					√	
Zebrus zebrus							√	
Thorogobius ephippiatus		√						
Thorogobius macrolepis		√						
Apletodon incognitus						√	√	
Lepadogaster candollii						√	√	
Lepadogaster lepadogaster							√	
Muraena helena		√						
Conger conger	√	√						
Gaidropsarus mediterraneus	√	√						
Total no. of species	2	6	5	7	6	5	6	3

Large-sized cryptobenthic fishes

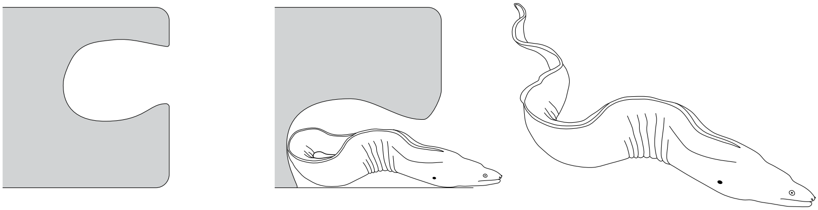


Figure 63: Large-sized cryptobenthic fish species and their habitat.

Some large-sized species (Figure 63) such as the European conger (*Conger conger*) and the moray eel (*Muraena helena*) (Figure 64) are always hiddden in their shelters. Such species are residents and use their cavities more or less continuously. Certain large-sized benthic invertebrates such as lobster (*Homarus gammarus*) and octopus (*Octopus vulgaris*) could also be considered a large sized cryptobenthic animals.

Figure 64: Moray eel (Muraena helena).

Endolithic fishes

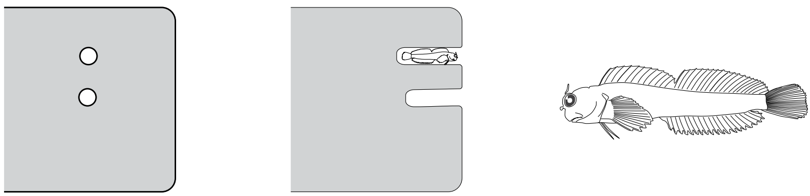


Figure 65: Endolithic fish species and their habitat.

For endolithic species, represented mainly by blennies (Figure 65), it is characteristic that males fiercely defend their holes, in which the females have laid their eggs. Normally, only their head protrudes from their hole (Figure 66). Many endolithic species are characterized by sexual dimorphism (expressed in males with coloured cheeks, head crests, vivid colour patterns). There are two groups of endolithic species:

a. **obligate endolithic species,** (B1), which only use naturally excavated holes by endolithic bivalves such as *Lithophaga lithophaga* and *Rocellaria dubia* and certain sponges (*Cliona celata*);

b. **facultative endolithic species,** (B2), which are not necessarily related to the availability of natural holes. Beside this, they also use artificially made holes (such as bottles, cans, parasol carriers).

Endolithic species occurr mostly in the intertidal belt; however, some species are known to colonize biogenic formations in the infralittoral and circalittoral belts.

Figure 66: Blenny heads are creeping out from occupied burrows.
Legend: A - Lipophrys canevae *male, B -* Microlipophrys dalmatinus, *C -* Lipophrys canevae *female, D -* Parablennius incognitus, *E -* Parablenniius rouxi *and F -* Parablennius tentacularis.

False cryptobenthic fishes

Figure 67: False cryptobenthic species and their habitat.

False cryptobenthic fish species always occur in the vicinity of cavities to which they retreat in case of danger (Figure 67). These species are not necessarily related to cryptobenthic habitats. They are in fact nectobenthic species. Such species include the brown wrasse (*Labrus merula*) and the painted comber (*Serranus scriba*) (Figure 68). In case of danger, they hide in the cavities of rocks and boulders, in larger spaces in the precoralligenous and under sandstone overhangs, which are common, for example, at the Cape Ronek.

Figure 68: The painted comber (Serranus scriba).

The brown meagre (*Johnius umbra*) (Figure 69) is also a typical species, which occurs in higher abundance on a vertical rocky wall at Cape Madona, and in lower numbers within the Strunjan Nature Reserve and near Fiesa. In all three cases, the species is found in precoralligenous habitats. In case of danger, the brown meagre rapidly escapes to cavities and waits till the danger ceases to exist. The same is also true for damselfishes (*Chromis chromis*); however, they also occur in a shallower environment.

Figure 69: The brown meagre (Johnius umbra).

Figure 69: The damselfish (Chromis chromis).

Epibenthic fishes

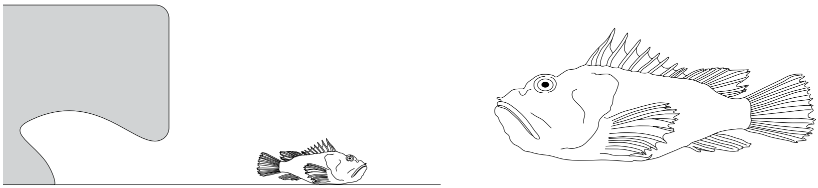


Figure 70: Epibenthic fishes and their habitat.

Epibenthic fish species occur on the surface of the substrate (Figures 70 and 71). Some of them are easy to detect, others are camouflaged or buried in sediment.

Figure 71: The red scorpionfish (Scorpaena scrofa).

Real epibenthic species

This group includes numerous fish species, which occur more or less motionless on the sea bottom and are easily detected in their environment. Sometimes, they retreat to spaces between rocks or large cracks. Such species are, for example, the red-mouthed goby (*Gobius cruentatus*), the giant goby (*G. cobitis*), the rock goby (*G. paganellus*) and Sarato's goby (*G. fallax*). Some blennies are also considered as real epibenthic species, for example, the tompot blenny (*Parablennius gattorugine*) and two triplefins (Figure 72), the yellow triplefin (*Tripterygion delaisi*) and the red-black triplefin (*T. tripteronotus*). This group also comprises bad swimmers such as pipefishes, represented by the great pipefish (*Syngnathus acus*) and both species of sea horses, the long-nosed seahorse (*Hippocampus guttulatus*) and the short-nosed seahorse (*Hippocampus hippocampus*).

Figure 72: The red-black (above) and the yellow triplefin (below).

Camouflaged epibenthic species

Some epibenthic species such as the Red scorpionfish (*S. scrofa*) and other smaller representatives of the genus *Scorpaena* (Figure 73) sometimes hide in cavities, but most of the time they are well camouflaged in their environment. They deceive their predators with their camouflage outfit. This group also includes some endolithic species that are well-camouflaging in their home range since their colour pattern blends into the environment. This is the case of the blackheaded blenny (*Microlipophrys nigriceps*).
On the huge biogenic formation off Cape Ronek and also on the border between the rocky and sandy bottom it is possible to find the Blochs topknot (*Zeugopterus regius*), which is well-camouflaged on large-sized pen shells (*Pinna nobilis*).

Figure 73: The black scorpionfish (Scorpaena porcus)*.*

Epipsammal fish species

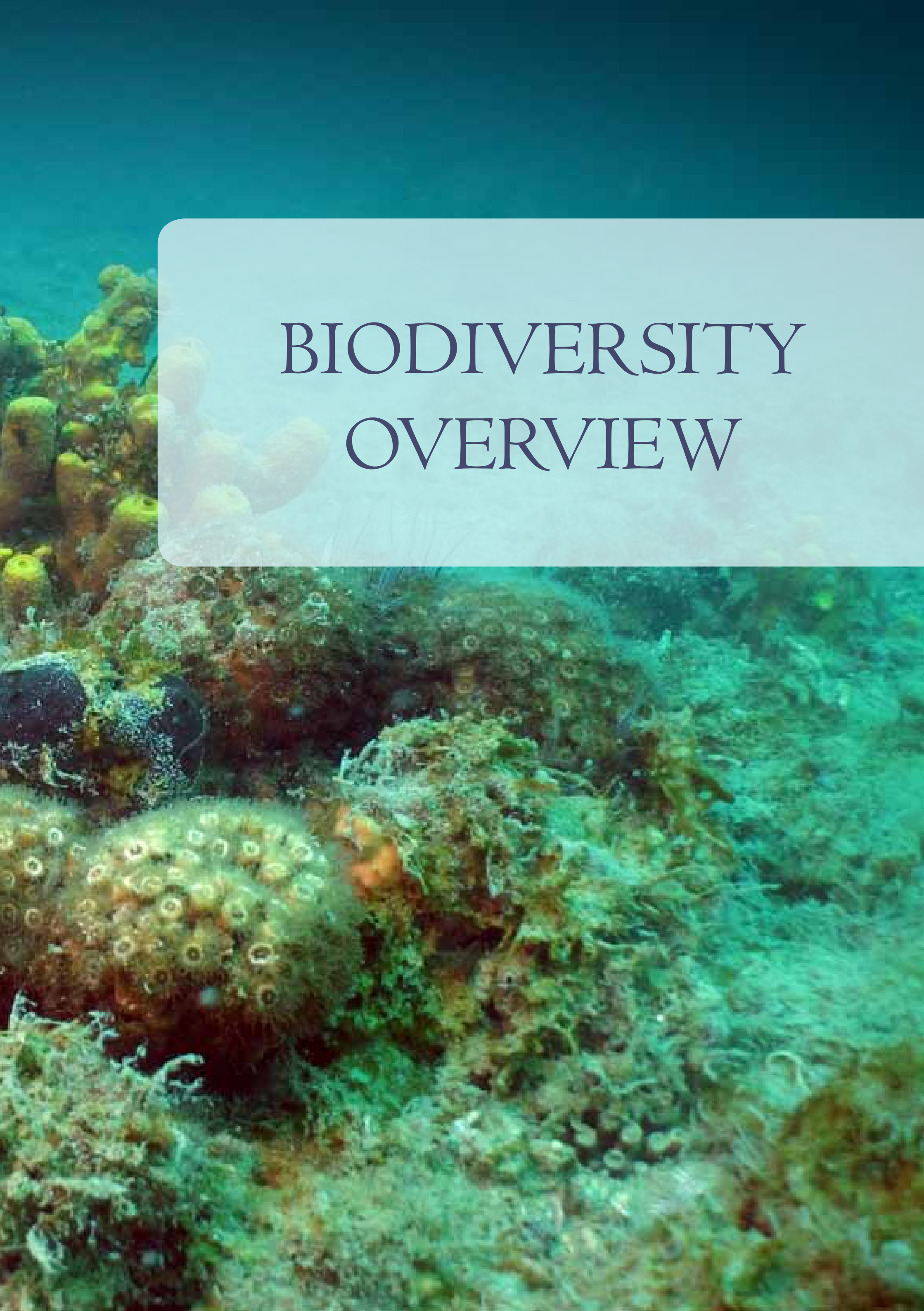
In areas where the rocky bottom is slowly changing into sandy or muddy bottom, some fish species can be found burying themselves in the sediment. Such fish species are dragonets (species of the genus *Callionymus*), weevers (species of the genera *Echichthys* and *Trachinus* (*Figure 74*)), and certain species of flatfish (genera *Solea, Arnoglossus, Buglossidium* and *Platichthys*). Also, as regards cartillaginous fishes, some epipsammal species can be found, for example, several species of ray (genus *Raja*) (Figure 75) and the electric marbled skate (*Torpedo marmorata*, Figure 76).

Figure 74: The weever Trachinus draco *(above) and the dragonet* Callionymus pusillus *(below) hiding in the sediment*.

Figure 75: The brown ray (Raja miraletus).

Figure 76: The electric marbled skate (Torpedo marmorata) *in normal coloration (left) and albino specimen found near Cape Madona (right)*.

BIODIVERSITY OVERVIEW



The flora of biogenic formations

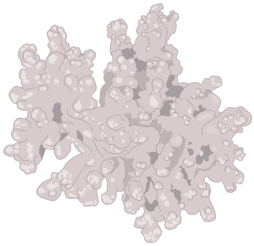
Red algae (Rhodophyta)

Lithophyllum racemus

The thallus only occurs in non-fixed, sub-spherical (rhodolithic) form with very crowded rigid protuberances (Bressan & Babbini, 2003; Falace *et al.*, 2011). The diameter ranges from 1 to 8 cm. The colour of fresh samples is bright pink, gray-pink or purple. In its free-living form, the species can be found in both the infralittoral and circalittoral belt.

Lithothamnion minervae

The form of the thallus differs from an encrusting to a branched form, with short protuberances (0.5-1 mm), to a sub-spherical shape (rhodolith) with longer protuberances (1-3 mm) (Falace *et al.*, 2011). The diameter ranges from 2 to 4 cm. The colour of fresh samples is bright purplish pink. The species only lives in the circalittoral belt, where its free-living (rhodolithic) form dominates. Encrusting thalli are epibionts, growing mainly on biogenic residues (*e.g.* of dead shells).



Lithothamnion philippii

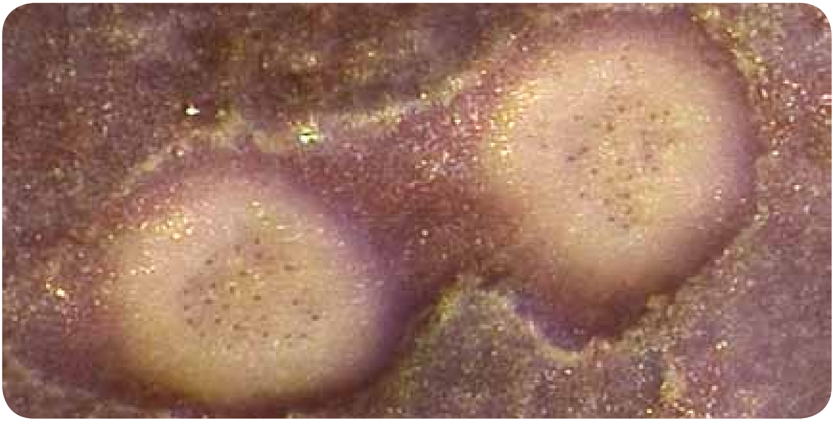
The thallus is mainly encrusting and firmly attached to the substrate, but it can also be found in its rhodolithic free form. The upper surface is flat or with rare roundish hills (Falace *et al.*, 2011). The diameter is smaller than 5 cm. The colour of fresh samples is bright magenta pink. The species only grows in the circalittoral belt. It is sciaphilic and its encrusting form is epibionthic, growing mainly on biogenic residues.

Phymatolithon lenormandii

The thallus is encrusting and firmly attached to the substrate. Adjacent thalli are often confluent or overlapping (Bressan & Babbini, 2003). The diameter ranges from 1 to 4.5 cm. The colour of fresh samples is light pink or grayish. The species is sciaphilic, growing in mediolittoral, infralittoral and circalittoral belts. It is epilithic (growing on rocks) and epibionthic (on biogenic residues).

Halymenia floresii

The thallus is laminar, with a gelatinous consistency, attached to the substrate with a small basal disk. The colour ranges from light red to light pink. The alga is 5 to 30 cm high. The agile upper part of the thallus is unevenly branched and in the water it looks like a flame. Thallus edges are sharp, giving the alga a serrated and notched appearance (Falace *et al.*, 2013). Single thalli are present in shadowy areas of infralittoral and circalittoral belts.



Pneophyllum confervicola

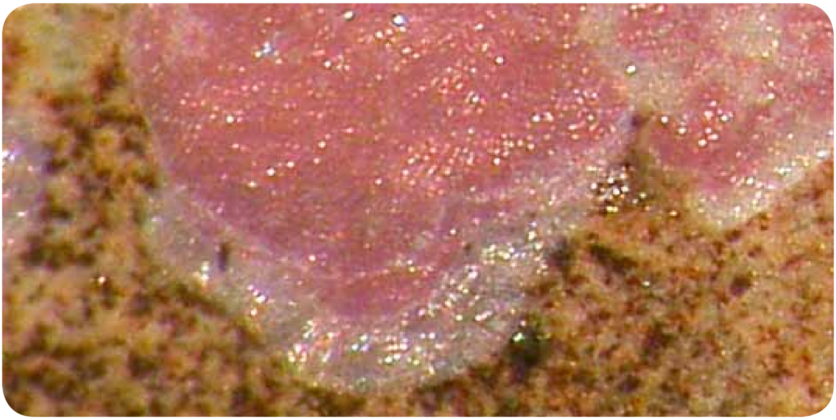
The thallus is encrusting, with a circular form, and partially attached to the substrate (Bressan & Babbini, 2003). The largest measured diameter is 12 mm. The colour of fresh samples is light pink or dark pink, and rather transparent. The species grows in mediolittoral, infralittoral and circalittoral belts. It is epilithic (growing on rocks) and epibionthic (growing mainly on thalli of other algae).

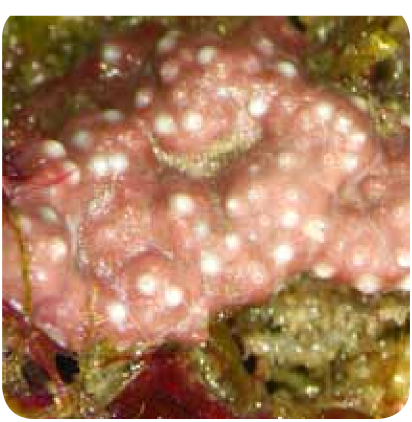
Pneophyllum fragile

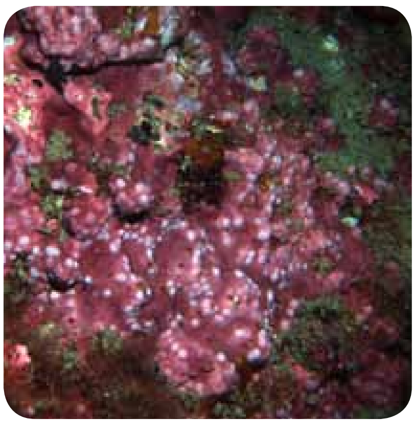
The thallus is encrusting, with a circular form, and firmly attached to the substrate (Bressan & Babbini, 2003). The upper surface is completely smooth. The largest measured diameter is 6 mm (Falace *et al.,* 2011). The colour of fresh samples is bright pink, red or light purple. The species grows in mediolittoral, infralittoral and circalittoral belts. It is an epibiont, growing mainly on the thalli of other algae and on seagrass leaves.

Titanoderma pustulatum

The thallus is encrusting, firmly attached to the substrate and mostly kidney-shaped (Bressan & Babbini, 2003). The diameter ranges from 1 to 3 cm. The colour of fresh samples is brilliant mauve pink. It is an epibiont and in the infralittoral belt grows on the thalli of other algae and on seagrass leaves. In the circalittoral belt, it lives attached to molluscs shells, polychaete tubes and tunicates. In the circalittoral belt, it can also be found in the rhodolithic free form.







Peyssonnelia squamaria

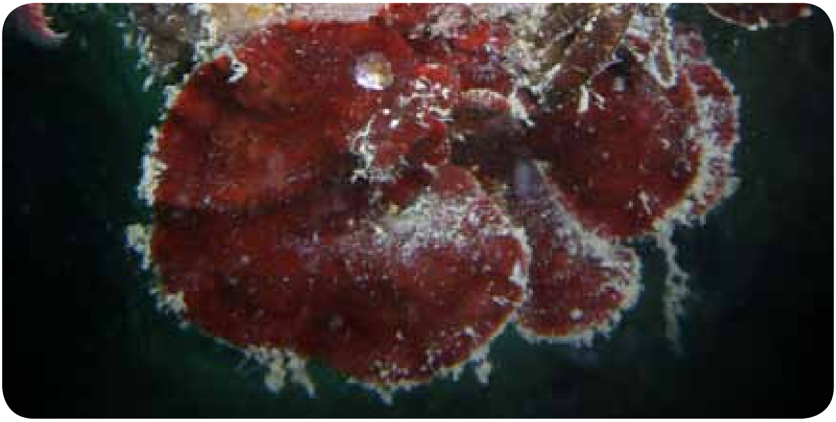
The thallus lies flat, it is round or kidney-shaped, and attached to the substrate only in its central part. The alga is composed of horizontal laminae, projecting one beyond another. Laminae are fan-shaped and their edge is irregularly radially cut. The upper surface is radially decorated. The colour of the thalli is red to red-brownish. The lower side is overgrown with dense and short rhizoids. The diameter ranges from 4 to 10 cm. It grows in the precoralligenous and in the circalittoral. It is often epiphytic, growing especially on the thalli of brown algae (such as *Cystoseira* spp.).

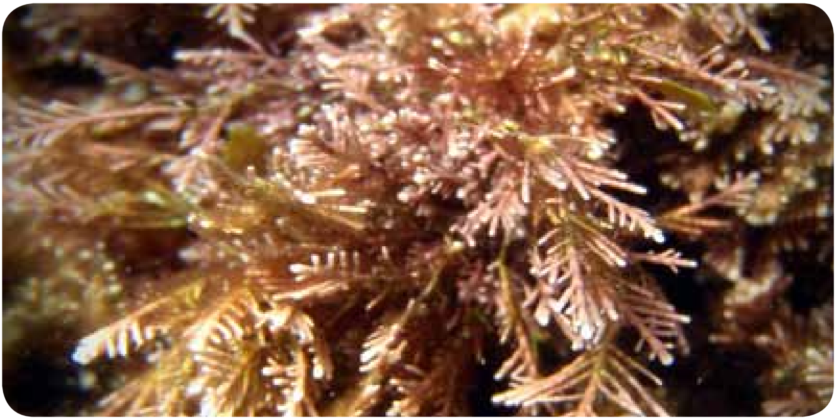
Corallina officinalis

The thallus has a bushy shape. It consists of a number of structured and vertical segments (fronds), which rise from a wide calcified disk. Calcified parts of the vertical segments are connected with non-calcified joints, and thus the thallus is hard and brittle. At the beginning of growth, segments are similar to spherical or oval buttons, which later rise and branch out irregularly. The species grows from 5 to 12 cm. Its colour varies from pale red, sometimes pale purple, to ivory-white. It grows in shadowy hard bottom areas of mediolittoral and infralittoral belts.

Jania virgata

The thallus is shrubby with a calcified fixing basal disk. Calcified parts of vertical segments (fronds) are connected via non-calcified joints, and thus the thallus is hard and brittle. Lower segments are mostly irregularly branched, while upper segments are oppositely pinnate arranged. The final height varies from 2 to 5 cm. The colour of fresh samples is pink purple, rarely coral pink. The species also grows in the lower mediolittoral, but mostly in the infralittoral belt. It grows as an epiphyte, primarily, on thalli of larger species, such as brown algae (*Cystoseira* spp.) and the red alga *Halopithys incurva*.





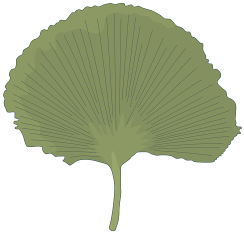
Green algae (Chlorophyta)

Halimeda tuna

The thallus is erect, yellowish-green in colour, but during growth becomes whitish due to calcification of cell walls. The alga consists of kidney-shaped segments (up to 15 mm width and 1 mm thick). The final height varies from 10 to 15 cm. Sexual reproduction is rare and takes place on the edge of the upper segments, which are surrounded by gametocysts. Female and male gametocysts are present on different thalli (dioecious alga). After releasing gametes, only the outer whitish involucre of the segments remains, due to the presence of calcium carbonate in cell walls. The species grows in the precoralligenous (in dimed rocky infralittoral areas).

Flabellia petiolata

The thallus is erect and of dark-green colour. It consists of an upright cylindrical peduncle that extends into a flat fan. Cell walls are not calcified. The fan is composed by primary fibres (arranged parallel on one level), which are sometimes dichotomously branched. The upper edges are often splintered. The final height can reach 10 cm. Sexual reproduction takes place with the formation of small male and larger female gametes in the fibres. After the release of gametes, the thallus becomes whitish and degenerates quickly (Falace *et al.,* 2013). The species grows in the precoralligenous (in dimed rocky infralittoral areas).



The fauna of biogenic formations

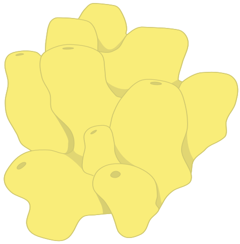
Sponges (Porifera)

Common antlers sponge *(Axinella polypoides)*

The common antlers sponge lives in areas with well-developed precoralligenous assemblages and it is commonly found in caves formed by large rocks. It can be recognized by high growth and yellow to orange colour. In the Slovenian Sea, more species of this genus can be found, but they are all considered relatively rare.

Yellow tube sponge *(Aplysina aerophoba)*

The yellow tube sponge forms characteristic yellow masses of tubes, which are among the most common sponge elements in the precoralligenous, on the coastal detritic bottom and on biogenic formations. Because of its high abundance, it is important for many invertebrates, which live in (infauna) and on (epifauna) the sponge. Some of the epifauna, such as the opistobranch *Tylodina perversa* or the seahorse *Hippocampus guttulatus,* adapt their colour pattern to the colour of the sponge. Some other species, such as the crabs *Dromia personata* and *Pisa nodipes,* cut out pieces of a sponge and use it as camouflage by covering their carapaces.



Stony sponge *(Petrosia ficiformis)*

The stony sponge is a very hard sponge, which is characteristically purple brown in colour due to symbiosis with cyanobacteria. It is a sciaphylic species encountered in the precoralligenous and in the shelter of large rocks and caves. It is not as common in the Slovenian Sea as it is more south in the Adriatic Sea, where the opistobranch *Peltodoris atromaculata* is a common companion of the sponge also.

Kidney-shaped sponge *(Chondrosia reniformis)*

The kidney-shaped sponge is a massive lobate, smooth sponge coloured in variable shades of grey and brown-violet on top, lighter at the sides. It is one of the most common sponges in the Slovenian Sea, especially in the precoralligenous and on other biogenic formations. It is commonly used for camouflage by the crab *D. personata.*

Chicken-liver sponge *(Chondrilla nucula)*

The chicken-liver sponge is an amorphously shaped sponge with dark-brown to walnut-brown or beige colour; it grows in flat, sometimes bulbous sheets in benthic communities. It is a very common sponge in the Slovenian Sea, especially in the precoralligenous and on other biogenic formations.

Pink tube sponge *(Haliclona mediterranea)*

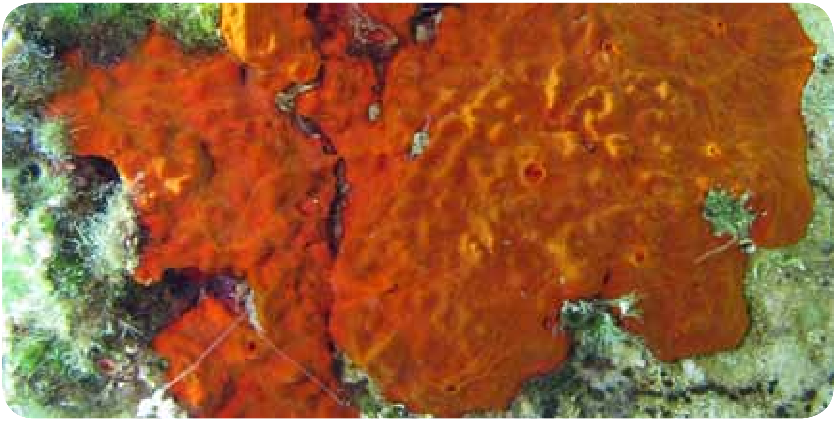
The pink tube sponge is an encrusting sponge forming cones or tubes rising up to 8 cm in height. It has a very intense pink to purple colour. It grows in shaded places and it is not very common. In the Slovenian Sea, it is most abundant in the area of the Cape Madona Natural Monument (Piran).

Orange encrusting sponge *(Spirastrella cunctathrix)*

The orange encrusting sponge grows as a thin soft crust on rocky substratum and has an orange to reddish colour. The surface is clearly marked with a network of venations, which are located around elevated osculae forming a starry pattern. It grows on shady rocky surfaces in the precoralligenous and in the biocoenosis of photophilic algae.

Brain sponge (*Geodia cydonium*)

The species is a large typically spherical yellow to whitish sponge with an irregural and generally hispid surface. It is the biggest sponge in the Slovenian Sea, growing to more than 0.5 m in diameter. It can be found on soft bottoms. In the Slovenian Sea, its presence has only been confirmed for a few locations, but it was discovered that it is quite frequent on biogenic formations at Cape Ronek and Cape Debeli Rtič.



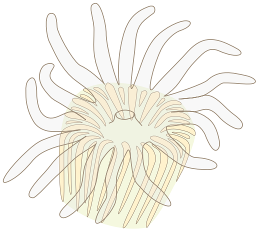
Cnidarians (Cnidaria)

Parasitic anemone *(Calliactis parasitica)*

The parasitic anemone is a sea anemone with a fairly tough and leathery column; it is yellowish/buff in colour with brownish to reddish vertical stripes. It has numerous tentacles (up to 700) that are moderately long, creamy, occasionally pink to orange in colour. This anemone usually lives in a mutualistic relationship with the hermit crab in sublittoral habitats. In the Slovenian Sea, it usually covers the shells of muricid snails such as *Hexaplex trunculus* and *Bolinus brandaris,* inhabited by the hermit crab *Paguristes eremita.*

Cloak anemone *(Adamsia palliata)*

The cloak anemone is a sea anemone with a characteristic shape and colour pattern; it has round lilac or red spots on the body known for completely overgrowing mollusc shells. The disc and tentacles are always located beneath the belly of the hermit crab. When disturbed, it emits numerous pink (rarely white) acontia. In the Slovenian Sea, it usually covers the shells of trochid sea snails *Gibbula magus,* inhabited by the hermit crab *Pagurus prideaux.*



Daisy anemone (*Cereus pedunculatus*)

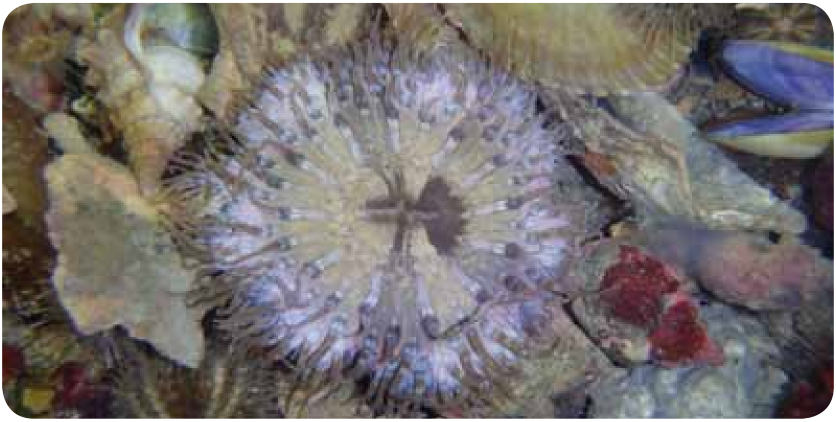
The daisy anemone has a base that is sometimes frilled at the edge. It is wider than the trunk, which is covered with small dots and can be cream, pink, brown or violet in colour and stalk- or trumpet-like. The oral disc may be 7 cm wide or even wider with more than 500 short, flaccid tentacles, which may be plain coloured, banded or speckled. It is typically found in pools, holes and crevices, or attached to stones beneath the surface of sediments in infralittoral and circalittoral belts.

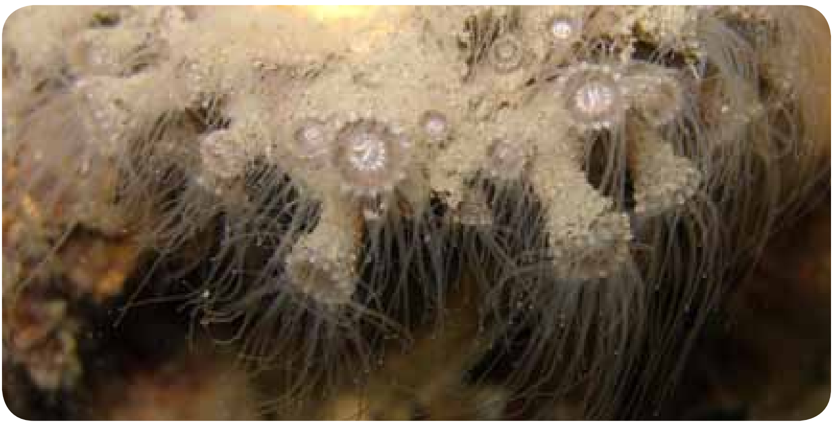
Mediterranean stony coral *(Cladocora caespitosa)*

The Mediterranean stony coral is a stony coral endemic to the Mediterranean Sea. It is composed of numerous individual polyps of clear maroon colour, forming cushion-shaped colonies. The colonies can reach over 50 cm in diameter and in some areas, like lake Veliko Jezero on the island of Mljet (Croatia), even over 1 m. The coral can be found on a wide range of substratum, although mainly rocky, from shallow areas (a few meters) to deep waters.

Zoanthid of genus *Epizoanthus*

Species of the genus *Epizoanthus* are colonial sea anemones of semi-translucent buff or pinkish colour. The polyps have a serrated parapet at the top of the column and long tentacles. They live attached to stones and shells in shaded parts of the infralittoral and down to the circalittoral belt.





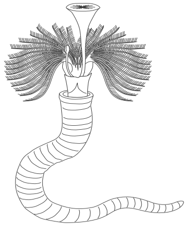
Polychaets (Polychaeta)

Australian tubeworm (*Ficopomatus enigmaticus*)

This is a small serpulid tubeworm living in whitish circular calcareous tubes ornamented with flared rings and bearing fig-shaped covering (operculum) with a crown of incurved horny spines in a concentric rings. It has up to 20 branching gill plumes, which are gray, green, or brown in colour. It grows in enclosed and brackish areas with tubes forming colony hummocks on hard surfaces near low tide. It is a cosmopolitan species, considered an invasive alien species in the Mediterranean Sea. In the Slovenian Sea, it is mostly known from coastal wetlands, like the Sečovlje Salina Nature Park and the Škocjanski Zatok Nature Reserve.

Mediterranean fanworm (*Sabella spallanzanii*)

The Mediterranean fanworm is a large (up to 40 cm) sedentary marine polychaete. It is characterised by a stiff parchment tube crowned by a retractable two-layered branchial fan with one layer forming a distinct spirale. The fan is very variable in colour but usually banded in orange, purple and white or it may be a uniform pale grey. The worm grows on soft sediments or on solid surfaces from very shallow areas down to the circalittoral belt, including the precoralligenous, clusters and big biogenic formations with Mediterranean stony coral.



Red tubeworm *(Serpula vermicularis)*

The red tubeworm lives in loosely curved calcareous tubes attached to solid surfaces. The branchial plume is commonly red, orange or pink and usually banded with white. It has a funnel-shaped lid with many (up to 160) fine creases around its edge. The red tubeworm is a cosmopolitan species occuring in the intertidal zone down to the circalittoral. It is one of the most common worms on biogenic formations in the Slovenian Sea.

Tubeworm *Serpula concharum*

The tubeworm *S. concharum* is very similar to the calcareous tubeworm mentioned above. The most obvious difference is the lid, which is bell-shaped and has fewer creases around its edge. This tubeworm is the most frequent species of polychaets living among the corallites of Mediterranean stony coral.

White-tufted worm (*Protula tubularia*)

The white-tufted worm is a solitary serpulid bristleworm, living in calcareous tube. The head has 20 to 45 white or pale pinnate tentacles that are marked with paired red blotches. The fan tuft measures approximately 3 cm in diameter. The white-tufted worm does not have a protective operculum for its calcified tube. It can be found on hard substrata in shallow coastal waters. It is a common species on biogenic formations.

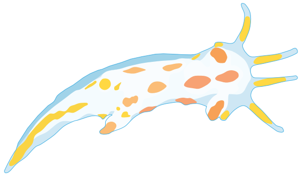
Gastropods (Gastropoda)

Purple flabellina nudibranch *(Flabellina affinis)*

The purple flabellina is one of the most colorful and abundant nudibranchs in European seas. It has a translucent body with pink-purple coloration, which is also true for the long, narrow and pointed cerata. Its presence depends on the presence of arborescent colonies of the athecate hydroid *Eudendrium sp.* on which it feeds and is usually found on dimly illuminated solid substrates.

Flabellina nudibranch *(Flabellina ischitana)*

This species is very similar to the above mentioned flabellina. It can be destingushed from it most obviously by the red-orange colour of the cerata, which is due to the branches of the digestive gland visible through the somewhat transparent skin of the ceras. The species is most frequently found in deeper precoraligenous facies, on transition to sandy and muddy bottoms. Both species of *Flabellina* can also be observed together, feeding on colonies of the hydroid *Eudendrium* sp.



Pilgrim hervia *(Cratena peregrina)*

The pilgrim hervia is one of the most frequent and abundant sea slugs in the Gulf of Trieste. Its body coloration is milky white with two orange spots on the head. It has 8 to 10 clusters of dorsal cerata, which can be bright red, purple, brown or blue, with the tips coloured in luminescent blue. It shares the same habitat and the same food as *F. ischitana* and its presence is likewisely dependant on the presence of its major prey, namely *Eudendrium* sp.

Orange Godiva *(Dondice banyulensis)*

The orange Godiva is the largest aeolid sea slug in the Mediterranean Sea, reaching up to 7 cm in lenght. It is unmistakable by its size and fiery orange coloration. It is a Mediterranean endemite, which can be found in a variety of habitats, such as colonies of hydrozoans, gorgonians, in the coralligenous, sandy bottoms, and rocky walls with photophilic algae. It is known to feed on the polyps of *Eudendrium sp.*, polychaets and even other aeolid sea slugs. As regards the Slovenian Sea, it has so far been found in the Bay of Piran and on the biogenic formation at Cape Debeli Rtič.

Onchidoris neapolitana

This is a small 1 cm long very flat oval sea slug. It is coloured red-orange with many brown spots in the centre of the back. It is also characterised by numerous digitiform papilae on the back of the body, which give the slug a hairy appearance. It is commonly found in many habitats, including biogenic formations, on encrusting bryozoans, like *Schizobrachiella sanguinea* on which it also feeds.

Trapania maculata

This is a small nudibranch reaching 15-20 mm in length. It is coloured white with yellow or orange spots on different parts of the body. It is most commonly found in the precoralligenous, more rarely among photophilic algae and is usually associated with sponges, mainly *Cacospongia scalaris.* It presumably feeds on kamptozoans, which live attached to the surface of sponges, bryozoans and hydroids.

Trapania lineata

Trapania lineata is very similar to the above mentioned *T. maculata.* It is a bit smaller reaching 10-15 mm in length and differing most obviously from it by a pattern of opaque white lines on the translucent white body. Both species also share the same habitat, mainly within the precoralligenous.

Dendrodoris grandiflora

Dendrodoris grandiflora is a large sea slug exceeding 10 cm in length. Its body is oval-shaped and has a very wide, wavy margin with dark radial grooves. The coloration is highly variable, from brownish, reddish, greyish, and greenish to almost black. On the back it generally bears numerous irregular spots that are darker than the general body colour. It is commonly found on sponges in very shallow waters down to circalittoral waters.

Clanculus cruciatus

Clanculus cruciatus is a relatively small sea snail belonging to the family of top snails with a maximum size of about 10 mm. The shell is pinkish, dark brown, blackish or pink, radiately maculated with white below the sutures, and dotted with white around the center of the base. In the Slovenian Sea, it can be found in Mediterranean stony coral colonies and on other biogenic formations.

Alvania cimex

Alvania cimex is a small sea snail growing to the size of 4 to 6 mm. The shell is conical with a big last whorl representing around 2/3 of total size. The surface is decorated with symmetrically arranged projections. The species can be found in the infralittoral throughout the Mediterranean Sea.

True worm-snail (*Vermetus triquetrus*)

The true worm-snail is a vermetid gastropod with an unusual and irregular tubular shell. It is found predominantly in shallow waters, where it is cemented on stones and rocks or certain large-sized organisms, such as the pen shell (*Pinna nobilis*). It can reach a length of about 30 to 50 mm. It is widespread in the north Atlantic and Mediterranean. It feeds on the suspended particulate matter in the water column. It is rather common in the Slovenian Sea, especially on biogenic formations.

Bivalves (Bivalvia)

Jewel box (*Chama gryphoides*)

The jewel box belongs to the family Chamidae, reaching a size of around 20 mm. The shell is whitish to beige, thick and heavy, almost oval and inequivalve. The left valve is large and deep and attached to the solid surface, while the right one is flatter and bears thin radial ribs and thorns, which are quite irregular and arranged in concentric rows. It lives in the Mediterranean Sea on bottoms with solid substrates, including Mediterranean stony coral colonies and other biogenic formations, in infralittoral and circalittoral belts.

Wrinkled rock borer (*Hiatella arctica*)

This clam has a white thick shell, more or less oblong, but highly irregular in shape, reaching the size of around 40 mm. The surface of the shell is sculptured with thick concentric ridges while two distinct ridges extend backwards from the beak on each valve. The type of substratum selected by juveniles determines whether they become burrowers or nestlers. This species can be found on the lower shore and down to the circalittoral and is one of the most frequent bivalves in Mediterranean stony coral colonies in the Slovenian Sea.

Flask-shell (*Rocellaria dubia*)

The flask-shell is a small marine clam reaching around 30 mm in length. The shell is greyish white, thin and fragile and never closes entirely, leaving a characteristic gap in the anterior part, in the shape of a droplet. It builds limy tubes (chimneys) reaching out from the surface in which the clam is hidden, and supporting the clam's siphons. It bores into solid substrates in infralittoral and circalittoral belts and is frequent on all types of biogenic formations.

Warty Venus (*Venus verrucosa*)

The warty Venus is a clam with bulky, oval and equally sized valves that can grow up to 10 cm. The shell is beige to brown and characterized by a series of 20 or more prominent concentric ridges intersected by radiating grooves resulting in wart-like spines. It can be found burrowed in soft sediments in infralittoral and circalittoral belts.

Noah's arch shell (*Arca noae*)

This is a relatively large-sized bivalve reaching around 10 cm. The shell is oblong, irregularly striped in brown and white and often heavily encrusted with epibionts (algae, sponges, tunicates). The shell is attached strongly by byssal threads to the solid substrate in the infralittoral and more rarely in the circalittoral belt.






Peanut worms (Sipuncula)

Aspidosiphon muelleri

This is a cylindrically shaped species, reaching up to 80 mm in length, with a dark chitinous shield at both ends of the trunk. With age, specimens become darker in colour and large specimens are frequently dark brown to black. It is found from the lower shore to a depth of about 1000 m. It commonly occupies gastropod and scaphopod shells and serpulid tubes but also lives in crevices, amongst coralline algae and in deep water. It is a characteristic bioeroder.

Bryozoans/Sea Mats (Bryozoa)

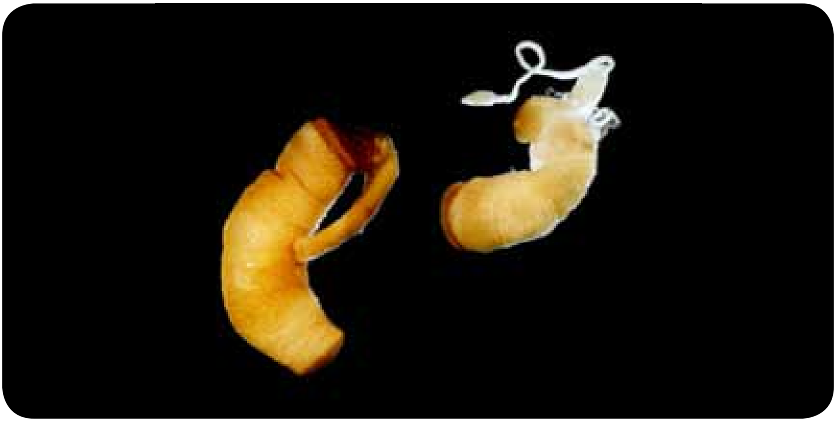
Schizobrachiella sanguinea

Schizobrachiella sanguinea is an encrusting bryozoan that forms broad redish colonies, often only partly attached to the substrate and developing erect, folded lobes or plates. It is essentially a warm temperate species, growing attached to hard substrates in the infralittoral down to the circalittoral and is frequent in coralligenous biocoenoses.

Horseshoe Worms (Phoronida)

Horseshoe worm (*Phoronis muelleri*)

Horseshoe worms derive their name from the crown of tentacles (lophophore), which is horseshoe shaped. They are a specific animal group, closely related to bryozoans. This species may be encountered forming tangled masses, encrusting rocks and shells on various vertical surfaces and pillars.



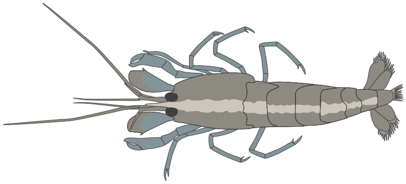
Crustaceans (Crustacea)

Common Lobster (*Homarus gammarus*)

The common lobster is a very large (50-100 cm) and long-living (over 15 years) species. It is blue-coloured above with coalescing spots and yellowish below. It is characterised by the first pair of walking legs, which carry massive pincers. The long abdomen terminates in a broad tail fan. It is territorial and lives mostly solitary life in a hole or under a stone in infralittoral and circalittoral belts.

Ethusa mascarone

Ethusa mascarone is a small-sized (up to 3 cm) crab with a characteristic rectangular greyish to brownish carapace. The fifth pair of legs is very small and used for carrying objects, which are used for camouflage. This crab lives on sandy and mudy bottoms down to 30 m depth. It is common in the Gulf of Trieste, as observed from the diet of certain shark species (e.g. *Mustelus mustelus, M. punctulatus*) that consume a significant amount of *Ethusa mascarone.*



Wrinkled spider crab (*Herbstia condylliata*)

The wrinkled spider crab is a brownish-greyish crab with noticeable redish legs and eyes. It grows to around 5 cm. It lives on rocky bottoms, hidden under stones, in caves and crevices that it leaves at night. It is a characteristic species of the coralligenous biocoenosis. As regards the Slovenian Sea, it has only been found in the precoralligenous around Cape Madona, Piran (Lipej *et al.,* 2010).

Sponge Crab (*Dromia personata*)

The sponge crab is one of the large-sized crabs in the Slovenian Sea. It has an oval carapace and is covered with short hairs giving the crab a furry appearance. It is characterised by distinctive pink pincers and the very small fourth and fifth legs, which it uses to carry comouflage covers cut out of sponges and tunicates. The most common cover it uses is the colonial tunicate *Aplidium conicum.* It can be found on rocky or stony substrata, often in the precoralligenous.

Long-clawed porcelain crab and Black porcelain crab (*Pisidia longimana in P. bluteli*)

These crabs are small and grow to around 5 mm. They have flattened bodies as an adaptation to living in rock crevices and large claws used for protecting their territories. They resemble true crabs by their round body and abdomen, which is pulled under the carapace but actually belong to hermit crabs (Anomura). They are common under rocks in the mediolittoral belt and down to the circalittoral belt.

Synalpheus gambarelloides

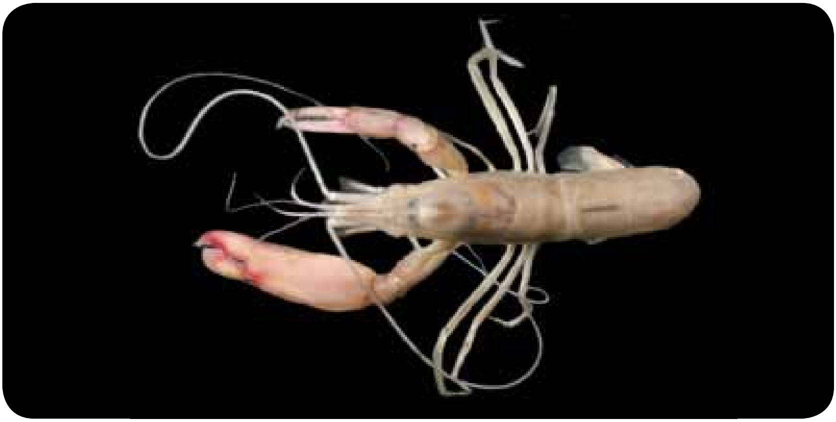
This species of snapping shrimp grows to 20 mm in length and is rose-coloured. Two thorns above the eyes extend to the end of the rostrum forming the tridentate apex of the cephalothorax that is characteristic of the species. It can be found in the infralittoral and circalittoral, where it lives in the canals inside the sponges. This species lives in highly organised groups with subgroups/casts specialised for certain actions (*e.g.* defence, reproduction).

Pistolcrab (*Alpheus dentipes*)

This shrimp is translucent and lightly brownish in colour. It grows to 25 mm and has very asymmetric claws, with the largest having characteristic bumps and channeles on the surface. By snapping its claws it produces specific sounds used for communication, defence and hunting. The intensity can reach 220 decibels, which is high enough to stun or kill a target from a distance of a few centimetres. It lives in tunnels under stones, between coralline algae, corals, coral debris and occasionally in sponges (*e.g. Geodia cydonium*) from the infralittoral down to the circalittoral belt.

Hooded shrimp (*Athanas nitescens*)

The hooded shrimp is a small shrimp measuring up to 20 mm in length. The rostrum is well-developed, long straight, unarmed, with an acutely pointed apex. Two anterior projections of the carapace cover the eyes dorsally, hence the name hooded shrimp. The shrimp’s colour is very variable but it always has a characteristic white stripe along the middle of the carapace. This species is often found in groups of adults and juveniles in the infralittoral and circalittoral belts.



Eisothistos macrurus

This is a small very elongated isopod, whitish in colour, growing to the size of few mm. The most evident characteristics are highly serrated margins of uropods and telson. They prey on serpulid worms and dwell in their calcareous tubes. In fact, the genus derives its name from this behaviour since Eisothistos in Ancient Greek means conqueror, invader.

Bristly crab (*Pilumnus hirtellus*)

This is a crab with a longitudinally convex reddish-brown, sometimes purplish carapace with 5 sharp unequally sized antero-lateral teeth on each side and smooth dorsal surface with numerous club-shaped setae. Chelipeds are stout and robust and brownish or purple in colour with orange to cream inner surfaces. Silt often accumulates among setae making the crab difficult to see on dark or silty surfaces. The species lives in crevices, cracks, holes of solid surfaces from the infralittoral down to the circalittoral belt.

Spinous squad lobster (*Galathea strigosa*)

The spinous squad lobster is easily recognised by the transverse blue stripes across the body. It can grow to the total lenght of 9 cm (carapace 5 cm). It can be found in the infralittoral and down to the circalittoral belt on shadded rocky substratum. During the daytime it is hidden in holes, crevices or under rocks, while during the night it comes out in the open searching for food.





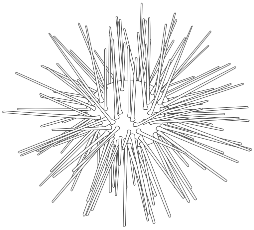
Echinoderms (Echinodermata)

Smooth brittle star (*Ophioderma longicauda*)

This is a species of brittle star whose surface is smooth with fine granulation and a leathery texture. It is usually chocolate brown in colour but may also be red-orange, dark brown or black. The arms often have lighter, greenish bands. It can be found on rocky bottoms, and sometimes on sandy ground and corals from the surface down to the circalittoral belt. It is highly photophobic so it normally hides under rocks during the day.

Tubular sea cucumber (*Holothuria tubulosa*)

This is a large sea cucumber with a cylindrical body about 6 cm in diameter and reaching 45 cm in length. Its colour is pale brown with sometimes purplish mottling to reddish brown, and the surface is covered by numerous dark long conical papillae. It extracts the organic particles from the sediment it ingests. It can be found on sandy bottoms, among seagrass or on muddy rocks from the infralittoral down to the circalittoral belt.



Violet sea urchin (*Sphaerechinus granularis*)

This is a large regular sea urchin, growing to 15 cm in diameter. The test is purple, while the short and blunt spines can be purple or more often white. It can be found in sheltered or semi-sheltered conditions amongst algae on rocky and gravel sea-beds in the infralittoral and circalittoral, where it grazes on algae, especially encrusting coralline algae, seagrass blades and their epiphytic organisms and detritus.

Purple sea urchin (*Paracentrotus lividus*)

This is a regular sea urchin, growing up to 7 cm in diameter. It has a greenish test, which is densely clothed in long and sharp pointed spines that are usually purple but can also be brown, light brown or olive green. It can be found on rocks and boulders, and more rarely in *Zostera marina* and *Posidonia oceanica* meadows, from just below the low water mark down to the beginning of the circalittoral belt.

Green sea urchin (*Psammechinus microtuberculatus*)

This is a small, brown, herbivorous sea urchin nearly spherical in shape, reaching 5 cm in diameter. It is covered with short greenish or whitish spines. It can be found on different bottoms, but usually near sandy areas, from the infralittoral down to the circalittoral belt.

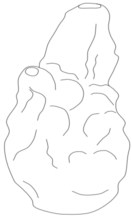
Tunicates (Tunicata)

Conical sea squirt *(Aplidium conicum)*

This is a colonial species with characteristic intensive orange colour. It is commonly conical in shape, reaching relatively large sizes of 30 cm or more in height. It can be found in different habitats from the infralittoral down to the circalittoral belt. It is frequently used as for camouflage by the sponge crab (*Dromia personata*).

Jelly-synascidian *(Diplosoma spongiforme)*

This ascidian forms an extensive transparent brightly greyish sheet over rock surfaces and other hard surfaces, and even organisms (*e.g.* sea grasses, noble pen shell). It is a common ascidian in a wide variety of habitats, from sheltered to exposed conditions and is also found in the precoralligenous and other biogenic formations.



Polysyncraton lacazei

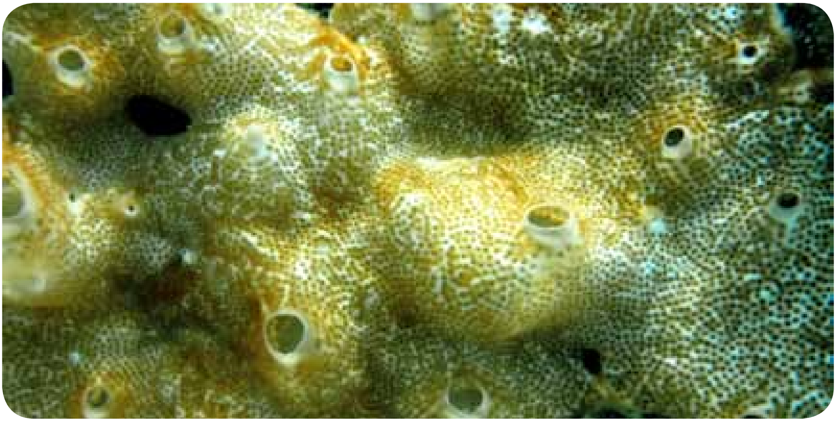
This colonial sea squirt resembles the jelly-synascidian *Diplosoma spongiforme,* but is orange in colour. In the Slovenian Sea, it can be found sporadically but it is not very common. It overgrows solid structures in the infralittoral and the circalittoral belts, most commonly in shaded areas.

Polycitor adriaticus

This colonial sea squirt forms a whitish group of lumps connected to the surface with a common thin stalk. It is common on trezze, in the Italian part of the Gulf of Trieste, but it is much less frequent and abundant in the Slovenian part, where it can be found on the precoralligenous of the southern coast of Piran and on biogenic formations at Cape Ronek and Cape Debeli rtič.

Red sea squirt *(Halocynthia papillosa)*

The red sea squirt is a solitary ascidian with intensive red, bordo-red colour reaching 10-20 cm in height. The margins of both siphons bear strong protruding setae. It is common on shaded rocky surfaces of the infralittoral and circalittoral belts.



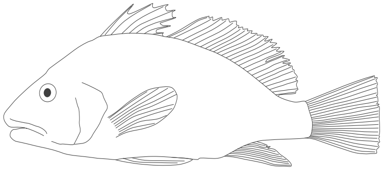
Bony fish (Osteichthyes)

Brown meagre (*Johnius umbra*)

The brown meagre is a typical inhabitant of biogenic and precoralligenous formations. Generally, it occurs in small schools, swimming close to crevices and cavities, into which it escapes in case of danger. Smaller specimens, which occur in bigger schools, are recognized by lower body depth and yellow fins. They are especially common between 7 and 12 m of depth within the Cape Madona Natural Monument area close to the old town of Piran.

Moray eel (*Muraena helena*)

The finding of a moray eel specimen in June 2011 in the Slovenian part of the Adriatic Sea was an unexpected event (Lipej & Moškon, 2011). It was found in a precoralligenous habitat covered by the dominant sponge *Aplysina aerophoba,* in a well-hidden vertical burrow. Prior to this finding, the northernmost record of this species was in the Kvarner archipelago (Croatia).



European conger (*Conger conger*)

The European conger is a typical cryptobenthic fish species, which can be found from 3 m of depth down to the circalittoral belt. It inhabits large cavities in rocky areas, especially in precoralligenous habitats. The conger leaves its shelter mainly to seek for food. It preys various fish mainly and to a lesser extent on benthic crustaceans.

Shore rockling (*Gaidropsarus mediterraneus*)

The shore rockling hides in cavities and spaces underneath rocks and sandstone boulders. It is considered a cryptobenthic fish species. Beside precoralligenous habitats, this species can be found in cryptic shallow habitats, which are not considered biogenic formations.

Zebra goby (*Zebrus zebrus*)

At least forty specimens of the zebra goby have been recorded to date in Slovenia. Specimens of this cryptobenthic species measured up to 53 mm in total length and were caught in the depth range from 0.5 to 4 m. The habitats that they inhabit are similar to those of Large-headed gobies, with which they share the same colour pattern and morphological characteristics. This species is also poorly known with only limited published information.

Large-headed goby (*MIllerigobius macrocephalus*)

The large-headed goby is a typical cryptobenthic species, which can be found under big flat stones and rocks in the upper infralittoral belt and more rarely in precoralligenous habitats. The majority of recorded Large-headed gobies measured less than 33 mm in total length. They occur mainly in rocky areas with big stones and where the algal community is dominated by *Padina pavonica* (biocoenosis of photophilic algae). Surprisingly, only limited information exists on the occurrence of this species in the Mediterranean Sea.

Leopard-spotted goby (*Thorogobius ephippiatus*)

The leopard-spotted goby that can be recognized by black spots on a grey background is a typical fish species of the coralligenous biocoenosis. It inhabits cavities and caves with sandy patches. In the Slovenian part of the Adriatic Sea, it was found in the Cape Madona Natural Monument (Lipej *et al.*, 2005), in a precoralligenous habitat with the typical sandy microhabitat at 10 m depth. This species has not been sighted or recorded since then.

Large-scaled goby (*Thorogobius macrolepis*)

The large-scaled goby is an endemic species in the Mediterranean Sea. It has pale body with golden or orange spots. This goby inhabits coarse sand patches within coralligenous formations. It is a cryptobenthic goby dwelling on sea bottom always close to caves, cavities or crevices. A specimen of this goby was recorded during visual census surveys carried in the Natural Monument of Cape Madona. It can attain a length of 7 cm. Probably, this species is likely to be far more common than currently thought.

Shore clingfish (*Lepadogaster lepadogaster*)

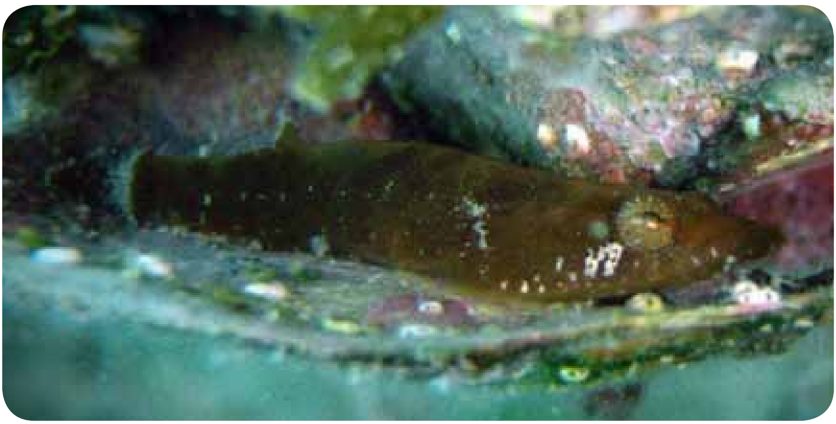
The shore clingfish occurs where the upper infralittoral borders on the mediolittoral belt at a depth ranging from 0.9 to 1.2 m. This intertidal clingfish is distinguished from the Connemarra clingfish by having a triangular-shaped head and typical blue dots on the head. Many specimens can be found in the high-tides period, in spring and autumn months. Its length can reach 65 mm.

Connemarra clingfis (*Lepadogaster condolii*)

The Connemarra clingfish occurs under big flat stones in the upper infralittoral belt from 2 to 8m of depth. The clingfish derives its name from the ability to attach itself to the surface of stones using its pectoral fins, modified as an adhering organ. It is generally olive green in colour with numerous small dots on the dorsal part of the body. It can reach 8 cm in total length.

Sea urchin clingfish (*Apletodon incognitus*)

This cryptobenthic fish species inhabits *Cymodocea nodosa* meadows and rarely precoralligenous habitats. The Sea urchin clingfish generally uses dead oysters for shelter and nesting in the reproductive period. Males guard the nest against intruders and predators. The species can also be found under stones and in the carapace of dead *Maja ramulosa* crabs. Its length can reach 45 mm.



Mediterranean rainbow wrasse (*Coris julis*)

This is one of the most vivid-coloured wrasses, characterized by evident sexual dimorphism. It can reach 25 cm in total length. The Mediterranean rainbow wrasse appeared in the Gulf of Trieste in the year 1999. Nowadays, it is considered a common species and it reproduces in the area. It is found in small schools, in precoralligenous habitats mainly.

Grey wrasse (*Symphodus cinereus*)

The grey wrasse is grey or brown coloured. It can reach 15 cm in total length. Like other wrasses, it builds beautiful nests using small shells, pebbles and seaweed. Males guard the brood tenaciously. Unlike other wrasses, the grey wrasse inhabits bare or poorly vegetated areas mainly. It can be found close to small and high biogenic formations, areas dominated by Mediterranean stony coral and in precoralligenous habitats.

Brown wrasse (*Labrus merula*)

The brown wrasse is the largest representative of the family of wrasses (Labridae) in the Slovenian part of the Adriatic Sea. It is recognized by its uniformly dark blue or green colour with a typical pale blue margin of dorsal and tail fins. It can reach a total length of 50 cm. It is a solitary species, found in habitats with many rocks and boulders. Sometimes, it hides in the cavities of boulders; however, it is not considered a cryptobenthic species. It is found mainly in precoralligenous habitats. Younger and smaller specimens inhabit shallower areas.




Mystery blenny *(Parablennius incognitus)*

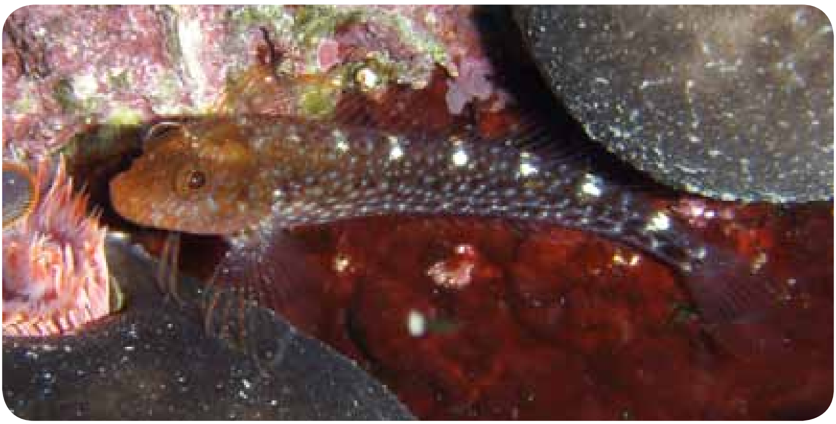
The mystery blenny is a typical endolithic species inhabiting the burrows created by date mussels, which are also its reproductive ground. Rarely the species can be found in the empty shells of larger bivalves or artificial burrows. It inhabits shallow areas to the lower border of precoralligenous habitats (Orlando-Bonaca & Lipej, 2007). Regarding choice of habitat, it is the least selective of all blennies (Kotrschal *et al.*, 1991).

Longstriped blenny (*Parablennius rouxi*)

The longstriped blenny is a typical blenny of the lower infralittoral belt, where it can be found in different biocoenoses, especially in the precoralligenous belt. It inhabits burrows excavated by the date mussel, which are not necessarily fitted to its head width. Such burrows are normally overgrown with coralline algae. This blenny is characterized by the fact that it also inhabits artificial holes, such as discarded bottles and even parasol carriers.

Zvonimir's or staghorn blenny (*Parablennius zvonimiri*)

The Zvonimir's blenny is a typical species of precoralligenous formations in dimly lit habitats such as overhanging rocks or caves, where it lives syntopically with the black-headed blenny. The body is brownish red or orange with six typical white spots on the back. The head tentacles resemble the horns of a stag. It is an obligatory endolithic species, which always chooses its burrow in a dim lit and well overgrown habitat. Zvonimir's blenny occurs deeper on rocky bottom than the majority of other blennies. It is also considered to be more aggressive in comparison with other relatives.



Tentacled blenny (*Parablennius tentacularis*)

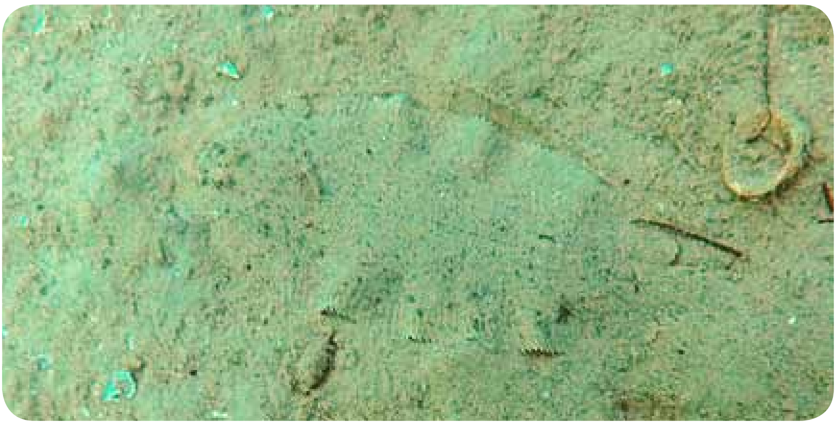
The tentacled blenny occurs mainly on large-sized biogenic formations and on clusters of stones and detritus on sedimentary bottom. It can also be found in precoralligenous areas. The male is differentiated from the female by its long head projections. It is the only blenny to prefer seagrass meadows and sedimentary bottoms over rocky areas.

Black-headed blenny (*Microlipophrys nigriceps*)

This cryptobenthic blenny can be found in precoralligenous habitats and is closely related to the presence of coralline algae. It occurs in burrows of smaller and bigger cavities or caves, often choosing a burrow on a cavity or cave roof, which offers shelter. It is characterized by pronounced sexual dimorphism, known also in other species from the genera *Lipophrys* and *Microlipophrys*. In the reproductive period, the cheeks of the males are yellow. Males and females are both vivid red coloured in order to camouflage themselves in precoralligenous habitats dominated by red coralline algae.

Common sole (*Solea solea*)

The common sole is a flatfish living on the sandy or muddy seabed. The eyes are located on the right side of the body. It burrows into sandy and muddy substrata. It is a widespread and abundant species in the Gulf of Trieste and throughout the Adriatic and Mediterranean Seas. It can reach almost 70 cm in total length.



Red scorpionfish (*Scorpaena scrofa*)

The red scorpionfish is an epibenthic fish species, reaching up to 50 cm in length. The red scorpionfish is common in rocky habitats with big rocks and boulders and also at a variety of biogenic formations. Usually, it lies motionless on the bottom ambushing on prey and moves only when disturbed. It has cryptic colouration which is highly variable from brick red to dark red. It preys crustaceans, molluscs and fish. It is also known as venomous fish causing painful stings. Red scorpionfish is considered as a highly valued commercial species throughout the Mediterranean Sea.

Black scorpionfish (*Scorpaena porcus*)

It is much smaller than the red scorpionfish, only occasionally reaching more than 25 cm and rarely more than 30 cm in total length. It is a common solitary benthic-dwelling fish on rocky bottom. The head is decorated with spines, tentacles and flaps of skin. It has cryptic colouration, which is generally brownish. There are three darker vertical stripes on the caudal fin. It preys other epibenthic fishes such as gobies and blennies, crabs and other crustaceans and other benthic invertebrates.

Streaked gurnard (*Trigloporus lastoviza*)

The streaked gurnard is a representative of the family of gurnards, characterized by their huge pectoral fins. The first three rays are separate and without a web. They are used for moving forward like walking and to remove their preferred prey species from the sediment. It feeds mainly on benthic crustaceans hiding in mud or sand. In case of danger, the streaked gurnard spreads out its vividly coloured pectoral fins to give an impression of a larger animal and thus disguise and frighten predators.

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legend: Position of illustrations and photographs.

t - top

m - middle

b - bottom

r - right

l - left

Acknowledgments

First we would like to express our immense gratitude to our colleagues at the RAC/SPA in Tunis for their invaluable support of our work and willingness to enable publication of this book. This publication would not have been possible without the precious help of our good friend and colleague, Mr. Robert Turk, who recognized the urge to publish our knowledge on the Slovenian biogenic peculiarities and has been supporting us for decades.

The authors would like to thank the colleagues from the Marine Biology Station of the National Institute of Biology who helped with the huge amount of work done. We are particularly grateful to: Milijan Šiško, whose creativity has contributed to the creation of the excellent graphic material, Tihomir Makovec for the excellent photographs, Dr. Janja Francé for her accurate and critical review of the text, Valentina Pitacco for some additional data, and Dr. Aleksander Vukovič who shared his immense knowledge with us.

A heartfelt thanks goes to external researchers with whom we have been collaborating for many years: Dr. Annalisa Falace and Dr. Sara Kaleb from the University of Trieste, Dr. Roberto Odorico from the Shoreline Soc. Coop., Dr. Petar Kružić from the University of Zagreb, Dr. Nicola Bettoso from the Regional Agency for Environmental Protection of Friuli, Venezia Giulia (ARPA), Dr. Sašo Moškon from Harpha Sea Koper, Dr. Simon Kerma from the University of Primorska, Iztok Škornik from the Sečovlje Salina Nature Park, and Dr. Paola Negro, Dr. Emiliano Gordini and Dr. Simonetta Lorenzon from the National Institute of Oceanography and Experimental Geophysics (OGS).

Last but not least, we wish to thank our directress, Prof. Dr. Tamara Lah Turnšek for her continuous support.

NOTES

The book was created with the help of the following institutions and in the framework of the projects:

UNEP

MAP

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MKH MEDKEYHABITATS

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