OVERVIEW ON THE SPONGE FAUNA OF THE LIMSKI KANAL, CROATIA, NORTHERN ADRIATIC SEA[1]

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[1]Dedicated to Werner E.G. Müller on the occasion of his 60th birthday he celebrated in Rovinj

ABSTRACT

Limski kanal is an 11 km long fjord-like bay located in the Istrian peninsula (Croatia, Northern Adriatic Sea), which lies along an E-W axis so that the two sides face north and south. The sponge fauna of the channel has been investigated at twelve locations, six for each side at different depth levels. A total of 42 species have been recorded, 5 of them have never been reported for this area before. Only few species have been found in all locations and distributional trends have been observed. Substrate, light exposition and the high sedimentation affect the sponge distribution along the channel.

KEY WORDS

Porifera, Rovinj, Limski kanal, benthic fauna, sponge fauna.

INTRODUCTION

From the beginning of marine science sponges from the Mediterranean Sea were part of the interest as they served for several purposes in daily life. Many type species of new described families and genera have been found in the Mediterranean, where a rich sponge fauna lives: PULITZER-FINALI (1983) listed around 550 sponge species and today at least 564 species are reported from the Mediterranean Sea (PANSINI, 1996). For the Croatian Adriatic Sea a number of 201 species (28 Calcarea and 173 Demospongiae) was given in 2000 and one of them is threatened (RADOVIĆ, 2000).

A first remarkable overview of the sponge fauna for the Adriatic Sea was given by SCHMIDT (1862) as he felt the lack of basic literature to determine his sponge samples. He complained about the imprecise descriptions of sponges in Olivi's "Zoologia Adriatica" (OLIVI, 1792) and the disinterest of Nardo, author of "Spongiariorum classificatio" (NARDO, 1833), to publish his own names and descriptions of a large number of sponge samples or at least to co-operate. The "Spongiariorum classificatio" contained a system based primarily on Adriatic sponges but as Schmidt missed the descriptions to Nardo's names he saw no other possibility then to ignore most of them.

Schmidt published a descriptive list of 115 species from which 95 were considered new to science (SCHMIDT, 1862). In this work he also suggested that the regenerative characteristics of sponges might be utilized in sponge culture. This idea was set to practice one year later on the island of Hvar (Lesina), Croatia (MOORE, 1908).
Based on these studies the Adriatic Sea became one of the best examined parts of the Mediterranean. This was advantaged by the foundation of several marine institutes and stations in the late 19th century, among those some of the oldest marine stations of the world. The Biological Station of Rovinj, Croatia, was founded in 1891 as field station of the Berliner Aquarium (Berlin, Germany) to provide it with living organisms. It is now a department of the Institute "Ruder Bošković", Zagreb (HR) (ZAVODNIK, 1995).

Systematic sponge studies in the area of Rovinj began with GRAEFFE (1882), who noted three species from Rovinj. ZIMMERMANN (1907) published a list of 25 species but the first (and most) comprehensive work for the area of Rovinj was done by VATOVA (1928) who gave an overview of the distribution of the benthic species, the geological history and the climate conditions (VATOVA, 1928). Including most former works he listed 60 sponge species with their distribution and bibliography. "With regard to its complexity and conception, this work has remained unique up to the present day" (ZAVODNIK, 1995).

But Vatova - like previous authors - was dependent on dredged sponges or on dried and fixed material that was collected in shallow waters and on the beach. This led to systematic confusion, because of the alterations of the sponges skeletons and morphology due to fixation and drying processes (RÜTZLER, 1965a).
Therefore Rützler used SCUBA diving for his examinations. He listed and described a total of 62 sponge species for the area of Rovinj (RÜTZLER 1965a). Combining this list with Vatova's work, unpublished findings and the work of some other authors, he sorted 112 sponge species according to their habitat (RÜTZLER, 1967).
Further strong interest for the sponges of the Rovinj area was shown by Müller who recorded several new species (MÜLLER & ZAHN, 1968; MÜLLER *et al.,* 1979, 1983) and published a list of 139 species (MÜLLER *et al.,* 1984) of which 137 seem to be valid today.

Concerning the Limski kanal, a closer examination of the sponge fauna has not been done yet, though several authors worked in the channel and reported a few species (VATOVA, 1928, 1931; MÜLLER & ZAHN, 1968; PULITZER-FINALI, 1983; MÜLLER *et al.,* 1984; SARÀ *et al.,* 1989). Research on its benthic fauna was done by VATOVA (1943), ZAVODNIK (1971) and GILLET (1986) but they reported no more sponges for the Limski. It was regarded as an example for a coastal terrigenous muddy bottom, an unsuitable habitat for most sponges.

Research Area

The Limski kanal is a 11 km long fjord-like bay, nearby Rovinj (Istrian peninsula, Croatia, Fig. 1), that lies along a E-W axis so that the two parallel coast lines face one the North and the other the South (Fig. 2).

The channel's western opening is between Rt Kriz (Punta Croce), in the northern side and Rt Sjole (Punta Tiolle) in the southern side. The maximum width is about 650 m and the maximum depth 32 m. The Limski is separated by a sediment barrier from the open sea, which rises a few meters above the bottom of the channel (PAUL, 1970).

Fig. 1. Mediterranean Sea an Istrian peninsula (in the frame).

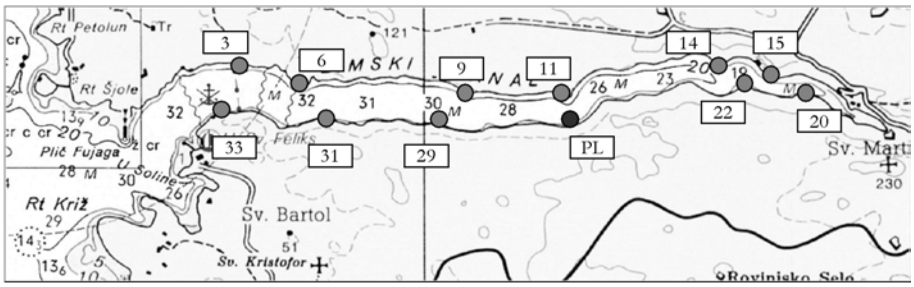

Fig. 2. Survey locations in the Limski kanal.

The geology of the Rovinj area is dominated by calcareous rock of grey and white dolomite. This calcareous material was deposited by Jurassic Brachiopoda and corals. In the Cretaceous a period of submersion, followed by an immersion one, occurred with consequent remodelling of the geographic profile. Later on, during the Oligocene the formation of the Julian Alps produced the submersion of the Istrian peninsula, then eroded by wind and heavy rainfalls during the Miocene and the Pliocene. In this age, the level of the sea was low and in the area where now the Limski kanal lies, the river Foiba was running down from the so called Limski draga, scavenging and eroding the calcareous rocks till the sea. During the Holocene the sea level started to increase penetrating through the valley produced by the Foiba and originating the current channel (VATOVA, 1928).

A calcareous rocky coast, with a lot of holes and caves, delimits the channel characterised by "macchia" and "garrigue" vegetation on the northern side and by a *Quercus ilex* forest and bushes on the southern side. Due to the carsic peculiarity of this area, a lot of small rivers and springs discharge into the channel underwater and their inflow becomes important during heavy rainfall periods. According to VATOVA (1928), an important spring incomes on the southern side, close to the project platform (see Fig. 2 and Tab. I) and another one opens in front of it, on the northern side. At the end of the channel the depth reduces rapidly and some small rivers and springs disembogue originating a shallow and brackish water area. The freshwater intake reaches its maximum in winter because of heavier rainfalls but does not really affect the rest of the water body. It drains of at the surface so that the channel is occasionally almost covered by a freshwater layer (UFFENORDE, 1970).

The oxygen saturation is nearby 100 % for around 8 months. With the warming of the upper waterlayers during spring a thermocline is formed and lasts until the water starts cooling down in late summer. During this time the O2-saturation decreases to a minimum of around 70 % near the bottom. While cooling down, the thermocline becomes unstable and water mixes vertically because of a rising convection current (PAUL, 1970). The water circulation is guaranteed by an outwards directed current close to the surface and an incoming current in the depth (KUZMANOVIC, 1985).

The bottom is flat and muddy in the centre and at the end of the channel and inhabited by the *Schizaster-Turritella*-biocenosis (VATOVA, 1931). It rises mainly as a detritic bottom with some rocky walls and cliffs to the surface. On both sides, but especially in the south, a 30 - 40 cm wide notch is present, followed, after not more than 50 cm of depth, by a small rocky wall that becomes a less inclined detritic cliff. This situation makes the Limski an inhomogeneous area with a broad variety of small scaled habitats.

Sediment rate appears to be high, especially in the second half of the channel and sediment bottom consists of fine particle fractions divided as follows: a diameter less than 6.3 μm = 53.9 %, 6.3 - 63 μm = 44.8 % and more than 63 μm = 1.1 % (ZAVODNIK, 1971). This mud is not stratified because of the digging activity of different organisms like *Callianassa stebbingi* The sedimentation rate of around 0.4 mm/a leaves the sediments for around 1000 years in the 30 - 50 cm wide range of this decapod (PAUL, 1970).

Today, part of the Limski kanal is a protected area, starting approximately from its middle part. Fish and mussel farms are present in this area.

MATERIAL AND METHODS

We surveyed in total 12 locations along the Limski kanal, 6 for each side (N and S), 4 at the eastern opening, 4 in the middle and 4 in the western end part (Fig. 2 and Tab. I). Vertical belt transects (2 m wide) from the surface to the bottom of the channel have been performed by SCUBA diving to get a general idea of the sponge species composition and the depth distribution. Species names and the number of specimens was written down on waterproof paper for every transect meter.

In addition, also any other observation coming from other surveys along the channel have been taken into account.

Sponges have been identified visually, except for some species, where identification was not possible underwater, even at genus level. Samples of these unidentified sponges have been collected and studied in laboratory. Sponges with spongin fibres were cut into pieces, macerated and the cleaned skeleton was observed under the microscope. Spicule slides have been prepared using concentrated HNO_3 to dissolve the organic material. Sponges were then identified with the help of literature (*e.g.* PULITZER-FINALI, 1983; SARÀ, 1983; BOURY-ESNAULT & RÜTZLER, 1997; VAN SOEST *et al.,* 2000; HOOPER & VAN SOEST, 2002).

Tab. I. List of the surveyed locations in the Limski kanal (map datum: WGS 84).

	Western opening		Middle Part		Eastern end	
Side	Loc. No.		Loc. No.		Loc. No.	
N	3	45°8.709' N	9	45°8.3' N	13	45°8.252' N
		13°37.513' E		13°40.154' E		13°42.413' E
N	6	45°8,82' N	11	45°7.956' N	15	45°8.110' N
		13°38.407' E		13°41.168' E		13°43.194' E
S	33	45°7.849' N	29	45°7.777' N	20	45°7.972' N
		13°37.587' E		13°39.861' E		13°43.734' E
S	31	45°7.816' N	35	45°7.779' N	24	45°8.88' N
		13°38.697' E		13°40.872' E		13°42.452' E

RESULTS

We found a total number of 42 species in the Limski kanal (Tab. II), not including about five unknown or undetermined species. Five species (marked with a asterisk in Tab. II) out of 42 were not reported before for the Rovinj area.

At the beginning of the channel - especially on the southern side - we found a very abundant but not very diverse sponge fauna. It consists mainly of *Aplysina aerophoba*, *Chondrilla nucula* and different "Keratosa" sponges (*e.g.* Dictyoceratida mainly belonging to Ircinidae and Spongiidae).

On both sides the diversity increases with the depth. This seems to change towards the end of the channel. Northern and southern side look quite similar and there is no strong change in species composition to deeper water.

On both sides sponges dominate the area lying directly under the notch. In addition to the most common species (like *A. aerophoba*, *C. nucula, Chondrosia reniformis*), we found *Tethya aurantium*, *Petrosia ficiformis* and others.

Where the bottom of the Limski is covered with mud, sponges can only be found occasionally either loose (*Dysidea avara*, *A. aerophoba*) or on bigger rocks emerging from the mud. These rocks are always covered with several species: the most abundant in this case are *Hemimycale columella*, *Sarcotragus foetidus*, *A. aerophoba* and *Crambe crambe*.

A few very large specimens of *G. cydonium* could be also found at different locations in the mud. Digitated specimens of *Ircinia variabilis*, almost completely sunk in the mud are common especially in the final part of the channel.

Tab. II. List of sponge species found in the Limski kanal (HR).

Species	**Family**
Calcarea	
Clathrina cf. *clathrus* (Schmidt, 1864)	Clathrinidae
Clathrina coriacea Montagu, 1819	Clathrinidae
Demospongiae	
Oscarella lobularis (Schmidt, 1862)	Plakinidae
Geodia cydonium (Jameson, 1811)	Geodiidae
Chondrosia reniformis Nardo, 1848	Chondrillidae
Chondrilla nucula Schmidt, 1864	Chondrillidae
Tethya aurantium (Pallas, 1766)	Tethyidae
Tethya cf. *limski* Müller & Zahn, 1969	Tethyidae
Tethya citrina Sarà & Melone, 1965	Tethyidae
Spirastrella cunctatrix Schmidt, 1869	Spirastrellidae
Cliona celata Grant, 1827	Clionaidae
Cliona vermifera Hancock, 1869	Clionaidae
Cliona viridis (Schmidt, 1862)	Clionaidae
Cliona nigricans (Schmidt, 1862)*	Clionaidae
Cliona rhodensis Rützler & Bromley 1981*	Clionaidae
Pione vastifica (Hancock, 1849)	Clionaidae
Suberites domuncula (Olivi, 1792)	Suberitidae
Terpios fugas Duchassaing & Michelotti, 1864	Suberitidae
Axinella verrucosa (Esper, 1794)	Axinellidae
Axinella polypoides Schmidt, 1862	Axinellidae
Axinella cannabina (Esper, 1794)*	Axinellidae
Crambe crambe (Schmidt, 1862)	Crambeidae
Hemimycale columella (Bowerbank, 1874)	Hymedesmiidae
Hamigera hamigera (Schmidt, 1862)	Hymedesmiidae
Phorbas tenacior Topsent, 1925	Hymedesmiidae
Phorbas fictitus (Bowerbank, 1866)	Hymedesmiidae
Antho (Antho) involvens (Schmidt, 1864)	Microcionidae
Haliclona (Haliclona) mediterranea Griessinger 1971*	Chalinidae
Haliclona sp.	Chalinidae
Petrosia ficiformis (Poiret, 1789)	Petrosiidae
Acanthella acuta Schmidt, 1863	Dictyonellidae
Aplysilla sulfurea Schulze, 1879	Darwinellidae
Dysidea avara Schmidt, 1863	Dysideiidae
Dysidea fragilis (Montague, 1818)	Dysideiidae
Spongia officinalis Linnaeus, 1759	Spongiidae
Aplysina aerophoba Schmidt, 1864	Aplysinidae
Hexadella racovitzai Topsent, 1896*	Aplysinidae
Ircinia variabilis (Schmidt, 1862)	Irciniidae
Ircinia spp.	Irciniidae
Sarcotragus foetidus (Schmidt, 1862)	Irciniidae

There are a few species which can be found all over the Limski kanal (*e.g. A. aerophoba*, *C. nucula*, *C. reniformis*, *Cliona celata* or *Ircinia* spp.) and some that seem to prefer the beginning and greater depths like *Axinella polypoides* or *Geodia cydonium*, that disappear towards the end of the channel. Other species can also be found all over the channel but more frequently at greater depths, *e.g. Oscarella lobularis*. No sponge species prefer the end of the Limski. However, the only exception is *Terpios gelatinosa*, often associated with *Cladocora caespitosa*, that we found from the middle to the backside of the channel, in agreement with VATOVA (1928).

DISCUSSION AND CONCLUSIONS

Rützler examined the sponge fauna of the surroundings of Rovinj in dependence of different ecological factors: depth, light exposition, sedimentation, current exposition (RÜTZLER, 1965a) and the size of substrate forming rocks. (RÜTZLER, 1965b). Smaller rocks can be removed easily by water movements and bigger ones have a longer idle period, that gives time for a diverse sponge development. He found that depth and current (if it is not too strong) have no real influence on the sponge fauna but especially sedimentation and light exposition strongly affect it, at least indirectly. Our results are concordant since we found a more diverse and abundant sponge fauna on the southern side and in greater depths where light is not as strong as nearby the surface. This is not due to the direct light impact but because algae seem to be a strong and successful competitor of sponges for space (RÜTZLER, 1965a). On the less shadowed northern side different algae can be found like *Padina pavonica*, *Codium bursa* or *Ulva rigida* in higher numbers than on the shadowed southern side. Moreover most of the benthos is covered during summertime with a fine algal or bacteria layer.

The changing fauna in the backside of the channel might be caused by higher sedimentation, lower current and the less inclined surfaces, where sediment is deposited more easily. The sponge coverage on rocks emerging from the mud seems to prove that the lack of sponges in this part of the Limski is mainly caused by the unsuitable substrate. Their high species diversity suggests that other factors play only a secondary role. If the high freshwater income during raining periods has also an effect on the sponge fauna has to be examined.

From the first visual impression the upper region close to the entrance on the southern side seems to be the most abundant part of the channel considering sponges, but the data shows that the diversity increases in deeper regions and towards the middle part of the channel. Preliminary results of first density studies of the most common species show a quite heterogeneous appearance (data not shown here). Further density and distribution investigations have to be done to get more information about these patterns. The correlation with one or most probably more environmental factors remains unclear and a more detailed study is necessary.

Anyway, according to our preliminary environmental data the Limski kanal appears to be a heterogeneous habitat, except for the exposition to light and current that seems to be similar on most of the surveyed locations on the same side. For this reason Limski kanal is still an interesting study area that could add important knowledge in the understanding of sponge distribution patterns along ecological gradients.

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