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Functionality of HELCOM HUB classification in describing variation in rocky shore communities of the northern Baltic Sea

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Abstract

Habitat classification schemes provide tools for harmonized mapping, monitoring and assessment of habitats across regions. They also offer ways to simplify large biodiversity datasets to reveal main environmental and biological characteristics of a region, which might be sufficient level of detail for example in regional planning processes. Since 2013, HELCOM underwater biotope and habitat classification system (HELCOM HUB) has provided a framework to classify the marine underwater nature of the Baltic Sea, but so far, its functionality in describing the variation in Baltic Sea biological communities has only rarely been tested. We tested the functionality of HELCOM HUB in describing variation in rocky shore communities on a large scale, across the Finnish marine area. We found the classification tool be very useful in simplifying complex biodiversity data and in creating quantitative presentations on community variation. The results show how the proportional occurrences of different rocky shore communities change in relation to each other along the environmental gradients of the northern Baltic Sea: along the coast in different salinity regimes, from sheltered archipelagos to the open sea and when going from shallow sublittoral to deeper waters. Although the importance of regional habitat classification schemes is recognized, we found also some weaknesses in HELCOM HUB. The red algal communities that are generally recognized as key components of northern Baltic Sea rocky shores were clearly "lost in classification", although they were shown to be both common and to occur in relatively high coverages, especially in the southwestern part of the study area. This was mainly due to division of red algae into many "sub-groups" at levels 5 and 6 in the classification (e.g. perennial foliose red algae and perennial non-filamentous corticated red algae) that led to their "fragmentation" within the classification. This further resulted in low coverages of red algae within the sub-groups, and finally, to their classification to other classes with such as blue mussels or other algal groups. The result highlights the need to consider the restrictions of any classification system when classified data is used in management contexts. When taxa are "lost in classification", we might not just ignore species or communities, but also key ecosystem functions.

1. Introduction

Habitat classification schemes, such as EUNIS of the European Union (Davies et al. 2004), provide tools for harmonized mapping, monitoring and assessment of habitats across regions, that are required by the EU Marine Strategy Framework Directive (Strong et al. 2019). The EUNIS classification system has for example, allowed the production of coherent, European-wide coarse-scale seabed habitat maps (Populus et al. 2017). One of the main benefits of biotope classification systems is that instead of presenting e.g. species- or habitat-specific maps, even large biodiversity datasets can be easily "simplified" to reveal main characteristics of the region in question, which might be sufficient level of detail, for example in regional planning processes. Community level maps may also serve as useful background information for scientific studies or for more detailed mapping.

Due to its special characteristics, e.g. the largely salinity driven variation in the biological communities, the Baltic Sea was poorly presented in the EUNIS classification system (Galparsoro et al. 2012). Therefore, a separate, but EUNIS compatible classification system was developed for the Baltic Sea in 2013; HELCOM underwater biotope and habitat classification system (hereafter HELCOM HUB, HELCOM 2013). As EUNIS, HELCOM HUB is hierarchical, with upper levels describing variation in physical factors and lower levels incorporating also biotic factors (Davies et al. 2004, HELCOM 2013, Schiele et al. 2014). In HUB, the habitats are classified according to "vertical zones" at level 2, based on "substrate" at level 3, by "community structure" at level 4, by "characteristic community" at level 5 and by "dominating taxa" at level 6 (HELCOM 2013). The development of HUB was based on an earlier classification Baltic Sea habitat classification system BalMar (Alleco 2012), and a relatively large dataset on marine biodiversity was used in defining the habitats (HELCOM 2013). So far, full-cover maps of biotopes or habitats using HUB classification have been produced only within few Baltic Sea areas (Schiele et al. 2015, SeaGIS project https://seagis.org/internt/). Although many marine mapping efforts in the Baltic Sea area, such as the national Marine Inventory Program for the Underwater Marine Environment (VELMU) in Finland (https://www.ymparisto.fi/en-US/VELMU/), have provided extensive datasets on marine biodiversity, the production of biotope maps is constrained by the availability and use restrictions of substrate data at biologically relevant scales (1:20 000).

Although classifications based primarily on physical characteristics at upper levels have many advantages, e.g. low seasonal and inter-annual variation in classes, they may fail to describe the true variation in biological communities. For example, Cooper et al. (2018) found that the same biologically defined communities were actually found within several upper level habitat classes. Furthermore, a fundamental difficulty with any habitat classification is that communities that tend to change gradually along environmental gradients are divided into distinct classes with clear boundaries (Strong et al. 2019). These kind of shortcomings in classifications systems may lead to e.g. inefficient monitoring of biological communities, if the habitat classes are used as basis for designing monitoring programs.

1.1. Rocky shores

Rocky shores of the northern Baltic Sea host algal and invertebrate assemblages, of which bladder wrack zones (*Fucus vesiculosus* L.) and blue mussel beds (*Mytilus trossulus*) (hereafter *Fucus* and *Mytilus*) are considered key habitats (Råberg & Kautsky 2007*,* Koivisto 2011). Rocky sublittoral zone hosting algal and mussel assemblages are also listed in the Habitats Directive Annex I as reefs or as underwater parts of boreal Baltic islets and islands in the outer archipelago (European Commission 2013), that should be protected within the Natura 2000 network of protected areas and whose status should be monitored on a regular basis. While *Fucus* and *Mytilus* have been subject to studies presenting their abundances and/or status on larger spatial scales (Torn et al. 2006, Westerbom et al. 2002, Rinne & Salovius-Laurén 2019), only the general occurrence ranges of many other rocky shore species, are known (Nielsen et al. 1995, Snoeijs 1999, Tolstoy & Österlund 2003, Kostamo et al. 2017). Also species distribution models built for many rocky shore species (e.g. Rinne et al. 2014, Virtanen et al. 2018) have brought valuable spatial information on their potential distributional ranges, yet information on their actual abundances and their commonness across environmental gradients is largely lacking. For example, the abundances of red algae, known to form a zone below the *Fucus* belt (Waern 1952, Kiirikki 1996, Snoeijs 1999, Kostamo 2008, Kostamo et al. 2017), , have been reported only in local studies (Häyrén 1950, Waern 1952, Ravanko 1968, Wallentinus 1979, Pogreboff &

Rönnberg 1987, Bergström & Bergström 1999, Rönnberg & Mathiesen 1998, Roos et al. 2003). Red algae occur generally in 2-10 m depth, but may reach 16-20 m depth (Kostamo 2008, Ruuskanen 2016). In the shallower waters, they often occur within the *Fucus* belt, but in deeper waters, they occur together with blue mussels (Kostamo et al. 2017). The encrusting *Hildenbrandia rubra* (Sommerf.) Menegh. is very common and occurs on almost all rocky shores (Rinne et al. 2011). Of the erect perennial species, the most common species is *Furcellaria lumbricalis* (Huds.) J.V.Lamour., but also e.g. *Polysiphonia fucoides* (Huds.) Grev. is relatively common (Rinne et al. 2011). Of the annual species, the most commonly occurring ones are *Ceramium tenuicorne* (Kütz.) Wærn as well as *Polysiphonia fibrillosa* (Dillwyn) Spreng. (Rinne et al. 2011). Of the foliose red algae, *Phyllophora pseudoceranoides* (S.G.Gmel.) Newroth et A.R.A. Taylor and *Coccotylus truncatus* (Pall.) M.J.Wynne et J.N.Heine occur in the area, especially in the more exposed outer archipelagos (Ruuskanen 2016). In the north, the distribution of many red algae are limited by low salinity and only some species occur in the Bothnian Bay, mainly *H. rubra* and *C. tenuicorne* of the common ones (Nielsen et al. 1995, Kostamo et al. 2017). In the Finnish IUCN threat assessment 2018, the red algal communities were classified as endangered, due to increased turbidity of the water, increased amounts of filamentous algae and lowering salinity (Kotilainen et al. 2018).

Another interesting taxa, whose quantitative contribution to the Baltic Sea rocky shore / reef communities remain largely unreported are the aquatic mosses that are key habitat-formers of the rocky shores in the low salinity regions of the Baltic Sea (Snoeijs 1999, Ylikörkkö 2012, Kostamo et al. 2017). They occupy hard bottoms mainly in 3-6 m depth and attach to the substrate with rhizoids (Ylikörkkö 2012, Kotilainen et al. 2018). As some of the species, e.g. the most commonly found *Fontinalis antipyretica*, can become relatively large, aquatic mosses can be important habitat-formers of the rocky shores in the areas where many larger algal species, e.g. *Fucus,* do not occur (Kostamo et al. 2017). Other commonly occurring aquatic moss species of the northern Baltic Sea are *Fissides fontanus, Fontinalis dalecarlica* and *Rhyncostegium riparioides* (Ylikörkkö 2012).

In addition to deficient knowledge on abundances of specific species or taxa on larger scale, the changes in the abundances of species in relation to each other across wide environmental gradients remain undescribed. These gaps in knowledge constrain our ability to characterize the reef communities in different parts of the Baltic Sea and thereby limit possibilities for establishing effective monitoring of these habitats.

1.2. Aim of the study

The aim of this study is to describe the large scale variation in the rocky shore communities of the northern Baltic Sea using HELCOM HUB classification. Simultaneously, the aim is to test the functionality of HELCOM HUB in in this kind of an analysis. So far, the functionality of HELCOM HUB has been tested only to minor extent and in areas with mainly soft and sandy substrates (Schiele et al. 2014, Schiele et al. 2015). As the classification is based on "characteristic community" and "dominating taxa" at lower hierarchical levels, it is possible that smaller, rarer, of less distinctive species or taxa may be overlooked in classification, although they could form structurally and/or functionally important parts of the rocky shore communities. Therefore, we also aim to test how the classification treats taxa that are recognized as important components of rocky shore communities, but are not particularly large, or do not form dense canopies or "mats", i.e. the red algal communities and the aquatic mosses. In this study, we use the term "community" when referring to both level 5 and level 6 HUB classes, as they are both outcomes of the classification, with the only difference being that the communities are classified at level 6 only if one species/species group is dominating over others. To test the classification, we first use it to produce graphs describing variation in rocky seabed communities across environmental gradients of the Finnish marine area, using extensive data collected within the marine inventory program VELMU and within mappings projects in the Åland Islands. We then assess the commonness and abundance of red algal and aquatic moss communities within different sea areas and investigate their representation in the classification results.

2. Materials and methods

2.1. Study area

The study area, including the Finnish marine area and the Exclusive Economic Zone (EEZ), is situated in the northern Baltic Sea (Figure 1) and is characterized by a distinct salinity gradient (2 - 6.5 PSU), with salinity decreasing northwards in the Gulf of Bothnia and towards east in the Gulf of Finland. In the area, archipelagos act as transition zones between the coast and the open sea, forming mainland to open sea gradients in exposure, salinity and water quality, all generally increasing towards the open sea. To divide the area into suitable units to study community composition across environmental gradients, we used the division into sea areas that is adopted in work related to the Water Framework Directive in Finland (WFD, Vuori et al. 2006), with the exception that the Archipelago Sea and the Western Gulf of Finland were considered as separate areas (Figure 1). Also the division into inner and outer archipelago was used (as well as middle archipelago defined for the Archipelago Sea and Åland), and the areas beyond the outer archipelago were defined as the open sea, continuing to the outer border of the Finnish EEZ. The division considers the above described environmental gradients in salinity and those associated with changes from the coast to the open sea.

2.2. The data

We used extensive data on macrophytes, macroalgae and epibenthic fauna collected during the VELMU program (Viitasalo et al. 2017) and in marine mapping projects in Åland (Kiviluoto 2013, Engström 2018, Rinne et al. 2019). The data consisted of >144 000 survey points collected in June-October during 2004-2018 using mainly scuba-diving transects and drop-video surveys but also using ROV, snorkeling, aquascope and wading to some extent. In Åland, the data was collected during 2010-2012 and 2017-2018 (only scuba-diving, snorkeling and drop-video used).

During SCUBA-diving surveys, the transects were placed using mostly stratified random sampling design, to ensure the coverage of different environmental gradients (e.g. exposure, different substrates) (Anonymous 2015). At each site, the 100 m long transect was placed perpendicular to the shoreline. In all transects, recordings of species and substrate cover (%) were made from an area of 4 m^2 either at 10 m horizontal (along the seafloor) or 1 m vertical (change in depth) intervals along the transects. In Åland, the species cover was recorded from a smaller area (2 m^2). The species-specific cover (%) of macrophytes, macroalgae and sessile fauna, as well as substrate, were recorded on a continuous scale from 0 - 100%. The substrate recordings were based on a 11-level classification (bedrock, boulders > 300 cm, boulders 120 - 300 cm, boulders 60 - 120 cm, stones 10 - 60 cm, stones 6 - 10 cm, gravel, sand, silt, clay and mud), modified from Wentworth (1922). Also the depth of the study point was recorded. If vegetation ended before 100 m was reached, (e.g. steep transects), the transect ended at the deepest extent of the vegetation.

The drop-video surveys were planned using stratified random sampling (stratification according to depth, exposure, turbidity and salinity) but also grid sampling with 100 m intervals were applied within some protected areas (Anonymous 2015). Also focused inventories of certain habitats and environments have occasionally been done. The drop-video surveys were carried out from a boat, where a video-recorder equipped with lights was lowered with a cable near the seafloor and the seafloor was filmed for one minute (covering 20 m^2 on average). The videos were later analysed to record substrate and species cover (%) (Anonymous 2015). From video, the species of filamentous algae cannot often be identified to the species level, and thus, larger groups were recorded (e.g. filamentous brown algae, filamentous red algae or just filamentous algae).

Snorkelling or wading were used mainly in very shallow waters and ROV in deep waters. Similar principles in data acquisition were applied also when using these methods, i.e. the percentage cover of epibenthic species, substrate and depth were recorded from specified areas that corresponded to areas used in scuba-diving or in drop-video. All species and substrate recordings (done along diving transects, from drop-video, ROV, snorkelling or wading) are hereafter referred to as study sites.

2.3. Data classification

The species data was classified according to HUB in Excel, to either level 5 or level 6. In HUB, level 6 is defined by the dominating taxa, and the communities are classified at this level only if the biovolume (=coverage * height) of one species or a defined species group is ≥ 50% (HELCOM 2013). If none of the species /species groups reach dominance with ≥ 50% biovolume, the classification is taken only to level 5 that describes the so called “characteristic community” (e.g. “submerged rooted plants”, “perennial algae” or “epibenthic bivalves”) of the site. At this level, the community is defined, first of all, by epibenthic animals or perennial groups that are attached, erect, and have ≥10% coverage. Only in the absence of such groups the community is defined by unattached, crustose or annual algae (see specific split rules in HELCOM 2013). If none of these characteristic communities reach ≥10% coverage, the community is defined as a “mixed epibentic macrocommunity”. If the total coverage of macroscopic vegetation or sessile epifauna is 0> <10%, the community is defined as a “sparse epibenthic community”, and if there is nothing (0% coverage), the site is classified to class “no macrocommunity”. To define biovolume, we multiplied the areal coverage derived from the inventories with the average plant heights (or relative weight factor for sessile animals) defined by the regional marine experts of Parks & Wildlife Finland. The records of “unidentified filamentous algae” were divided into annual and perennial species using a depth limit of 6 m based on recommendation of regional marine experts (depth > 6 m → unidentified filamentous algae classified as perennial filamentous algae, otherwise as annual filamentous algae). This was done as it is not possible to implement the classification without knowing whether the algae are perennial or annual, and leaving out all data with records of “unidentified filamentous algae” would have resulted in deletion of tens of thousands of study points. Therefore, this artificial division must be accounted for when interpreting the results, and it is safest to interpret perennial and annual filamentous algae together as “filamentous algae”. As the data included only epibenthic species, only such parts of the classification system were considered. No division to photic or non-photic sites were done, as we were interested in communities at all depths. As our aim was to look only at communities occupying hard substrates, we chose only sites that had ≥50% coverage of rock, boulders, stones or gravel. After this selection, we ended up with 57 824 study points. The numbers of study sites/sea area are presented in table 1.

Table 1. The number of study sites with ≥50% coverage of hard bottom / sea area.

	Inner	Middle	Outer	Open
Gulf of Finland	1677		9970	624
W. Gulf of Finland	584		8478	1360
Archipelago Sea	229	586	9383	95
Åland	230	266	1686	0
Bothnian Sea	1255		3763	391

Kvarken	385	8636	73
Bothnian Bay	1082	6765	306

2.4. The analyses on red algae and aquatic mosses

When looking into the abundances and commonness of red algae and aquatic mosses within the different sea areas, they were grouped based on the division used in HELCOM HUB classification. The red algae were grouped into "erect red algae" (all species except for *H. rubra* and *Rhodochortron purpureum*), "foliose red algae" (*Coccotylus truncatus* and *Phyllophora pseudoceranoides*) and to "non-filamentous corticated red algae" (*Furcellaria lumbricalis*). As in the classification, aquatic mosses were treated as one group. In addition, all red algae were also analyzed together (including all species), to get an idea about the total abundances of red algae in different areas and to relate it to the abundances of groups used in HUB. When looking at commonness and the "fate" of red algae and erect red algae in HUB, we chose to use only ≥10% coverages, as we wanted to look occurrences forming a significant contribution to the rocky bottom community, not just scarce individuals. For aquatic mosses that generally occur in low coverages we studied commonness of both all presences as well as ≥10% coverages. As the data / depth strata was scarce in most of the open sea areas, we focused the commonness analyses to the inner and outer archipelago areas (and middle archipelagos where applicable). The aquatic mosses were generally rare, and therefore their abundances as well as their "fate" in the HUB classification were studied in all inner and outer archipelagos where they occurred. However, the same analyses for red algae were done only in the outer archipelago areas, where the red algae were common (table 2) and also the data was most abundant (Table 1). For all groups used, the mean coverages were calculated for the study sites where they occurred.

3. Results

3.1. Variation in rocky shore communities

The rocky shore community graphs created using HELCOM HUB classification showed high variation in communities across the Finnish marine area (Figure 1).

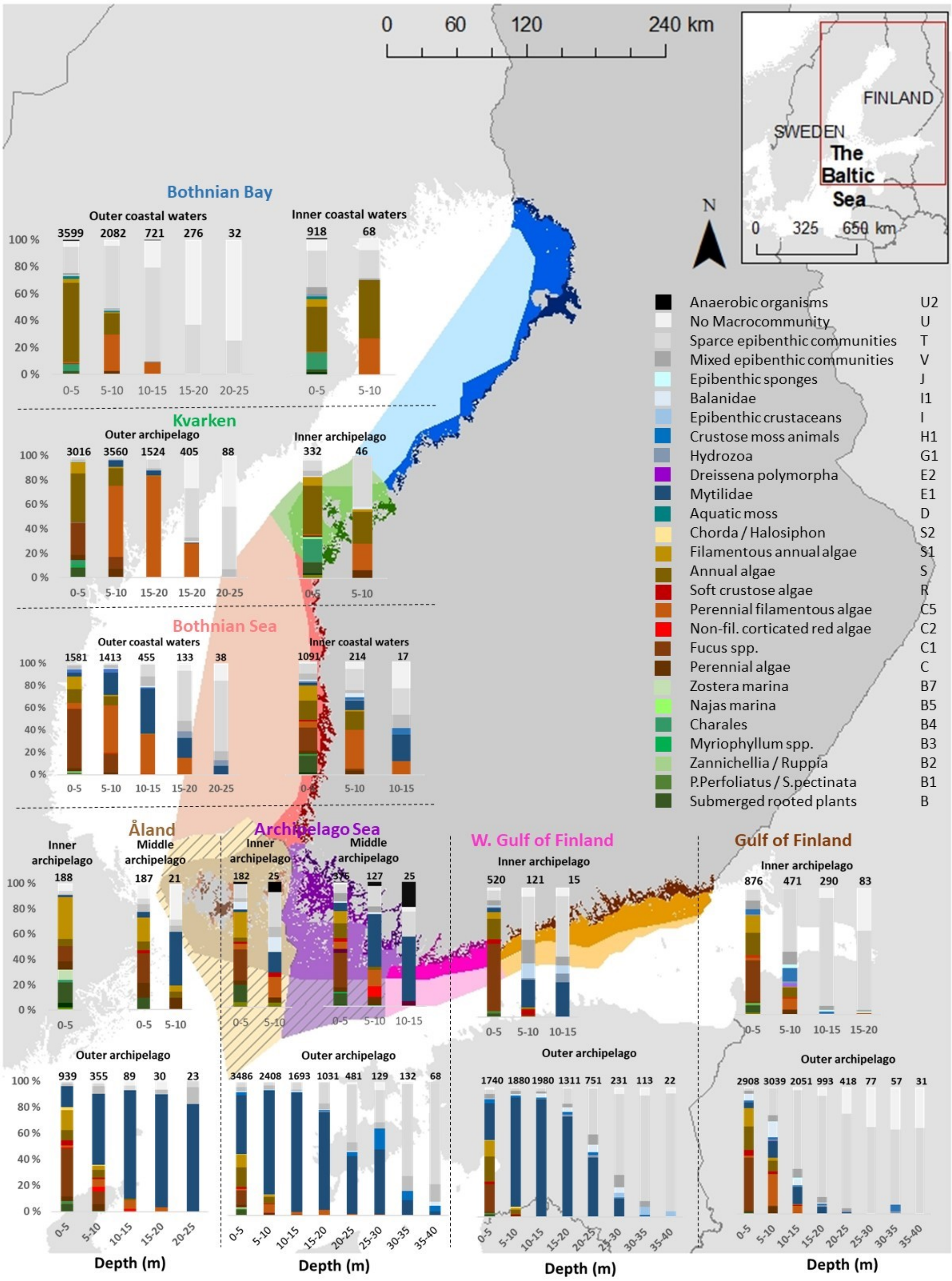

Figure 1. The rocky shore communities according to HELCOM HUB classification in the inner, middle and outer archipelago areas within the Finnish marine area, in different depth zones (m). The number of study sites/depth zone are presented above bars. Inner archipelagos are shown in darkest colors, colors lightening towards the open sea. The open sea graphs are in supplement 1. Hatched areas had no data. Depths of 0-5m, represent actual depths of 0-4.99 m, 5-10 m are actual depths of 5-9.99 m and so on. HELCOM HUB class code is given with the class name. Level 5 in biotopes have only a letter, while level 6 biotopes have also a number.

On the rocky shores of the outer archipelagos of Åland, the Archipelago Sea and the western Gulf of Finland, *Mytilus*-dominated communities were clearly the most common ones in > 5 m depth (down to 25-30 m depth), but their proportion decreased when going to the Bothnian Sea and to the eastern Gulf of Finland. In the Archipelago Sea and in the western Gulf of Finland, *Mytilus*-dominated rocky shores were very common also in 0-5 m depth.

The proportion of *Fucus*-dominated communities was high in 0-5 m depth in the outer archipelagos of Åland, Bothnian Sea and the eastern Gulf of Finland (Figure 1). However, in between these areas, in the Archipelago Sea and in the western Gulf of Finland, the proportion of *Fucus*-dominated communities was actually higher in the inner than in the outer archipelago areas. *Fucus* communities rarely reached 5-10 m zone, but in Åland, in the Bothnian Sea and Kvarken, they constituted approximately 10-15% of the rocky bottom in that depth zone. The proportion of communities dominated by filamentous algae in the 0-5 m depth zone was relatively constant (~20-30%), both in the outer and inner archipelagos from eastern Gulf of Finland to Åland (Figure 1). The proportion increased when going northwards to the Bothnian Sea, Kvarken and especially to Bothnian Bay, where annual (filamentous) algae were by far the most common community type. According to the HELCOM HUB classification, the communities dominated by red algae (non-filamentous corticated red algae, foliose red algae as well as soft crustose algae) were rare in all areas. At highest, non-filamentous corticated red algae (= *F. lumbricalis*) dominated in 8% of the rocky sites in the 5-10 m depth zone in the middle Archipelago Sea. Foliose red algae never reached dominance within the study area. Also communities dominated by soft crustose algae were rare, and occurred most often in the 0-5 m zone in the Gulf of Finland and in Åland (approximately on 4% of the rocky seabed sites in these areas). The aquatic mosses were rarely visible in the community figures. They reached dominance only in 0.5% of the sites in the 0-5 m depth in the outer archipelago of Kvarken, and in 2% of the sites in the 0-5 m depth zone of the Bothnian Bay (both inner and outer archipelago).

3.2. Red algal communities

On the contrary to findings based on HELCOM HUB classification, according to analyses on commonness and abundance, red algae occurred commonly especially in the outer archipelago of Åland, but also in the Bothnian Sea and in the Archipelago Sea (Table 2). Generally, red algae were most common in the 0-5 m depths but especially in the outer archipelago areas of Åland, red algae in ≥10 % coverages were still very common down to 10-15 m depth. Red algae became notably rarer in the Kvarken area (Table 2), and were extremely rare in the Bothnian Bay (Table 2).

Table 2. The percentage (%) of study sites with ≥10% coverage of red algae / ≥10% coverage of erect red algae of all hard bottom sites in the inner, middle and outer archipelago areas. The numbers are presented only for areas and depth zones that had ≥10 study sites with ≥50% coverage of hard bottom.

	0-5m	5-10m	10-15m	15-20m
Gulf of Finland, inner	21.1 / 5.9	9.66 / 1.1	1.5 / 0	0 / 0
Gulf of Finland, outer	35.6 / 20.3	20.5 / 12.3	4.3 / 0.8	0.4 / 0
W. Gulf of Finland, inner	11.8 / 1.3	12.0 / 0.9	0 / 0	
W. Gulf of Finland, outer	23.1 / 15.1	15.0 / 9.4	8.2 / 2.8	1.8 / 0
Archipelago Sea, inner	15.7 / 4.7	18.8 / 9.4		
Archipelago Sea, middle	35.3 / 15.8	33.1 / 14.6	4.0 / 0	
Archipelago Sea, outer	34.6 / 20.4	20.2 / 8.7	10.0 / 2.2	3.4 / 0.6
Åland, inner	17.0 / 5.5			
Åland, middle	25.1 / 5.0	18.2 / 4.5		
Åland, outer	47.1 / 25.8	51.0 / 29.7	36.6 / 30.4	5.9 / 0
Bothnian Sea, inner	25.6 / 13.2	12.9 / 9.7	0 / 0	
Bothnian Sea, outer	35.9 / 27.5	31.1 / 8.9	13.1 / 12.4	3.1 / 0
Kvarken, inner	2.0 / 0.3	2.4 / 0		
Kvarken, outer	13.1 / 11.4	12.0 / 11.0	2.1 / 1.9	0 / 0
Bothnian Bay, inner	1.5 / 1.5	0 / 0		
Bothnian Bay, outer	0.3 / 0.2	0.1 / 0.1	0 / 0	0 / 0

Also highest coverages of red algae were reached in Åland, and in comparison to other areas, the coverages remained high down to 15 m depth (Figure 2a). When looking only at erect red algae, the coverages were lower, approximately 20% from Kvarken to western Gulf of Finland in the 0-5 m depth. In Åland, Bothnian Sea and in Kvarken the coverage remained around 20% also in the 5-10 depth zone, while decreasing steeply in other areas. The coverages of foliose and non-filamentous corticated red algae were generally very low, with foliose algae coverages peaking in Åland and corticated red algae being highest in 5-15 m depths in Åland and in 5-10 m depths in the Bothnian Sea.

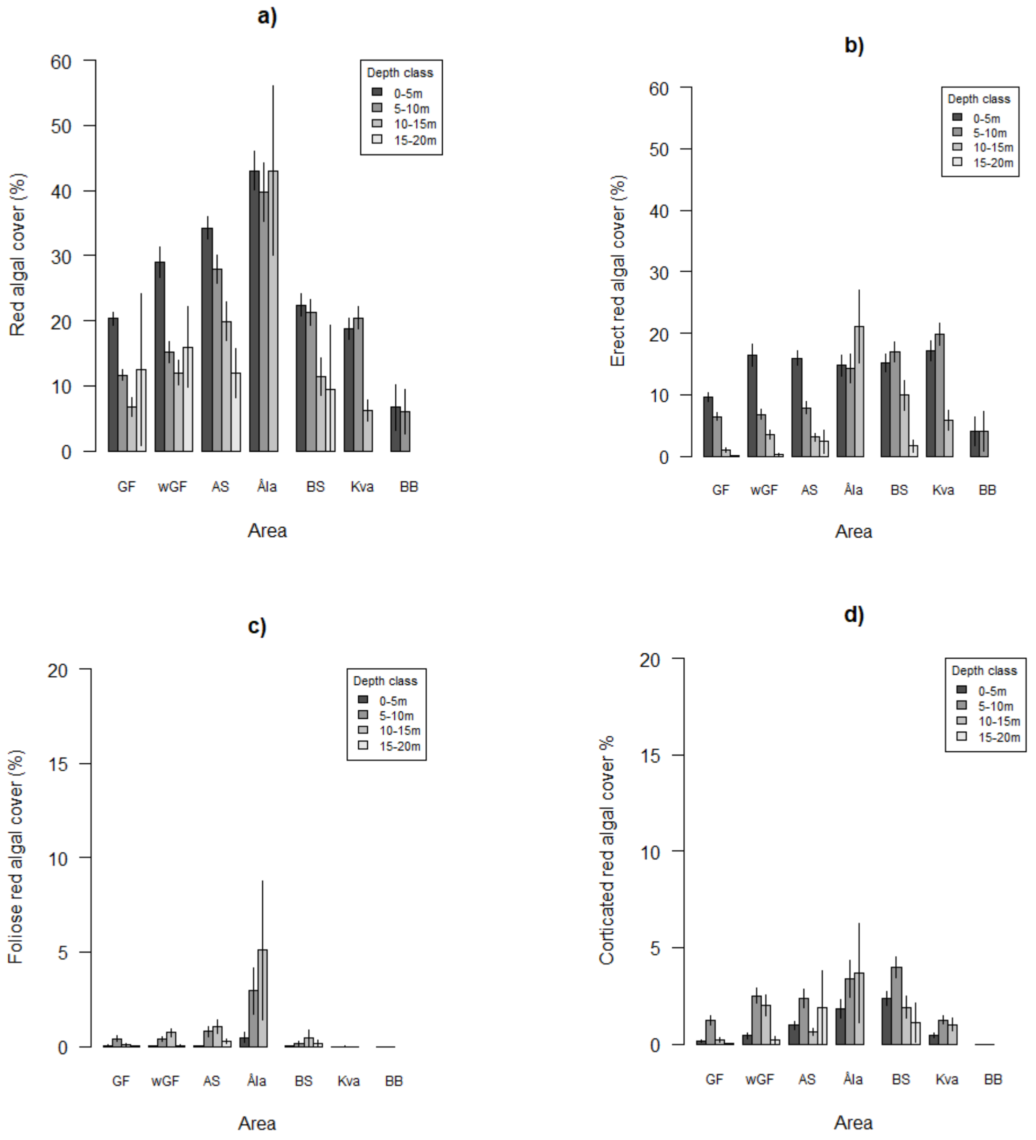

Figure 2. The % coverages (mean ±SE) of a) all red algae b) erect red algae, c) foliose red algae and d) non-filamentous corticated red algal cover at different depths in the outer archipelagos of the Finnish marine area. The mean is calculated for study sites, where red algae occurred. GF=Gulf of Finland, wGF=western Gulf of Finland, AS=Archipelago Sea, Åla= Åland, BS=Bothnian Sea, Kva=Kvarken, BB=Bothnian Bay.

The assessment of the “fate” of red algal communities in the HUB classification revealed that in the 0-5 m depth zone, red algae (in ≥10% coverages) are most often classified to *Fucus* or *Mytilus*-dominated communities, but also to communities characterized by annual or perennial filamentous algae, or even Balanidae or moss animals (Figure 3a). Less than 10% are classified to “red algal groups” i.e. to soft crustose algae or non-filamentous corticated red algae. In the deeper zones they are increasingly often classified to *Mytilus*-dominated communities. When looking at all red algae, the percentages of red algae (≥10% coverage) classified to “red algal groups” remain low across all depth groups. However, in the 15-20 m depth zone, > 30 % of the *erect* red algae (≥10% coverage) are classified to non-filamentous corticated algae (Figure 3b), indicating that only in this depth zone, the red algae are not mainly “lost in classification” due to e.g. animal taxa or perennial algae that are prioritized in the classification.

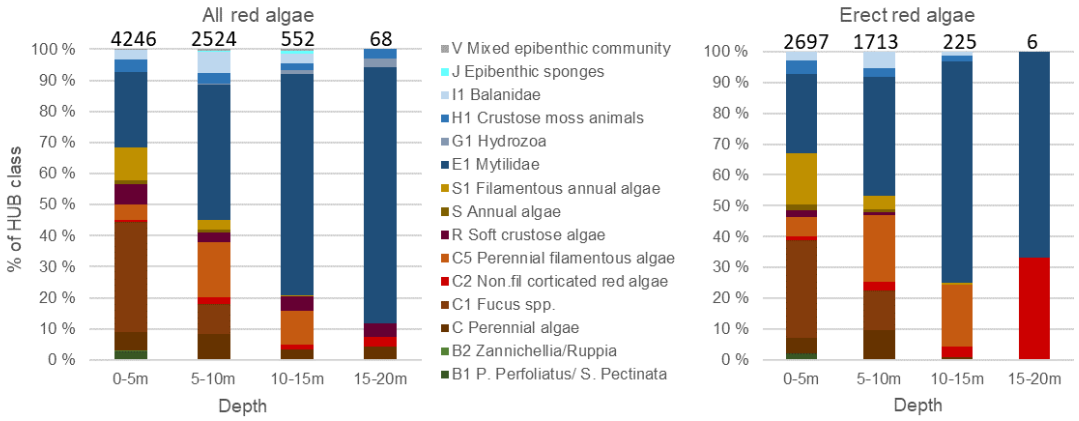

Figure 3. HUB (level 5 or 6) classes where sites with ≥10% coverage of a) all red algae and b) erect red algae are classified in the outer archipelago areas of the Finnish marine area. The number of sites per depth zone are given above bars. Only classes that had ≥10% coverage of red algae in over 10 cases across assessed depths are included in the figure.

3.3. Aquatic mosses

Aquatic mosses occurred most commonly in the outer archipelagos of Kvarken and Bothnian Bay, mainly in the 0-5 m depth zone, but also deeper (Table 3). They also occurred to some extent in the Bothnian Sea, and to minor extent in the Gulf of Finland, but were practically non-existent in the western Gulf of Finland, Archipelago Sea and Åland (only some individuals). However, sites with ≥10% occurrence of aquatic mosses were rare in all areas (0-2.5% of sites reaching such coverages), only slightly more frequent occurrence in the outer archipelago of Kvarken (Table 3).

Table 3. The percentage (%) of sites with aquatic mosses / with ≥10% coverage of aquatic mosses of all hard bottom sites in the marine areas where they occur. No aquatic mosses were found > 10 m depth.

	0-5m	5-10m
Gulf of Finland, inner	1.4 / 0.3	0.22 / 0
Gulf of Finland, outer	0.04 / 0.03	0 / 0
Bothnian Sea, inner	7.8 / 1.0	2.7 / 0
Bothnian Sea, outer	10.1 / 1.2	6.4 / 0.07
Kvarken, inner	1.7 / 0.3	0 / 0
Kvarken, outer	23.2 / 7.2	9.9 / 2.2
Bothnian Bay, inner	8.0 / 2.5	2.0 / 0
Bothnian Bay, outer	21.8 / 2.1	9.6 / 0.4

The aquatic mosses were found generally also in low coverages, their average coverage where they occurred being < 10% in all sea areas where they were common (Figure 4). The coverages were highest in the 0-5 depth zone in outer archipelago of Kvarken and generally decreased south and northwards (except for Gulf of Finland with approximately 5% average coverage but high variation).

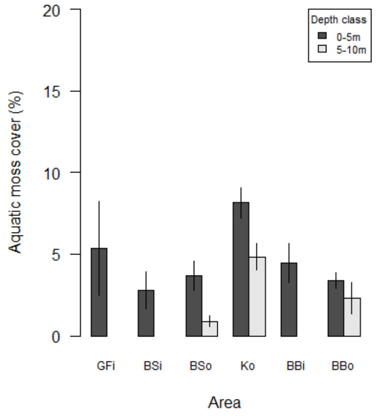

Figure 4. The % coverage (mean ± SE) of aquatic moss at different depths in the Finnish marine areas where they occur (> 10 findings / depth strata). The mean is calculated for study sites, where aquatic mosses occurred. GF=Gulf of Finland, BS=Bothnian Sea, K=Kvarken, BB=Bothnian Bay, i=inner archipelago, o=outer archipelago.

When looking into the fate of all aquatic mosses in HUB classification (all sites where they occurred included), they were mostly classified to different algal communities, either *Fucus* dominated communities or to filamentous algal communities (Figure 4a). Less than 10% were classified to aquatic moss communities. However, when looking at sites where aquatic mosses reached ≥10%

coverage, about 30% in the 0-5 depth zone were classified to aquatic moss dominated communities (Figure 4b), while the majority were classified to *Fucus* dominated communities.

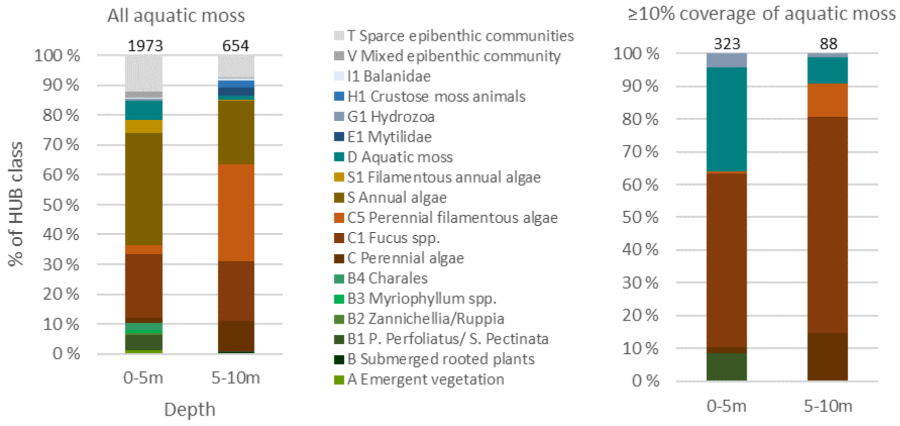

Figure 5. HUB (level 5 or 6) classes where sites with a) aquatic mosses present or b) aquatic mosses with ≥10% coverage are classified in the Finnish marine area. The number of sites per depth zone are given above bars. Only classes that had aquatic moss / aquatic mosses in ≥10% coverage in > 10 cases across assessed depths are included in the figure.

4. Discussion

Benefits of having a common biotope classification system for the Baltic Sea, or any other marine region, are undisputable. The classification system with clear division rules at every level, allowed us to classify a large amount of marine biodiversity data into biotope classes and produce coherent graphs describing the northern Baltic Sea rocky seabed communities. Using the same classification, creating coherent graphs in any other location within the Baltic Sea would be possible, allowing direct comparison over large areas.

The produced graphs show, for the first time in a quantitative way, the changes in the rocky seabed community distribution across the environmental gradients of the northern Baltic Sea. The graphs also highlight the environment-induced differences that are found in habitat characteristics of reefs and underwater parts of the Boreal Baltic islets and islands in the outer archipelago, both listed in the Habitats Directive (European Commission 2013). The baseline knowledge on the differences across environmental gradients are of relevance for example when assessing their status and designing monitoring of these habitats.

In the outer archipelago areas, the most notable pattern is the salinity driven change from the mainly *Mytilus*-dominated rocky shores in the southwest (Westerbom et al. 2002), towards algae-dominated ones when moving north and east. In the Archipelago Sea, *Mytilus*-dominated seabed was found even in 45-50 m depth (indicating at least 10% coverage) and it was the most common community type down to 25-30 m depth. It is also likely that *Mytilus* beds occur in similar depths (as in the Archipelago Sea) in Åland, where data from >25m depths were scarce, as >80% of the hard seabed was occupied by *Mytilus*-dominated communities in 20-25 m depth. In contrast, most of the rocky shores in the Bothnian Sea and Kvarken had mainly “sparse epibenthic communities” indicating total species coverages of <10% or “no macrocommunity” already at 15-20 m depths, and in the Gulf of Finland and Bothnian Bay at 10-15 m depths.

As indicated in earlier studies (e.g. Kautsky & van der Maarel 1990¸ Eriksson et al. 1998), the 0-5 m depth zone of rocky shores was dominated by different algal communities, with *Fucus* and annual algae-dominated communities being the most common ones. In the outer Archipelago Sea, where *Fucus* declined in the 1970’s (Rönnberg et al. 1985) and its proportional occurrence is still lower than in the adjacent areas (Rinne & Salovius-Laurén 2019), it seems to be replaced by *Mytilus*-dominated seabed. This shift may be due to reduced competition for space after *Fucus* disappeared, allowing *Mytilus* to increase, or it may also reflect the classification rules: when the large canopy-forming species disappears, the species underneath may become dominating, despite little or no change in its actual abundance. *Fucus*-dominated shores were most common, occupying almost 60% of hard seabed, in 0-5 m depth zone in the Bothnian Sea, while annual algae became more common towards the north.

As the algae reported as unidentified filamentous algae in the video data were classified to perennial filamentous algae in > 6 m depth, the commonly occurring seabed dominated by perennial filamentous algae in > 5 m depths in some areas (e.g. outer archipelago of Kvarken and Bothnian Sea) should be interpreted as seabed with any kind of filamentous algae. Overall, the fact that filamentous algae are divided to two different groups (annual algae and perennial algae) already at level 5 in HUB classification is somewhat problematic. As diving surveys (including sampling and microscopy) are expensive, many marine surveys are carried out using drop-video or e.g. ROV. Using these techniques, it is often impossible to distinguish between species and therefore to evaluate whether they are perennial or annual. As a result, lot of the data may contain groups such as “unidentified filamentous algae”, as the extensive VELMU data we used here. As just “filamentous algae” cannot be classified at level 5, which is the first level where meaningful biological entities are presented, the only options were either to exclude a large proportion of the data or to make an artificial division into perennial and annual species, as we did. Although the differences in characteristics of annual vs. perennial species are recognized (e.g. perennial species forming habitats with less seasonal variation), it could be beneficial if filamentous algae were first considered as a uniform group at level 5 in classification, and only at level 6 further divided to finer groups (e.g. annual vs. perennial and/or red vs. brown vs. green algae).

The inner archipelago areas had clearly more algae-dominated than *Mytilus*-dominated communities, also in the southwest, probably caused by higher sedimentation rates in the less exposed areas, leading to negative effects on *Mytilus* recruitment (Westerbom & Jattu 2006). The common occurrence of aquatic plants in the 0-5 m depth zone in all inner archipelagos was likely due to mixed substrates at sites classified as hard seabed (0-49.99% of other substrates than those classified as hard), hosting relatively large species that become dominating although their coverages do not exceed 50%. Of the inner archipelago areas, *Fucus*-dominated seabed was most common in the western Gulf of Finland. Both in the western Gulf of Finland and in the Archipelago Sea, *Fucus*-dominated communities were more common in the inner than in the outer archipelago (similar pattern observed also in Vahteri & Vuorinen 2017), which is somewhat surprising, given the species’ general preference for more exposed areas (Rinne et al. 2011).

The red algal communities are often described to form a zone below the *Fucus* belt (Waern 1952, Kiirikki 1996). Also our analyses on the commonness (Table 2) and the coverage of red algae (Figure 2) show that red algae both occur commonly (up to 47.1% of rocky shore sites) and reach relatively high coverages (up to 40% on average), especially in outer archipelago areas of Åland. Coverages of ≥10% are also very common in the outer Bothnian Sea (up to 35.9% of rocky shore study sites), and in the Archipelago Sea (up to 35.3%). Even erect red algae in ≥10% coverages occur in 25-30% of the sites in Åland (0-15 m depth) and in the Bothnian Sea (0-5 m). The coverage of all red algae in Åland is approximately 40% on average (0-15 m depths), and in the Bothnian Sea and the western Gulf of Finland about 30% (0-5m). The coverages of erect red algae in the 0-5 m zone were rather constant (~15%) from Kvarken to western Gulf of Finland and were found in similar amounts in the 5-10 m depth from Kvarken to Åland. In the 10-15 m depth zone the coverages were <10% in all other areas except for Åland, where they were about 20%. These measures suggest, that at least in Åland but also in the Bothnian Sea and in the Archipelago Sea, the red algal communities are much more frequent and reach higher coverages than would be expected based on the HUB classification results, especially in 5-15 m depths. According to the HUB classification, communities dominated by red algae reached 5% share of all communities in only one depth zone in one sea area.

One of the main reasons for the low presentation of red algal belts in the classification results is that red algae, not even the erect ones, are not considered as a joint group. Instead, already when going from level 4 to level 5 in classification, red algae are divided to 3 different groups within “the habitats characterized by macroscopic epibenthic biotic structures”; the (erect) perennial algae (including red algae such as *Polysiphonia fucoides, Furcellaria lumbricalis*), soft crustose algae (such as *Hildenbrandia rubra*) and to annual algae (such as *Ceramium tenuicorne* and *Polysiphonia fibrillosa*). Epibenthic animals and erect perennial algae are given the highest priority in classification, followed by crustose algae and finally by annual algae. Thus, any perennial algal taxa or epibenthic (sessile) fauna (*Mytilus, Electra crustulenta*) having ≥10% coverage, will override any larger coverages of crustose or annual algae in the classification (e.g. 100% cover of annual red algae). Furthermore, of the attached erect groups, it is the most dominant of the groups with ≥10% coverage that define the group at level 5. Here, the perennial red algae will be considered within the group “perennial algae”, but for example when perennial red algae appear at a site in <30% coverage, together with high coverages of annual and crustose red algae (i.e. forming the generally known red algal belt) but with

30% coverage of *Mytilus*, the site will be classified as a habitat characterized by epibenthic bivalves at level 5. Due to these classification rules, it is likely that many sites with medium to high coverages of red algae are likely to "fall off" already at this level.

When going further to level 6, it is the species/species group with ≥50% biovolume (coverage x height) that define the final class. Here, within "perennial red algae" at level 5, the red algae are again divided into 3 groups "perennial non-filamentous corticated red algae", the "perennial foliose red algae" and filamentous red algae within "perennial filamentous algae" (HELCOM 2013). As the species within both groups consisting solely of red algae are generally small in the northern Baltic Sea (*F. lumbricalis, C. truncatus, P. pseudoceranoides*), they would need to reach really high coverages to "compete" with significantly larger *F. vesiculosus* to become the group with the ≥50% biovolume that defines the class. However, their coverages are generally low (Figure 2c and d). Further, the filamentous reds are "lost" within the perennial filamentous algae.

Given the above-described divisions at different levels, it is no surprise that the red algal communities are very rare in the graphs describing variation in rocky shore communities, and they are mainly classified to other communities (as shown in figure 3). As red algae are generally small in size in relation to e.g. *Fucus*, and some of the most commonly occurring red algal species are annual (*C. tenuicorne, P. fibrillosa*), this may be justified. However, as red algal belts found below the *Fucus* belt are a well-known and a frequently reported part of the northern Baltic Sea rocky shore communities (e.g. Eriksson & Bergström 2005, Ruuskanen 2016) and they are also used as entities in different management contexts (Kotilainen et al. 2018), their underestimation in classification results may be somewhat problematic. For example, if they remain unrecognized in a classification, they are further disregarded in biodiversity/habitat maps based on the classification (as produced in Schiele et al. 2015), leading to underestimation of their contribution to Baltic Sea biodiversity. Therefore, in its current form, HELCOM HUB is not the best tool to map red algal communities, and instead, alternative ways need to be considered. If red algae were considered in larger entities, e.g. all erect perennial red algae together, they would most likely increase their proportional occurrence in relation to other HUB classes, at least below the *Fucus* zone. Furthermore, they would also better represent the generally known concept “red algal belt”, often mentioned in literature. Keeping them separate in the classification would be justified, if the different groups were recognized to play clearly different ecological roles and to have different ecological functions within the Baltic Sea rocky shores. However, so far, e.g. faunal composition within these species/species groups has been rarely studied (Wernberg et al. 2013, Saarinen et al. 2018). Thus, increasing knowledge on the ecological functions of red algal communities and as well as their role in supporting faunal communities would be important.

The coverages of aquatic mosses were generally very low in all areas where they occurred, < 10% on average. As at least 10% coverage, as well as dominance over other perennial vegetation and/or epibenthic animals, is needed to reach the class “aquatic moss” at level 5, the rare appearance of the class in the community figures is justified. Although aquatic mosses constitute the only larger perennial component of the rocky shores in areas where many larger algal species do not occur, e.g. in the Bothnian Bay, their ecological relevance on larger spatial scale, within the Baltic Sea, can be considered low. However, as the mosses sometimes occur in high coverages locally, they may host more diverse herbivore communities than the smaller filamentous algae (Ylikörkkö 2012), and therefore be of local importance.

Although HELCOM HUB classification was developed already in 2013 (HELCOM 2013), there are only few scientific studies that have assessed its applicability in presenting large scale biodiversity data (Schiele et al. 2014, Schiele et al. 2015). No studies regarding specifically habitats with hard substrate were found, and therefore, e.g. comparison of classification outcomes to other areas in the Baltic Sea, e.g. with more common and diverse (Nielsen et al. 1995, Snoeijs 1999) red algal communities, is not possible. Although their approach was different, Schiele et al. (2014), found the application of HUB feasible: all identified benthic communities on soft and sandy habitats could be assigned to HUB level 6 communities. However, some identified communities had to be grouped together to fit classification and were therefore “lost”. In accordance with our study, Shciele et al. (2014) found that the division (at level 2 in HELCOM HUB) into photic and non-photic was not necessary as the majority of the identified communities were found in both non-photic and photic benthos. We decided already when classifying the data, to omit the division into non-photic and photic, as it would have complicated the classification significantly and produced unnecessary and often artificial “boundaries”.

5. Conclusions

The HELCOM HUB offered a valuable tool to study large-scale variation in the rocky-shore communities of the northern Baltic Sea. By providing a framework to classify a large amount of mainly species-level marine biodiversity data into more manageable units, the classification made it possible to produce quantitative presentations of variation in biological communities and their proportional occurrences over large areas. Such presentations are very valuable, not only in describing habitats and communities across larger scales, but also when assessing the relative importance of different communities within and between different marine areas. Even more importantly, by being a regional Baltic Sea -wide tool, HELCOM HUB makes directly comparable assessments within the whole region possible. However, some weaknesses in the classification were identified in this study as the red algal communities of the northern Baltic Sea became almost invisible in the community graphs. This is likely not only due to the relatively small size of red algae in the region, reducing their possibilities to become dominating, but also due to their division into many “sub-groups” at different levels of the classification. By combining some of these groups (at least perennial corticated and foliose red algae, perhaps even perennial filamentous red algae) into one unit, their appearance in the community graphs would most likely increase in the sea areas, where their significant contribution to the rocky shore communities is evident. The found weaknesses highlight the need to consider the restrictions of any classification system when classified data is used e.g. in management contexts. When taxa are “lost in classification”, we might not lose just species or communities, but also some key ecosystem functions that we are not even aware of. Thus, increasing our knowledge on ecosystem functions that different species and communities have, would be essential, in order to consider also functional elements in classification systems, not just taxonomical entities.

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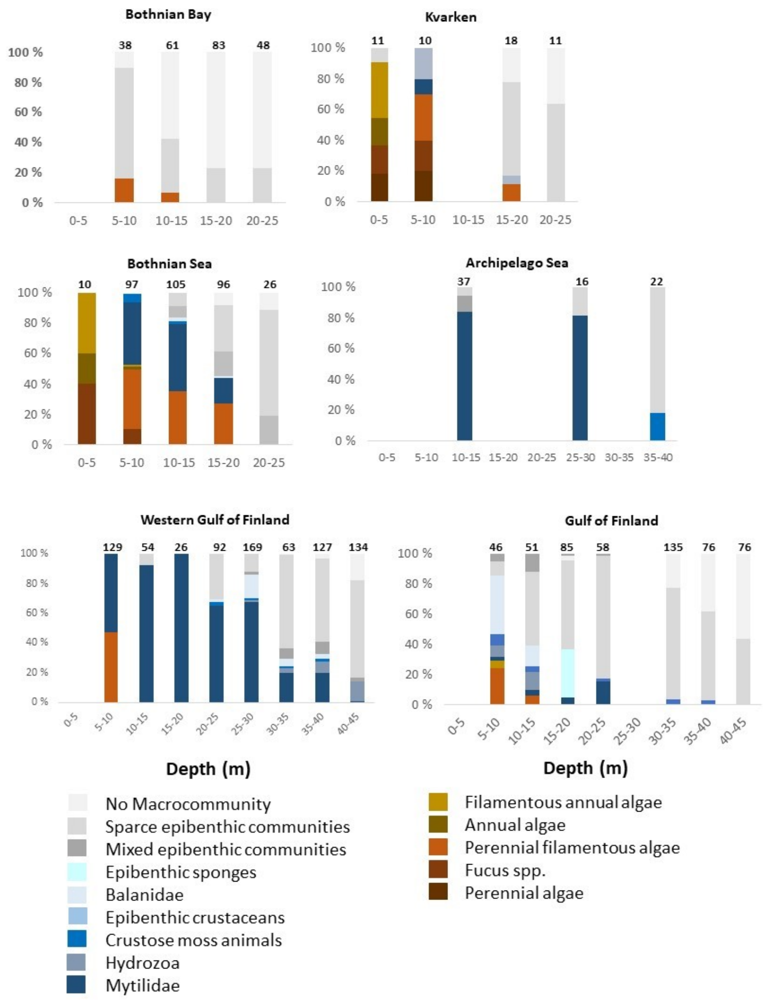

Supplement 1. The rocky bottom communities of the open sea areas, within the Finnish marine area, in different depth zones (m). See Figure 1 for division of areas. The number of sites / depth zone are presented above bars. In Åland, there was no data in the open sea areas. Depths of 0-5 m, represent actual depths of 0-4.99 m, 5-10 m are actual depths of 5-9.99 m and so on.