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MASTERARBEIT / MASTER'S THESIS

The molluscan assemblages of shallow water *Posidonia oceanica* settlements with different anthropogenic impact in the Kvarner Bay (Croatia).

verfasst von / submitted by
Alexander Heidenbauer BSc

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Index:

Abstract:

The molluscan assemblages inhabiting the leaf and rhizome layers of two shallow water (7.5 m water depth) *Posidonia oceanica* (L.) Delile settlements with different anthropogenic impact (popular touristic bay with a lot of boat-anchoring vs. non-touristic uninhabited island) were studied in the Kvarner Bay (Croatia) in September 2016. The associated malacofauna of *P. oceanica* is well documented in the western Mediterranean Sea, but almost no data exists from the Adriatic Sea, especially from the northern Adriatic. This study revealed 86 molluscan species, belonging to 62 genera, 37 families and four classes. The foliar and the rhizome layers are represented by 12 and 14 character species, respectively, which differ significantly from studies of other regions. The leaf layer is less species-rich (40 species) than the rhizome layer (79 species) and this trend also applies to the feeding guilds. The direct human impact on one of the two seagrass beds seems to have a negative influence on the shoot density and on the abundance of molluscs but the molluscan species richness does not seem to be affected. However, the species composition between the two seagrass beds is significantly different in both, the leaf and the rhizome layer, and affects the trophic composition too.

Zusammenfassung:

Ziel dieser Studie war die Untersuchung der mit *P. oceanica* assoziierten Malakofauna in der Kvarner Bucht in Kroatien. Untersucht wurde sowohl die Blatt- als auch die Rhizomschichten zweier Seegraswiesen mit unterschiedlichem anthropogenem Einfluss (Touristenstrand mit ankernden Booten und unbewohnte Insel ohne Tourismus). Die Probennahme fand im September 2016 in einer Wassertiefe von 7,5 m statt. Ähnliche Studien wurden überwiegend im westlichen Mittelmeer durchgeführt und beschränkten sich meist auf die Blattschicht der Seegraswiesen, nahezu keine Daten existieren von der Adria. Insgesamt wurden 86 Molluskenarten aus 62 Gattungen, 37 Familien und vier Klassen gefunden. Die Blatt- bzw. Rhizomschichten konnten durch 12 bzw. 14 Charakter-Arten definiert werden, welche sich deutlich von Studien aus anderen Regionen unterscheiden. Die Blattschicht (40 Arten) zeigte eine geringere Artenzahl als die Rhizomschicht (79 Arten), dieser Trend ist auch bei der Anzahl der Nahrungsgilden zu sehen. Der höhere anthropogene Einfluss auf eine der beiden Seegraswiesen spiegelt sich in einer geringeren Sprossdichte und Abundanz der Mollusken wider, der Artenreichtum scheint davon aber nicht beeinflusst zu sein. Die Artzusammensetzung zwischen den beiden Seegraswiesen ist sehr unterschiedlich, sowohl

in der Blatt- als auch in der Rhizomschicht, dies wirkt sich auch auf die trophische Zusammensetzung aus.

Introduction

1.1 Seagrasses

Seagrasses belong to monocotyledonous flowering plants. Its ancestors evolved on land and took place in marine habitats between 70 and 100 million years ago (Les et al., 1997). Seagrasses are a polyphyletic group and did not evolve from a single evolutionary lineage. They contain worldwide a low taxonomic diversity with 72 species in six families and 14 genera (Short et al., 2016). Nevertheless, they established successfully and colonized all but the most polar seas, covering 0.1 - 0.2 % of the global oceans (Duarte, 2002).

Seagrasses play an important role in coastal marine ecosystems and act in numerous ecological services to the marine environment (Constanza et al., 1997). As ecological engineer, they influence the physical, chemical and biological environment by building vast structures, called meadows. They play a number of key functions for littoral ecosystems (Hemminga and Duarte, 2000):

- Seagrass stabilizes the seabed and reduces coastal erosion (Hemminga and Duarte, 2000).
- The three-dimensional structure of seagrass meadows offers food source, living space and variety of ecological niches. The biodiversity in seagrass meadows is higher than in adjacent unvegetated areas, and faunal densities are orders of magnitude higher inside the meadows (Hemminga and Duarte, 2000).
- Seagrass meadows modify currents and waves, trapping and storing both sediments and nutrients, and effectively filter nutrient inputs to the coastal ocean (Hemminga and Duarte, 2000).
- Seagrass meadows are areas of refuge, spawning and nursery for different taxa, also for economically important species (Beck et al., 2001).
- Seagrass meadows produce and export large amounts of organic matter. Especially *P. oceanica* reaches the highest overall biomass of all marine MPO (Multicellular Photosynthetic Organism) with values up to 1640 gDW/m^2 in the leaf layer and 5500 gDW/m^2 in the rhizome layer (Boudouresque et al., 2006a).
- The primary production of some seagrasses is comparable to the highest observed values in terrestrial ecosystems (e.g. *P. oceanica* reaches biomass up to 3000 gDW/m^2/y^1, of which 15-30% comes from epiphytes) (Boudouresque et al., 2006b).

- Seagrass oxygenates coastal waters (e.g. up to 14 liters oxygen day^{-1} m^2 in *P. oceanica)* (Hofrichter, 2001).

1.2 Decline of seagrasses

Seagrasses have a long evolutionary history but now they are affected by multiple anthropogenic stressors (Boudouresque et al., 2006; Di Carlo et al., 2011; Orth et al., 2006):

- Pollution
- Increase of sediment and nutrient runoff
- Decrease in water quality and clarity
- Overgrazing and algal blooms
- Loss of habitat due to human activity (e.g. buildings, harbors, tourism, anchoring)
- Alteration of water movements
- Commercial fishing and aquaculture
- Invasive alien species
- Global warming

Seagrasses are very sensitive to environmental changes and these stressors result in an enormous decline on a scale of hundreds of square kilometers all over the globe (Evans et al., 2018, Orth et al., 2006, Waycott et al., 2009). According to Cancemi et al. (2003) and Boudouresque et al. (2006a), the main pressures are pollution, over-sedimentation, eutrophication and increased water turbidity. Dennison et al. (1993) stated that seagrasses require much higher light levels (up to 25% of incident radiation) than most other plant groups (e.g. 1% or less are required in other angiosperm species). They acutely respond to alterations in water clarity. Because of this, seagrasses are considered as biological indicators to determine the quality of coastal waters and, in general, the ecological status of marine environments (Romero et al., 2007, Gobert et al., 2009; Lopez y Royo et al., 2010). Declines in distribution and regression in coverage, shoot density and the maximum depth limit of seagrasses cause important losses of ecosystem services and affect a lot of associated species. Reported declines have led to increased awareness of the need for seagrass, but at a global scale, targeted conservation effort (reduction of watershed nutrient and sediment inputs, management, monitoring, restoration, educational program et cetera) is critical needed.

1.3 *Posidonia oceanica*

P. oceanica is an endemic seagrass species in the Mediterranean, that colonizes sandy and hard bottoms. It forms extended and persistent meadows ranging from the surface down to 40 m depth. The morphology of *P. oceanica* is similar to land plants. It can be divided into roots, shoot axis, leaves and flowers and the pollen dispersal is driven water movements. The rhizome is creeping beneath the substrate with branched roots at the nodes and sheet-like scales covering the rhizome. Lateral erecting shoots arise from the rhizome and end in bundles of distichously arranged leaves. Leaves reach a maximum length of 100 cm and a width of 1 cm (Hofrichter, 2001). *P. oceanica* builds dense meadows with up to 1000 shoots per square meter and forms reefs called "matte", consisting of rhizome, dead leaves, trapped sediment and other organic matter from various organisms, which accumulate over centuries and attain several meters in height (Hemminga and Duarte, 2000).

P. oceanica is the most representative and most important seagrass species in these waters (Buia et al., 2004). The biodiversity inhabiting *P. oceanica* meadows is estimated to several thousand of species (Boudouresque et al., 2006a), but only a small part really depends on the habitat. According to Pérès and Picard (1964) the habitat *P. oceanica* consists of two different substrates with different ecological conditions and different associated species: the upper leaf layer and the lower rhizome layer. Bianchi et al. (1989) even divided it into four different biocoenosis: The motile fauna, the epifauna on the leaves, the epifauna on the rhizome and the endofauna in the rhizomes. Epiphytes inhibit photosynthesis rates of the plant and need to be removed, when coverage is too high. Therefore, the leaves arise from a basal meristem as a countermeasure against dense epiphyte growth. The oldest part of the leaf, including high epiphyte coverage, is always on the top and will be eroded or dropped off by the plant. The leaf dropping occurs in autumn, when the nutrient supplies in the water are depleted from the productive summer times and the density of epiphyte larvae is low (Hofrichter, 2001). Intense leaf growth takes place over wintertime and slows down to a minimum in the spring and summer time, when epiphytes start again to settle down. However, rhizome growth takes place in the warm season and carbohydrates are stored, which supplies the leaf growth in winter (Ott, 1980). This drastic change and export of biomass within the annual cycle, is a very important source for adjacent habitats (Cardona et al., 2007) and keeps the biodiversity high. Sexual reproduction is rare among many seagrass species (Micheli et al., 2010) and the main growth is based on vegetative reproduction by cloning (Boudouresque et al., 2006a). The oldest *P. oceanica* individual ever found was estimated to an age of 80.000 -200.000 years (Arnoud-Haond et al., 2012).

1.4 Status of *Posidonia oceanica*

P. oceanica covers about 25% (2.5 to 4.5 million ha) of the Mediterranean basin having a water depth of less than 40 meters (Borum et al., 2004). Declines of *P. oceanica* meadows have been documented for several areas (Boudouresque et al., 2006; Di Carlo et al., 2011). According to Telesca et al. (2015) the regression during the last 50 years amounted to 34%. Such losses, in combination with the slow growth rate (1-6 cm yr^{-1}), are irreversible. For these reasons *P. oceanica* meadows are protected by the Habitat Directive 92/43/EU (Annex I, Posidonion oceanicae, code 1120) and are included in the reference list of priority habitats of the SPA/BIO Protocol of Barcelona Convention (Association with *Posidonia oceanica*, code III.5.1)(Relini and Giaccone, 2009). Its conservation status is represented and ranked by 5 categories: vulnerability, heritage value, rarity, aesthetic and economic significance (Hofrichter, 2001).

Many studies were undertaken to better understand this endangered ecosystem and associated faunas. Most previous research focused on the western Mediterranean, much less attention has been devoted to eastern parts such as the Adriatic Sea, where *P. oceanica,* in the most northern parts, has already disappeared (Zavodnik and Jaklin, 1990). The MedPosidonia Project is a monitoring program, that collects data of the distribution and status of *P. oceanica*, as a base for future conservation efforts like Marine Protected Areas (MPA). In 2017 the project expanded also to Croatian waters, called the Monitoring Protocol for *P. oceanica* meadows in Croatia. A pilot project was carried out in 2014 in the Kvarner bay.

1.5 Aim of the study

Gastropods and bivalves are among the most studied taxa in *P. oceanica* and especially the molluscan assemblage inhabiting the leaf layer is well documented in the western Mediterranean Sea. Less attention was paid to the assemblages of the rhizome layer and, except of Solustri et al. (2002) and Beqiraj et al. (2008), nobody focused on the molluscs in *P. oceanica* of the Adriatic Sea so far.

The aim of this study was to characterize the composition (qualitative data) and structure (quantitative data) of the molluscan assemblages living both on the leaves and rhizomes of two different shallow water *Posidonia oceanica* settlements in the Kvarner Bay (North Adriatic Sea, Croatia) with different anthropogenic impact (popular touristic bay with a lot of boat-anchoring vs. non-touristic uninhabited island).

Several studies showed that anthropogenic impacts oftentimes affect the health of seagrass meadows and its inhabitants (Cancemi et al., 2003, Boudouresque et al., 2006a). For example, an increase of nutrient runoff (e.g. wastewaters, fish farming,) decreases the water quality and clarity and results in a shallower depth limit of the seagrass meadows (Delgado et al., 1999) while mechanical stress like boat-anchoring causes a reduction of meadow coverage and shoot density (Francour et al., 1999, Montefalcone et al., 2008). Such alterations may also affect the molluscan diversity and therefore the species composition and the trophic composition.

As the seagrass meadow at Krk is faced with higher anthropogenic pressures (especially boat-anchoring) than the seagrass meadow at Kormati, the following hypotheses are expected and will be tested in this present study:

- Lower shoot density of the seagrass meadow at Krk island
- Lower molluscan abundance in the seagrass meadow at Krk island
- Lower molluscan diversity in the seagrass meadow at Krk island
- Different species composition between the seagrass meadows at Kormati and Krk
- Different trophic composition between the seagrass meadows at Kormati and Krk

Materials and Methods

2.1 Study area

Sampling took place in two separated *P. oceanica* meadows in the Kvarner Bay in Croatia (Fig. 1). Seagrass meadow 1 is located along the south-western coast of the island Kormati, seagrass meadow 2 is located at the south-western coast of Krk island. The distance between the two sites is about 7.80 km.

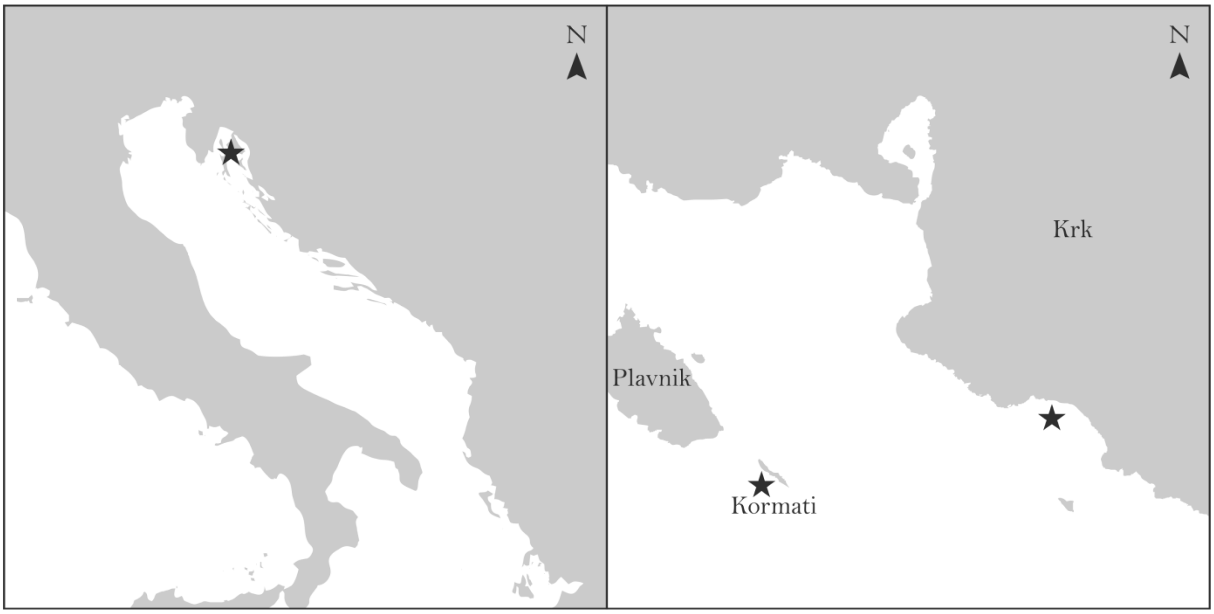

Figure 1 - Overview of the study area in the Kvarner Bay (North Adriatic Sea).
(Source: Google Earth modified)

The seagrass meadow at Kormati island

The seagrass meadow is located at the south-western coast of Kormati island. Kormati itself is an uninhabited flat and narrow rocky island (approximately 100m x 1000m), that hosts a colony of gulls, see Figure 2. Kormati`s bigger neighbor-island Plavnik (about 1,5 km north) is also uninhabited, but some bays are popular for tourist boats and scuba divers during summertime. Kormati and Plavnik are located at the sea strait, called Srednja Vrata, between the bigger islands Krk and Cres. The seagrass meadow abruptly starts growing at around 5 to 8 m and continuously expands on the flat seafloor. The substrate is predominantly rocky but also interrupted by small sand areas. The seagrass meadow is interrupted by a steep drop off wall at the southern tip of Kormati island.

According to the local fishermen and tourist boat owners there are usually no boats anchoring at Kormati, except of some rare visits from scuba diving boats on the southern tip of the island. There is no pollution or nutrient runoff from the island itself, the next human settlement is about 8 km away (Krk city & Punat).

Figure 2 - Kormati island

The seagrass meadow at Krk island

The seagrass meadow is located at the southwestern part of the island Krk, about 500 m north of the village Stara Baška and is surrounded by high karst hills (Figure 3 & 4). The seagrass meadow starts growing at around 7 m depth on a predominantly rocky bottom. It is disjointed and patchy with dead matte and sand areas.

The seagrass meadow is located just in front of a campsite and two highly frequented bays by tourists in summertime. Boat anchoring in front of the bays is common, but at least the campsite provides mooring buoys for small boats. It can be assumed, that there is more pollution, due to wastewater runoff from the village and the campsite and from tourist activities, than at Kormati island.

Figure 3 - The seagrass meadow at Oprna Bay (Krk) in summertime
(Source: https://hotelikrk.hr/de/blog/die-schonsten-strande-der-insel-krk-100/)

Figure 4 - The seagrass meadow in front of Camp Skrila
(Source: https://meinmobilheim.de/campingplatz/mobilehime-auf-dem-skrila-sunny-camping/)

2.2 Environmental parameters at the sampling areas

Wind

The Kvarner Bay is dominated by a powerful downslope wind from northeastern direction, called Bora, see Figure 5. It is a dry and cold wind, coming from the Dinaric Alps, that gets channeled in canyons and valleys and is notorious for strong squalls. The mean annual wind speed (10 m above ground level) next to the sampling area is 5 to 6 ms^{-1} and reaches top speeds up to 69 ms^{-1} in wintertime (Zaninović et al., 2008). When Bora occurs, the surface water drifts offshore and results in an upwelling from cold and clear water from the deep and in a vertical mixing in the North Adriatic basin (Rachev and Purini, 2001). Another wind system, that occurs (not that frequent) in the Kvarner Bay, is called Jugo. Jugo is, unlike Bora, a humid, warm and uniform wind coming from south-east. It often brings large amounts of precipitation and a strong Jugo can create high waves (Zaninović et al., 2008).

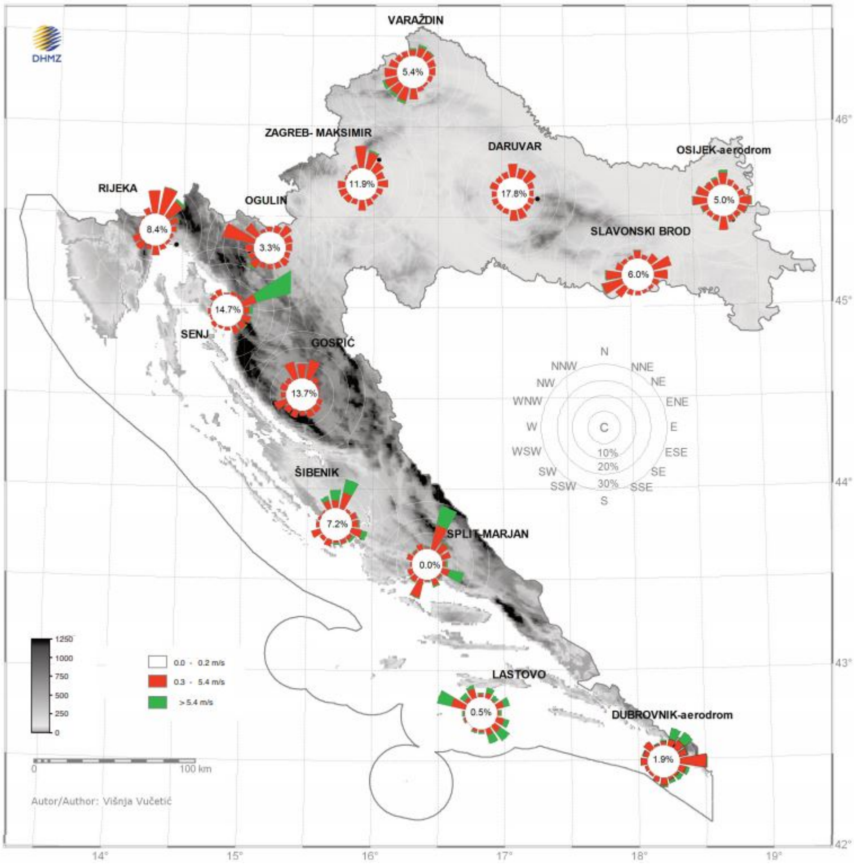

Figure 5 - Annual wind rose Croatia (Zaninović et al., 2008)

Precipitation and Freshwater runoff

According to the Köppen-climate-classification (Köppen, W. 1918), the Kvarner Bay island is located at the transition zone between warm (Cfb) and hot (Cfa), humid summers with mild to cool winters, see Figure 6. Precipitation occurs primarily, when the wind Jugo brings warm and humid air from the southern Adriatic Sea. The precipitation seeps away in the rugged karst rocks, which are typical for the Croatian coast, and runs slowly off into the sea. This is the case especially for the sampling site at Krk, because it is surrounded by karst hills. The freshwater outlet from the rocks is noticeably colder than the seawater and due to the lower density, it forms a thin surface layer, as long, as there are no disturbances such as wind or waves.

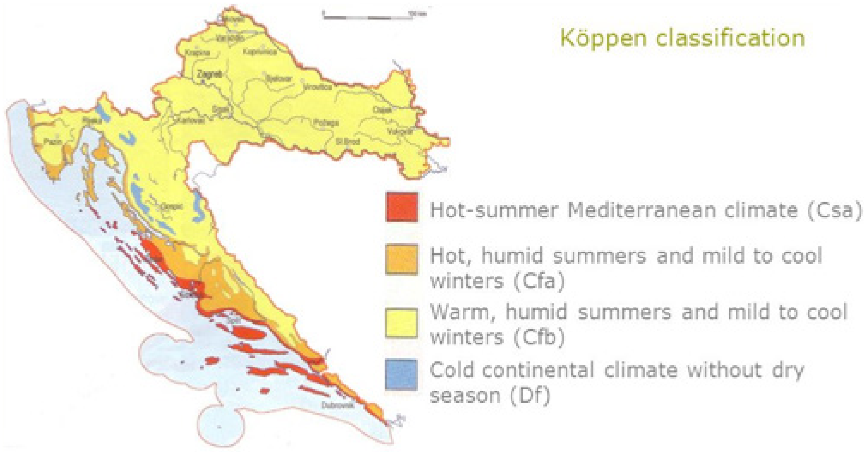

Figure 6 - Climate classification according to Köppen (Köppen, W. 1918)

2.3 Sampling methodology

Samples were taken in September 2016 at a depth of 7.5 m by scuba diving. Details about the stations are given in Table 1. At each station three replicates, with an area of 1 m^2, were randomly chosen in the middle of the patch (Figure 7). The leaf and rhizome layer were sampled separately, therefore some devices were self-made and fitted to the needs. To guarantee a successful sampling methodology, a test trial (Station Nr. 1) was undertaken. As the attained data from the test trial were not complete, they are not included in this study. It focuses only on the data from station 2 & 3 (Replicate 4 - 9) located at Kormati island and station 4 & 5 (Replicate 10 - 15) located at Krk island.

Station Nr.	Test station	2	3	4	5
Sample Nr.	R1 R2 R3	R4 R5 R6	R7 R8 R9	R10 R11 R12	R13 R14 R15
Location	Kormati Island	Kormati Island	Kormati Island	Krk Island	Krk Island
Longitude	14°34'23.7"E	14°34'04.1"E	14°34'34.7"E	14°40'34.7"E	14°40'13.9"E
Latitude	44°56'44.5"N	44°56'55.9"N	44°56'37.7"N	44°57'50.5"N	44°57'54.2"N
Sampling method	Net & ALS	Net & ALS	Net & ALS	Net & ALS	Net & ALS
Depth	7.5 m	7.5 m	7.5 m	7.5 m	7.5 m
Date	31.08.2016	08.09.2016	08.09.2016	20.09.2016	20.09.2016

Table 1 - Overview of the sampling stations, dates and coordinates. Net stands for Handnet-Sampling, ALS stands for Airlift-Sampling.

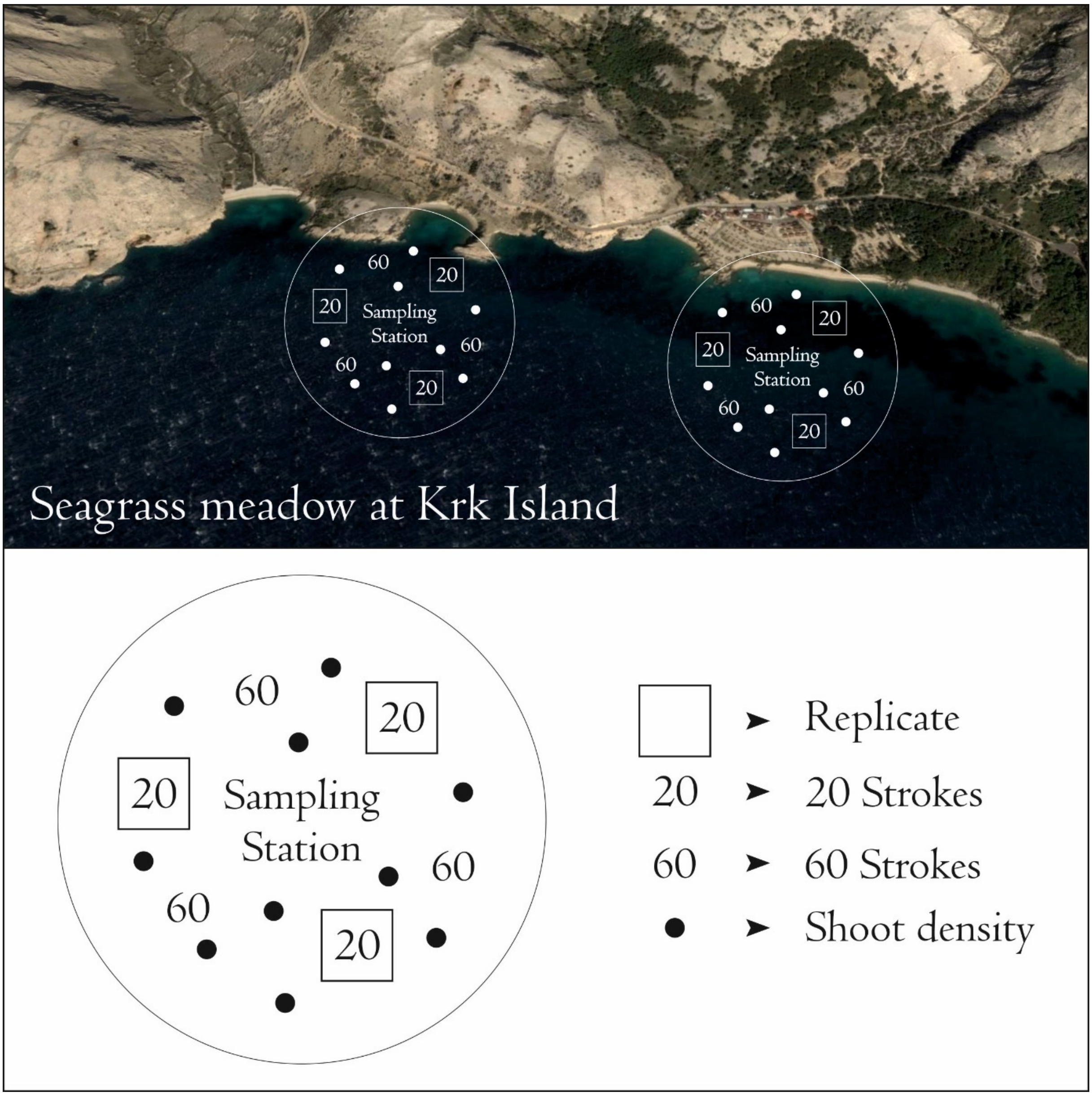

Figure 7 - Overview of the sampling stations at Krk Island (above) and the sampling scheme of a station (below). Frames indicate a replicate (1 m²), where the rhizome layer was sampled with an Air Lift Sampler. 20 and 60 indicate the number of strokes done with a handnet to collect animals from the leaf layer. Points stand for counting the shoot density (within a 0,4 m x 0,4 m area). (Source: Google Earth modified)

Sampling the leaf layer:

A hand net was used to collect the molluscs crawling on the *Posidonia* leaves. Sampling was carried out with net-strokes at the base of the shoots. The sampling intensity was quantified by 60 strokes per replicate, as proposed by Russo and Vinci (1991), but it was modified as follows:

- 60 strokes next to each 1-m² replicate (later named as L4, L5, L6, e.t.c.)
- 20 strokes directly on each of the three 1-m² replicates which were later defoliated and sampled by suction sampling for the rhizome assemblage. This method was used

to reduce the chance of molluscs falling down from the leaf layer into the rhizome layer while defoliation. The data of the 3 x 20 strokes were pooled and treated like a 60 strokes sample (later named as LSt2, LSt3, LSt4, LSt5).

In total 240 strokes (3 x 20 strokes, 3 x 60 strokes) per station (station 2 = L4 + L5 + L6 + LSt2, station 3 = L7 + L8 + L9 + LSt3) were carried out, see Figure 7. The hand nets were constructed of stainless steel with an opening of 40 x 20 cm. Nets with a mesh size of 0.5 mm were sewed and a system to remove and replace the nets under water without losing the samples was designed and mounted on the frame.

Sampling the rhizome layer:

An Air Lift Sampler was used to collect animals from the rhizome layer. To enhance collecting efficacy, each replicate area was defoliated before sampling (Bonfitto et al., 1998) and sampling itself was standardised with an air-consumption of 1200 liters (12 l Tank, 100 Bar). In total three square meters (3 x 1 m^2) were sampled at each station. The sampling procedure is demonstrated in Figures 8 & 9. The Air Lift Sampler was made of a PVC tube with a length of 100 cm and a diameter of 8 cm, equipped with a valve and connected to a SCUBA cylinder. The supplying air from the SCUBA cylinder was channeled and attached 10 cm above the mouth of the tube. Self-sewed mesh bags with a mesh size of 0.5 mm, which could be replaced underwater, were attached to the other end of the PVC tube.

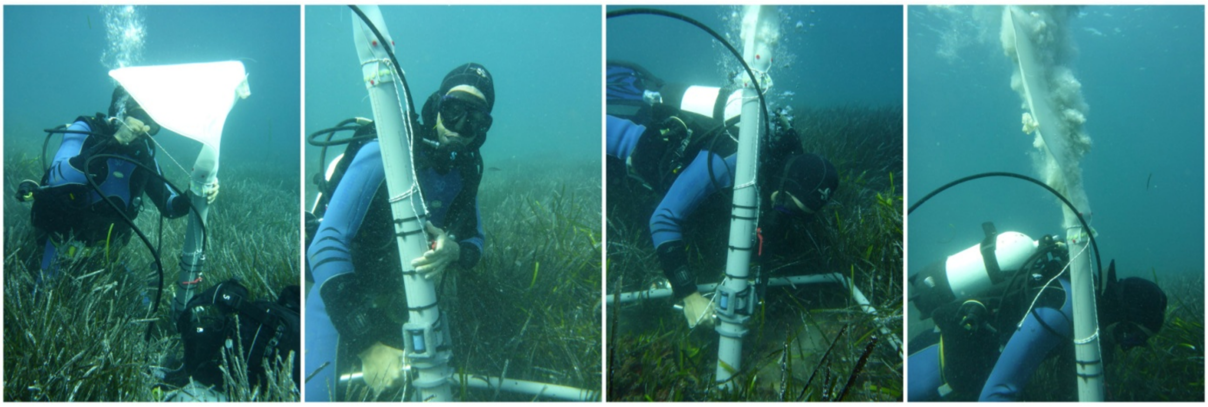

Figure 8 - Air Lift sampling procedure demonstrated by pictures.

During sampling the rhizome layer some problems occurred:

- At replicate 8 the net of the Air Lift Sampler broke off during sampling and some sediment was lost. It was not possible to do another run of sampling.

- At the whole station 4 (R10-R12), only 80 Bar (960 liters) instead of 100 Bar (1200 liters) could be used for the air-lift-sampling, because the high-pressure-hose of the Finimeter (from the Air Lift Sampler) suddenly exploded under water, while preparing the sampling setup for replicate 10. The "sampling tank" was empty, but also the diving equipment was useless in this moment. For this reason, the whole sampling of station 4 (rhizome, leaves and shoot density) could only be done by one diver, instead of two. This complicated sampling drastically and the air consumption for air-lift-sampling needed to be reduced to 80 Bar to get (any) comparable results out of this difficult situation.

Counting the shoot density:

The shoot densities were recorded in order to get an overview of the state of the seagrass meadows. Shoots were counted ten times at each station within a frame of 0.4 x 0.4 m and extrapolated to shoots per square meter.

Sieving, sorting and analysing the samples:

The collected samples were sieved with meshes of different sizes (0.5, 1, 5 mm). The fraction from 0.5-1 mm was dried and stored for future research. The remaining fractions were kept in seawater and supplied with air to keep the animals alive. The living molluscs were sorted using a binocular and finally preserved in ethanol, see Figure 10. The molluscs were sorted into morphospecies and identified to the species level whenever possible.

Figure 9 - Equipment transport from the boat to the sample area (left); preparing the equipment for sampling (right). (Pictures: Roberto Pinyero)

Figure 10 - Outcome from a handnet sampling with 60 strokes (top left); sieving a fraction (top center); outcome of a fraction > 5mm (top right); different fractions kept separately and provided with fresh seawater (bottom left); living molluscs found in a fraction (bottom center); preserved molluscs (bottom right).

2.4 Data analysis

The samples were sorted into morphospecies and identified to the species level whenever possible. The taxonomy follows the database "WORMS - World Register of Marine Species" (http://www.marinespecies.org/). Several diversity indices (Number of individuals, number of species, the Shannon index and Evenness index) and the dominance and frequency of every species were calculated for both the leaf and the rhizome layer of each replicate.

To interpret the differences in species richness between the seagrass meadows, an individual rarefaction estimation, based on the lowest sample size, was used to get comparable data. Results were visualized with a sample-size-based rarefaction and extrapolation curve. Statistical tests between the groups were performed using One-Way ANOVA.

To describe the species composition of the seagrass meadows, several approaches were used. A non-metric multidimensional scaling plot (NMDS-Plot) was performed to visualize the differences between the seagrass meadow of Kormati and Krk and between the leaf and rhizome layer, respectively. The results were testet statistically with PERMANOVA, using square-root transformed data and the Bray-Curtis similarity coefficient. Rank abundance curves and tables from both the leaf and the rhizome layer were used to visualize and represent the relative dominance of species and families respectively. SIMPER Routine (Similarity Percentage) was used to locate species that most contribute to differences between groups (leaves vs. rhizome, Kormati vs. Krk). INDVAL (Indicator Values) analysis was used to determine indicator species that are indicative for one of the two seagrass meadows (Kormati vs. Krk) and its specific environmental conditions.

To describe the trophic composition within the seagrass meadows, the feeding habits of every single species were determined and merged together in groups of feeding guilds. In order to allow comparison with other studies, the classification of feeding guilds proposed by Rueda et al. (2009) was used. The relative abundance of each feeding guild was calculated for each biocoenosis (leaves vs. rhizome) and location (Kormati vs. Krk) in scales of replicates, stations and locations. The results were given in tables and visualized by different figures (Box-plots, NMDS-plots).

To assess the differences in the shoot density between the two seagrass meadows, the Mann-Whitney test was used. The Spearman correlation was then used to test the correlation between the shoot density and the molluscan abundance and species richness respectively, in both, the leaf and the rhizome layer.

The following software packages and Online-tools were used for statistical analysis:

<u>PAST 3.15 (Hammer et al., 2001)</u>

- Boxplot
- Diversity Indices
- Individual Rarefaction
- NMDS – Non-metric multidimensional scaling
- One-Way ANOVA – One-way analysis of variance
- PERMANOVA – Permutational multivariate analysis of variance
- SIMPER – Similarity Percentage
- Spearman`s Correlation

<u>R – Statistics (R Core Team, 2013)</u>

- INDVAL – Indicator Values

iNext Online (Hsieh et al., 2013)

- Species Accumulation Curve

Microsoft Excel

- Rank Abundance Curve

Results

3.1 Status of the *Posidonia oceanica* meadows

Shoot density

The shoot density was measured at 7.5 meters water depth. The mean shoot density per square meter was 618±123 and 430±152 at Kormati Island and Krk Island, respectively. The shoot density at the two locations was significantly different (Mann-Whitney, $z = -3.5853$; $p = 0.0003$) and according to the monitoring protocol for *Posidonia oceanica* beds (UNEP/MAP-RAC/SPA, 2011), the status of the meadows can be categorized as "Good" and "Poor" respectively.

To categorize the data, the values at 7 meters and 8 meters (Table 2) were averaged to a depth of 7.5 meters as follows: "Poor" is ranging from 271.5 to 437.5 shoots/m^2, "Moderate" from 437.5 to 603 shoots/m^2 and "Good" from 603 to 769 shoots/m^2.

Table 2 - Picture clip of the classification values of meadow cover (UNEP/MAP-RAC/SPA, 2011 modified).

Depth (m)	High	Good	Moderate	Poor	Bad
1	> 1133	1133 to 930	930 to 727	727 to 524	< 524
2	> 1067	1067 to 863	863 to 659	659 to 456	< 456
3	> 1005	1005 to 808	808 to 612	612 to 415	< 415
4	> 947	947 to 757	757 to 567	567 to 377	< 377
5	> 892	892 to 709	709 to 526	526 to 343	< 343
6	> 841	841 to 665	665 to 489	489 to 312	< 312
7	> 792	792 to 623	623 to 454	454 to 284	< 284
8	> 746	746 to 584	584 to 421	421 to 259	< 259
9	> 703	703 to 547	547 to 391	391 to 235	< 235
10	> 662	662 to 513	513 to 364	364 to 214	< 214
11	> 624	624 to 481	481 to 338	338 to 195	< 195
12	> 588	588 to 451	451 to 314	314 to 177	< 177
13	> 554	554 to 423	423 to 292	292 to 161	< 161
14	> 522	522 to 397	397 to 272	272 to 147	< 147
15	> 492	492 to 372	372 to 253	253 to 134	< 134
16	> 463	463 to 349	349 to 236	236 to 122	< 122
17	> 436	436 to 328	328 to 219	219 to 111	< 111
18	> 411	411 to 308	308 to 204	204 to 101	< 101
19	> 387	387 to 289	289 to 190	190 to 92	< 92
20	> 365	365 to 271	271 to 177	177 to 83	< 83
21	> 344	344 to 255	255 to 165	165 to 76	< 76
22	> 324	324 to 239	239 to 154	154 to 69	< 69
23	> 305	305 to 224	224 to 144	144 to 63	< 63
24	> 288	288 to 211	211 to 134	134 to 57	< 57
25	> 271	271 to 198	198 to 125	125 to 52	< 52
26	> 255	255 to 186	186 to 117	117 to 47	< 47
27	> 240	240 to 175	175 to 109	109 to 43	< 43
28	> 227	227 to 164	164 to 102	102 to 39	< 39
29	> 213	213 to 154	154 to 95	95 to 36	< 36
30	> 201	201 to 145	145 to 89	89 to 32	< 32

3.2 The malacofauna of the seagrass meadows

Overview

A total of 3494 individuals of molluscs belonging to four classes (Bivalvia, Gastropoda, Polyplacophora and Scaphopoda) and 37 families were collected. Eighty-six taxa within 62 genera could be identified, 82 at species level and four at genus level.

The seagrass meadow at Kormati island showed a higher abundance (2113 at Kormati, 1381 at Krk) and a higher biodiversity (73 taxa at Kormati, 66 taxa at Krk) than the seagrass meadow at Krk island.

- The molluscan assemblage of the leaf layer was more abundant with 2414 individuals (1533 at Kormati, 881 at Krk) than the rhizome layer with 1080 individuals (580 at Kormati, 500 at Krk). The species richness was higher in the rhizome layer with 79 taxa (65 at Kormati, 63 at Krk) than in the leaf layer with 40 taxa (33 at Kormati, 27 at Krk).

- Gastropoda dominated with 2632 individuals (1752 at Kormati, 880 at Krk), followed by Bivalvia with 854 individuals (357 at Kormati, 497 at Krk), Polyplacophora with seven individuals (three at Kormati, four at Krk) and Scaphopoda with one individual at Kormati island.

- The species richness was highest within the Gastropoda with 61 species (51 at Kormati, 45 at Krk), followed by Bivalvia with 21 species (19 at Kormati, 19 at Krk), Polyplacophora with three species (two at Kormati, two at Krk) and Scaphopoda with one species at Kormati island.

- The most species-rich families were the Rissoidae (12 spp.), Pyramidellidae (six spp.), Eulimidae (five spp.), Raphitomidae (five spp.), Cerithiidae (four spp.) and Cerithiopsidae (four spp.) within the Gastropoda and Mytilidae (five spp.) and Veneridae (four spp.) within the Bivalvia.

P. oceanica can be divided into two different substrates with two different biocoenosis. For this reason, these two biocoenosis will be treated separately in some of the following sections.

Table 3 - Faunistic list of molluscs found in the Posidonia leaves with quantitative data. The total number of individuals in each sample and location (Ko = Kormati, Kr = Krk), the dominance index %D (blue font), the frequency %F and the feeding guild (diet) code are given (E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers). L4 to L15 stands each for 60 handnet strokes which were taken next to the 1 m² replicates. LSt2 to LSt5 stands each for the pooled 3 x 20 strokes directly on the 1 m² replicates. A station consists of 4 samples (e.g. station 2 = L4 + L5 + L6 + LSt2). Biodiversity indices are reported at the bottom of the table.

		Diet	%F	L4	L5	L6	LSt2	L7	L8	L9	LSt3	Ko	L10	L11	L12	LSt4	L13	L14	L15	LSt5	Kr
1	*Acanthochitona fascicularis*	MG	6,3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
	(Linnaeus, 1767)			-	-	-	-	-	-	-	-	-	-	-	1,2	-	-	-	-	-	0,1
2	*Haliotis tuberculata*	MG	12,5	1	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-
	Linnaeus, 1758			0,3	-	-	-	0,7	-	-	-	0,1	-	-	-	-	-	-	-	-	-
3	*Scissurella costata*	MG	6,3	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	d'Orbigny, 1824			-	-	-	0,5	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-
4	*Jujubinus exasperatus*	MG	6,3	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
	(Pennant, 1777)			-	-	-	-	-	0,7	-	-	0,1	-	-	-	-	-	-	-	-	-
5	*Tricolia pullus*	MG	25	-	-	-	4	-	2	2	3	11	-	-	-	-	-	-	-	-	-
	(Linnaeus, 1758)			-	-	-	1,9	-	1,4	1,1	3,2	0,7	-	-	-	-	-	-	-	-	-
6	*Tricolia speciosa*	MG	37,5	-	1	2	3	1	-	-	1	8	-	-	-	-	1	-	-	-	1
	(Megerle von Mühlfeld, 1824)			-	0,6	0,7	1,4	0,7	-	-	1,1	0,5	-	-	-	-	0,9	-	-	-	0,1
7	*Bittium latreillii*	MG	87,5	6	3	4	5	8	7	19	8	60	-	2	2	-	4	2	2	1	13
	(Payraudeau, 1826)			2,1	1,7	1,3	2,3	5,9	5,0	10,3	8,6	3,9	-	1,6	2,5	-	3,8	1,9	1,6	0,9	1,5
8	*Bittium reticulatum*	MG	31,3	-	1	-	2	-	-	2	-	5	-	-	1	10	-	-	-	-	11
	(da Costa, 1778)			-	0,6	-	0,9	-	-	1,1	-	0,3	-	-	1,2	11,5	-	-	-	-	1,2
9	*Marshallora adversa*	E	43,8	-	-	-	-	-	-	-	-	-	1	1	1	1	3	1	-	2	10
	(Montagu, 1803)			-	-	-	-	-	-	-	-	-	0,7	0,8	1,2	1,1	2,8	1,0	-	1,8	1,1
10	*Monophorus perversus*	E	6,3	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	(Linnaeus, 1758)			0,3	-	-	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-
11	*Cerithiopsis* sp. 2	E	6,3	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	-			-	0,6	-	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-
12	*Cerithiopsis* sp. 4	E	6,3	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	-			-	0,6	-	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-

		Diet	%F	L4	L5	L6	LSt2	L7	L8	L9	LSt3	Ko	L10	L11	L12	LSt4	L13	L14	L15	LSt5	Kr
13	*Cerithiopsis tubercularis*	E	43,8	-	-	-	1	1	2	-	1	5	-	-	-	-	1	2	1	-	4
	(Montagu, 1803)			-	-	-	0,5	0,7	1,4	-	1,1	0,3	-	-	-	-	0,9	1,9	0,8	-	0,5
14	*Alvania cancellata*	MG	6,3	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	(da Costa, 1778)			0,3	-	-	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-
15	*Crisilla semistriata*	MG	18,8	-	-	-	-	-	1	1	1	3	-	-	-	-	-	-	-	-	-
	(Montagu, 1808)			-	-	-	-	-	0,7	0,5	1,1	0,2	-	-	-	-	-	-	-	-	-
16	*Pusillina lineolata*	MG	100	97	82	90	62	48	59	56	31	525	58	59	35	29	26	40	32	38	317
	(Michaud, 1830)			33,2	47,7	29,7	29,1	35,3	42,4	30,3	33,3	34,2	42,3	46,5	43,2	33,3	24,5	38,5	24,8	34,5	36,0
17	*Pusillina marginata*	MG	6,3	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
	(Michaud, 1830)			-	-	0,3	-	-	-	-	-	0,1	-	-	-	-	-	-	-	-	-
18	*Pusillina philippi*	MG	100	129	59	169	58	34	18	32	17	516	18	18	8	5	15	10	15	12	101
	(Aradas & Maggiore, 1844)			44,2	34,3	55,8	27,2	25,0	12,9	17,3	18,3	33,7	13,1	14,2	9,9	5,7	14,2	9,6	11,6	10,9	11,5
19	*Rissoa rodhensis*	MG	93,8	7	4	10	3	8	4	4	-	40	11	10	4	5	15	14	18	6	83
	Verduin, 1985			2,4	2,3	3,3	1,4	5,9	2,9	2,2	-	2,6	8,0	7,9	4,9	5,7	14,2	13,5	14,0	5,5	9,4
20	*Rissoa splendida*	MG	100	30	9	12	11	17	20	18	6	123	10	11	17	12	6	8	6	5	75
	Eichwald, 1830			10,3	5,2	4,0	5,2	12,5	14,4	9,7	6,5	8,0	7,3	8,7	21,0	13,8	5,7	7,7	4,7	4,5	8,5
21	*Rissoa violacea*	MG	100	5	7	5	7	5	9	6	1	45	19	8	9	3	5	1	7	1	53
	Desmarest, 1814			1,7	4,1	1,7	3,3	3,7	6,5	3,2	1,1	2,9	13,9	6,3	11,1	3,4	4,7	1,0	5,4	0,9	6,0
22	*Caecum subannulatum*	MG	25	-	-	-	1	-	-	-	1	2	-	-	-	-	-	1	-	1	2
	de Folin, 1870			-	-	-	0,5	-	-	-	1,1	0,1	-	-	-	-	-	1,0	-	0,9	0,2
23	*Parvioris ibizenca*	E	12,5	-	-	-	2	-	-	-	-	2	-	1	-	-	-	-	-	-	1
	(Nordsieck, 1968)			-	-	-	0,9	-	-	-	-	0,1	-	0,8	-	-	-	-	-	-	0,1
24	*Vitreolina philippi*	E	31,3	-	-	-	-	-	-	-	-	-	-	1	-	1	1	2	-	2	7
	(de Rayneval & Ponzi, 1854)			-	-	-	-	-	-	-	-	-	-	0,8	-	1,1	0,9	1,9	-	1,8	0,8
25	*Rissoella inflata*	MG	87,5	7	4	9	5	10	8	8	5	56	1	-	-	1	3	1	7	1	14
	(Monterosato, 1880)			2,4	2,3	3,0	2,3	7,4	5,8	4,3	5,4	3,7	0,7	-	-	1,1	2,8	1,0	5,4	0,9	1,6
26	*Weinkauffia turgidula*	MG	6,3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
	(Forbes, 1844)			-	-	-	-	-	-	-	-	-	-	-	-	-	0,9	-	-	-	0,1
27	*Megastomia conspicua*	E	18,8	-	-	-	-	1	2	-	-	3	-	-	-	-	-	-	1	-	1
	(Alder, 1850)			-	-	-	-	0,7	1,4	-	-	0,2	-	-	-	-	-	-	0,8	-	0,1

		Diet	%F	L4	L5	L6	LSt2	L7	L8	L9	LSt3	Ko	L10	L11	L12	LSt4	L13	L14	L15	LSt5	Kr
28	*Odostomella doliolum*	E	6,3	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-
	(Philippi, 1844)			-	-	-	-	-	1,4	-	-	0,1	-	-	-	-	-	-	-	-	-
29	*Parthenina* cf. *monozona*	E	6,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
	(Brusina, 1869)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	0,1
30	*Turbonilla* cf. *pusilla*	E	6,3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
	(Philippi, 1844)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,0	-	-	0,1
31	*Musculus costulatus*	F	75	2	-	-	8	2	-	15	1	28	3	1	-	2	2	2	8	4	22
	(Risso, 1826)			0,7	-	-	3,8	1,5	-	8,1	1,1	1,8	2,2	0,8	-	2,3	1,9	1,9	6,2	3,6	2,5
32	*Musculus subpictus*	F	81,3	3	-	-	2	-	1	11	5	22	3	1	1	2	1	2	3	2	15
	(Cantraine, 1835)			1,0	-	-	0,9	-	0,7	5,9	5,4	1,4	2,2	0,8	1,2	2,3	0,9	1,9	2,3	1,8	1,7
33	*Striarca lactea*	F	12,5	-	-	-	-	-	-	1	2	3	-	-	-	-	-	-	-	-	-
	(Linnaeus, 1758)			-	-	-	-	-	-	0,5	2,2	0,2	-	-	-	-	-	-	-	-	-
34	*Anomia ephippium*	MG	75	1	-	-	20	-	1	4	5	31	8	11	-	10	14	12	16	30	101
	Linnaeus, 1758			0,3	-	-	9,4	-	0,7	2,2	5,4	2,0	5,8	8,7	-	11,5	13,2	11,5	12,4	27,3	11,5
35	*Flexopecten hyalinus*	F	62,5	1	-	-	1	-	-	-	-	2	4	1	1	5	2	4	6	4	27
	(Poli, 1795)			0,3	-	-	0,5	-	-	-	-	0,1	2,9	0,8	1,2	5,7	1,9	3,8	4,7	3,6	3,1
36	*Crenella arenaria*	F	6,3	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
	Monterosato, 1875 ex H. Martin, ms.			-	-	-	-	-	0,7	-	-	0,1	-	-	-	-	-	-	-	-	-
37	*Papillicardium papillosum*	F	6,3	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
	(Poli, 1791)			-	-	-	-	-	-	-	-	-	-	0,8	-	-	-	-	-	-	0,1
38	*Parvicardium scriptum*	F	18,8	-	-	1	-	-	-	-	-	1	-	-	1	-	-	-	-	1	2
	(Bucquoy, Dautzenberg & Dollfus, 1892)			-	-	0,3	-	-	-	-	-	0,1	-	-	1,2	-	-	-	-	0,9	0,2
39	*Kellia suborbicularis*	F	18,8	-	-	-	2	-	1	-	-	3	-	1	-	-	-	-	-	-	1
	(Montagu, 1803)			-	-	-	0,9	-	0,7	-	-	0,2	-	0,8	-	-	-	-	-	-	0,1
40	*Hiatella arctica*	F	50	1	-	-	15	-	-	6	5	27	1	-	-	1	6	-	7	-	15
	(Linnaeus, 1767)			0,3	-	-	7,0	-	-	3,2	5,4	1,8	0,7	-	-	1,1	5,7	-	5,4	-	1,7
				L4	**L5**	**L6**	**LSt2**	**L7**	**L8**	**L9**	**LSt3**	**Ko**	**L10**	**L11**	**L12**	**LSt4**	**L13**	**L14**	**L15**	**LSt5**	**Kr**
	Number of Individuals			292	172	303	213	136	139	185	93	1533	137	127	81	87	106	104	129	110	881
	Number of Species			15	11	10	20	12	17	15	16	33	12	15	12	14	17	17	14	15	27
	Shannon_H			1,49	1,37	1,23	2,16	1,83	1,96	2,18	2,18	1,90	1,84	1,80	1,73	2,12	2,33	2,08	2,29	1,94	2,20
	Evenness_e^H/S			0,29	0,36	0,34	0,43	0,52	0,42	0,59	0,55	0,20	0,53	0,40	0,47	0,60	0,60	0,47	0,70	0,46	0,33

Table 4 - Mean numbers and standard deviation of individuals and species found per station and location in the Posidonia leaves.

	Station 2	**Station 3**	**Kormati**	**Station 4**	**Station 5**	**Krk**
No. of Individuals	245 ± 63	138 ± 38	192 ± 75	108 ± 28	112 ± 11	110 ± 20
No. of Species	14 ± 5	15 ± 2	15 ± 3	13 ± 2	16 ± 2	16 ± 2

The number of individuals found per replicate varies between 81 and 303, the species richness between 10 and 20, the Shannon-Wiener index between 1.23 and 2.33 and the Evenness between 0.29 and 0.70 (see Table 3). Kormati showed almost twice as many individuals and six more species, but Krk revealed a higher Shannon index and Evenness. The test for equal means (One-way ANOVA) showed that there are significant differences within the stations in terms of individuals, Shannon index and Eveness ($p<0.05$), but not in terms of species ($p>0.05$). The test between Kormati and Krk showed that the differences are only significant in terms of number of individuals ($p<0.05$), but not in terms of number of species, Shannon index and Eveness ($p>0.05$).

The top dominant species in the leaf layer at Kormati are *Pusillina lineolata* (34.2%), *Pusillina philippi* (33.6%), *Rissoa splendida* (8.0%), *Bittium latreillii* (3.9%), *Rissoella inflata* (3.6%), *Rissoa violacea* (2.9%), *Rissoa rodhensis* (2.6%) and *Anomia ephippium* (2.0%) (Figure 11). The molluscan assemblage in the leaf layer at Kormati is dominated by five families, which account for 95% of the molluscan abundance (Table 5): Rissoidae (81.8%), Cerithiidae (4.2%), Rissoellidae (3.7%), Mytilidae (3.3%) and Anomiidae (2%).

The top dominant species in the leaf layer of Krk are *Pusillina lineolata* (35.9%), *Anomia ephippium* (11.4%), *Pusillina philippi* (11.4%), *Rissoa rodhensis* (9.4%), *Rissoa splendida* (8.5%), *Rissoa violacea* (6.0%), *Flexopecten hyalinus* (3.0%), *Musculus costulatus* (2.5%), *Hiatella arctica* (1.7%)(Figure 11). The five dominating families in the leaf layer at Krk are Rissoidae (71.4%), Anomiidae (11.5%), Mytilidae (4.2%), Pectinidae (3.1 %) and Cerithiidae (2.7%), see Table 5.

The most frequent species (Table 3) across the replicates are *Pusillina lineolata, P. philippi, Rissoa splendida* and *R. violacea* with 100% frequency each, followed by *R. rodhensis* (94%), *Risoella inflata* (88%), *Bittium latreillii* (88%) and *Musculus subpictus* (81%). 14 species (35% out of 40 species) are singletons (i.e., they were found only in a single replicate).

13 species were found only at Kormati (*Striarca lactea, Crenella arenaria, Alvania cancellata, Crisilla semistriata, Pusillina marginata, Cerithiopsis 2, Cerithiopsis 4, Monophorus perversus,*

Odostomella doliolum, Haliotis tuberculata, Scissurella costata, Tricolia pullus, Jujubinus exasperatus) while seven species were found only at Krk (*Papillicardium papillosum, Vitreolina philippi, Marshallora adversa, Turbonilla* cf. *pusilla, Parthenina* cf. *monozona, Weinkauffia turgidula, Acanthochitona fascicularis).*

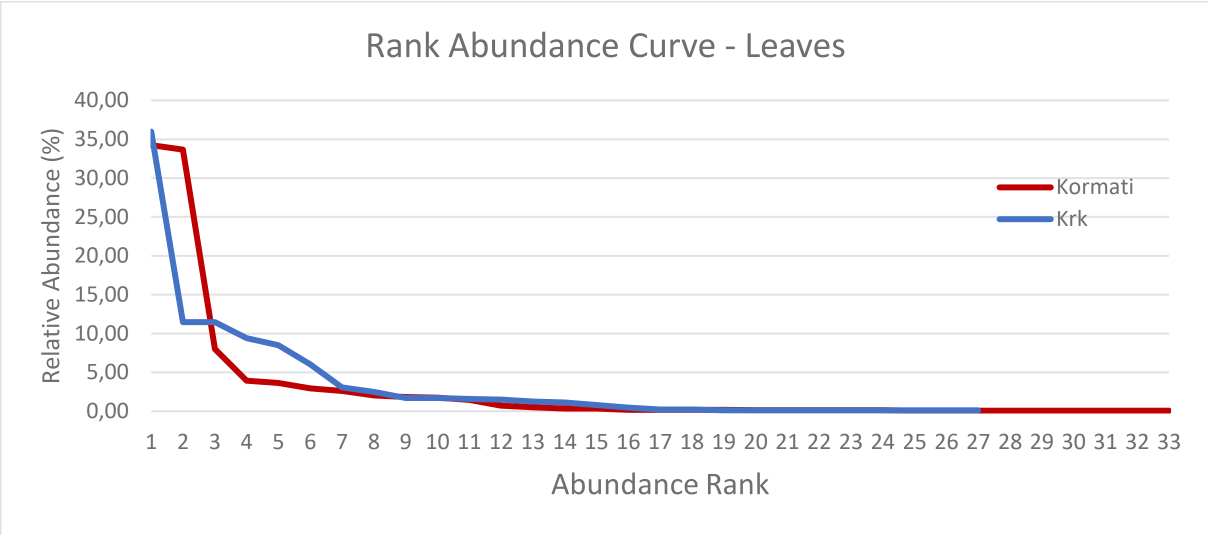

Figure 11 - Species Rank Abundance Curve of the leaf substrate

Table 5 - Abundance Rank of the leaf layer at family level and mollusc class

	Kormati	%D		Krk	%D
1	Rissoidae	81,8	1	Rissoidae	71,4
2	Cerithiidae	4,2	2	Anomiidae	11,5
3	Rissoellidae	3,7	3	Mytilidae	4,2
4	Mytilidae	3,3	4	Pectinidae	3,1
5	Anomiidae	2,0	5	Cerithiidae	2,7
6	Hiatellidae	1,8	6	Hiatellidae	1,7
7	Phasianellidae	1,2	7	Rissoellidae	1,6
8	Cerithiopsidae	0,5	8	Triphoridae	1,1
9	Pyramidellidae	0,3	9	Eulimidae	0,9
10	Noetiidae	0,2	10	Cerithiopsidae	0,5
11	Kelliidae	0,2	11	Cardiidae	0,3
12	Pectinidae	0,1	12	Pyramidellidae	0,3
13	Haliotidae	0,1	13	Caecidae	0,2
14	Eulimidae	0,1	14	Acanthochitonidae	0,1
15	Caecidae	0,1	15	Haminoeidae	0,1
16	Trochidae	0,1	16	Kelliidae	0,1
17	Triphoridae	0,1	17	Phasianellidae	0,1
18	Scissurellidae	0,1			
19	Cardiidae	0,1			
	Gastropoda	92,3		Gastropoda	79,1
	Bivalves	7,7		Bivalves	20,8

Table 6 - Faunistic list of molluscs found in the Posidonia rhizome with quantitative data. The total number of individuals in each sample and location (Ko = Kormati, Kr = Krk), the dominance index %D (blue font), the frequency %F and the feeding guild code (diet) are given (C carnivores feeding on mobile organisms; SC scavengers; D deposit feeders; E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers; SY symbiont-bearing species). A station consists of 3 replicates (e.g. station 2 = R4 + R5 + R6). Biodiversity indices are reported at the bottom of the table.

		Diet	%F	R4	R5	R6	R7	R8	R9	Ko	R10	R11	R12	R13	R14	R15	Kr
1	*Lepidopleurus cajetanus*	MG	8,3	-	-	2	-	-	-	2	-	-	-	-	-	-	-
	(Poli, 1791)			-	-	1,7	-	-	-	0,3	-	-	-	-	-	-	-
2	*Callochiton septemvalvis*	MG	25	1	-	-	-	-	-	1	-	-	-	1	-	1	2
	(Montagu, 1803)			0,9	-	-	-	-	-	0,2	-	-	-	1,0	-	1,4	0,4
3	*Acanthochitona fascicularis*	MG	8,3	-	-	-	-	-	-	-	-	-	-	-	1	-	1
	(Linnaeus, 1767)			-	-	-	-	-	-	-	-	-	-	-	0,8	-	0,2
4	*Haliotis tuberculata*	MG	16,7	1	-	-	-	1	-	2	-	-	-	-	-	-	-
	Linnaeus, 1758			0,9	-	-	-	4,0	-	0,3	-	-	-	-	-	-	-
5	*Jujubinus exasperatus*	MG	41,7	-	1	-	-	1	1	3	-	1	-	-	2	-	3
	(Pennant, 1777)			-	0,6	-	-	4,0	1,5	0,5	-	1,2	-	-	1,6	-	0,6
6	*Steromphala umbilicaris*	MG	8,3	-	-	-	-	-	-	-	-	-	-	1	-	-	1
	(Linnaeus, 1758)			-	-	-	-	-	-	-	-	-	-	1,0	-	-	0,2
7	*Tricolia pullus*	MG	25	-	3	1	1	-	-	5	-	-	-	-	-	-	-
	(Linnaeus, 1758)			-	1,8	0,8	1,1	-	-	0,9	-	-	-	-	-	-	-
8	*Tricolia speciosa*	MG	8,3	-	-	-	1	-	-	1	-	-	-	-	-	-	-
	(Megerle von Mühlfeld, 1824)			-	-	-	1,1	-	-	0,2	-	-	-	-	-	-	-
9	*Bittium latreillii*	MG	75	5	10	3	8	-	12	38	1	1	1	-	2	-	5
	(Payraudeau, 1826)			4,6	5,8	2,5	8,8	-	17,9	6,6	1,6	1,2	1,9	-	1,6	-	1,0
10	*Bittium reticulatum*	MG	33,3	1	6	2	-	-	-	9	-	-	-	2	-	-	2
	(da Costa, 1778)			0,9	3,5	1,7	-	-	-	1,6	-	-	-	2,0	-	-	0,4
11	*Cerithium haustellum*	MG	25	1	-	-	-	-	-	1	-	2	-	-	1	-	3
	Bivona Ant. in Bivona And., 1838			0,9	-	-	-	-	-	0,2	-	2,4	-	-	0,8	-	0,6
12	*Cerithium vulgatum*	MG	41,7	2	-	-	-	-	1	3	-	1	-	1	-	1	3
	Bruguière, 1792			1,9	-	-	-	-	1,5	0,5	-	1,2	-	1,0	-	1,4	0,6
13	*Euspira nitida*	C	100	8	2	7	1	1	3	22	6	9	8	5	2	7	37
	(Donovan, 1804)			7,4	1,2	5,9	1,1	4,0	4,5	3,8	9,5	10,6	15,1	5,0	1,6	9,6	7,4
14	*Marshallora adversa*	E	58,3	-	1	-	1	-	1	3	-	1	-	3	1	1	6
	(Montagu, 1803)			-	0,6	-	1,1	-	1,5	0,5	-	1,2	-	3,0	0,8	1,4	1,2

		Diet	%F	R4	R5	R6	R7	R8	R9	Ko	R10	R11	R12	R13	R14	R15	Kr
15	*Metaxia metaxa* *(Delle Chiaje, 1828)*	E	16,7	- -	- -	1 0,8	1 1,1	- -	- -	2 0,3	- -	- -	- -	- -	- -	- -	- -
16	*Monophorus perversus* (Linnaeus, 1758)	E	16,7	- -	1 0,6	- -	- -	- -	- -	1 0,2	- -	3 3,5	- -	- -	- -	- -	3 0,6
17	*Cerithiopsis* sp. 3 -	E	25	- -	1 0,6	- -	1 1,1	- -	- -	2 0,3	- -	- -	- -	- -	1 0,8	- -	1 0,2
18	*Cerithiopsis tubercularis* (Montagu, 1803)	E	33,3	2 1,9	9 5,3	1 0,8	- -	- -	- -	12 2,1	- -	- -	- -	- -	- -	2 2,7	2 0,4
19	*Alvania beanii* (Hanley in Thorpe, 1844)	MG	25	- -	- -	- -	2 2,2	- -	1 1,5	3 0,5	- -	- -	1 1,9	- -	- -	- -	1 0,2
20	*Alvania cancellata* (da Costa, 1778)	MG	50	20 18,5	3 1,8	6 5,1	7 7,7	2 8,0	1 1,5	39 6,7	- -	- -	- -	- -	- -	- -	- -
21	*Alvania cimex* (Linnaeus, 1758)	MG	25	2 1,9	- -	- -	1 1,1	1 4,0	- -	4 0,7	- -	- -	- -	- -	- -	- -	- -
22	*Alvania geryonia* (Nardo, 1847)	MG	83,3	5 4,6	2 1,2	4 3,4	5 5,5	- -	5 7,5	21 3,6	6 9,5	7 8,2	2 3,8	2 2,0	7 5,6	- -	24 4,8
23	*Crisilla semistriata* (Montagu, 1808)	MG	8,3	- -	1 0,6	- -	- -	- -	- -	1 0,2	- -	- -	- -	- -	- -	- -	- -
24	*Manzonia crassa* (Kanmacher, 1798)	MG	16,7	- -	- -	- -	2 2,2	- -	- -	2 0,3	- -	- -	1 1,9	- -	- -	- -	1 0,2
25	*Pusillina lineolata* (Michaud, 1830)	MG	75	- -	- -	1 0,8	1 1,1	- -	2 3,0	4 0,7	2 3,2	1 1,2	1 1,9	1 1,0	2 1,6	2 2,7	9 1,8
26	*Pusillina philippi* (Aradas & Maggiore, 1844)	MG	41,7	- -	8 4,7	1 0,8	- -	- -	- -	9 1,6	- -	1 1,2	1 1,9	- -	1 0,8	- -	3 0,6
27	*Rissoa rodhensis* Verduin, 1985	MG	33,3	- -	2 1,2	- -	2 2,2	- -	- -	4 0,7	1 1,6	- -	- -	- -	1 0,8	- -	2 0,4
28	*Rissoa splendida* Eichwald, 1830	MG	8,3	- -	- -	- -	- -	- -	- -	- -	- -	2 2,4	- -	- -	- -	- -	2 0,4
29	*Rissoa violacea* Desmarest, 1814	MG	8,3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1 1,0	- -	- -	1 0,2
30	*Rissoina bruguieri* (Payraudeau, 1826)	MG	58,3	6 5,6	1 0,6	40 33,9	3 3,3	- -	12 17,9	62 10,7	- -	- -	- -	- -	3 2,4	1 1,4	4 0,8
31	*Caecum auriculatum* de Folin, 1868	MG	8,3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1 1,4	1 0,2

		Diet	%F	R4	R5	R6	R7	R8	R9	Ko	R10	R11	R12	R13	R14	R15	Kr
32	*Caecum subannulatum*	MG	58,3	1	6	-	-	-	-	7	1	7	-	4	6	2	20
	de Folin, 1870			0,9	3,5	-	-	-	-	1,2	1,6	8,2	-	4,0	4,8	2,7	4,0
33	*Caecum trachea*	MG	41,7	-	-	-	-	-	-	-	-	1	1	1	1	1	5
	(Montagu, 1803)			-	-	-	-	-	-	-	-	1,2	1,9	1,0	0,8	1,4	1,0
34	*Eulima glabra*	E	33,3	1	-	1	2	-	-	4	-	-	-	2	-	-	2
	(da Costa, 1778)			0,9	-	0,8	2,2	-	-	0,7	-	-	-	2,0	-	-	0,4
35	*Parvioris ibizenca*	E	58,3	3	5	-	-	1	1	10	1	1	-	1	-	-	3
	(Nordsieck, 1968)			2,8	2,9	-	-	4,0	1,5	1,7	1,6	1,2	-	1,0	-	-	0,6
36	*Sticteulima jeffreysiana*	E	8,3	-	1	-	-	-	-	1	-	-	-	-	-	-	-
	(Brusina, 1869)			-	0,6	-	-	-	-	0,2	-	-	-	-	-	-	-
37	*Vitreolina curva*	E	8,3	-	-	1	-	-	-	1	-	-	-	-	-	-	-
	(Monterosato, 1874)			-	-	0,8	-	-	-	0,2	-	-	-	-	-	-	-
38	*Vitreolina philippi*	E	25	-	7	-	-	-	-	7	-	1	-	1	-	-	2
	(de Rayneval & Ponzi, 1854)			-	4,1	-	-	-	-	1,2	-	1,2	-	1,0	-	-	0,4
39	*Tritia incrassata*	SC	33,3	1	1	-	-	-	2	4	-	-	-	-	1	-	1
	(Strøm, 1768)			0,9	0,6	-	-	-	3,0	0,7	-	-	-	-	0,8	-	0,2
40	*Ocinebrina aciculata*	C	8,3	1	-	-	-	-	-	1	-	-	-	-	-	-	-
	(Lamarck, 1822)			0,9	-	-	-	-	-	0,2	-	-	-	-	-	-	-
41	*Typhinellus labiatus*	C	8,3	-	-	1	-	-	-	1	-	-	-	-	-	-	-
	(de Cristofori & Jan, 1832)			-	-	0,8	-	-	-	0,2	-	-	-	-	-	-	-
42	*Haedropleura septangularis*	C	25	-	1	-	-	-	-	1	-	-	1	1	-	-	2
	(Montagu, 1803)			-	0,6	-	-	-	-	0,2	-	-	1,9	1,0	-	-	0,4
43	*Mangelia attenuata*	C	25	-	-	-	-	-	-	-	-	1	-	1	1	-	3
	(Montagu, 1803)			-	-	-	-	-	-	-	-	1,2	-	1,0	0,8	-	0,6
44	*Mangelia* sp. 4	C	41,7	-	1	-	-	1	-	2	2	-	1	-	4	-	7
	-			-	0,6	-	-	4,0	-	0,3	3,2	-	1,9	-	3,2	-	1,4
45	*Mangelia stossiciana*	C	8,3	-	-	-	-	-	-	-	-	-	-	-	2	-	2
	Brusina, 1869			-	-	-	-	-	-	-	-	-	-	-	1,6	-	0,4
46	*Raphitoma* cf. *locardi*	C	8,3	1	-	-	-	-	-	1	-	-	-	-	-	-	-
	Pusateri & Giannuzzi-Savelli, 2013			0,9	-	-	-	-	-	0,2	-	-	-	-	-	-	-
47	*Raphitoma concinna*	C	41,7	1	4	1	-	2	-	8	-	-	-	1	-	-	1
	(Scacchi, 1836)			0,9	2,3	0,8	-	8,0	-	1,4	-	-	-	1,0	-	-	0,2
48	*Raphitoma leufroyi*	C	16,7	1	-	-	-	-	-	1	1	-	-	-	-	-	1
	(Michaud, 1828)			0,9	-	-	-	-	-	0,2	1,6	-	-	-	-	-	0,2

		Diet	%F	R4	R5	R6	R7	R8	R9	Ko	R10	R11	R12	R13	R14	R15	Kr
49	*Raphitoma linearis*	C	83,3	8	8	5	5	1	3	30	1	3	-	-	2	2	8
	(Montagu, 1803)			7,4	4,7	4,2	5,5	4,0	4,5	5,2	1,6	3,5	-	-	1,6	2,7	1,6
50	*Raphitoma philberti*	C	16,7	-	-	1	-	-	-	1	-	-	-	-	1	-	1
	(Michaud, 1829)			-	-	0,8	-	-	-	0,2	-	-	-	-	0,8	-	0,2
51	*Acteon tornatilis*	C	8,3	-	-	-	-	-	-	-	1	-	-	-	-	-	1
	(Linnaeus, 1758)			-	-	-	-	-	-	-	1,6	-	-	-	-	-	0,2
52	*Rissoella inflata*	MG	8,3	-	-	-	-	-	-	-	-	-	-	-	1	-	1
	(Monterosato, 1880)			-	-	-	-	-	-	-	-	-	-	-	0,8	-	0,2
53	*Atys jeffreysi*	MG	8,3	-	-	-	-	-	-	-	-	1	-	-	-	-	1
	(Weinkauff, 1866)			-	-	-	-	-	-	-	-	1,2	-	-	-	-	0,2
54	*Weinkauffia turgidula*	MG	16,7	-	-	-	-	-	-	-	1	2	-	-	-	-	3
	(Forbes, 1844)			-	-	-	-	-	-	-	1,6	2,4	-	-	-	-	0,6
55	*Folinella excavata*	E	16,7	-	-	-	1	-	-	1	-	1	-	-	-	-	1
	(Phillippi, 1836)			-	-	-	1,1	-	-	0,2	-	1,2	-	-	-	-	0,2
56	*Megastomia conoidae*	E	33,3	1	-	-	-	-	-	1	2	-	1	-	-	1	4
	(Brocchi, 1814)			0,9	-	-	-	-	-	0,2	3,2	-	1,9	-	-	1,4	0,8
57	*Megastomia conspicua*	E	16,7	-	-	-	-	1	-	1	1	-	-	-	-	-	1
	(Alder, 1850)			-	-	-	-	4,0	-	0,2	1,6	-	-	-	-	-	0,2
58	*Odostomella doliolum*	E	8,3	1	-	-	-	-	-	1	-	-	-	-	-	-	-
	(Philippi, 1844)			0,9	-	-	-	-	-	0,2	-	-	-	-	-	-	-
59	*Modiolus barbatus*	F	50	-	-	-	1	-	-	1	2	-	1	2	2	4	11
	(Linnaeus, 1758)			-	-	-	1,1	-	-	0,2	3,2	-	1,9	2,0	1,6	5,5	2,2
60	*Modiolula phaseolina*	F	50	1	1	2	-	-	1	5	-	-	-	-	1	1	2
	(Philippi, 1844)			0,9	0,6	1,7	-	-	1,5	0,9	-	-	-	-	0,8	1,4	0,4
61	*Musculus costulatus*	F	83,3	3	5	-	6	1	-	15	6	3	5	3	7	3	27
	(Risso, 1826)			2,8	2,9	-	6,6	4,0	-	2,6	9,5	3,5	9,4	3,0	5,6	4,1	5,4
62	*Musculus subpictus*	F	91,7	2	21	4	4	2	4	37	-	2	2	1	6	2	13
	(Cantraine, 1835)			1,9	12,3	3,4	4,4	8,0	6,0	6,4	-	2,4	3,8	1,0	4,8	2,7	2,6
63	*Striarca lactea*	F	91,7	7	10	12	10	1	6	46	-	1	2	15	13	5	36
	(Linnaeus, 1758)			6,5	5,8	10,2	11,0	4,0	9,0	7,9	-	1,2	3,8	14,9	10,4	6,8	7,2
64	*Anomia ephippium*	F	41,7	-	1	2	-	1	-	4	-	-	1	-	-	1	2
	Linnaeus, 1758			-	0,6	1,7	-	4,0	-	0,7	-	-	1,9	-	-	1,4	0,4
65	*Flexopecten hyalinus*	F	58,3	-	2	-	1	-	-	3	6	3	3	7	1	-	20
	(Poli, 1795)			-	1,2	-	1,1	-	-	0,5	9,5	3,5	5,7	6,9	0,8	-	4,0

		Diet	%F	R4	R5	R6	R7	R8	R9	Ko	R10	R11	R12	R13	R14	R15	Kr
66	*Ctena decussata*	SY	25	2	-	1	-	-	-	3	-	-	-	-	2	-	2
	(O. G. Costa, 1829)			1,9	-	0,8	-	-	-	0,5	-	-	-	-	1,6	-	0,4
67	*Loripes orbicularis*	SY	75	7	-	4	-	-	1	12	6	15	4	11	9	4	49
	Poli, 1791			6,5	-	3,4	-	-	1,5	2,1	9,5	17,6	7,5	10,9	7,2	5,5	9,8
68	*Papillicardium papillosum*	F	75	-	1	1	2	-	1	5	-	2	1	1	2	1	7
	(Poli, 1791)			-	0,6	0,8	2,2	-	1,5	0,9	-	2,4	1,9	1,0	1,6	1,4	1,4
69	*Parvicardium scriptum*	F	25	-	-	1	-	-	-	1	-	-	2	-	3	-	5
	(Bucquoy, Dautzenberg & Dollfus, 1892)			-	-	0,8	-	-	-	0,2	-	-	3,8	-	2,4	-	1,0
70	*Kellia suborbicularis*	F	50	1	6	1	3	2	-	13	1	-	-	-	-	-	1
	(Montagu, 1803)			0,9	3,5	0,8	3,3	8,0	-	2,2	1,6	-	-	-	-	-	0,2
71	*Kurtiella bidentata*	F	8,3	-	-	-	-	-	-	-	1	-	-	-	-	-	1
	(Montagu, 1803)			-	-	-	-	-	-	-	1,6	-	-	-	-	-	0,2
72	*Arcopella balaustina*	D	58,3	2	-	-	-	-	-	2	1	1	1	3	3	4	13
	(Linnaeus, 1758)			1,9	-	-	-	-	-	0,3	1,6	1,2	1,9	3,0	2,4	5,5	2,6
73	*Gouldia minima*	F	100	4	1	3	8	1	5	22	4	8	9	16	28	17	82
	(Montagu, 1803)			3,7	0,6	2,5	8,8	4,0	7,5	3,8	6,3	9,4	17,0	15,8	22,4	23,3	16,4
74	*Irus irus*	F	8,3	-	-	-	1	-	-	1	-	-	-	-	-	-	-
	(Linnaeus, 1758)			-	-	-	1,1	-	-	0,2	-	-	-	-	-	-	-
75	*Pitar rudis*	F	8,3	-	-	-	-	-	-	-	-	-	-	2	-	-	2
	(Poli, 1795)			-	-	-	-	-	-	-	-	-	-	2,0	-	-	0,4
76	*Venus verrucosa*	F	75	1	1	1	3	-	1	7	1	-	-	4	1	2	8
	Linnaeus, 1758			0,9	0,6	0,8	3,3	-	1,5	1,2	1,6	-	-	4,0	0,8	2,7	1,6
77	*Hiatella arctica*	F	100	2	32	5	4	2	1	46	5	3	2	3	1	7	21
	(Linnaeus, 1767)			1,9	18,7	4,2	4,4	8,0	1,5	7,9	7,9	3,5	3,8	3,0	0,8	9,6	4,2
78	*Thracia distorta*	F	83,3	1	5	2	3	3	2	16	3	-	1	4	3	-	11
	(Montagu, 1803)			0,9	2,9	1,7	3,3	12,0	3,0	2,8	4,8	-	1,9	4,0	2,4	-	2,2
79	*Antalis vulgaris*	C	8,3	1	-	-	-	-	-	1	-	-	-	-	-	-	-
	(da Costa, 1778)			0,9	-	-	-	-	-	0,2	-	-	-	-	-	-	-
				R4	**R5**	**R6**	**R7**	**R8**	**R9**	**Ko**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**Kr**
	Number of Individuals			108	171	118	91	25	67	580	63	85	53	101	125	73	500
	Number of Species			36	36	31	30	18	22	65	25	29	24	30	36	24	63
	Shannon_H			3,12	3,03	2,67	3,11	2,81	2,67	3,42	2,93	2,94	2,83	2,93	3,02	2,76	3,31
	Evenness_e^H/S			0,63	0,57	0,47	0,74	0,92	0,66	0,47	0,75	0,65	0,71	0,63	0,57	0,66	0,43

Table 7 - Mean Numbers of Individuals and Species found per Station and Location in the Posidonia rhizome.

	Station 2	**Station 3**	**Kormati**	**Station 4**	**Station 5**	**Krk**
No. of Individuals	132 ± 34	61 ± 33	97 ± 49	67 ± 16	100 ± 26	83 ± 26
No. of Species	34 ± 3	23 ± 6	29 ± 7	26 ± 3	30 ± 6	28 ± 5

The number of individuals found per replicate varies between 25 and 171, the number of species between 18 and 36, the Shannon Diversity Index between 2.67 and 3.12 and the Evenness between 0.47 and 0.92 (Table 6). Kormati shows slightly higher values in all categories (Table 6 & 7). The test for equal means (One-way ANOVA) showed that there are no significant differences between the stations and between Kormati and Krk, respectively, in terms of number of individuals and species, Shannon-Wiener index and Eveness ($p>0.05$).

The most dominant species in the rhizome layer at Kormati are *Rissoina bruguieri* (10,6%), *Hiatella arctica* (7.9%), *Striarca lactea* (7.9%), *Alvania cancellata* (6.7%), *Bittium latreillii* (6.5%), *Musculus subpictus* (6.3%) and *Raphitoma linearis (5.1%)* as given in Figure 12. The top dominant species vary from replicate to replicate: *Alvania cancellata* (R4), *Hiatella arctica* (R5), *Rissoina bruguieri* (R6 & R9), *Striarca lactea* (R7), *Bittium latreillii* (R8 & R9). Two thirds of the molluscan assemblage in the rhizome layer at Kormati are dominated by seven families (Table 8): Rissoidae (15%), Rissoinidae (10.7%), Mytilidae (10%), Cerithiidae (8.8%), Noetiidae (7.9%), Hiatellidae (7.9%) and Raphitomidae (7.1%).

The most dominant species of the rhizome layer at Krk are *Gouldia minima* (16.4%), *Loripes orbicularis* (9.8%), *Euspira nitida* (7.4%), *Striarca lactea* (7.2%), *Musculus costulatus* (5.4%) and *Alvania geryonia* (4.8%) (Figure 12). The seven dominating families (Table 8) are Veneridae (18.4%), Mytilidae (10.6%), Lucinidae (10.2%), Rissoidae (8.6%), Naticidae (7.4%), Noetiidae (7.2%) and Caecidae (5.2%).

The most frequent species (Table 6) in the rhizomes are *Euspira nitida* (100%), *Gouldia minima* (100%), *Hiatella arctica* (100%), *Striarca lactea* (91,7%), *Alvania geryonia* (83,3%), *Musculus costulatus* (83,3%), *Raphitoma linearis* (83,3%), *Thracia distorta* (83,3*%), Venus verrucosa* (75%) *and Loripes orbicularis* (75%), while 22 species (27,7% out of 79 species) are singletons.

16 species were found only at Kormati (*Irus irus, Alvania cimex, Alvania cancellata, Crisilla semistriata, Sticteulima jeffreysiana, Vitreolina curva, Raphitoma* cf. *locardi, Ocinebrina aciculata, Typhinellus labiatus, Metaxia metaxa, Odostomella doliolum, Haliotis tuberculata, Tricolia pullus, Tricolia speciosa, Lepidopleurus cajetanus, Antalis vulgaris)* while 14 species

were found only at Krk (*Pitar rudis, Kurtiella bidentata, Rissoa splendida, Rissoa violacea, Caecum auriculatum, Caecum trachea, Mangelia attenuata, Mangelia stossiciana, Acteon tornatilis, Rissoella inflata, Atys jeffreysi, Weinkauffia turgidula, Steromphala umbilicaris, Acanthochitona fascicularis).*

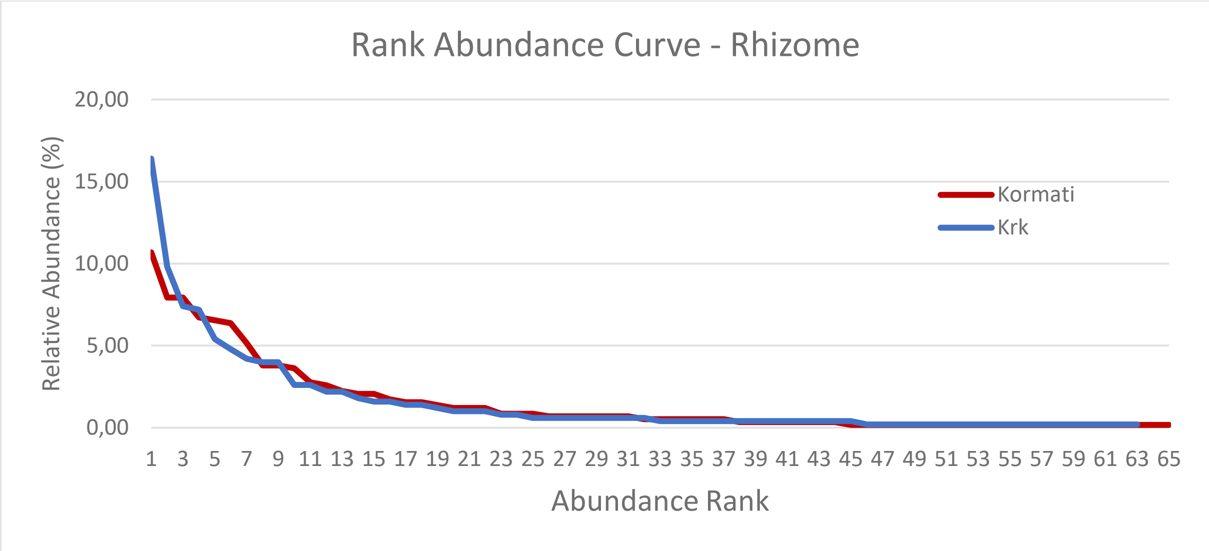

Figure 12 - Species Rank Abundance Curve of the rhizome layer

Table 8 - Abundance Rank of the rhizome layer at family level and mollusc class

	Kormati	%D		Krk	%D
1	Rissoidae	15,0	1	Veneridae	18,4
2	Rissoinidae	10,7	2	Mytilidae	10,6
3	Mytilidae	10,0	3	Lucinidae	10,2
4	Cerithiidae	8,8	4	Rissoidae	8,6
5	Noetiidae	7,9	5	Naticidae	7,4
6	Hiatellidae	7,9	6	Noetiidae	7,2
7	Raphitomidae	7,1	7	Caecidae	5,2
8	Veneridae	5,2	8	Hiatellidae	4,2
9	Eulimidae	4,0	9	Pectinidae	4,0
10	Naticidae	3,8	10	Cerithiidae	2,6
11	Thraciidae	2,8	11	Tellinidae	2,6
12	Lucinidae	2,6	12	Cardiidae	2,4
13	Cerithiopsidae	2,4	13	Mangeliidae	2,4
14	Kelliidae	2,2	14	Raphitomidae	2,2
15	Caecidae	1,2	15	Thraciidae	2,2
16	Cardiidae	1,0	16	Triphoridae	1,8
17	Triphoridae	1,0	17	Eulimidae	1,4
18	Phasianellidae	1,0	18	Pyramidellidae	1,2
19	Pyramidellidae	0,7	19	Rissoinidae	0,8
20	Anomiidae	0,7	20	Trochidae	0,8
21	Nassariidae	0,7	21	Haminoeidae	0,8
22	Pectinidae	0,5	22	Cerithiopsidae	0,6
23	Trochidae	0,5	23	Anomiidae	0,4
24	Tellinidae	0,3	24	Horaiclavidae	0,4
25	Mangeliidae	0,3	25	Callochitonidae	0,4
26	Haliotidae	0,3	26	Kelliidae	0,2
27	Muricidae	0,3	27	Nassariidae	0,2
28	Leptochitonidae	0,3	28	Lasaeidae	0,2
29	Horaiclavidae	0,2	29	Actenoidae	0,2
30	Callochitonidae	0,2	30	Rissoellidae	0,2
31	Dentaliidae	0,2	31	Acanthochitonidae	0,2
	Gastropoda	58,1		Gastropoda	36,8
	Bivalvia	41,2		Bivalvia	62,6

3.3 Comparison of the seagrass meadows

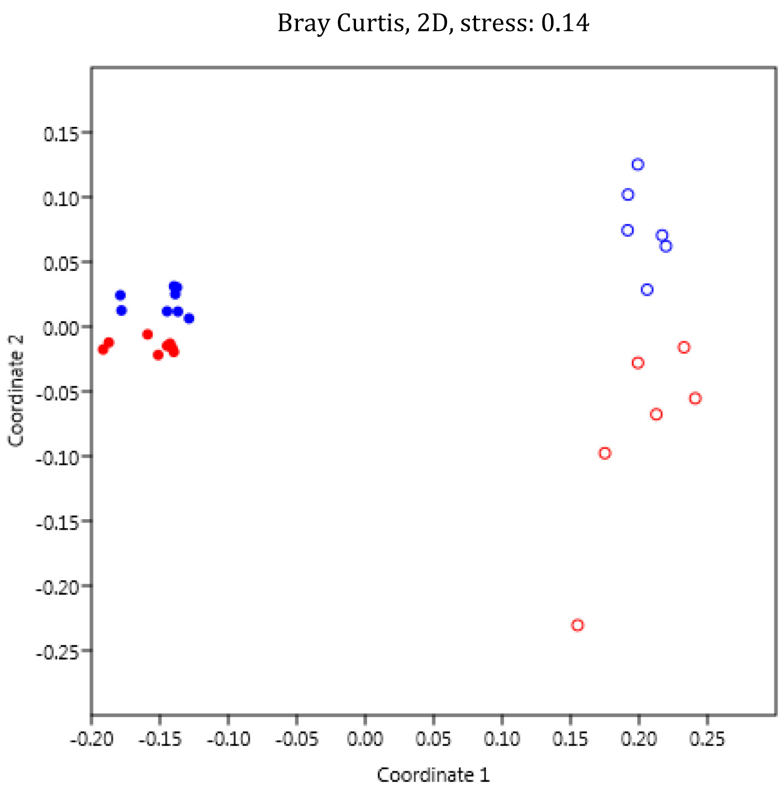

Figure 13 - Non-metric multi-dimensional scaling plot representing replicates of the Posidonia oceanica leaves (solid circles) and rhizomes (empty circles) at Kormati island (red) and Krk island (blue).

The NMDS plot (Figure 13) distinguishes clearly between the rhizome (empty circles) and leaf (solid circles) biocoenosis, so does the statistical PERMANOVA test (F= 44.319; p=0.0001). Moreover, it shows significant differences between the two seagrass meadows at Kormati (red) and Krk (blue) island (F=7.7364; p=0.0009).

Correlation with shoot density

- There is a positive, but non-significant correlation (Spearman correlation) between the shoot density and the total number of individuals per replicate in both, the foliar ($r_s = 0.8$, $p > 0.05$) and the rhizome layer ($r_s = -0.2$, $p > 0.05$).

- There is a positive, but non-significant correlation (Spearman correlation) between the shoot density and the total number of species per replicate in both, the foliar ($r_s = 0.8$, $p > 0.05$) and the rhizome layer ($r_s = -0.2$, $p > 0.05$).

Comparison of the species richness between Kormati and Krk

Individual Rarefaction

The number of observed species correlates with the number of individuals found in each replicate, station and location: The larger the sample size, the higher the probability to find more species. To get comparable data, a rarefaction/extrapolation approach was done, which estimates the species richness at a given sample size.

The leaf layer

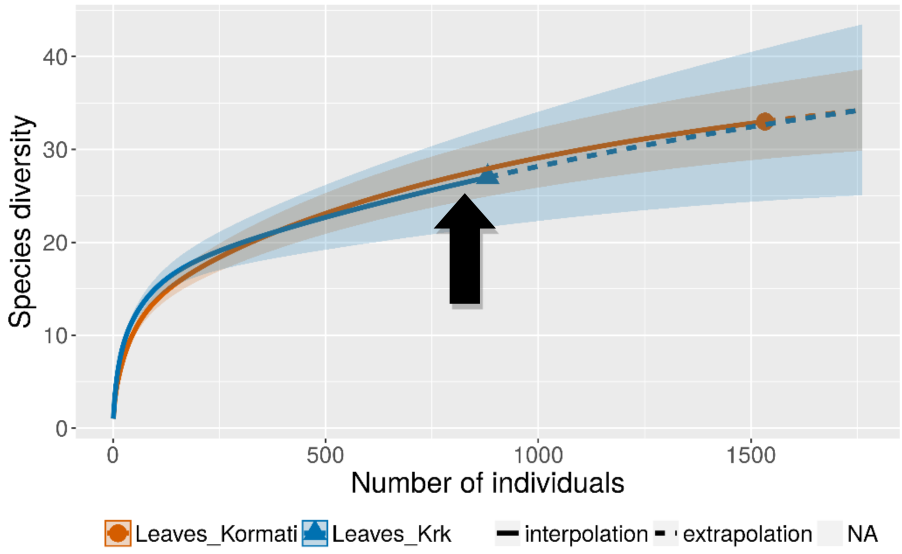

Figure 14 - Sample-size-based rarefaction and extrapolation sampling curve of the leaf layer

The sample size-based rarefaction and extrapolation sampling curves (Table 14) are lying within the 95% confidence interval and suggest, that the species richness in the leaf layer is not significantly different between Kormati and Krk.

To specify this approach more precisely, a rarefaction to the lowest sample size at each scale (replicates, stations, locations) was estimated. Example given: At the scale of replicates, a sample size of 81 individuals, which matches the lowest sample size of replicate L12 (Table 3 & 9), was chosen.

Table 9 - Individual Rarefaction based on the molluscs found in the Posidonia leaves. L4 to L15 stands each for 60 handnet strokes which were taken next to the 1 m² replicates. LSt2 to LSt5 stands each for the pooled 3 x 20 strokes directly on the 1 m² replicates. A station consists of 4 samples (e.g. station 2 = L4 + L5 + L6 + LSt2).

Sample size	Number of Species															
	L4	**L5**	**L6**	**LSt2**	**L7**	**L8**	**L9**	**LSt3**	**L10**	**L11**	**L12**	**LSt4**	**L13**	**L14**	**L15**	**LSt5**
81	9,2	8,6	7,4	15,1	10,2	13,8	13,0	15,2	10,6	12,0	12,0	13,7	15,7	15,4	13,1	13,5
	Station 2				**Station 3**				**Station 4**				**Station 5**			
432	20,1				22,7				20,0				21,8			
	Kormati								**Krk**							
881	27,9								27,0							

The individual rarefaction estimates a species richness between 7.4 and 15.7, 20 and 22.7 and 27 and 27.9 species at the scale of replicates, stations and locations respectively. The differences in species richness between the stations and locations, respectively, are not significant (One-way ANOVA, p>0.05).

The rhizome layer:

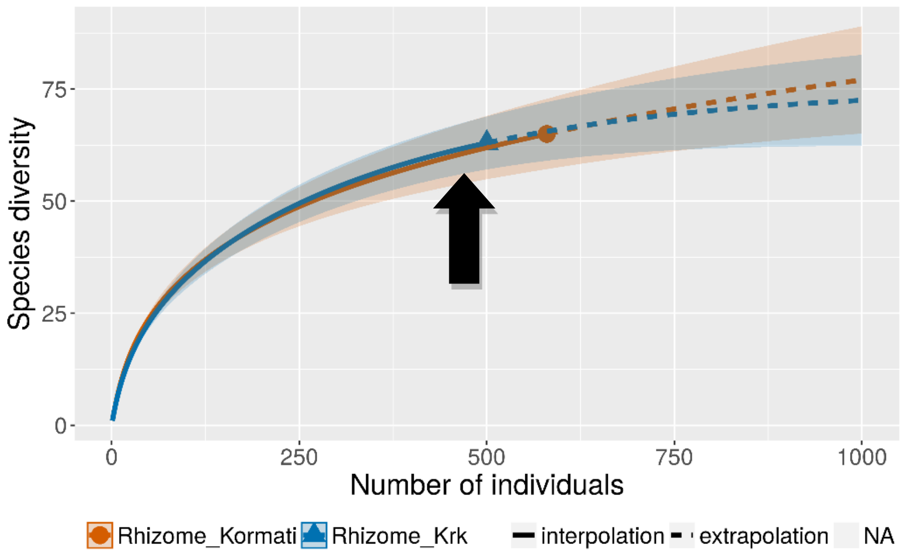

Figure 15 - Sample-size-based rarefaction and extrapolation sampling curve of the rhizome layer

The sample-size-based rarefaction and extrapolation sampling curves (Figure 15) are within the 95% confidence intervals and suggest that the species richness in the rhizome layer is not significantly different between Kormati and Krk.

To specify this approach more precise, a rarefaction to the lowest sample size at each spatial scale (replicates, stations, locations) was estimated. Example given: At the scale of replicates, a sample size of 25 individuals was chosen, which matches the lowest sample size of replicate R8 (Table 6 & 10).

Table 10 - Individual Rarefaction based on the lowest sample size in the Posidonia rhizome

Sample size	Number of Species											
	R4	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
25	15,6	14,5	12,9	15,8	18,0	13,1	15,1	14,7	15,0	14,4	14,7	13,8
	Station 2			**Station 3**			**Station 4**			**Station 5**		
183	42,3			41,0			43,3			42,4		
	Kormati						**Krk**					
500	62,0						63,0					

The individual rarefaction estimates a species richness from 12.9 to 18, 41 to 43.3 and 62 to 63 species at the scale of replicates, stations and locations, respectively. The differences in species richness between the stations and locations, respectively, are not significant (One-way ANOVA, p>0.05).

Kormati vs. Krk:

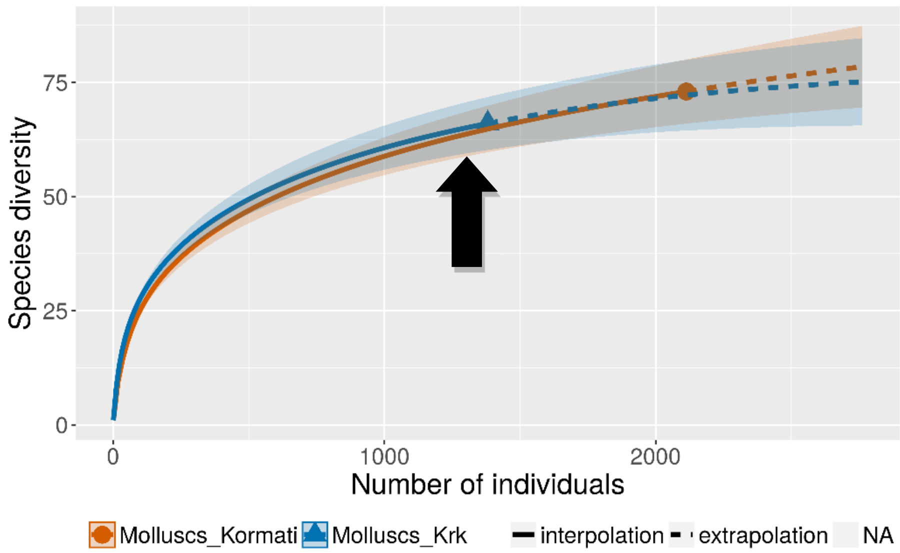

Figure 16 - Sample-size-based rarefaction and extrapolation sampling curve of the whole molluscan assemblage

The sample size-based rarefaction and extrapolation sampling curves (Figure 16) are within the 95% confidence interval and suggest that the species richness between Kormati and Krk is not significantly different.

Table 11 - Individual Rarefaction based on the lowest sample size (Leaves and rhizome merged together)

Sample size	Number of Species											
	R4	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
158	29,8	30,4	25,4	31,7	28,5	27,1	28,1	30,2	30,0	34,6	35,9	29,1
	Station 2			**Station 3**			**Station 4**			**Station 5**		
621	49,7			48,9			48,7			54,0		
	Kormati						**Krk**					
1371	64,7						65,9					

The individual rarefaction estimates a species richness from 25.4 to 35.9, 48.7 to 54 and 64.7 to 65.9 species at the scale of replicates, stations and locations, respectively. The differences in species richness between the stations and locations, respectively, are not significant (One-way ANOVA, $p>0.05$).

Comparison of the species composition between the leaf and the rhizome layer

SIMPER Routine:

The SIMPER Routine confirms the clear separation of the leaf and the rhizome biocoenosis shown in the NMDS-Plot (Figure 13) and from the PERMANOVA test (F= 44.319; p=0.0001). The Overall Dissimilarity between the leaf and the rhizome layer is 80.56. The species contributing most to differences are *Pusillina lineolata, Pusillina philippi, Rissoa splendida, Gouldia minima, Rissoa rodhensis, Rissoa violacea, Striarca lactea, Euspira nitida* and many more, see in Table 12.

Table 12 – SIMPER (Similarity Percentage) analysis of the associated molluscs found in the leaf and rhizome layers. An overview of the top 20 species.

	Taxon	Contrib. %	Mean Leaves	Mean Rhizome
1	*Pusillina lineolata*	9,681	7,11	0,888
2	*Pusillina philippi*	7,595	5,46	0,569
3	*Rissoa splendida*	5,147	3,41	0,118
4	*Gouldia minima*	4,116	0	2,67
5	*Rissoa rodhensis*	3,564	2,59	0,402
6	*Rissoa violacea*	3,527	2,33	0,0833
7	*Striarca lactea*	3,29	0,151	2,33
8	*Euspira nitida*	3,279	0	2,1
9	*Anomia ephippium*	3,22	2,29	0,451
10	*Loripes orbicularis*	2,831	0	1,86
11	*Rissoella inflata*	2,719	1,83	0,0833
12	*Alvania geryonia*	2,586	0	1,72
13	*Hiatella arctica*	2,397	1,04	2,04
14	*Raphitoma linearis*	2,287	0	1,54
15	*Rissoina bruguieri*	2,172	0	1,48
16	*Bittium latreillii*	2,086	1,86	1,49
17	*Thracia distorta*	2,062	0	1,33
18	*Musculus costulatus*	1,781	1,4	1,66
19	*Alvania cancellata*	1,693	0,0625	1,14
20	*Flexopecten hyalinus*	1,644	1,01	0,998

Overall Dissimilarity: 80.56

Comparison of the species composition between the seagrass meadows

SIMPER Routine:

The SIMPER Routine confirms the clear separation between the seagrass meadow of Kormati and Krk as shown in the NMDS-Plot (Figure 13) and from the PERMANOVA test (F=7.7364; p=0.0009).

Kormati vs. Krk:

The Overall Dissimilarity between Kormati and Krk is 63.75, if the whole dataset of the leaves and the rhizomes are used. This is attributed to the different frequencies of abundant species (e.g. *Pusillina philippi, P. lineolata, Rissoa splendida, etc.)* but also to the incidence and abundance of species that occur exclusively in one of the two layers (e.g. *Alvania cancellata, Tricolia pullus, Haliotis tuberculata, Alvania cimex*, e.t.c.), see Table 13.

Kormati vs. Krk in the leaf layer:

The Overall Dissimilarity between the leaf layers at Kormati and Krk island is 39.73. The species most contributing to differences are *Pusillina philippi, Anomia ephippium, Pusillina lineolata, Risoella inflata, Bittium latreillii* and many more (Table 14).

Kormati vs. Krk in the rhizome layer:

The Overall Dissimilarity between the rhizome layers at Kormati and Krk island is 56.77. The species most contributing to differences are *Alvania cancellata, Rissoina bruguieri, Loripes orbicularis, Gouldia minima, Bittium lattreillii* and many more (Table 15).

Table 13 - SIMPER (Similarity Percentage) analysis of the associated molluscs found at both locations. An overview of the top 20 species.

	Taxon	Contrib. %	Mean Kormati	Mean Krk
1	*Pusillina philippi*	7,709	4,52	2,21
2	*Pusillina lineolata*	7,647	4,81	4,08
3	*Rissoa splendida*	4,009	2,18	1,82
4	*Anomia ephippium*	3,873	1,01	2
5	*Bittium latreillii*	3,315	2,46	0,934
6	*Rissoa rodhensis*	3,266	1,37	1,93
7	*Gouldia minima*	3,101	0,771	1,52
8	*Flexopecten hyalinus*	2,948	0,315	1,69
9	*Rissoa violacea*	2,904	1,32	1,41
10	*Rissoella inflata*	2,879	1,5	0,67
11	*Striarca lactea*	2,769	1,31	0,866
12	*Hiatella arctica*	2,724	1,66	1,28
13	*Musculus costulatus*	2,417	1,28	1,74
14	*Loripes orbicularis*	2,36	0,403	1,19
15	*Euspira nitida*	2,338	0,759	1,04
16	*Rissoina bruguieri*	2,107	1,07	0,195
17	*Musculus subpictus*	1,977	1,65	1,31
18	*Alvania cancellata*	1,953	1,05	0
19	*Alvania geryonia*	1,941	0,723	0,755
20	*Raphitoma linearis*	1,847	0,919	0,397

Overall Dissimilarity: 63.75

Table 14 - SIMPER (Similarity Percentage) analysis of the associated molluscs found in the leaf substratum at both locations. An overview of the top 20 species.

	Taxon	Contrib. %	Mean Kormati Leaves	Mean Krk Leaves
1	*Pusillina philippi*	13,49	7,44	3,49
2	*Anomia ephippium*	8,501	1,34	3,25
3	*Pusillina lineolata*	6,876	7,99	6,23
4	*Rissoella inflata*	5,704	2,62	1,05
5	*Bittium latreillii*	5,394	2,63	1,08
6	*Flexopecten hyalinus*	5,3	0,25	1,76
7	*Hiatella arctica*	4,397	1,19	0,887
8	*Rissoa rodhensis*	4,361	2,05	3,13
9	*Musculus costulatus*	4,231	1,32	1,48
10	*Rissoa splendida*	3,634	3,82	3
11	*Marshallora adversa*	3,546	0	1,02
12	*Musculus subpictus*	3,462	1,21	1,34
13	*Rissoa violacea*	3,273	2,31	2,35
14	*Tricolia pullus*	2,747	0,82	0
15	*Bittium reticulatum*	2,724	0,479	0,52
16	*Tricolia speciosa*	2,562	0,768	0,125
17	*Vitreolina philippi*	2,506	0	0,729
18	*Cerithiopsis tubercularis*	2,054	0,552	0,427
19	*Crisilla semistriata*	1,314	0,375	0
20	*Megastomia conspicua*	1,286	0,302	0,125

Overall Dissimilarity: 39.73

Table 15 - SIMPER (Similarity Percentage) analysis of the associated molluscs found in the rhizome substratum at both locations. An overview of the top 20 species.

	Taxon	Contrib. %	Mean Kormati Rhizome	Mean Krk Rhizome
1	*Alvania cancellata*	4,457	2,29	0
2	*Rissoina bruguieri*	4,443	2,5	0,455
3	*Loripes orbicularis*	3,944	0,941	2,77
4	*Gouldia minima*	3,586	1,8	3,54
5	*Bittium latreillii*	3,471	2,24	0,736
6	*Striarca lactea*	2,943	2,65	2,02
7	*Flexopecten hyalinus*	2,841	0,402	1,59
8	*Caecum subannulatum*	2,756	0,575	1,58
9	*Acropella balaustina*	2,557	0,236	1,41
10	*Raphitoma linearis*	2,517	2,14	0,927
11	*Musculus costulatus*	2,285	1,24	2,09
12	*Modiolus* cf. *barbatus*	2,26	0,167	1,21
13	*Kellia suborbicularis*	2,25	1,27	0,167
14	*Musculus subpictus*	2,133	2,24	1,28
15	*Alvania geryonia*	2,11	1,69	1,76
16	*Hiatella arctica*	2,067	2,29	1,79
17	*Euspira nitida*	1,994	1,77	2,43
18	*Raphitoma concinna*	1,702	0,902	0,167
19	*Caecum trachea*	1,681	0	0,833
20	*Thracia distorta*	1,658	1,59	1,08

Overall Dissimilarity: 56.77

INDVAL – Indicator Values

The INDVAL analysis statistically determined the following indicator species for one of the two seagrass meadows (Kormati vs. Krk) and its specific environmental conditions:

- In the leaf layer *Pusillina philippi, Bittium latreillii, Rissoella inflata and Pusillina lineolata* are indicator species for the seagrass meadow at Kormati, while *Flexopecten hyalinus, Marshallora adversa, Rissoa rodhensis and Vitreolina philippi* are indicators for the seagreass meadow at Krk (Table 16).

- In the rhizome layer *Alvania cancellata*, *Raphitoma linearis* and *Kellia suborbicularis* are indicator species for the seagrass meadow at Kormati, while *Acropella balaustina, Caecum trachea, Loripes orbicularis, Gouldia minima, Modiolus barbatus* and *Flexopecten hyalinus* are indicators for the seagrass meadow at Krk (Table 17).

Table 16 - Indicator Values (IndVal) analysis showing the significant indicator species of the leaf substratum from both locations.

cluster indicator_value probability	Location	IndVal	pvalue
Pusillina philippi	Kormati	0.8363	0.001
Bittium latreillii	Kormati	0.8219	0.001
Rissoella inflata	Kormati	0.8000	0.004
Pusillina lineolata	Kormati	0.6235	0.010
Flexopecten hyalinus	Krk	0.9310	0.001
Marshallora adversa	Krk	0.8750	0.001
Rissoa rodhensis	Krk	0.6748	0.032
Vitreolina philippi	Krk	0.6250	0.025
Sum of probabilities		= 25.223	
Sum of Indicator Values		= 14.01	
Sum of Significant Indicator Values		= 6.19	
Number of Significant Indicators		8	

Table 17 - Indicator Values (IndVal) analysis showing the significant indicator species of the rhizome substratum from both locations.

cluster indicator_value probability	**Location**	**IndVal**	**pvalue**
Alvania cancellata	Kormati	1	0.002
Raphitoma linearis	Kormati	0.7895	0.030
Kellia suborbicularis	Kormati	0.7738	0.034
Acropella balaustina	Krk	0.8667	0.012
Caecum trachea	Krk	0.8333	0.009
Loripes orbicularis...lucinalis.	Krk	0.8033	0.025
Gouldia minima	Krk	0.7885	0.023
Modiolus barbatus	Krk	0.7639	0.028
Flexopecten hyalinus	Krk	0.7246	0.050
Sum of probabilities		= 50.685	
Sum of Indicator Values		= 29.54	
Sum of Significant Indicator Values		= 7.34	
Number of Significant Indicators		9	

Comparison of the trophic composition between Kormati and Krk

To describe the trophic composition within the seagrass meadows, the feeding habits of every species was determined (Table 3 & 6) and merged together in groups of feeding guilds. In order to allow comparison with other studies, the classification of feeding guilds proposed by Rueda et al. (2009) was used. The leaf layer hosts only three trophic groups (Ectoparasites, filter feeders and microalgal herbivores) while the rhizome hosts additional four groups (Carnivores, deposit feeders, scavengers and symbiont bearing). The results are given in Figure 17 for the leaves and in Figure 18 for the rhizomes.

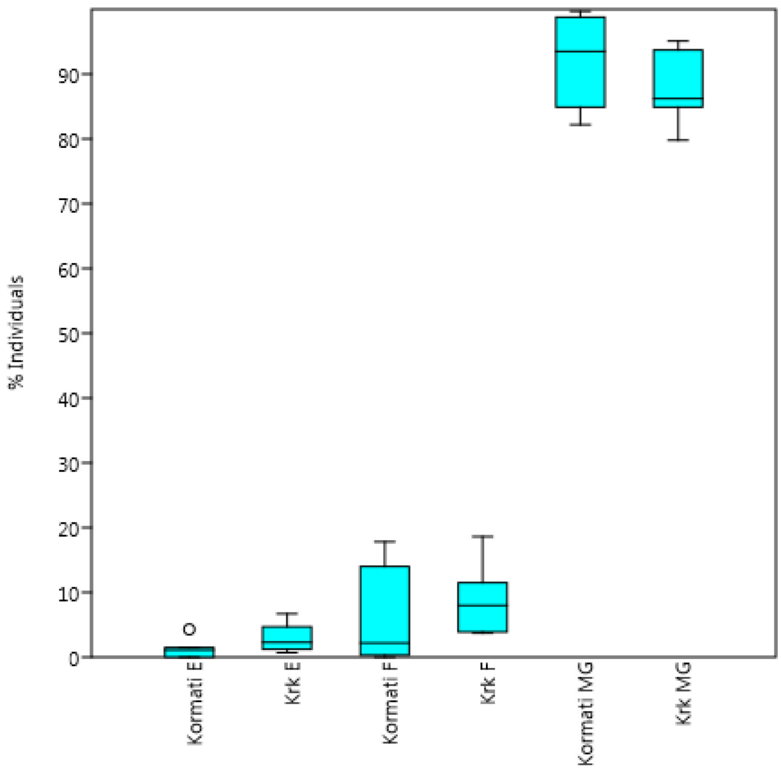

Figure 17 - Comparison of the abundance proportions of mollusc feeding guilds in the leaf layer. (Feeding guild codes: E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers).

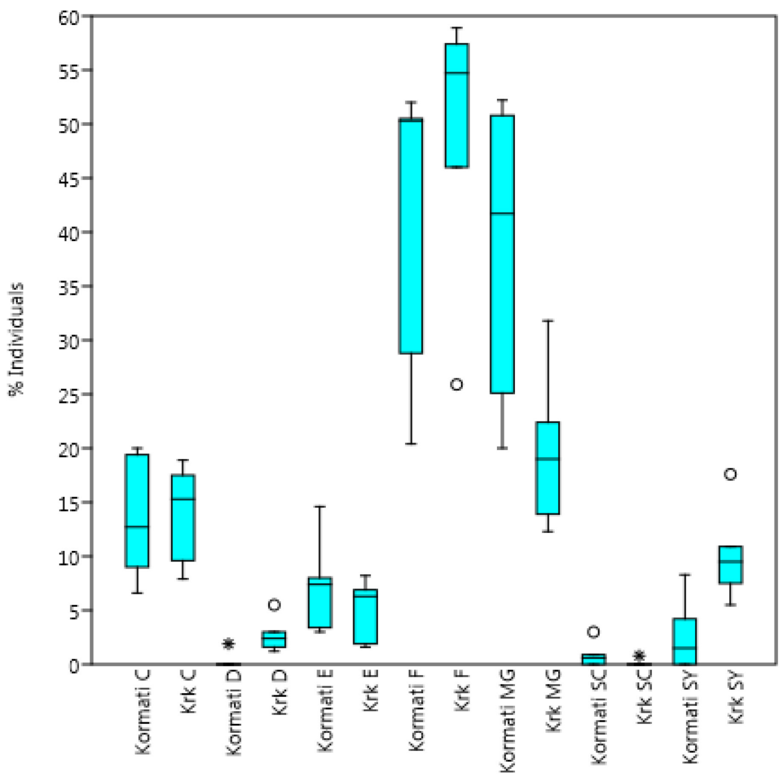

Figure 18 – Comparison of the abundance proportions of mollusc feeding guilds in the rhizome layer. (Feeding guild codes: C carnivores feeding on mobile organisms; D deposit feeders; E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers; SC scavengers; SY symbiont-bearing species).

To avoid data scattering from species that may have fallen from the leaves into the rhizomes, but also from mobile species that may switch between the two layers, the overall data (Leaves and rhizomes merged together) was used to get the proportions of feeding guilds within the whole meadows (Table 18 & 19 and Figure 19 & 20).

As shown in Figure 19, microalgal herbivores dominate, followed by filter feeders, carnivores, ectoparasites, symbiont-bearing species, deposit feeders and scavengers. The NMDS-Plot (Figure 20) representing the abundance proportions of mollusc feeding guilds separates clearly between the seagrass meadow of Kormati and Krk island. So does the PERMANOVA test (F=8.011, p=0.013). The ratio between carnivores and micrograzers is very low with mean values (Table 19) between 0.04 ± 0.01 (Kormati) and 0.08 ± 0.01 (Krk).

Table 18 - Percentage of individuals and species for each feeding guild of the Posidonia oceanica replicates (Kormati island = R4 – R9; Krk island = R10 – R15).

		R4	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
C	% Individuals	4,6	3,7	3,1	2,5	2,3	2,2	5,0	5,1	6,3	3,5	4,6	3,5
Carnivores	% Species	13,0	9,1	10,6	4,8	10,0	5,3	13,5	6,5	7,9	8,5	11,3	4,8
D	% Individuals	0,4	0,0	0,0	0,0	0,0	0,0	0,5	0,4	0,6	1,3	1,1	1,6
Deposit feeders	% Species	1,9	0,0	0,0	0,0	0,0	0,0	2,7	2,2	2,6	2,1	1,9	2,4
E	% Individuals	2,0	6,9	0,8	3,3	3,6	1,1	2,8	4,3	1,3	5,3	3,8	3,5
Ectoparasites	% Species	11,1	20,0	8,5	16,7	12,5	7,9	10,8	17,4	5,3	14,9	13,2	16,7
F	% Individuals	8,3	22,1	9,1	19,8	12,7	20,1	19,3	11,7	23,4	31,6	30,2	27,9
Filter feeders	% Species	25,9	27,3	31,9	31,0	35,0	31,6	35,1	26,1	42,1	31,9	28,3	35,7
MG	% Individuals	82,5	67,1	86,0	74,4	81,4	75,5	69,7	72,8	65,8	53,5	55,7	62,0
Microalgal grazers	% Species	42,6	41,8	44,7	47,6	42,5	50,0	35,1	45,7	39,5	40,4	39,6	38,1
SC	% Individuals	0,2	0,2	0,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	0,4	0,0
Scavengers	% Species	1,9	1,8	0,0	0,0	0,0	2,6	0,0	0,0	0,0	0,0	1,9	0,0
SY	% Individuals	2,0	0,0	1,0	0,0	0,0	0,4	2,8	5,8	2,5	4,8	4,2	1,6
Symbiont-bearing	% Species	3,7	0,0	4,3	0,0	0,0	2,6	2,7	2,2	2,6	2,1	3,8	2,4
C/MG ratio	% Individuals	0,06	0,05	0,04	0,03	0,03	0,03	0,07	0,07	0,10	0,07	0,08	0,06

Table 19 - Mean percentage of individuals for each feeding guild within stations and locations. (Feeding guild codes: C carnivores feeding on mobile organisms; D deposit feeders; E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers; SC scavengers; SY symbiont-bearing species).

	Station 2	**Station 3**	**Kormati**	**Station 4**	**Station 5**	**Krk**	**Total**
C	3.80 ± 0.75	2.33 ± 0.15	3.07 ± 0.94	5.47 ± 0.72	3.87 ± 0.64	4.67 ± 1.07	3.87 ± 1.27
D	0.13 ±0.23	-	0.07 ± 0.16	0.50 ± 0.10	1.33 ± 0.25	0.92 ± 0.49	0.49 ± 0.56
E	3.23 ± 3.23	2.67 ± 1.37	2.95 ± 2.24	2.80 ± 1.50	4.20 ± 0.96	3.50 ± 1.36	3.23 ± 1.79
F	13.17 ± 7.75	17.53 ± 4.19	15.35 ± 6.06	18.13 ± 5.94	29.90 ± 1.87	24.02 ± 7.55	19.68 ± 7.94
MG	78.53 ± 10.06	77.10 ± 3.76	77.82 ± 6.84	69.43 ± 3.51	57.07 ± 4.41	63.25 ± 7.65	70.53 ± 10.28
SC	0.13 ± 0.12	0.23 ± 0.40	0.18 ± 0.27	-	0.13 ± 0.23	0.07 ± 0.16	0.13 ± 0.22
SY	1.00 ± 1.00	0.13 ± 0.23	0.57 ± 0.80	3.70 ± 1.82	3.53 ± 1.70	3.62 ± 1.58	2.09 ± 1.99
C/MG	0.05 ± 0.01	0.03 ± 0.00	0.04 ± 0.01	0.08 ± 0,02	0.07 ± 0.01	0.08 ± 0.01	0,06 ± 0.02

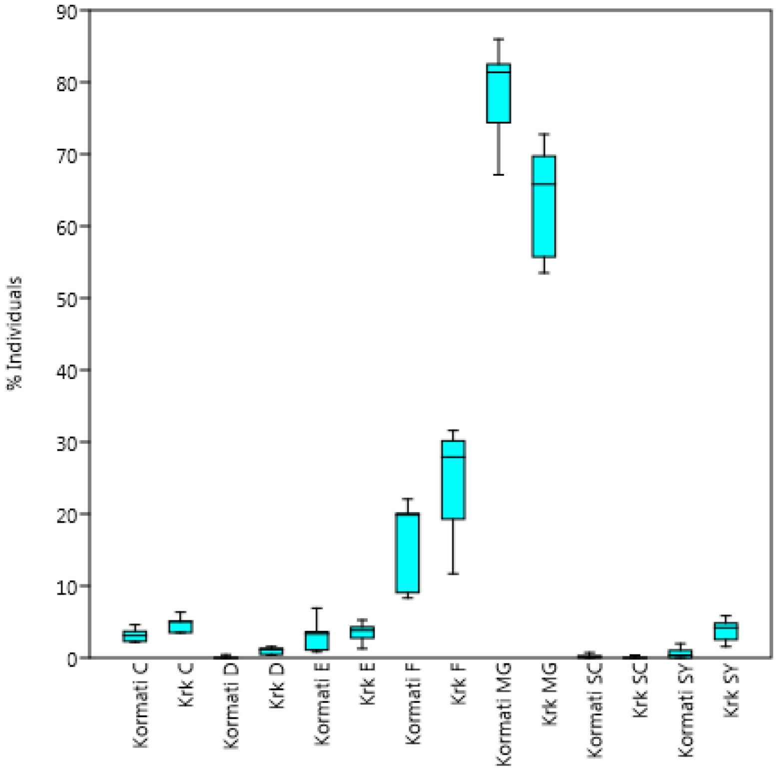

Figure 19 - Comparison of the abundance proportions of mollusc feeding guilds between the seagrass meadows of Kormati and Krk. (Feeding guild codes: C carnivores feeding on mobile organisms; D deposit feeders; E ectoparasites and specialized carnivores; F filter feeders; MG microalgal or periphyton grazers; SC scavengers; SY symbiont-bearing species).

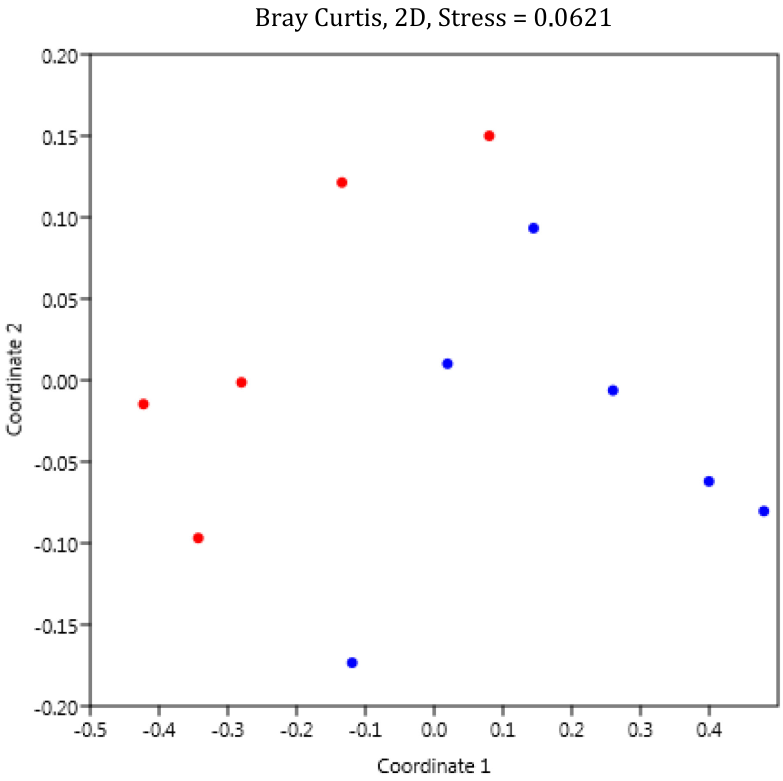

Figure 20- Non-metric multi-dimensional scaling plot representing the abundance proportions of mollusc feeding guilds among the Posidonia oceanica replicates (Kormati island = red; Krk island = blue).

Discussion

4.1 Status of the *Posidonia oceanica* meadows

As expected, the shoot density of the seagrass meadow at Krk is lower than at Kormati. As the sample size in this study was very low, it is not clear if these differences can be due to the anthropogenic impact or are from natural origin. The seagrass meadow at Kormati (618±123 shoots/m^2) can be categorized as “Good”, the seagrass meadow at Krk (430±152 shoots/m^2) only reaches the category “Poor”. Guala et al. (2014), who did a monitoring on *P. oceanica* in this region, stated that the meadow at Krk is one of the most impacted sites among the regions they investigated and categorized the seagrass meadow even worse as “Bad” and Poor” respectively, depending on the point of view (They used several descriptors).

The structure and morphometry of the two seagrass meadows are similar. Both are located at the western site of an island and start growing on a flat rocky slope at around 5 to 8 m and pass over slowly into a sandy or rocky seafloor in the deep. They are similarly exposed to the dominating wind and wave systems. Kormati is probably better supplied by currents from the southern Adriatic Sea, as it is located at the channel between Krk and Cres island, where a lot of water is shifted. These abiotic factors (wave exposure and intensity, dominant currents) may have an effect to the food supply and the larval dispersion and may cause differences between Kormati and Krk. The topographies around the two sample sites differ and cause different conditions that affect the seagrass beds. While Kormati is a small and very flat rocky island, the sample area at Krk is surrounded by high karst hills and bays. In case of rain, but also when the Bora is strong, it can be assumed, that at Krk more sediment enters the sea. This was seen during sampling, as the coverage of fine sediment on the leaves was much higher at Krk.

4.2 The malacofauna of the seagrass meadows

Overview & comparison of the species richness with different areas

This present study revealed a total of 86 species, belonging to 37 families and 62 genera (61 gastropods, 21 bivalves, three polyplacophors, one scaphopod). Fourty species were found on the leaf layer and 79 species in the rhizome layer.

Comparing these results with different areas is a difficult task, as there are only a few studies dealing with the molluscan assemblage associated with *P. oceanica* within the eastern

Mediterranean and especially within the Adriatic Sea the knowledge goes to almost zero (Solustri et al., 2002). Several studies were conducted in Italian waters in the western Mediterranean Sea, but they mainly concerned the leaf substrate. Moreover, the sampling techniques between the studies often differ and there are natural differences at large regional scales, too (Russo and Terlizzi, 1997). In addition, molluscs show zonation patterns that change with various factors, such as exposure, daily (nocturnal) and seasonal migration but also with the depth (Russo et al., 1984a; Russo et al., 1984b).

To get an idea of how many molluscan species have been found in other regions, a few studies are presented as follows. A highly diverse molluscan assemblage with 171 species were found in the northwestern Alboran Sea (Urra et al., 2013) and the northeastern (Mediterranean) part of the Iberian Peninsula (Peñas and Almera, 2001). Russo et al. (1991) found 57 species on the leaf layer (at different depth and time) at north-western Sardinia, while Vetere et al. (2006) found 87 species on the leaves at Punta Manara in the eastern Ligurian Sea. Albano and Sabelli (2011) focused on deep water seagrass meadows in the central Tyrrhenian Sea and found 14 species on the leaf and 88 species in the rhizome layer. Only two studies from the Adriatic Sea focused on the molluscs in *P. oceanica*. Beqiraj et al. (2008) intensely sampled along the Albanian coast in the southern Adriatic using an Ekman grab and hand nets. Beside of other invertebrates, they found a total of 125 mollusc species (73 gastropods, 47 bivalves, four scaphopods) of which 51 were recorded for the first time in Albania. Another study was conducted by Solustri et al. (2002) who sampled the leaves and the rhizomes of a shallow water *P. oceanica* field (4m and 11m) next to the island of Vrgada in central Croatia. They found a total of 37 species of which 15 were found within the rhizome layer and 31 within the leaf layer.

It seems that the molluscan biodiversity inhabiting *P. oceanica* is lower in the Adriatic Sea, compared to regions of the western Mediterranean Sea (177 species in western Mediterranean, 125 species at Albania, 86 species in the Kvarner Bay). Especially the leaf layer shows a decreasing gradient from west to east, as the species found in the Tyrrhenian Sea reach up to 87 species, while the Adriatic revealed only 31 to 40 species. As the studies from Croatian waters (Solustri et al., 2002 and this present study) were relatively small with respect to sample sizes, it can be expected to find more species if more data is collected. In order to realize the real trends in biodiversity, it would be necessary to sample through different depths and seasons along the Adriatic coast.

Comparison of the molluscan abundance between Kormati and Krk

One of the hypotheses to be answered in this study was if there are noticeable differences in the molluscan abundance between the two seagrass meadows, which suffer from different human pressures.

Indeed, the obtained data confirm the expectations that the molluscan abundance is lower at Krk in both, the leaf and the rhizome layer. Krk revealed a total of 1381 individuals (leaves: 881, rhizomes: 500) while 2113 individuals were found at Kormati (leaves: 1533, rhizome: 580). This difference may be due to the lower shoot density at Krk island, as the dominating species (especially in the leaf layer) are generally gastropods that feed on epiphytes. Fewer shoots per square meter means less space for epiphytes to grow. As a result, less feeding ground is available which regulates the abundance of gastropods (Kormati: 1752 gastropods, Krk: 880 gastropods).

The correlation test between shoot density and the abundance was positive, but not significant in both, the foliar and the rhizome layer (Spearman correlation, $p < 0.05$). This may be due to a small sample size of the shoot density, as it was measured on a scale of stations (mean value of ten samples per station) but only four stations were sampled in total. To get significant results in future studies this approach should be improved.

Comparison of the molluscan species richness between Kormati and Krk

Although the abundance of molluscs is lower at Krk, it does not seem to affect the molluscan species richness. The results do not confirm the expected hypothesis of a lower molluscan biodiversity at Krk. The first look on the species richness seemed to agree with the hypothesis (Kormati: 73 species, Krk: 66 species), but the comparison of the diversity indices showed, that the differences are not significant in all categories (leaves, rhizomes and the overall data). As there occurred some problems during sampling the rhizome layer which may affect the results, an additional approach was used to test whether the species richness is different at the two locations: An individual rarefaction estimation. This approach estimates the species richness at a given sample size and in this case the replicate with the smallest sample size was used and all other replicates were brought to the same level. According to the sample-size-based rarefaction and extrapolation sampling curves and the One-way ANOVA tests, not a single scenario showed significant differences in species richness between the meadow at Kormati and Krk.

The correlation test between shoot density and the species richness was positive, but again not significant in both, the leaf and the rhizome layer (Spearman correlation, $p < 0.05$). This (again) may be due to a low sample size of the shoot density, as it was measured on a scale of stations (mean value of ten samples per station) but only four stations were sampled in total. To get significant results in future studies this approach should be improved.

Comparison of the species composition between the leaf and the rhizome layer

Pérès and Picard (1964) stated, that the habitat *P. oceanica* can be divided into two different substrates and host therefore two different kind of molluscan biocoenosis, which differ significantly from each other: The biocoenosis of the rhizome substrate and of the leaf substrate. This could be confirmed in terms of abundance (rhizomes: 1080 individuals, leaves: 2414 individuals), species richness (rhizomes: 79 species; leaves: 40 species), feeding guilds (rhizome: 7; leaves: 3) and by the species composition. The Overall Dissimilarity, calculated by SIMPER, between the leaf and the rhizome layer is 80.56 and explains the clear separation in the NMDS-Plot (Figure 13) and the results from the PERMANOVA test ($F= 44.319$; $p=0.0001$). The species most contributing to differences are shown in Table 12.

Comparison of the species composition between Kormati and Krk

The multi-dimensional scaling plot in Figure 13 suggests that there are differences between Kormati and Krk in both, the rhizome and the leaf layer. The hypothesis of different species compositions between the seagrass meadows at Kormati and Krk can be confirmed as follows.

The rhizome layer:

The species composition of the rhizome layers showed that Kormati is dominated by gastropods (58.1%), while Krk is home to more bivalves (62.6%). Moreover, the species composition varies greatly between the two sites. The rhizome at Kormati is dominated by other species (e.g. *Rissoina bruguieri, Hiatella arctica*, *Striarca lactea*, *Alvania cancellata*, *Bittium latreillii*, *Musculus subpictus*, *Raphitoma linearis)* than the rhizome at Krk (e.g. *Gouldia minima*, *Loripes orbicularis*, *Euspira nitida*, *Striarca lactea*, *Musculus costulatus*, *Alvania geryonia*). The same applies to the distribution of the dominating families (Table 8), as only two of the top dominant families have approximately the same proportion in relative abundance (Mytilids and Noetiids). Rissoids are top dominant at Kormati (15%) but reach only rank four at Krk (8%). Rissoinids are on second rank at Kormati (10.7%), but they are hardly found at Krk (0,8%). Cerithiids are about three times more abundant at Kormati (8.8%) and a similar situation is found within the raphitomids (7.1%). Vice versa, venerids are top dominant at Krk (18.4%) but only on rank eight at Kormati (5.2%). Lucinids (10.2%) and caecids (5.2%) are about four times and naticids (7.4%) about two times more abundant at Krk.

The seagrass meadow at Krk is surrounded by hills, which continuously set free sediment under the influence of wind and precipitation. The seagrass meadow acts as sediment trap, and therefore the content of sediment is higher, even if the seafloor is rather rocky. This sand layer covering the hard bottom, increases the complexity of the habitat and forms niches for species associated to soft bottoms. This is very clearly demonstrated by the results from Krk: (1) The overall dominance of venerids and lucinids, (2) the indicator species determined via INDVAL analysis that reflect the specific environmental conditions (e.g. *Arcopella balaustina, Caecum trachea, Loripes orbicularis, Gouldia minima*) and (3) by some species occurring only at Krk (e.g. *Pitar rudis, Kurtiella bidentata, Caecum trachea, Caecum auriculatum, Mangelia attenuata, M. stossiciana, Acteon tornatilis*). For this reason, the shift of dominating molluscs in favor of bivalves and species preferring soft bottoms at Krk is not surprising. It explains the high value of Overall Dissimilarity (56.77) from SIMPER Routine and the separation in the NMDS-Plot (Figure 13), but it is not clear, however, whether these differences are entirely natural in origin, or are caused by human influence, too.

The leaf layer:

The species composition of the leaf layer is, compared to the rhizome layer, more balanced. The SIMPER Routine calculated an Overall Dissimilarity of 39.73 and only five families host more than 95% of the mollusc individuals at both locations. Rissoids are by far dominating the leaf layer with values between 71.4% (Krk) and 81% (Kormati). The relative abundances of the remaining important families (Cerithiidae, Rissoelidae, Mytilidae, Hiatellidae) are more or less in equilibrium with the exceptions of Anomidae (11.5% at Krk, 2% at Kormati) and Pectinidae (3.1% at Krk, 0.1% at Kormati), which offset the approximately 10% difference in the rissoids (Table 5). The dominant species are similar in both places, but they differ in relative proportions. *Pusillina lineolata* and *P. phillipi* dominate by far, followed by *Anomia ephippium* (especially at Krk), *Rissoa splendida, R. rodhensis, R. violacea, Bittium latreillii* (especially at Kormati), *Rissoella inflata* (especially at Kormati), *Flexopecten hyalinus* (especially at Krk), *Hiatella arctica, Musculus costulatus* and *M. subpictus*.

In total, the leaf layers are clearly dominated by gastropods (Kormati: 92.3%, Krk: 79.1%), but Krk again showed a higher number of bivalves (Kormati: 7.7%, Krk: 20.8%). This could be due (again) to the increased input of sediments and thus nutrients at Krk. As experienced during sampling, the loose sediment in Krk is very easily whirled up in strong winds (Bora) and the nutrients become accessible again to the filter feeders. It could also be, that the less dense seagrass meadow at Krk offers these species a generally better access to the water column than would a very densely vegetated seagrass meadow with different water flow conditions.

In comparison, Russo et al. (1991) observed 99% gastropods and only 1% bivalves in the leaf substratum in the central Mediterranean Sea. These differences could be due to the methodology that may differ a little bit. In this study, all leaves that landed unintentionally in the nets while sampling, were scrutinized exactly for little gastropods crawling on it but also for attached bivalves. Especially two bivalve species were found with relatively high abundance with this methodology, which are totally absent in the studies from Russo et al. (1991) and Vetere et al. (2006): *Anomia ephippum* and *Flexopecten hyalinus.* Both species attach themselves, at least for a part of their lifetime, to the rhizomes and leaves of *P. oceanica*. Most of the individuals found were very small and both species were found in the rhizome layer as well.

Comparison of the species composition with different areas

The rhizome layer:

This present study first time gives an idea, which molluscs are typical for a shallow water rhizome of the Kvarner Bay in autumn. It revealed following characteristic species (relative abundance > 2%): *Gouldia minima, Striarca lactea, Hiatella arctica, Loripes orbicularis, Musculus subpictus, Musculus costulatus, Thracia distorta* and *Flexopecten hyalinus* within the bivalves and *Rissoina bruguieri, Euspira nitida, Alvania geryonia, Bittium latreillii, Raphitoma linearis, Caecum subannulatum* within the gastropods. These 14 species (out of 86) account for more than 70% of quantitative dominance.

The only comparable study that focused on the molluscs of *P. oceanica* and distinguished between the molluscs of the leaf and the rhizome layer in Croatian waters was conducted by Solustri et al. (2002). The sample size of this study was very small and in different depths (4 m and 11 m). It revealed a total of only 31 species and the species composition between the depths differed by 91%. The most abundant species at 4 m depth were *Tricolia tenuis,* *Alvania discors, Bittium latreillii, Rissoa splendida* and *Gouldia minima*. The abundance of the species at 11 m depth was very low in all species, but *Venus verrucosa* and *Rissoa violacea* dominated.

Comparing these results shows that there are regional differences, but at least two dominating species are in common: *Bittium latreillii* and *Gouldia minima*.

The leaf layer

The leaf layers are better documented as the rhizome layers. Russo et al. (1984b) described a "fundamental stock" of mollusc species, that are dominant at each depth and season at the leaf substrate in the Gulf of Naples: Trochidae (*Gibbula ardens, G. umbilicaris, Jujubinus striatus, J. exaspiratus*), Rissoidae (*Rissoa auriscalpium, R. violacea*, *Alvania lineata*), Cerithiidae (*Bittium reticulatum*) and Marginellidae (*Gibberulina clandestina*). Vetere et al. (2006) described ten "core stock" species for the leaves around Punta Manara (Eastern Ligurian Sea): Rissoidae (*Rissoa guerinii, R. violacea, R. auriscalpium, R. variabilis, Pusillina philippi, P. radiata, P. inconspicua and* Cerithiidae (*Bittium latreilli, B. reticulatum, B. jadertinum)*. Solustri et al. (2002) sampled the leaf layers at 4 m and 11 m depth in central Croatia, but the sample size was very small and revealed only 15 species in total, which also varied widely between the depths. The most common and frequent species in the leaves were *Bittium latreillii, Jujubinus striatus* and *Tricolia tenuis*.

This present study revealed 12 character species (accounting for 95.7% of quantitative dominance) that are, at least, typical for the shallow water community of the leaves in the Kvarner Bay in autumn: *Pusillina lineolata, P. philippi, Rissoa splendida, R. rodhensis, R. violacea, Bittium latreillii* and *Risoella inflata* within the gastropods and *Anomia ephippium, Hiatella arctica*, *Musculus costulatus*, *Musculus subpictus* and *Flexopecten hyalinus* within the bivalves.

The comparison of these species between Kvarner Bay, Southern Croatia, Eastern Ligurian Sea and the Gulf of Naples confirms that there are natural variations among geographical zones: There are only three dominating species in common (*Rissoa violacea, Pusillina lineolata* and *Bittium latreillii*), while all other species are absent or occur only in low abundance.

Comparison of the trophic composition between Kormati and Krk

As different as the species composition is, so is the trophic composition between the two locations and confirms the expectations. Depending on the point of view, the results differ in severity.

The leaf layer revealed three different feeding guilds that are relatively well balanced between the seagrass meadows (Figure 20): Micrograzers (88-92%) are absolutely dominating this biocoenosis, followed by filter feeders (6-9%) and ectoparasites (1-3%). The habitat complexity of the rhizomes is generally high and resulted in a total of seven feeding guilds: Filter feeders (39-50%) dominate the rhizomes, followed by micrograzers (19-38%), carnivores (~13%), symbiont-bearing (2-10%), ectoparasites (5-7%), deposit feeders (0.3-2.6%) and scavengers (0.1-0.7%). As we know that Krk hosts more bivalves, it is not surprising, that the feeding groups are not that well balanced between the seagrass meadows. The bivalves found at Krk are not only filter feeders, but also symbiont-bearing species of the family of Lucinidae, which are common for this habitat.

A look on the seagrass meadows as a total (rhizomes and leaves merged together) reminds that the abundance of molluscs found on the leaves was very high compared to the rhizomes and shifts the results as follows: In total, micrograzers (63-78%) are by far dominating the seagrass meadows, followed by filter feeders (15-24%), carnivores (3-5%), ectoparasites (~3%), symbiont bearing (0.5-3.5%) and scavengers (~0,1%).

4.3 Conclusion and future perspective

P. oceanica is among the most important habitats of the Mediterranean Sea and as there is a rapid decline in seagrasses all over the globe, the interest in this habitat slowly, but gradually increases. The seagrass meadows of the western Mediterranean are already well documented and since a few years the monitoring of *P. oceanica* takes also place in the eastern parts, such as the Adriatic Sea. This present study first time focused on the molluscan assemblages inhabiting the *P. oceanica* leaves and rhizomes in the Northern Adriatic Sea, a region where *P. oceanica* almost disappeared. It provides ecological data from a habitat, which probably will be altered or even gone in the upcoming years or decades. As this study was a relatively small approach with small sample sizes, it can be expected to find more species if more data is collected. In order to get a better understanding of the associated species and to realize the real trends in biodiversity in this region, it would be necessary to sample through different seagrass meadows in different depths and seasons along the

Adriatic coast. A good way to do this would be to implement such research approaches in the MedPosidonia Project which collects data of the distribution and status of *P. oceanica* as a base for future conservation efforts. This program could be expanded to collect more accurate data about the benthic communities in the seagrass meadows and this would even highlight the importance of this habitat. Moreover, it would provide information about how this habitat and the associated fauna is reacting to human impacts, which is also very important for future conservation efforts. This question was also part of this actual study, as the molluscan communities of two seagrass meadows with different human impact were analysed and compared. The results revealed several differences between the communities, but, probably due to the low sample size, it is not clear if the differences are man-made or from natural origin. For future studies a bigger approach, testing more different seagrass meadows with a higher number of samples and more environmental descriptors, is recommended.

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Appendix

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