Video or dive?

Methods for integrated monitoring and mapping of marine habitats in the Hvaler-Koster area

A report from project Hav möter Land

Hav möter Land

Klimat vatten samhällsplanering tillsammans

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Författare: Göran Sundblad, Hege Gundersen, Janne. K. Gitmark, Martin Isæus och Mats Lindegarth
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Authors:
Göran Sundblad[1] (goran.sundblad@aquabiota.se)
Hege Gundersen[2] (hege.gundersen@niva.no)
Janne. K. Gitmark[2] (janne.kim.gitmark@niva.no)
Martin Isæus[1] (martin.isaeus@aquabiota.se)
Mats Lindegarth[3] (mats.lindegarth@havsmiljoinstitutet.se)

[1]AquaBiota Water Research
[2]Norwegian Institute for Water Research – NIVA
[3]The Swedish Institute for the Marine Environment, University of Gothenburg

Contact information:
AquaBiota Water Research AB
Adress: Löjtnantsgatan 25, SE-115 50 Stockholm, Sweden
Tel: +46 8 522 302 40
www.aquabiota.se

Distribution:
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Internet version:
Downloadable at www.aquabiota.se

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PREFACE

The present report summarises the project "Methodology for integrated monitoring and mapping of benthic habitats in the Skagerrak / Kattegat" (Metode for integrert overvåking, oppfølging og kartlegging av habitatbyggende flora og fauna på havbunn i Skagerrak/Kattegat). The project was organised by Petter Torgersen at Østfold County Council (ØFK) from September 2012 to January 2013, and thereafter by Arne Kjellsen at The County Governor of Telemark towards the end of the project at 1st of March 2013. Project leader was Hege Gundersen at the Norwegian Institute for Water Research (NIVA). AquaBiota Water Research by Martin Isæus has been subcontracted to NIVA, where Göran Sundblad has performed most of the analysis and reporting efforts. From NIVA Janne K. Gitmark, Kjell Magnus Norderhaug and Camilla W. Fagerli performed the fieldwork. The video analyses were performed by Janne K. Gitmark and Andrea Johansson (University of Gothenburg, GU).

NIVA has in this project, which has been called "the HvalerKoster-pilot" (NIVA project no. O-12317) conducted a pilot study in the form of a survey of benthic flora and fauna of Koster and Hvaler national marine parks, and a description of the arrangements for implementation of methods that are potentially suitable for future environmental monitoring in the Kattegat-Skagerrak area.

The data from the fieldwork and video analysis were submitted to ØFK on the 30th of November as stated in the agreement.

We want to acknowledge Arne Kjellsen, Petter Torgersen and Johan Erlandsson from Sea meets land (Hav möter land), thematic group 2:3, Environmental Monitoring, and thank them for good cooperation throughout the project.

Oslo, 19.02.2013

Hege Gundersen

CONTENTS

EXECUTIVE SUMMARY

In order to prepare for integrated monitoring and mapping in the marine national parks Ytre Hvaler and Koster at the Norwegian-Swedish border this pilot study has evaluated alternative drop video techniques and diving observations in terms of taxonomic resolution, precision and cost. The report further gives recommendations regarding sampling design and the expected effort required for a certain precision is given using a specific drop video technique. Lastly the report highlights how monitoring and predictive mapping may be integrated by providing examples of species distribution modelling using various sampling designs.

Two drop video techniques were initially compared, Free and Guided. The Guided technique, whereby ten randomized stops are analysed quantitatively and the entire film qualitatively, was shown to be less dependent of the person analysing the film, thereby providing a more precise estimate compared to Free interpretation. Taxonomic resolution was substantially better when diving compared to video, yielding about twice as many vegetation taxa and seven times as many animals. The difference between video and dive increased with diversity, and although video appeared to capture relative diversity, diving is required for certain identification of individual species. However, in terms of cover, video and diving largely identified the same dominating habitat forming groups. Similarly, the more comprehensive comparison from the related "Visual methods project" could in general not find any difference between Free video and dive regarding repeatability and uncertainty in terms of cover estimates. No comparison of uncertainty and repeatability between the Guided video technique and diving could be performed and the suitability of the Guided technique for other areas needs to be further evaluated.

A stratified sampling design clearly reduced the effort needed for attaining a normally accepted precision and power in terms of monitoring cover and diversity. On hard substrates between 0 and 15 m depth, precise estimates may be obtained with as low as 100 stations for a majority of habitat forming taxa. Combined with estimated costs, this was roughly equivalent to a minimum of 75-95 person hours under optimal conditions. However, there is a risk of underestimation over a 6 year assessment period (in relation to the WFD) since not all issues of total uncertainty has been covered. Future studies need to address the uncertainty related to temporal dynamics.

Integrating predictive mapping and monitoring is feasible, both regarding occurrence and abundance distribution. Although there are some conflicts regarding the benefits of stratification versus random sampling, there are suitable modelling techniques for these kinds of data available. It is important to note however, that if the aim is to obtain full coverage maps of both the qualitative distribution and quantitative abundance the effort would have to be increased compared to the minimum requirements outlined above.

INTRODUCTION

Description and purpose of the study

The overarching purpose of the project was to evaluate methods for monitoring and mapping of habitat supporting benthic flora and fauna in the Skagerrak / Kattegat in terms of precision and costs. The study has compared alternative video methods with traditional diving methods in terms of taxonomic resolution, uncertainty, precision and cost effectiveness in order to provide a pilot study for the future monitoring of the marine national parks Ytre Hvaler and Koster at the Norwegian-Swedish border. Recommendations regarding sampling design and efforts are given using a specific drop video analyses technique.

The Hvaler-Koster pilot is a project under "Sea meets Land", which is an Interreg IVA Project owned by Østfold county. One of the primary aims of Sea meets Land is to work towards harmonized water management and environmental monitoring in the Nordic countries, which is further supported by this collaboration between the Norwegian NIVA and the Swedish AquaBiota.

Background

The need for standardized methods for monitoring and mapping of habitat-forming species has been identified in a variety of contexts. These contexts include e.g. monitoring of protected areas, biogeographic monitoring under the Habitats Directive, monitoring under the Marine Strategy Directive and as a knowledgebase for marine spatial planning. Many have pointed at the potential use of visual methods, such as various types of video or still image techniques, as they are generally considered cost effective in the sense that many samples may be collected over broad scales in relatively short time. Several examples of variations of such methods exist, but thorough "cost-benefit" analysis, analysis of precision and bias and explicit testing of various alternative protocols and sampling designs are lacking.

There are various on-going initiatives relating to monitoring and mapping using visual methods. As specified by the assignment, this project has had a particularly close contact with a Swedish project called "Visuella metoder" (Visual methods), which has had similar objectives as well as overlapping project members. The Visual methods project has evaluated and optimized data collection from video by comparing both free and still-image analysis, as well as diving observations, in terms of uncertainty, precision and cost. Although the goals and aims of the Hvaler-Koster pilot and the Visual methods project to a large extent overlapped, this project had a later starting date. The later date allowed us to test an additional design of extracting information from video data, thus complementing the findings in the Visual methods project. Also, the Hvaler-Koster pilot had an additional overarching aim of showing how a video method can be used for integrated monitoring and mapping.

The focus of the Hvaler-Koster project, as well as the Visual methods project, has been the distribution of habitat forming species, e.g. various dominant or sensitive macroalgae, eelgrass and mussels that can be visually estimated from video samples. The reason for this focus has been the ecological importance of habitat forming taxa as well as the management aspect of a unifying methodology for compliance with various directives such as the Marine Strategy Directive and the Water Directive, although specific indicators have not yet become operational.

Research institutions

Norwegian Institute for Water Research (NIVA)

NIVA is the leading resource centre for aquatic related issues. NIVA contributes to water related professional expertise and information dissemination among professionals, politicians and the general public and increasingly contribute to the solution of international water matters.

NIVAs research and development work include surveys and assessments of conditions in rivers, lakes, groundwater, fjords and coastal waters from an ecosystem perspective. In addition, NIVA performs environmental engineering research in water treatment, industrial processes and biotechnology aimed at finding practical solutions to environmental problems in aquatic systems. The institute is also working to improve methods for integrated water resource management and prepare action plans to improve the environment.

AquaBiota Water Research

AquaBiota Water Research (AquaBiota) is a Swedish research company with a marine focus. Since its inception in 2006 the company has largely served as a competence centre for marine management in Sweden and has participated in several major EU projects with a marine focus. AquaBiota specialises in fieldwork, analysis and modelling of the marine environment and about 75% of the employees have attained a Ph.D. AquaBiota participates in the Visual methods project, financed by the Swedish Agency for Marine and Water Management, that share many similarities with this project.

Content of the study

The Hvaler-Koster project can primarily be considered a pilot study that describes the design and methods relating to future monitoring of the marine national parks Hvaler and Koster. The work includes fieldwork (preparing and conducting it), analysis of video films, preparation of data, statistical analysis, data delivery and reporting of findings. The report consists of:

- An assessment of the differences in precision and cost for different strategies of video interpretation

- An assessment of the differences in taxonomic resolution between video and diving (but see also the Visual methods project (Gullström et al. in prep.) for a more comprehensive comparison)
- Monitoring benthic habitats
    - Mapping of variables of particular importance for the management of the Hvaler / Koster area
    - An assessment of the uncertainty and effort needed for monitoring relevant variables at a certain precision in relation to environmental conditions
    - Proposed method description for meeting monitoring and management objectives, including expected uncertainty and associated costs
- Integration of monitoring and predictive mapping using species distribution modelling

METHODS AND MATERIALS

Field design and sampling

Following the project plan, an initial 180 stations were randomly stratified by depth in equal proportions between the two marine parks. In each park, we randomly allocated 30 stations at each of three depth strata, 0-5, 5-15 and 15-30 metres respectively, as defined by available bathymetric maps.

The field campaign lasted September 19-21 (video) and 24-26 (dive + video). Weather and wave conditions during this time were rough and delayed the sampling and reduced the total number of video locations from 180 to 150 stations (Fig. 1), although it was still made within the planned time frame (end of September).

Drop video sampling

The positions for the pre-selected stations were plotted on a GPS and sampling began when the position was within 10 m. The camera was lowered to the substrate, whereby a new waypoint was taken. In order to film approximately 5x5 metres the driver of the boat tried to remain within a 5 m radius of the new waypoint. However, weather and wave conditions during this time were rough and the filmed area therefore varied. At the end of each film a secondary waypoint was marked, potentially allowing distance analyses to be performed. A few of the preloaded stations were on land or in places the boat was unable to reach due to weather conditions. A new station was then placed as close as possible to the originally intended one, but some had to be omitted completely.

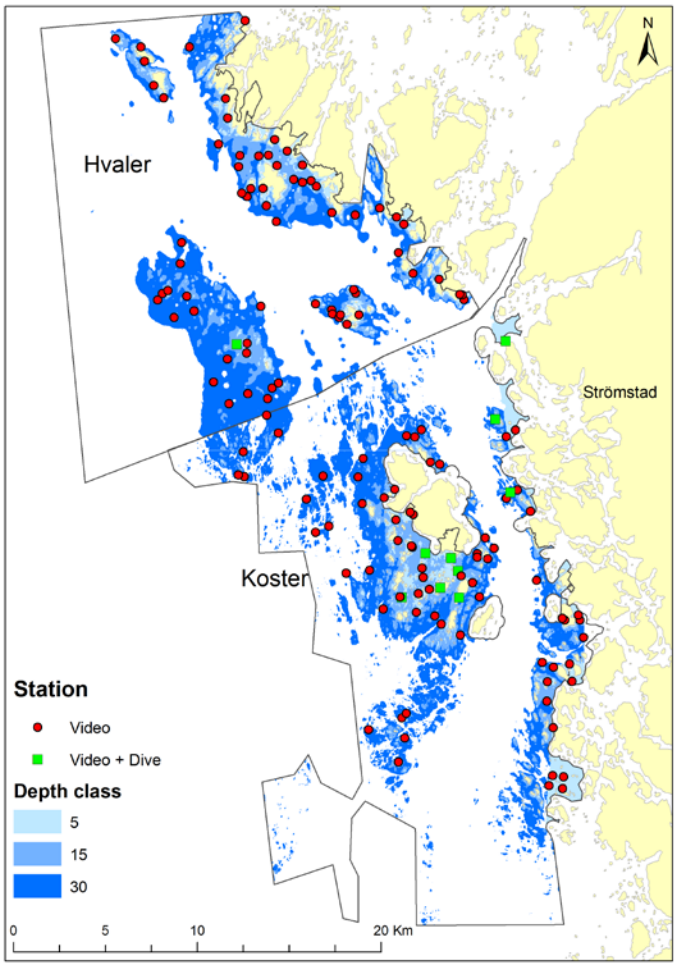

Figure 1. The extent of the marine parks and the spatial distribution of sampled stations.

Diving

The selection of diving stations was based on recordings from the films. Before sampling a lead line was posted in a 5x5 m square, in accordance with the Visual methods project. The corners were marked with floating buoys, GPS position and depth was noted. Surveying was done by the divers moving in a zig-zag pattern across the square. At each station, substrate type and percentage cover of macroscopic algae and sessile or slow moving animals were noted. Two of the proposed dive stations proved to be unsuitable for diving due to large exposure to waves and were reallocated, and also filmed using the method above.

Of the 150 stations, 10 were also sampled using divers, 5 were dominated by hard substrates and 5 were dominated by soft substrates. Two parallel divers noted the cover of fauna and flora, respectively. At three stations an additional diver, i.e. two divers, noted the cover of fauna (Table 1).

Nine of the 10 dive stations were used in an initial comparison of two drop video analysis techniques (Video lab in Table 1), aimed at estimating uncertainty and precision between and within readers in order to complement the Visual methods project.

Table 1. *Station ID (waypoint) per method and analyst (person A:D) for the 10 stations that was analysed with more than one method. The total 150 stations, including these 10, were analysed by Person A after the initial comparison of two drop video techniques.*

Method	Dive (fauna)		Dive (flora)		Video lab (flora+fauna)	
Person	C	D	A	D	A	B
Station ID		41		41		
	97	97	97		97	97
		113	113		113	113
	115		115		115	115
	136		136		136	136
	139		139		139	139
	145	145	145		145	145
	149		149		149	149
	274	274	274		274	274
	277		277		277	277

Initial comparison of drop video analysis techniques

In an initial comparison we compared two techniques for extracting information from film analyses, Free and Guided. The setup was similar to that in the Visual methods project and consisted of two readers analysing each movie twice, using both techniques. The Free interpretation was used also in the Visual methods project, while Guided had not been tested and was included as a complement also for that project. The order of films was randomized.

With the Free technique the reader watches the whole film and notes the percentage cover of all taxa that can be identified. Additionally, the percentage cover of soft and hard substrate as well as the amount of unvegetated substrate was also noted. Maximum cover per taxa and substrate was 100, although the total sum may exceed this if the vegetation consists of several layers. Since the analyses are done in the lab it is possible to pause and rewind as deemed necessary by the reader.

With the Guided technique the film is divided into ten equally long parts. Within each part the reader stops the film at a random time and uses a grid with 10 points to aid (guide) the estimated cover. That is, the estimated cover per film (station) is based on ten stops, each with ten points. Hence 10 was the maximum cover per stop, which was corrected for in the subsequent analyses. All taxa behind at least one point were noted in the protocol, as well as the point-estimated cover of soft, hard and unvegetated substrate. The guided method was a modified version of methods used to monitor cover and diversity of corals in Australia (Hill and Wilkinson 2004).

The comparison between Free and Guided consisted of 9 stations (out of the 10 that were also sampled by divers, Table 1).

A total of 30 unique taxa, of different resolution, were summed in a number of variables that were meant to reflect habitat forming biotopes that have the potential to be identified by video. Variables were partly selected to target particularly important variables as identified by the county administration board of Västra Götaland and the Swedish Environmental Protection Agency in the management plan for the Kosterhavet National Park (Naturvårdsverket 2009). Two of the variables aimed to measure the same thing but were estimated in different ways. The first one, Total Cover, was calculated as the sum of all vegetation, while the other, Vegetated substrate, was calculated as the inverse of the estimated unvegetated substrate. Additional indicators were the cover of non-filamentous algae, filamentous algae, total cover of red macroalgae, total cover of Fucaceae, total cover of kelp and the cover of *Zostera*. Additionally we included one measure of diversity in this initial analysis, the number of vegetation taxa.

Comparison between drop video and dive data

Taxonomic resolution was compared using the 10 stations where both diving and video using the Guided technique was performed, i.e. from the second round of analysis of all videos. The comparison is primarily intended as a qualitative assessment of the taxonomic resolution with different methods. Although it may be difficult to compare directly, as the two methods are based on two different ways of assessing cover, we also show the mean cover of individual taxa as the relative rank within methods should be comparable.

Predictive mapping of benthic habitats using video

In order to assess the effect of stratification on the ability to predict habitat distribution and abundance we fitted distribution models for the full dataset (n=143) as well as for

the proposed stratified dataset (n=54). Both qualitative, i.e. occurrence, and quantitative, i.e. abundance (cover/diversity) models, were fitted using generalized additive models (GAM, Wood 2006) via the 'mgcv' library in R. GAM is a flexible, semi-parametric technique that uses smooth functions to describe species-environment relationships. The relationships were initially allowed a maximum flexibility using 4 degrees of freedom but the resulting relationship was based on an integrated model selection that penalizes the smooth (Wood and Augustin 2002). Continuous environmental variables were field measured depth and modelled wave exposure (Isæus 2004). Percentage cover of hard substrate was also used for the full dataset, but not for the stratified since all stations was then dominated by hard substrate. Response variables were selected based on the mean and occurrence frequency (i.e. prevalence) in the two datasets in order to represent taxa going from rare to commonly occurring as well as going from low to high mean cover in the full and stratified datasets. Responses were also chosen to represent both flora and fauna. In addition, two response variables that could only be modelled using either occurrence (binomial) or abundance (Poisson) distributions were included. Model fit was evaluated using the amount of explained deviance (i.e. the proportion of the null deviance, a measure equivalent to explained variation) and internally evaluated AUC and normalised RMSE (area-under-curve and root-mean-square-error, respectively). AUC is a standard measure for evaluating discriminatory power for occurrence models. It ranges between 0.5 and 1, where 1 equals perfect discriminatory ability and 0.5 equals chance. Values above 0.7 is often considered useful and above 0.8 as good and above 0.9 as excellent. The RMSE is a measure of the error in abundance models, so that low values are small errors and vice versa, on the original scale of the measurements. Normalisation was done by dividing by the mean in order to ease comparison between datasets and is thus a measure of the percentage error in relation to the mean (nRMSE).

RESULTS AND DISCUSSION

Initial comparison of drop video analysis techniques

Precision and uncertainty

The initial assessment of comparing means of all squares between and within readers suggested that the difference within a person, i.e. between readings, was most often small, for both techniques. However, the difference between readers was in general larger using the Free technique compared to the Guided technique. Also, this difference seemed to be larger with higher mean cover (Appendix 1 Taxa overall).

By plotting the two readers estimate against each other we could assess the reason for this difference by looking at the slope of the regressions. This suggested a tendency for one reader to generally set higher cover than the other reader with the Free technique, while the Guided technique tended to be more similar to the expected 1:1 line (Appendix 1 Regression readers).

In order to assess the precision and uncertainty associated with different sources, linear mixed models in the statistical software R (version 2.8.1) and the package lme4 were used to obtain variance components. We focused the comparison on the total uncertainty related to a single station that would be analysed by one reader at one occasion, as the objective of this pilot was to recommend a method for further analysis of the remaining stations. This uncertainty was expressed as the coefficient of variation (CV = sd / mean) based on the variance components, thus taking into account the mean of the variable of interest. Other sources of uncertainty are however obtained simultaneously, such as the variance associated with differences between stations, readers and the interaction between them. Overall the difference between techniques was not large, except when the average total cover was very low (<5 %). In the cases where the estimates were more certain, i.e. higher averages, and the differences in CV were larger than 5-6 % the analysis suggested that Guided had a small advantage over Free. That is, there seemed to be less uncertainty associated with an analysis of a single station using Guided than Free. One could also note that the largest source of uncertainty was, as expected, the spatial component of differences between stations.

Importantly, the precision among readings within method and reader (i.e. the within person precision) was strongly dependent on reader with the Free technique. That is, one reader was very precise between readings, while the other reader tended to have less precision among readings. On the other hand, with the Guided technique, the within reader precision was more similar between readers than with the Free technique, which is important if the monitoring method should be repeatable and have a similar precision regardless of who performs the analysis. Or put in other words, although the average within-reader precision is slightly higher with the Guided technique, it is less dependent on a specific reader, strongly suggesting that the Guided technique is a more repeatable and thus better method in a monitoring context (Fig 2).

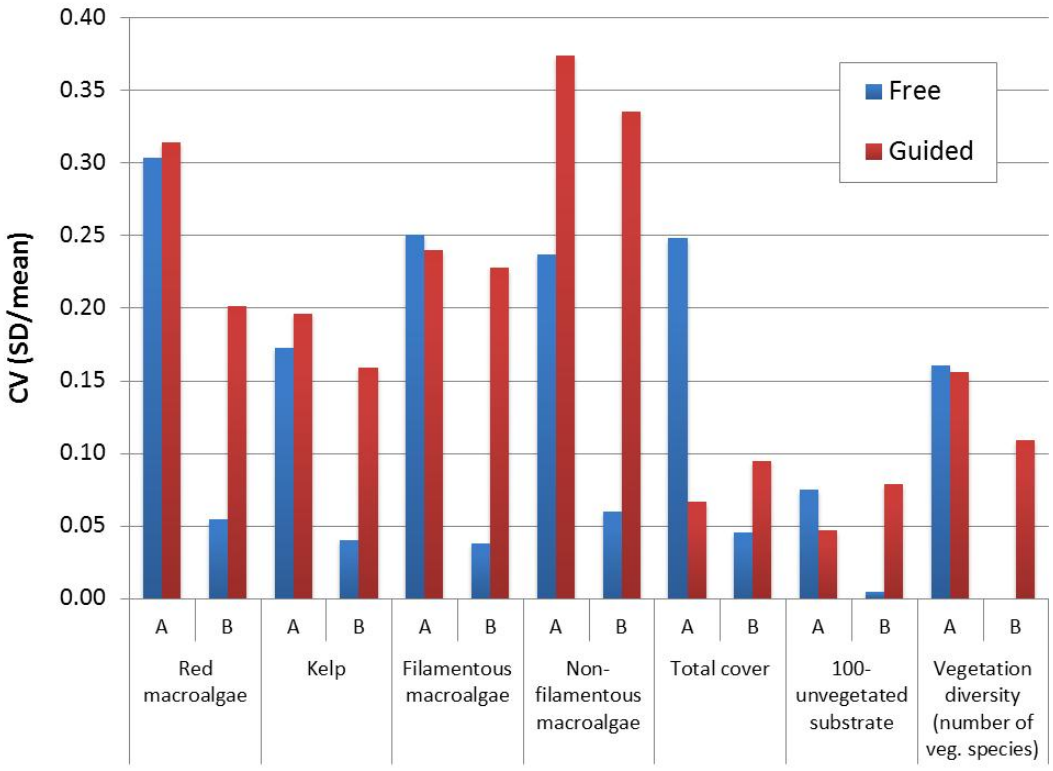

***Figure 2**. Precision, measured as Coefficient of Variation (CV) among readings within method and reader. The precision within reader was more dependent on the reader (A and B) using the Free technique (blue bars) than using the Guided technique (red bars). Bar pairs of similar heights show good repeatability.*

Costs

Looking at the time spent on analysis, i.e. the cost, there was a small advantage for the Free technique compared to the Guided, but the variation was lower with Guided suggesting that the estimated time required for a certain effort is more predictable (Fig 3).

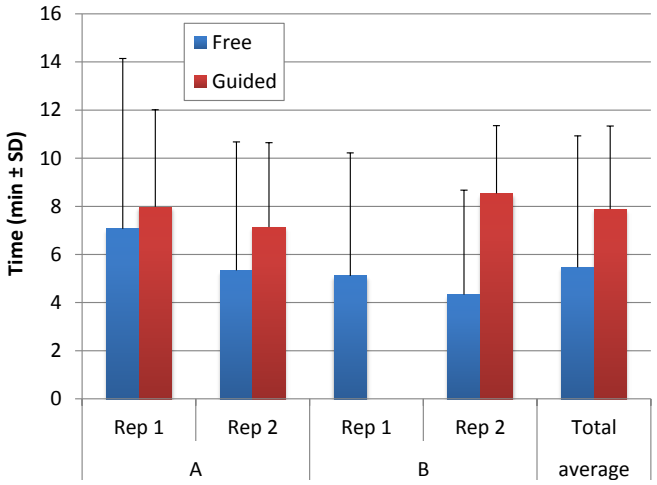

***Figure 3**. Cost, measured as time, for the two techniques Free and Guided from the initial comparison (n=9 stations). The average time spent analysing one station was slightly higher with the Guided technique (7.9 min ± 3.5 SD) compared to the Free technique (5.5 min ± 5.5 SD) but the variation was lower.*

Summarising the results it appeared that the most suitable method for the continued analysis of the remaining stations was the Guided technique. However, the analyses showed that the primary diversity measure

used up until now, the number of vegetation species, was not fully captured using the Guided technique. This was primarily due to the fact that the estimate was based on 10 stops and only 10 points at each stop, allowing taxa to be excluded if they were not directly behind a point. To solve this problem we decided that the reader should note the presence of all identifiable taxa during the time in between stops, i.e. assessing diversity throughout the whole film.

In conclusion, based on these initial analyses of different methods to extract information from video sequences we suggest that an approach consisting of qualitative estimates of diversity (presence or absence of species) covering the entire length of the film, and a guided quantitative estimate of covers based on ten replicate stops, thus utilising all the information available in the film, was the most appropriate for further analyses of the remaining films.

Comparison between drop video and dive data

The Visual methods project, with which this study has been collaborating, has performed a comprehensive comparison between dive and drop video data, analysed with different techniques (Gullström et al. in prep.). They conclude that in terms of estimating various organisms cover and distribution, diving and drop video had similar precision (using the same criteria as in this report, see below). Also, repeatability between readers (analysts) regarding cover estimates was in general similar between dive and drop video methods. However, the drop video analysis technique used in that comparison was the equivalent of Free rather than the technique we recommend in this report, i.e. the Guided method, which in this study had an increased repeatability compared to Free. Unfortunately, a comparison of repeatability between Guided and dive data was not possible since there was only one diver who estimated cover of flora and fauna respectively (Table 1). The biggest differences between dive and drop video observed in the Visual methods project were related to costs and taxonomic resolution. The time required in the field, in the lab and in total differed between the east and west coast of Sweden, requiring more time with increased complexity (i.e. west coast). The total time required was between two and three times higher when diving compared to drop video sampling, but a larger number of taxa, and with higher taxonomic detail, was found using diving than video.

Taxonomic resolution Koster–Hvaler

As expected, divers found higher numbers of observed taxa and at a higher taxonomic resolution, similar to the Visual methods project (Gullström et al. in prep.). Regarding fauna diversity, the quantitative estimates from the video (based on 10 stops) noted a total of only 4 separate taxa, while the qualitative estimates using the entire film noted 9 (including the 4 from the quantitative stops), showing that there is much to be gained by including diversity estimates from the entire film. In comparison, diving resulted in 61 taxa on substrates and 23 as epiphytes and a total of 66 unique taxa (excluding fish). Details are found in Appendix 2, Taxonomic resolution video:dive fauna.

Similarly for vegetation, the number of taxa was higher when diving than using video (Appendix 3, Taxonomic resolution video:dive flora). A total of 52 taxa was found when diving, of which 46 was found on substrates and 27 as epiphytes. The total number of taxa found with video was 27 using the qualitative part of the film and 22 in the quantitative stops, again supporting the benefit of analysing the whole film for diversity. The same number of taxa (11) of red algae (Rodophyta) and brown algae (Phaeophyceae), was found using video, while diving showed a much higher diversity of red algae than brown. Although the total number of taxa was about twice the number identified by video, it appeared that video was still able to relatively separate high and low diversity. Stations where divers noted high diversity also had the highest diversity using video, but the diversity was on average three times as high for a given station using divers (Fig 4). However, the difference between methods increased with diversity, suggesting that individual taxa are to a larger extent overlooked by video in high diversity areas. This difference was probably likely due to an increased ability to assess different layers and more closely look for small growing or rare taxa when diving. This pattern was also seen in the Visual methods project (Gullström et al. in prep., fig. 2), although the slope of the regression was slightly different (i.e. smaller difference between methods).

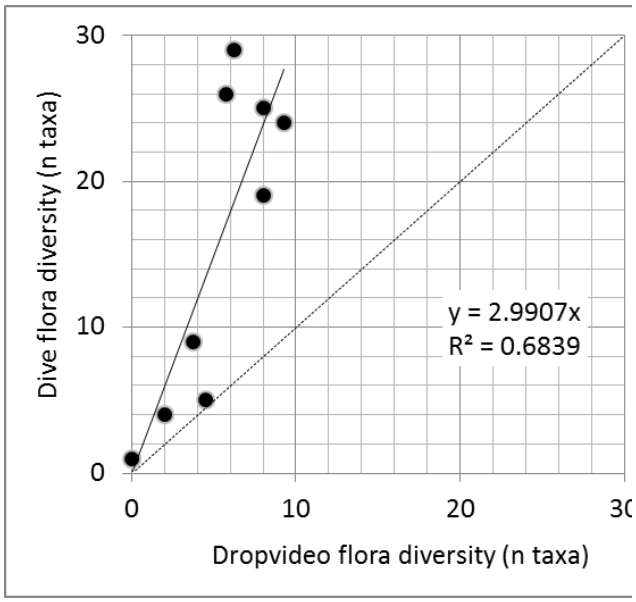

Figure 4*. Diversity at 9 overlapping stations using drop video and dive analysis. Diving identified more taxa than drop video and the difference increased with diversity. A similar pattern was seen in the Visual methods project (see text).*

Qualitatively there was an apparent, and expected, difference between the two methods. For instance, video identified the genus *Cladophora* sp., while divers distinguished *C. albida* and *Chaetomorpha melagonium*. Similar patterns were also apparent with the complexes *Pyllophora/Coccotylus*, *Polysiphonia/Ceramium* and *Sphacelaria* sp. in video, which were separated into separate species when diving (Appendix 3, Taxonomic resolution video:dive flora).

Quantitatively, diverse red algae had the highest mean cover using video, while for diving *Polysiphonia elongata* had the highest mean cover (except *Corallinaceae*), suggesting that the two methods identify the same type of (upright growing) biotope as the most commonly occurring one. This suggests that although the number of taxa is generally more than double in this area using diving techniques, the patterns at lower taxonomic level (i.e. habitat forming species or biotopes) may be identifiable using video methods. Also, one of the major issues is deciding the required taxonomic resolution.

What level of detail is necessary for the question at hand, e.g. assessing and monitoring environmental status?

Monitoring of benthic habitats using video

In the subsequent section the whole dataset was utilised to assess features that are important for potential monitoring and integrated mapping of benthic habitats in the Hvaler-Koster area. Of the 150 stations we excluded 7 stations where the 10 quantitative stops were not possible to obtain (due to bad weather conditions that reduced the length of the films) or due to the stations being situated to deep, thus leaving 143 stations (final dataset) for the analysis and design of a potential monitoring program. Films from all stations were analysed using the guided technique, i.e. using 10 quantitative stops and a qualitative notation of observed taxa along the entire length of the film. The 143 stations were distributed along the depth gradient in the following way, 0-5 m 22 stations, 5-15 m 70 stations and 15-30 m 51 stations. The distribution and cover (based on the 10 quantitative stops) of the habitat classes are given in Appendix 4.

Mapping of variables of particular importance for the management of the Hvaler-Koster area

Drop video is a suitable technique for assessing the distribution of habitats, biotopes or species clusters, rather than describing the distribution of single species unless they are easily identifiable. Therefore the analyses are focused on the distribution of a set of combined habitats (i.e. biotopes or characteristic species) meant to reflect various taxonomic and/or ecological groups.

In total 23 faunal and 40 floral taxa were observed, and subsequently grouped into representative "habitat classes", divided into flora, fauna and diversity (Table 3). Floral classes encompassed 10 different habitats as well as two measures of total cover and also the amount of hard substrate. Attached fauna was similarly to flora assessed by its cover (i.e. by counting the number of points at the 10 quantitative stops), but as most taxa were rare further analyses included only taxa above 10 % prevalence. Diversity was measured using both the quantitative stops and the qualitative assessment, and diversity was divided into five groups (Table 3).

Similarly to the reduced dataset used in the comparison with dive data (Table 1, n=9) the most commonly occurring taxa was 'various red algae', which was found at 62 % of the stations and with the highest mean cover (17 %) across all stations. However, the total number of observed floral taxa increased from 27 to 40 and faunal taxa from 9 to 23 with the final dataset, suggesting that the comparison between dive and video was made in a subset of the various habitat types found between 0 and 30 m depth in the Hvaler-Koster area. It further suggests that a relatively large number of taxa can be identified using drop video, at least when a person with experience of both diving and video does the analyses as was the case here. Based on typical species associated with habitats listed in the Habitat Directive, the Visual methods project has produced a list of

species, including taxonomic resolution, that one can expect to identify when using drop video (Gullström et al. in prep.).

There is probably room for improved quality in taxonomic identification and thus decreased uncertainty in estimation of diversity and cover. In particular, effects of unsteadiness of the camera due to waves sometimes caused the quality of video sequences to be very poor. Some of these problems may be alleviated by using more standardised methods in the field, for example by sampling only at calm weather or using some arrangement to drag the camera along the bottom.

***Table 3**. Taxa found with video using the final dataset (n=143). The column 'No. of stations' is based on both quantitative stops and qualitative presence notation along the entire length of the film. Prevalence (Prev.) is the occurrence frequency. Mean cover is based on quantitative stops only and na indicates that the taxa was only found in between stops. Associated habitat classifications are given for each observed taxa.*

Taxa	No. of stations	Prev. (%)	Mean cover (%)	Habitat class	Fil. algae	Perennial macroalgae	Perennial macroalg. (no fil. alg.)	Kelp
Corallina officinalis	12	8	0.1	Encrust				
Cruoria sp	23	16	0.05	Encrust				
Hildenbrandia rubra	2	1	na	Encrust				
Litothamnion sp	86	60	9.7	Encrust				
Brown encrusting algae	17	12	0.03	Encrust				
Various red algae	89	62	16.5	Red				
cf Callithamnion sp	2	1	0.01	Red	x			
Chondrus crispus	9	6	0.1	Red		x	x	
Delesseraia sanguinea	26	18	0.5	Red		x	x	
Delesseria/Phycodrys	53	37	2.1	Red		x	x	
Phycodrys rubens	1	0.7	0.1	Red		x	x	
Dilsea carnosa	39	27	0.9	Red		x	x	
Furcellaria lumbricalis	30	21	0.7	Red		x	x	
Phyllophora/Coccotylus	44	31	0.3	Red		x	x	
Phyllophora pseudoceranoides	5	3	0.1	Red		x	x	
Polysiphonia/Ceramium	25	17	1.6	Red	x	x		
cf Polysiphonia elongata	11	8	0.1	Red	x	x		
Polysiphonia elongata	7	5	0.04	Red	x	x		
cf Rhodomela confervoides	17	12	0.2	Red	x	x		
cf Trailiella intricata	46	32	0.8	Red	x	x		
Various filamentous brown algae	7	5	0.05	Brown	x			
cf Asperococcus	1	0.7	na	Brown	x			
Chorda filum	13	9	0.7	Brown				
Chordaria flagelliformis	3	2	na	Brown				
Desmarestia aculeata	31	22	0.6	Brown		x	x	
Ectocarpales	13	9	0.4	Brown	x			
Fucus serratus	10	7	1.9	Brown		x	x	

Cont.

Taxa	No. of stations	Prev. (%)	Mean cover (%)	Habitat class	Fil. algae	Perennial macroalgae	Perennial macroalg. (no fil. alg.)	Kelp
Fucus sp	1	0.7	0.1	Brown		x	x	
Halidrys siliquosa	19	13	1.5	Brown		x	x	
Laminaria hyperborea	51	36	9.8	Brown		x	x	x
Saccharina latissima	27	19	1.5	Brown		x	x	x
Laminaria sp. juvenile	4	3	0.1	Brown		x	x	x
Sargassum muticum	7	5	0.2	Brown		x	x	
Sphacelaria sp	1	0.7	na	Brown	x	x		
cf Acrosiphonia	1	0.7	na	Green	x			
Cladophora sp	3	2	0.01	Green	x			
cf Cladophora rupestris	11	8	0.03	Green	x			
Ulva sp. (Enteromorpha)	1	0.7	0.01	Green	x			
cf Ulva lactuca	4	3	na	Green				
Zostera marina	3	2	1.0	Zostera				
Loose lying algae	32	22	2.1	Loose				
Arenicola marina	12	8.4	0.11	Fauna				
Actix on zozma	1	0.7	na	Fauna				
Alcyonium digitatum	17	11.9	0.04	Fauna				
Ascidier	4	2.8	0.04	Fauna				
Asterias rubens	53	37.1	0.09	Fauna	Asteroidea			
Balanus sp	3	2.1	na	Fauna				
cf Crania anomala	1	0.7	0.03	Fauna				
Cariophylla smithii	10	7.0	0.03	Fauna				
Ciona intestinalis	1	0.7	0.01	Fauna				
Crossaster papposus	2	1.4	0.01	Fauna	Asteroidea			
Dynamena pumila	1	0.7	na	Fauna	Hydroida			
Yellow sponge	35	24.5	0.09	Fauna	Porifera			
Halichondria panicea	15	10.5	0.21	Fauna	Porifera			
cf Halecium halecinum	1	0.7	0.03	Fauna	Hydroida			
Hydroids	21	14.7	0.04	Fauna	Hydroida			
cf Funiculina quadrangularis	1	0.7	0.01	Fauna				
Calcareous tube marks (Pomatoceros or Hydroides)	2	1.4	na	Fauna				
cf Kirchenpaureria sp	1	0.7	0.02	Fauna	Hydroida			
Marthasterias glacialis	3	2.1	0.01	Fauna	Asteroidea			
Mytilus edulis	1	0.7	0.01	Fauna				
Pennatula phosphorea	1	0.7	0.01	Fauna				
cf Polychaete tubes	4	2.8	0.03	Fauna				
cf Securiflustra sp	2	1.4	0.09	Fauna				
Number of flora taxa	40			Diversity				
Number of red taxa	14			Diversity				
Number of brown taxa	13			Diversity				
Number of green taxa	5			Diversity				
Number of fauna taxa	23			Diversity				

Focusing on the habitat classifications, there were large differences in mean floral and faunal cover, as well as diversity, when assessing the area as a whole (Fig. 5). Green macroalgae, mainly consisting of filamentous taxa, occurred at few stations and with very low mean cover (0.04 %) and was therefore excluded from further analysis. Similarly, the majority of the faunal taxa occurred at very few stations and although focus was put on the taxa with >10 % prevalence, their mean cover was extremely low (<1 %). Considering diversity, there were more floral than faunal taxa, with red macroalgae having the highest average number of taxa (Fig. 5).

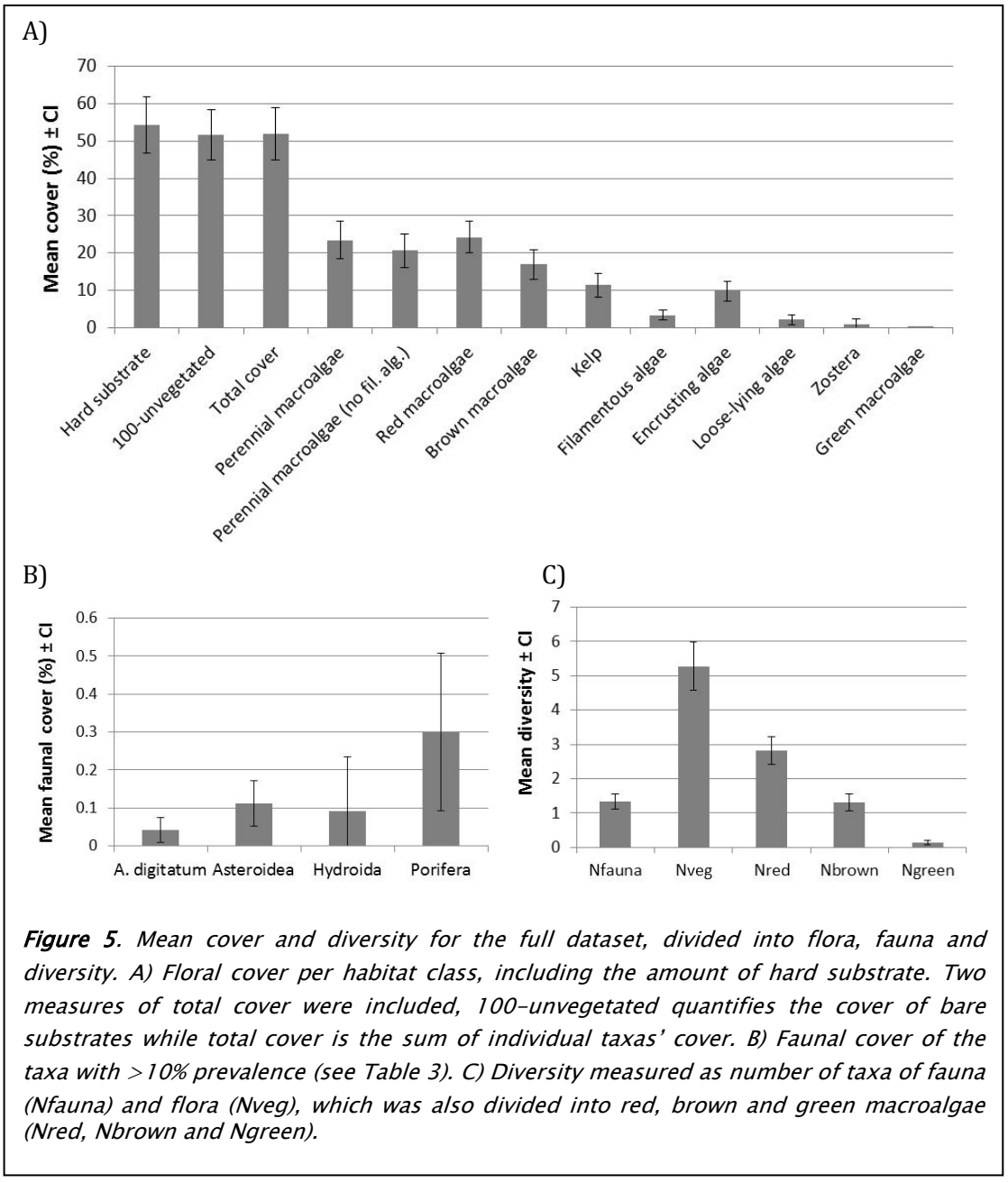

Figure 5*. Mean cover and diversity for the full dataset, divided into flora, fauna and diversity. A) Floral cover per habitat class, including the amount of hard substrate. Two measures of total cover were included, 100-unvegetated quantifies the cover of bare substrates while total cover is the sum of individual taxas' cover. B) Faunal cover of the taxa with >10% prevalence (see Table 3). C) Diversity measured as number of taxa of fauna (Nfauna) and flora (Nveg), which was also divided into red, brown and green macroalgae (Nred, Nbrown and Ngreen).*

Uncertainty and effort needed for monitoring relevant variables at a certain precision

Many factors are important when designing a monitoring program. Besides factors affecting the mean of the variable of interest, knowledge on parameters regarding temporal, spatial and method specific variation are important when designing coherent monitoring programs (e.g. Lindegarth et al. 2013). In this section we have focused on obtaining quantitative estimates of the spatial variation in relation to a set of environmental factors that influence the response variables distribution. Concurrently we have calculated, for all habitat classes, how many samples are needed for a certain precision. As basis for this we have used a report by Svensson et al. (2011) that summarises and expands on (Swedish) national guidelines regarding uncertainty and the precision of estimates (Haglund 2010). In essence, the requirements aim for a precision where the confidence intervals (CI) are within 20% of the mean. However, as target indicators and critical thresholds are set in accordance with European directives, it is beneficial (in the optimal case) that the width of the confidence interval is smaller than the difference between the threshold and the technical threshold determining environmental status (Carstensen 2007). For now, we followed equation 3 (page 32) in Svensson et al. (2011) and calculated the minimum number of samples needed for a certain precision, with a two-sided CI (Snedecor and Cochran 1989):

$$n_{prec} \geq 2^2 \times s^2 \div L^2, \text{ (eq. 1).}$$

where s^2 is the estimated variance, in this case the squared standard deviation among stations, and L is the allowed deviation from the mean (L = 0.2 * estimated mean). Although this equation is approximate for small sample sizes (n≤30), it is relatively safe to assume a normal distribution as an approximation for confidence at sample sizes >5 (Lindegarth et al. 2013).

Related to this way of estimating uncertainty is the calculation of the number of samples needed for having 80 % probability (statistical power) of detecting a deviation of 20 % from a desired threshold (n_{power}). There is a strong linear relationship (r^2=0.999) between n_{prec} and n_{power} (Svensson et al. 2011, page 54):

$$n_{power} = 2.3 \times n_{prec} + 1.2, \text{ (eq. 2).}$$

An important pattern that has been observed in earlier work is the relationship between the cover of benthic organisms and the number of samples needed for a certain precision, i.e. a larger sample size is needed for a rare organism compared to a more common organism. Interestingly this relationship seems to be independent of sampling method (Svensson et al. 2011, fig 3.24). These results are supported by the Hvaler-Koster dataset, and the relationship was largely independent of the depth strata (Fig 6).

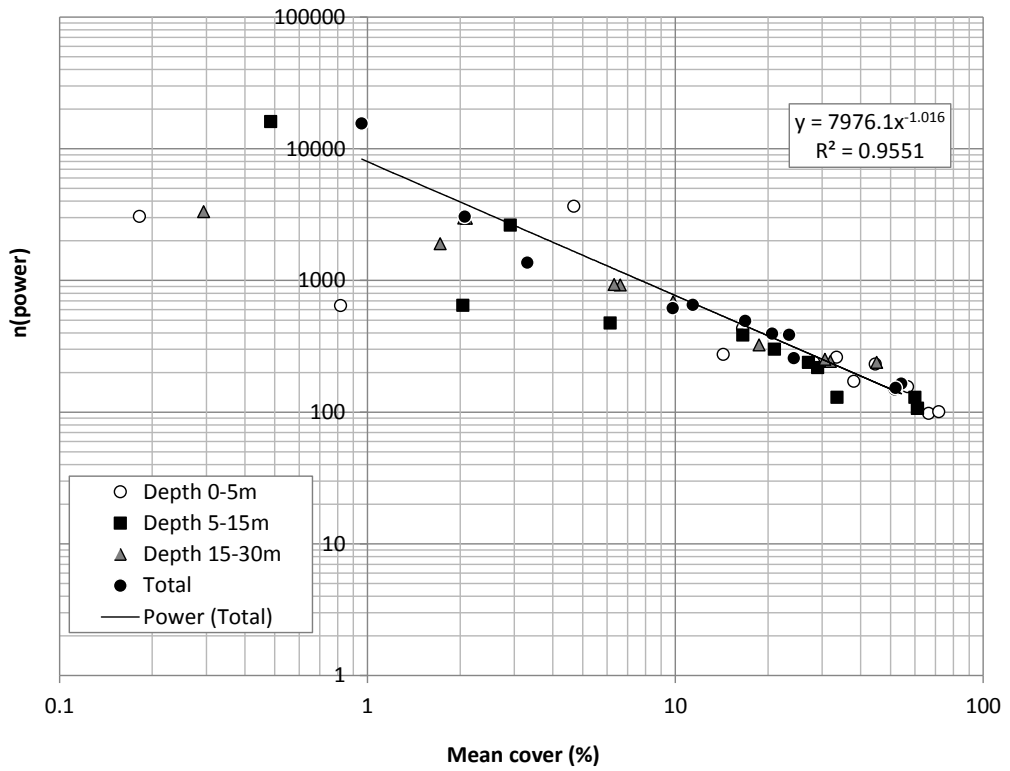

***Figure 6**. Number of samples needed for a certain statistical power (n_{power}, 80 % probability of detecting a 20 % deviation) as a function of mean cover (%) for the floral habitat classes. The regression is based on all data regardless of depth.*

Such a relationship, although interesting in itself, has strong implications for monitoring programmes as it implies that the mean plays a crucial role for the required effort. A common approach to increase the mean is by stratification. Therefore we conducted a suite of tests using various stratification schemes, starting with substrate. The purpose of detailing the various steps below is that it allows flexibility for potential users to themselves further investigate preferred stratifications, which may become useful in the future.

Stratification by substrate

Stratifying by substrate revealed a clear increase in mean, and thus precision (Fig. 7). Regarding vegetation, the effect was more apparent on hard substrates too which the majority of habitat classes are associated. As expected, mean cover of *Zostera* and Loose-lying algae increased on soft substrates, although the mean cover was still low. Diversity revealed a similar pattern, with higher numbers of taxa at hard substrates. Faunal groups also increased at hard substrates but since the cover was initially extremely low (0.04 – 0.11 %) the effect appears marginal. The fact that *Alcyonium digitatum* seemed to appear on soft substrates needs perhaps an explanation. The classification of stations into hard or soft substrates was defined based on the dominating substrate (estimated in the quantitative stops). Thus, individual quantitative stops within a film may have

contained a hard surface, such as a rock, although the station as a whole was dominated by soft substrates, and classified accordingly. With such low covers as *A. digitatum* displays, individual stops within station may become important and the results are unstable. Diversity was higher on hard substrates compared to soft, thus following the patterns observed for floral habitats (Fig. 7).

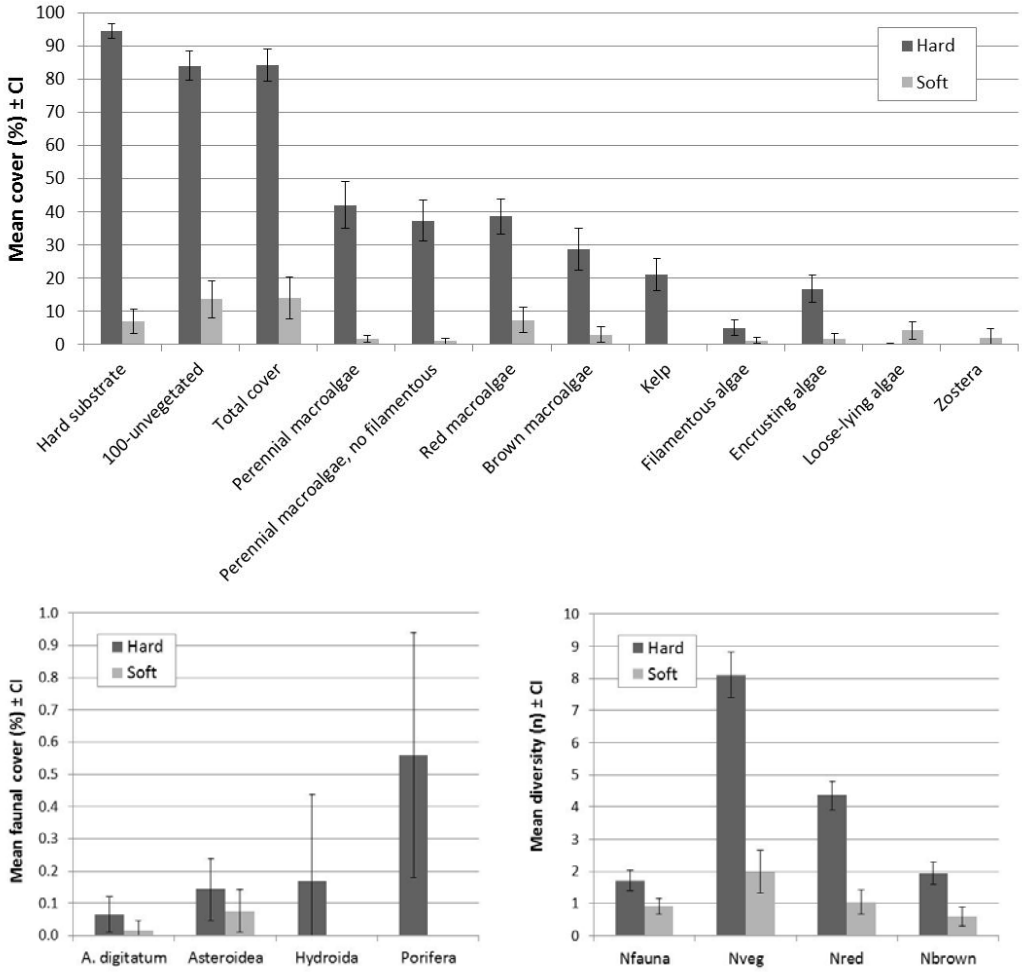

Figure 7 *Mean cover and diversity stratified by substrate, divided into flora, fauna and diversity (compare Fig. 5). Stratifying by substrate increased the mean for almost all habitat classes, especially on hard substrates. Total n=143, Hard substrate n=77 and Soft substrate n=66.*

Stratification by depth and exposure to waves

Focusing on vegetation on hard substrates, which showed the greatest increases in mean cover – what happens with additional stratification by depth? Figure 8 compares the first stratification by substrate with additional division by various depth strata, 0-5 m, 5-15 m, the combined depth 0-15 m and 15-30 m.

In general, stratification also by depth tended to increase the mean for almost all habitat classes, with the largest effect seen when splitting at 15 metres. Although filamentous algae, perennial and brown macroalgae habitats appeared to have higher means at the

most shallow class (0-5 m), filamentous algae appeared to be the only significantly different habitat preferring 0-5 metres. A suitable depth class for the remainder of the floral habitat classes was 0-15 metres (Fig. 8). Encrusting algae was mainly found below 15 metres with mean cover of about 40%, probably also because it was easier to find at depths were upright algae have low cover. Thus, two depth classes 0-15 and 15-30 metres depth seemed appropriate.

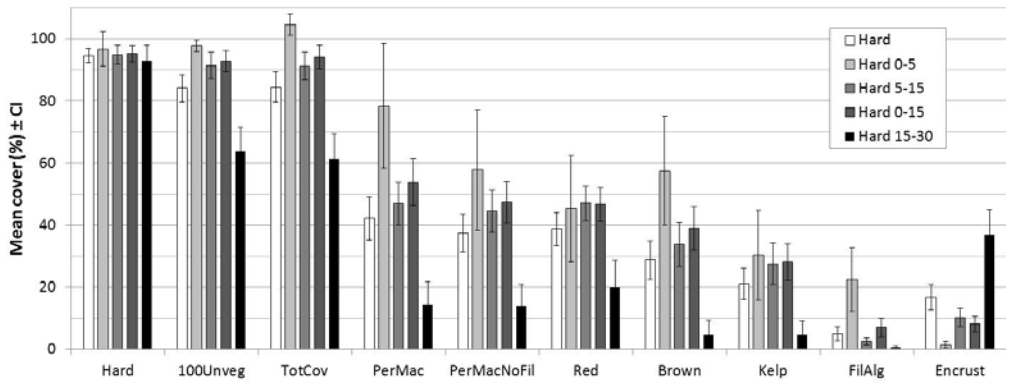

***Figure 8**. Mean cover of floral habitats stratified by hard substrate and different depth classes. Hard substrates (white bars) are duplicated from Fig. 7 to ease comparison. Grey bars are three depth stratas between 0 and 15 metres depth and black bars are between 15 and 30 metres depth. Stratification also by depth tended to increase the mean for almost all habitat classes, and the largest effect was seen when splitting at 15 m. Hard substrate n = 77, Hard 0–5 n = 12, Hard 5–15 n = 42, Hard 0–15 n = 54 and Hard 15–30 n = 23.*

Similar graphs also including exposure to waves did not reveal any more consistent improvement. Some patterns were suggested by the data, e.g. filamentous algae seemed to concentrate in sheltered areas, but as only ten replicates were available the conclusions are weak. However, for the other biotopes it seems that exposed areas require fewer samples than moderately exposed and sheltered areas, but this needs larger sample sizes to be thoroughly analysed.

Regarding soft substrates, stratification by depth increased the mean cover of both *Zostera* (0-5m) and Loose lying algae (5-15m), but the CIs were large (10±20 and 7±6%, n=10 and 28, respectively). Further stratification by exposure indicated specific preferences, i.e. extremely sheltered areas for *Zostera* and moderately exposed for loose lying, but the sample sizes was much too low for specific recommendations (n=2 and 9, respectively). However, with a suitable stratified sampling design that includes substrate, depth and exposure, both of these variables should be possible to monitor using drop video analysis. An option for these types of clustered responses is adaptive cluster sampling (Thompson 1990), by which samples are added once positive observations have been made and unbiased population estimates may be obtained.

Regarding faunal groups, similar analysis with stratification by substrate and depth revealed patterns of improvement, but the means were still extremely low and it would thus require large efforts to follow their cover quantitatively. Most promise was shown

by Asteroidean and Hydroids at hard bottoms between 15 and 30m depth, but given this dataset efforts would still entail >400 stations for a good precision.

The patterns regarding diversity were similar to those observed on cover. The number of vegetative taxa increased on hard substrates and showed a clear separation at 15 metres depth (Fig 9.).

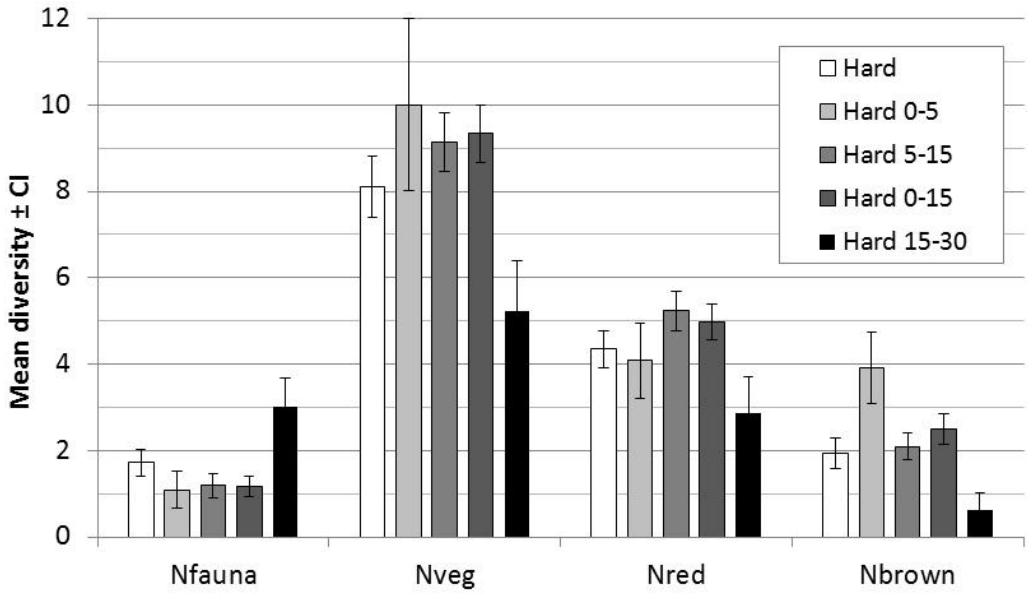

Figure 9. Mean diversity stratified by hard substrate and different depth classes. Hard substrates (white bars) is duplicated from Fig. 6 to ease comparison. Grey bars are three depth stratas between 0 and 15 metres depth and black bars are between 15 and 30 metres depth. Stratification by depth had the largest effect when splitting at 15m. Hard substrate n=77, Hard 0-5 n=12, Hard 5-15 n=42, Hard 0-15 n=54 and Hard 15-30 n=23.

As expected (from an ecological perspective) the diversity of brown algae was higher at the most shallow depth strata (0-5m), whereas red algae tended to have a higher diversity slightly deeper (5-15 m). The difference was however very small with only marginal effects on the effort required for a certain precision, thus statistically motivating the same separation at 15 metres depth as was done for cover.

Costs

Cost is here measured as time for video interpretation, using the guided technique with both 10 quantitative stops and qualitative presence of individual taxa along the entire length of the film. Analyses time is divided by substrate and depth and took between 4 and 9 minutes per film (Fig. 10).

Average film length time was 51 seconds (±0.02 SD), which is relatively short. A standardised method description regarding drop video technique is under way from the Swedish EPA, and the reader is advised to check the latest version before conducting field work. However, the current recommendation (Naturvårdsverket in prep) is that a

standardised surface is filmed (25m^2), by manoeuvring slower than 15 metres per minute (0.5 knots) and fixing the camera at a 45 degree angle. Distance from the seafloor will vary with the camera lens and the recommendation is that this is calibrated in advance.

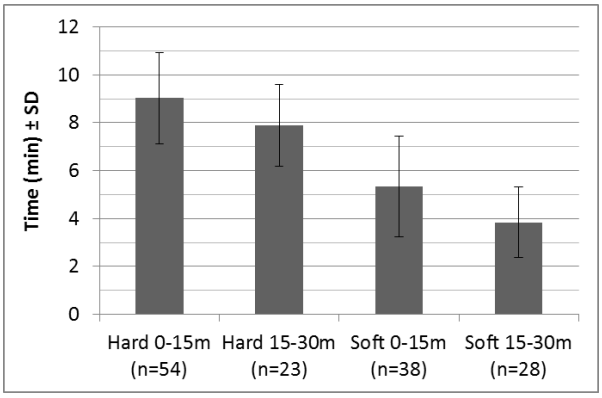

***Figure 10**. Cost, measured as analysis time, for the Guided technique using the total amount of stations <30 metres deep, by dominating substrate and two depth strata. Effort is given in parenthesis along the x-axis. The average time spent analysing one station was 6.8 min ± 2.8 SD (n=143).*

Based on this projects field experience our best estimate is that it is possible to sample approximately 20 stations on windy days and 40 in good weather in the Koster-Hvaler area, yet considering that the films should generally be longer (to cover a standardised surface) a maximum of about 30 films per day is probably more feasible, assuming good weather.

Proposed method description for meeting monitoring and management objectives

Summarising previous sections and using equation 1 and 2, the number of stations that are needed for a normally accepted precision and power can be calculated for the most appropriate stratification scheme. As detailed above, both cover and diversity was higher on hard substrates compared to soft substrates, and similarly, cover and diversity was higher in depths shallower than 15 metres compared to deeper areas.

In order to follow the cover and diversity of the most important floral habitat forming groups on hard substrates down to 15m depth, about 100 stations appear adequate (Fig. 11). However, filamentous algae require more samples than this, almost triple, in order to achieve a high precision. Note also that to include encrusting algae the required sample size needs to be added as it is situated at deeper stations.

To calculate the cost of a monitoring programme several factors need to be included. In the simplest case here, with a 100 stations dominated by hard substrate between 0-15m depth, the analyses time would be approximately 900 minutes. The time to collect the films would be about three to four days, in good weather conditions (see Costs above). This roughly equates to a total of about 75-95 person hours (with two people and 10 hour field days) to collect and prepare the data for analysis, in optimal conditions. In return, the expected output would be cover estimates of a wide range of habitat forming taxa, with a precision where the confidence intervals are within 20 % of the mean. Such information is important for assessments of ecological status, as developed in the Water Framework Directive. The directive also dictates that the assessments are made in relation to various criteria, e.g. regarding indicators of status, reference conditions and class boundaries which are only cursory evaluated in this report.

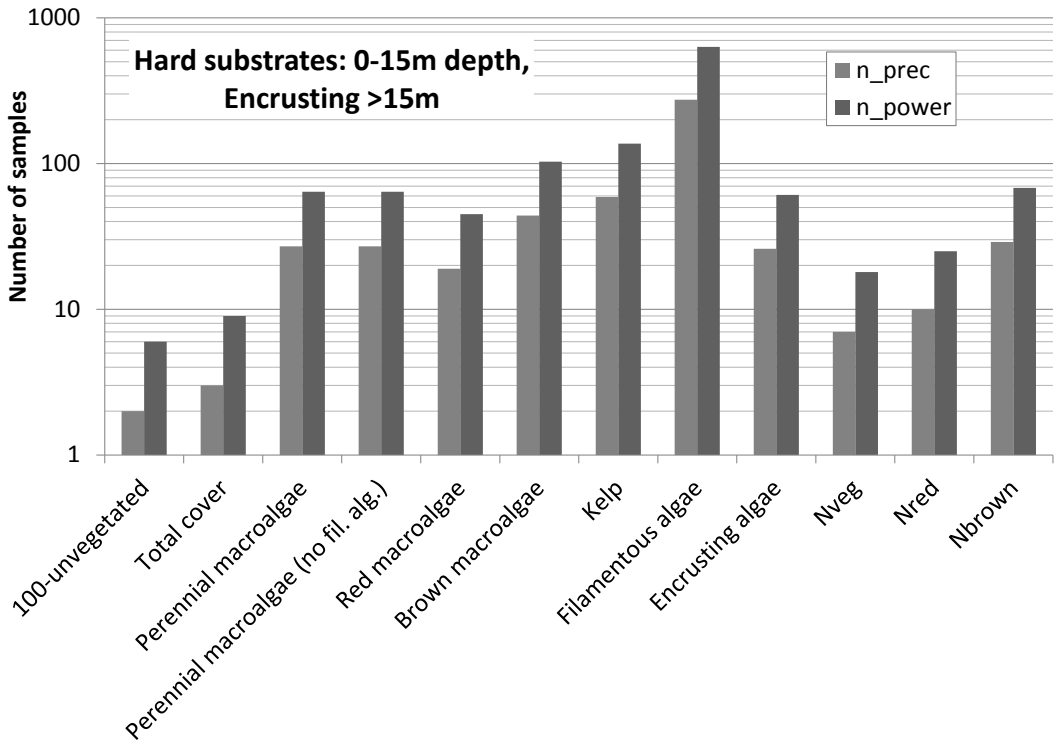

***Figure 11**. Number of samples stratified by substrate and depth that are needed for a normally accepted precision and power. The precision is defined as CI's that are within 20 % of the mean and a power with 80 % probability of detecting a deviation of 20 %. Stratification by depth is 0–15 meters depth, except for encrusting algae which are only shown for deeper stations (15–30 m).*

Another issue of importance is the sampling design. The conclusion that all films should be dominated by hard substrates requires a sampling design that ensures that enough stations are sampled with a suitable substrate. Hard substrate was in this report defined based on the dominating substrate, as estimated from the video analyses. Nevertheless, deciding whether the station is dominated by soft or hard is possible already in the field, and prior information from e.g. earlier projects or local knowledge may further assist the selection of stations. The concept is similar to sampling designs using grab samplers such as van Veen and Smith-McIntyre which are only applicable on soft substrates and similar procedures could be used to sample only stations dominated by hard substrates.

As mentioned above, there are three main aspects of uncertainty; temporal, spatial and method specific sources. Thus far we have discussed method specific aspects, such as how to estimate cover and diversity, and spatial aspects, particularly small scale fluctuations and how various environmental factors influence distribution and cover. An aspect not considered in this report, since it is based on data collected at one occasion, is the temporal uncertainty. Nevertheless, the findings in this study are influenced by temporal variation and will likely deviate to some (so far) unknown extent with time. We recommend that the temporal variation is quantified, before or coincident with, the potential implementation of a monitoring program. The temporal variation can be further divided into interannual, seasonal, diurnal and irregular fluctuations, where

some aspects may be fixed (i.e. predictable) and some random (Lindegarth et al. 2013). Regarding benthic vegetation (and fauna) it is primarily the first two that are of importance in this context. The seasonal component, at least the fixed part of it, may be reduced by sampling at the height of the vegetation period, i.e. late summer/early autumn. However, since the height of the vegetation period may vary both between years and spatially, fixed dates may not be the most appropriate definition of season. Rather the appropriate sampling time is an effect of several interacting factors, e.g. food web interactions, nutrient conditions etc., which occurred (at least) during the months previous to sampling, and season may therefore be relevant depending on how well the sampling actually occurs during the height of the vegetation period or not. The other primary source of temporal variability is associated with interannual fluctuations, including the interaction with random spatial gradients. This can only be assessed by sampling several years. However, if the monitoring program is meant to follow the 6 year assessment periods of the most important EU-directives (the Marine Strategy Framework Directive, the Habitats Directive and the Water Framework Directive), and sampling is conducted each year, the random component of year may be removed in the estimate of total uncertainty (Lindegarth et al. 2013). Year may however be important from another aspect as well, depending on if the design over years is orthogonal, i.e. same sites each year, or nested, i.e. new sites each year. This is because it affects how the total variability around the estimated mean is calculated (i.e. uncertainty from all three aspects). In short, one can say that a nested design is preferable when there is a large spatial variability and the spatio-temporal dynamic is low, i.e. remain the same over years. This is because a nested design can be said to sample more of space with each year. It is worth noting also that the benefit of a nested compared to an orthogonal design increases with time, although the choice of design is dependent on how the spatio-temporal variability is divided (Lindegarth et al. 2013). This line of reasoning, which is dealt with intensely in Lindegarth et al. (2013), would have become more important if we instead of randomly allocating the filmed stations had nested them within sites. In summary, quantifying all sources of uncertainty benefits the development of a monitoring program in many ways, not the least by reducing the risk of underestimation of total uncertainty. Therefore we suggest that future studies further investigate the temporal aspects of the proposed sampling method and design in the Hvaler-Koster area. Such endeavours would be expected to aid an analysis of how the stations could be allocated, not only in relation to substrate and depth, but also with respect to e.g. years, in order to provide a comprehensive monitoring programme that include solid estimates of total uncertainty.

Integrated monitoring and predictive mapping using video

In the previous chapters we have dealt with how relevant habitat forming taxa are distributed in relation to broad environmental conditions and how method specific and spatial uncertainty influence monitoring aspects such as the precision of cover and diversity estimates. A primary conclusion was that stratification increases precision and power, thereby reducing the cost of potential monitoring programs. However, there is another aspect of mapping benthic habitats that is relevant from an applied spatial aspect, namely predictive mapping of organism distribution. Knowing where benthic

habitats are located, and how much there is, is essential for successful marine spatial planning (e.g. Crowder and Norse 2008), as well as the establishment of coherent marine protected area networks (Sundblad et al. 2011). Since all areas are in practice not possible to map due to the costs involved, species distribution modelling provides a suitable alternative (Elith and Leathwick 2009). The process is based on statistical models relating observations of species occurrence or abundance with environmental conditions. Given that environmental information is available in a GIS, the models can be used to predict the distribution over a wider area, also including uncertainty estimates. It is generally recommended that the entire distributional range along the relevant environmental variables of a species is covered (Thuiller at al. 2004), i.e. that both optimal and unsuitable conditions are sampled. However, this would be the opposite of stratification where the aim is to increase abundance by focusing on the key distributional areas. Thus, the question is – what effect does stratification to improve monitoring have on our ability to predict habitat distribution and abundance in the Hvaler-Koster area?

For occurrence models, which yield predictions on the probability of presence, there was a strong negative effect of reducing the dataset (i.e. stratification), both in terms of explained deviance and discriminatory ability (Table 4). This was most likely due to the reduced environmental (depth and wave exposure) ranges and does not necessarily reflect a poorer model (AquaBiota unpublished). All models maintained an AUC above 0.7, which is indicative of potentially useful models. Especially since the species-environment relationships maintained their general shape between the full and reduced dataset (not shown), which suggest that both the full and the reduced model would predict similar areas when projected onto a map.

The effect on abundance models was not so clear (Table 4). The amount of explained deviance was reduced with the stratified dataset, which indicates poorer fit. However, the relative error (nRMSE) was also reduced, indicating a higher precision (in relation to the mean). This could have been due to overfitted models, but model residuals and checks for overdispersion indicated no general problem (except for the reduced Kelp model which appeared to be overdispersed, and there was one outlier in the Total Cover model). Spatial autocorrelation was not investigated. Nevertheless, although these results are somewhat contradictory, the increased precision with the reduced dataset mirrors the results of the stratification in the sense that precision increased with the mean.

Based on these results, it appears that there are strong possibilities to integrate monitoring and predictive mapping purposes using drop video, but there are some pitfalls to consider. If the aim is to delineate areas with high and low probability of occurrence it appears that the occurrence evaluation measures are reduced with stratification. Although this is partly a statistical artefact not necessarily reflecting poorer models, it is important to remember that if the aim is to delineate presence from absence areas it is still advisable to capture the tails of preferred environmental conditions (i.e. including also some areas where the response variable is absent). This is because the environmental range limits the extent of the study and predictions onto a map will only be possible within environmental conditions that have also been sampled,

thus potentially leading to a map with large blank and unknown areas when using stratified data.

***Table 4**. Distribution model performance with full and stratified (reduced) datasets for two model types. Model performance was measured as the amount of variation explained (Dev. Expl.), and as AUC or normalised RMSE for occurrence and abundance models respectively. Frequency of occurrence (prevalence) and mean cover is also given per model type. Note that a negative ΔnRMSE signifies an increase in performance since it is a measure of the error percentage. Response variable abbreviations are based on Table 3.*

		Dev. Expl.(%)			AUC / nRMSE			Prev. / Mean (%)	
Model Type	Response	Full	Stratified	ΔDev expl	Full	Stratified	ΔAUC/ nRMSE	Full	Stratified
Occurrence (presence / absence)	Green	42.9	18.8	-24.1	0.94	0.78	-0.16	3.5	9.3
	FilAlgae	30.1	39.7	9.6	0.85	0.88	0.03	30.8	50.0
	Kelp	68	3.9	-64.1	0.97	0.70	-0.27	39.2	88.9
	Encrust	73.7	45.1	-28.6	0.98	0.92	-0.06	54.5	87.0
	Porifera	64.2	55	-9.2	0.97	0.93	-0.04	12.6	29.6
Abundance (cover)	TotCov	74.7	35.9	-38.8	0.33	0.11	-0.22	52.0	94.2
	FilAlgae	70.2	68.1	-2.1	1.46	1.00	-0.46	3.3	7.0
	Kelp	75.2	20.3	-54.9	1.07	0.67	-0.40	11.4	28.2
	Encrust	86.4	55.9	-30.5	0.69	0.72	0.03	9.8	8.3
	Porifera	70.6	66.1	-4.5	3.29	1.98	-1.32	0.3	0.8

Regarding abundance, results for the full and stratified model performance were inconsistent, yet followed a similar pattern of increased precision when stratifying and increasing the mean. This highlights the potential use of step-wise models often referred to as delta or hurdle models (e.g. Heinänen et al. 2008). The first step of a hurdle model includes an occurrence model to delineate suitable habitats and the second step utilises (only) the abundance data to infer habitat quality. The approach is ecologically appealing as it consider that the processes affecting occurrence, e.g. dispersal, settlement etc., can be different from the processes regulating abundance, e.g. predation and growth. Such an approach can potentially be integrated with the minimum requirements for monitoring of shallow hard substrates outlined above, e.g. by utilising large datasets (similar to the full dataset) for delineating occurrence and the stratified dataset for modelling abundance within suitable habitats. Note however, that in order to properly evaluate a predicted distribution map, independent data is also necessary.

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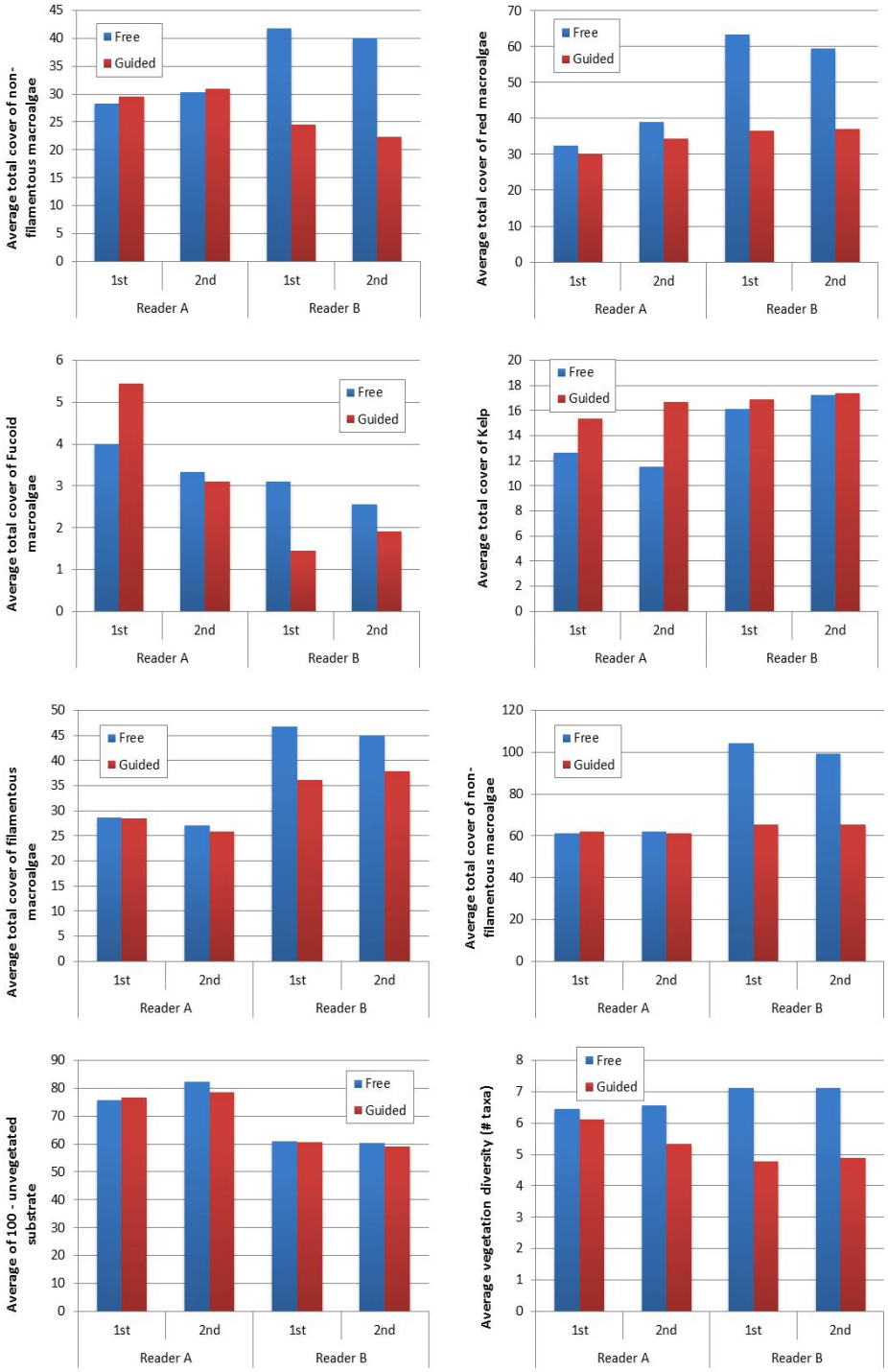
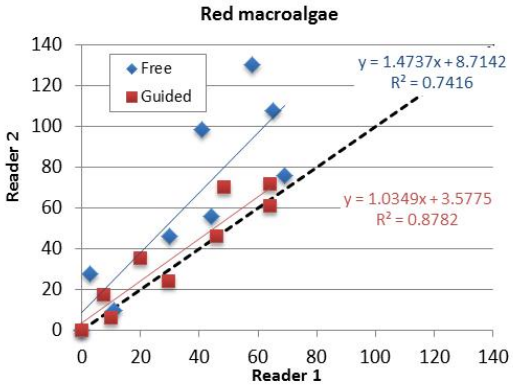
APPENDICES

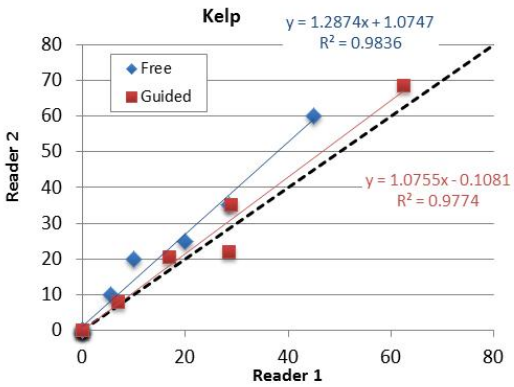
Appendix 1. Comparison Free vs. Guided

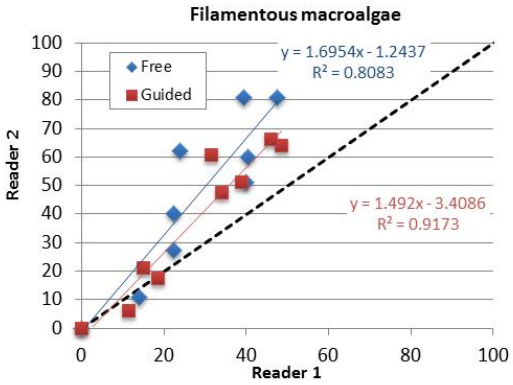
Taxa overall ***(means per reader and repetition)***

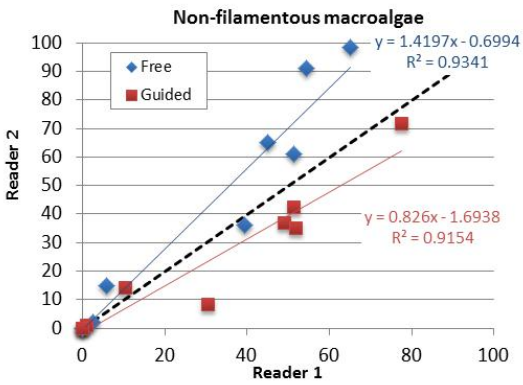


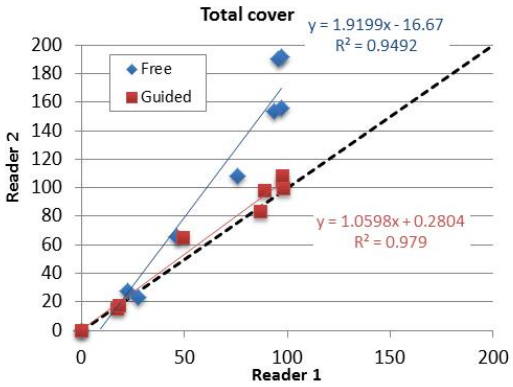
Regression readers ***(regression between readers using stations as replicate)***

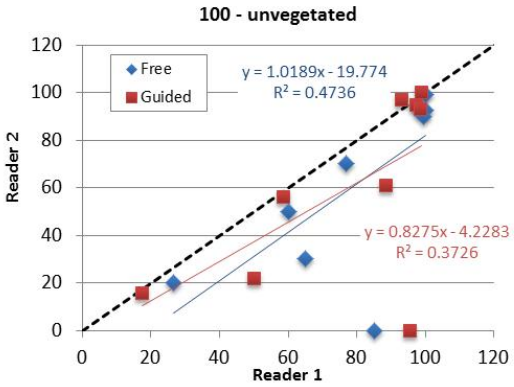


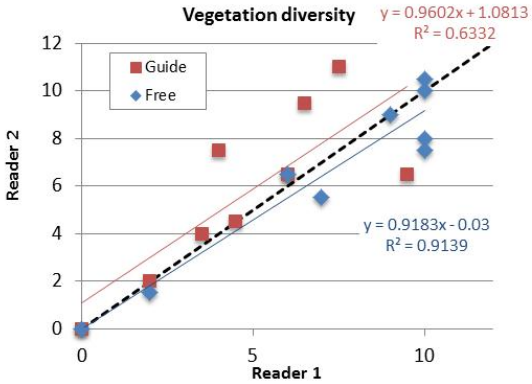












Appendix 2 Taxonomic resolution video:dive fauna

Animal diversity using nine overlapping stations. For Video, mean cover is given for the 10 quantitative stops, and the presence or absence (PA) when qualitatively assessing the entire film in between stops. For Dive, mean cover is given after transforming the estimated cover per substrate (hard rock:sand) and as epiphytes, as well as total unique taxa.

	Video		**Dive**		
	Mean cover quantitative	PA qualitative	Mean cover on Substrate	as Epiphytes	Dive total
Porifera	0.03	1			
Halichondria panicea	0.01	1	1.78	0.71	1
Sycon ciliatum			0.12	0.14	1
Laucosolenia complicata			0.06		1
Hydroida	0	1			
Hydroida indet.			0.11		1
Campanularia johnstoni			0.15		1
Eudendrium sp.			0.18		1
cf Laomedea sp.	0	1			
Laomedea geniculata			0.27	0.57	1
Dynamena pumila			0.08		1
Hydralmania falcata			0.11		1
Schupozoa					
Haliclystussp.				0.14	1
Anthozoa					
Metridium senile			0.22		1
Metridium senile pallidum			0.14		1
Alcyonium digitatum			0.08		1
Sagatiogeteon viduatus			0.08		1
Gonactinia prolifera			0.05		1
Protanthea simplex			0.05		1
Polychaeta					
Spirorbis spirillum			0.29	1.00	1
Pomatoceros triqueter			0.37		1
Arenicola marina			0.62		1
Polychaeta sp.			0.08		1
Crustacea					
Cancer pagarus	0	1	0.01		1
Carcinus maenas			0.48		1
Hyas araneus			0.01		1
Galathea sp.			0.08		1
Pagurus bernhardus			1.38		1
Balanus sp.	0	1			
Balanus balanus			0.18		1
Polyplacophora					
Polyplacophora sp.			0.14	0.14	1
Gastropoda					
Gibbula cineraria			0.23	0.57	1
Lacuna vincta			0.12		1
Rissoa membranacea			0.08		1

Rissoidae			0.05		1
Onchidoris sp.			0.05		1
Acmaea sp.			0.08		1
Littorina littorea			0.09		1
Nassarius reticulatus			0.08		1
Calyptraeidae sp.			0.08		1
Bivalvia					
Pectinidae			0.11		1
Modiolus modiolus			0.02		1
Ostrea edulis			1.23		1
Ensis arcuatus			0.46		1
Bryozoa					
Bryozoa indet. encrusting			0.66	0.29	1
Electra / Membranipora	0.3	1			
Membranipora membranacea				10.00	1
Electra pilosa				5.71	1
Umbonula littoralis			0.14	0.29	1
Crisia eburnea			1.25	2.86	1
Scrupocellaria reptans			0.47	0.86	1
Scrupocellaria scruposa			0.75	0.71	1
Cryptosula pallasiana			0.31	0.29	1
Tubulipora sp.			0.29		1
Callopora rylandi				0.14	1
Asteroidae					
Marthasterias glacialis juv.			0.05		1
Marthasterias glacialis			0.08		1
Henricia sanguinolenta			0.15		1
Asterias rubens juv.			0.39	0.43	1
Asterias rubens	0.01	1	0.74	0.29	1
Leptasteras mulleri			0.02		1
Echinoidea					
Strongylocentrotus droebachiencis			0.08		1
Tunicata	0	1			
Clavelina lepadiformis			0.11		1
Botryllus schlosseri			0.09	0.29	1
Ascidiella scabra				0.14	1
Botrylloides leachi			0.09	1.00	1
Dendrodua grossularia			0.20		1
Diplosoma listerianum			0.02		1
Corella parallelogramma			0.36	0.43	1
Ascidiella adspersa			0.07		1
Ascidia mentula			0.22	0.86	1
Osteichthyes (Fish)					
Pomatoschistus minutus			1.17	0.14	
Ctenolabrus rupestris			0.31	0.43	
Myoxocephalus scorpius			0.18		
Other					
Breathing holes			0.23		
Number of taxa (excluding fish)	4	9	61	23	66

Appendix 3 Taxonomic resolution video:dive flora

Vegetation taxa found with video and dive methods at the 9 overlapping stations. Quantitative mean cover for video is based on the Guided technique with 10 stops, and qualitative presence or absence (PA) is based on the entire length of the film. For diving, mean cover is separated between cover on the substrate (bottom) and epiphytic cover. Dive total is a measure of unique taxa.

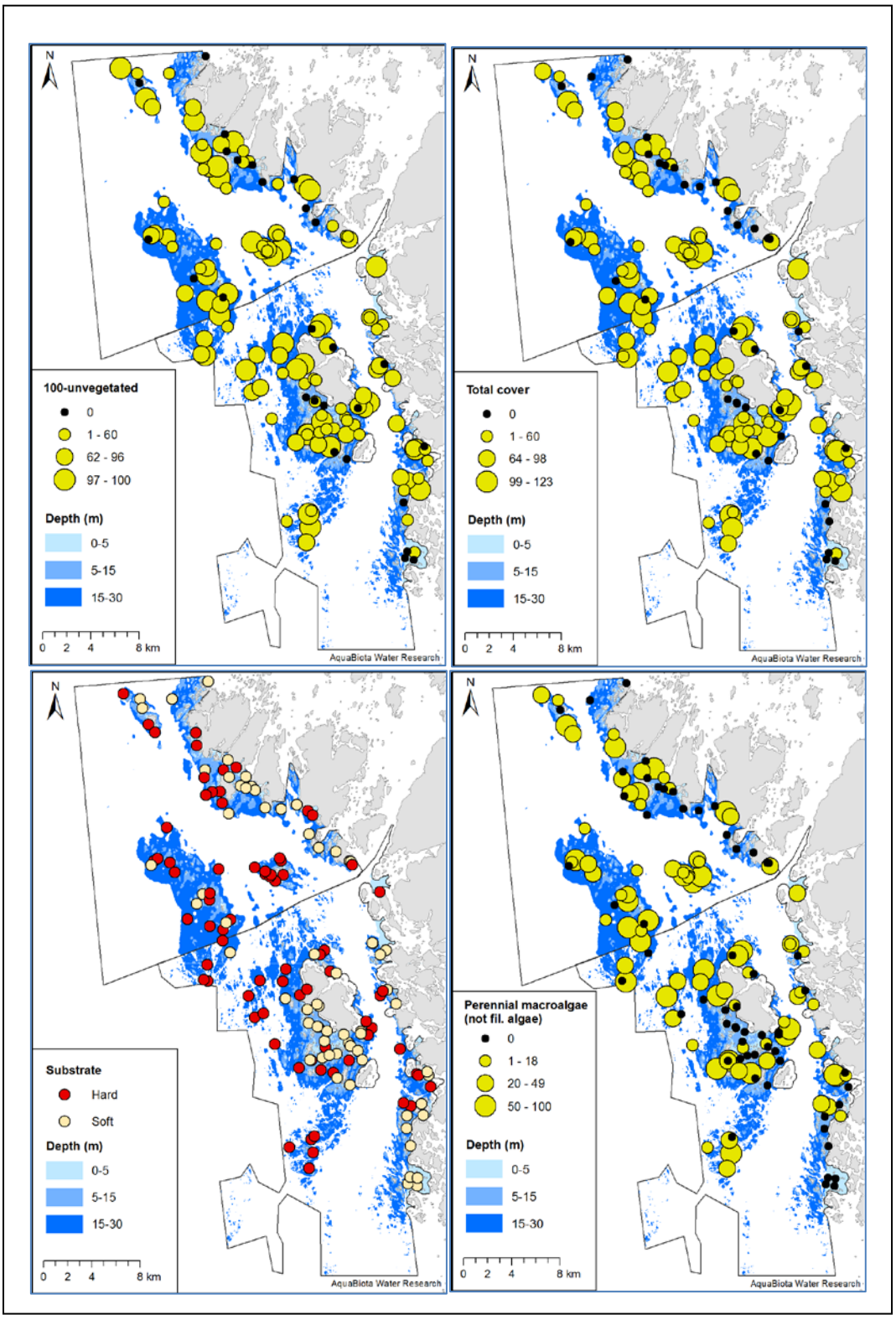
	Video flora		**Dive flora**		
	Mean cover quantitative	PA qualitative	Mean cover on Substrate	as Epiphytes	Dive total
Corallinaceae			36.8		1
Cruoria sp	0.3	1	6.3		1
Litothamnion sp	4	1			
Hildenbrandia rubra			0.5		1
Corallina officinalis			8		1
Various red algae	19.3	1			
Ahnfelta plicata			0.03		1
Audouinella in bryozoids and hydroids				0.3	1
Brongniartella byssoides			0.4	1.7	1
cf Callithamnion sp	0.2	1			
Callithamnion corymbosum			0.1	4.8	1
Ceramium virgatum			3.1	17.8	1
Chondrus crispus			8.9		1
Delesseria/Phycodrys	0.6	1			
Cystoclonium purpureum			0.3	0.2	1
Delesseria sanguinea			6.5	1.1	1
Dilsea carnosa	0.1	1	1.3		1
Furcellaria lumbricalis	1.1	1	8.5		1
Gracilaria gracilis			1		1
Heterosiphonia japonica			2.4	13.3	1
Heterosiphonia plumosa			0.02		1
Lomentaria clavellosa			0.1	0.1	1
Melobesia sp				0.1	1
Membranoptera alata				0.1	1
Palmaria palmata			0.02	3.4	1
Phycodrys rubens			3.6	3.3	1
Phyllophora/Coccotylus	0.5	1			
Phyllophora pseudoceranoides		1	5.9	1.1	1
Phyllophora truncata			0.1		1
Plumaria plumosa			2	1.3	1
Polysiphonia/Ceramium	8.7	1			
Polysiphonia elongata	0.2	1	24.4	0.1	1
Polysiphonia fibrillosa			1.6		1
Polysiphonia fucoides			1.9	3.4	1
Polysiphonia stricta			0.2	0.3	1

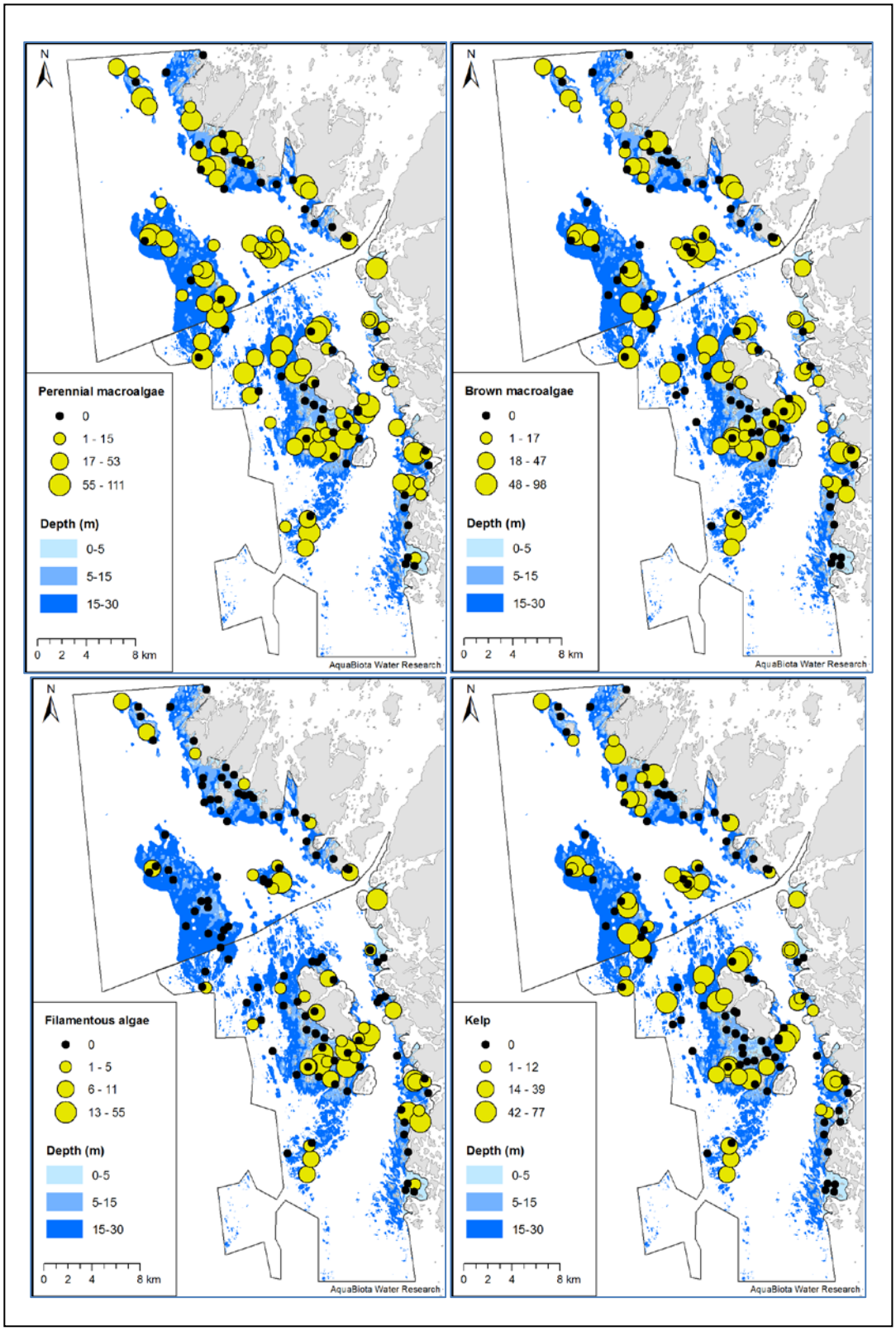
Cont.	**Video flora** Mean cover quantitative	PA qualitative	**Dive flora** Mean cover on Substrate	as Epiphytes	Dive total
Pterothamnion cf crispum			0.1		1
Rhodomela confervoides		1	1.1	0.3	1
Trailliella intricata	1.7	1	21.4	31.2	1
Trailliella intricata + Spermothamnion repens			3.2	4.4	1
Various filamentous brown algae		1			
Chorda filum	0.4	1	1.8		1
Chordaria flagelliformis		1			
Desmarestia aculeata	1.6	1	2.2		1
Ectocarpales	1.5	1			
Ectocarpus sp.			0.01	1.1	1
Elachista fucicola				0.1	1
Fucus serratus	0.1	1	0.8		1
Halidrys siliculosus	0.1	1	1.9		1
Laminaria hyperborea	11.2	1	5.6		1
Laminaria sp germlings			0.4	0.1	1
Pylaiella littoralis				1.1	1
Saccharina latissima	4.4	1	7.8		1
Sargassum muticum	1.9	1	1		1
Sphacelaria sp		1			
Sphacelaria cf bipinnata				2.2	1
Sphacelaria cirrosa			0.4	0.4	1
Sphacelaria plumosa			0.2		1
Sphacelaria radicans			0.1		1
Cladophora sp	0.1	1			
Chaetomorpha melagonium			0.3		1
Cladophora albida			0.1	0.1	1
Cladophora rupestris	0.2	1	1		1
Zostera marina	1.6	1	9		1
Number of taxa total	22	27	46	27	52
Number of red taxa	9	11	26	20	29
Number of brown taxa	8	11	12	6	15

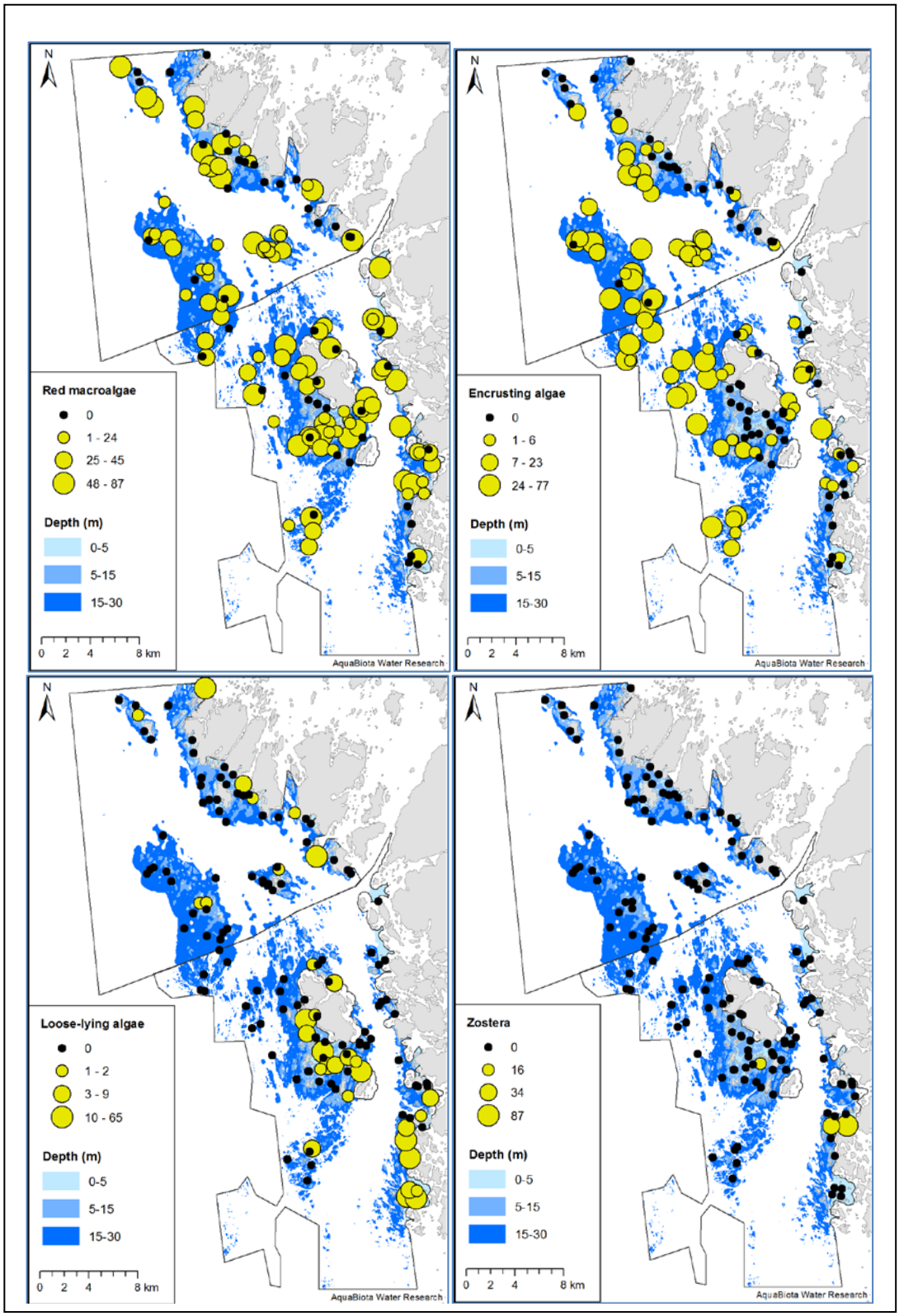
Appendix 4 Quantitative spatial distribution

Mean cover of classified habitat groups from the 10 quantitative stops (i.e. absence locations, denoted by zero, may still have had the variable present qualitatively). Diversity includes both quantitative and qualitative data.

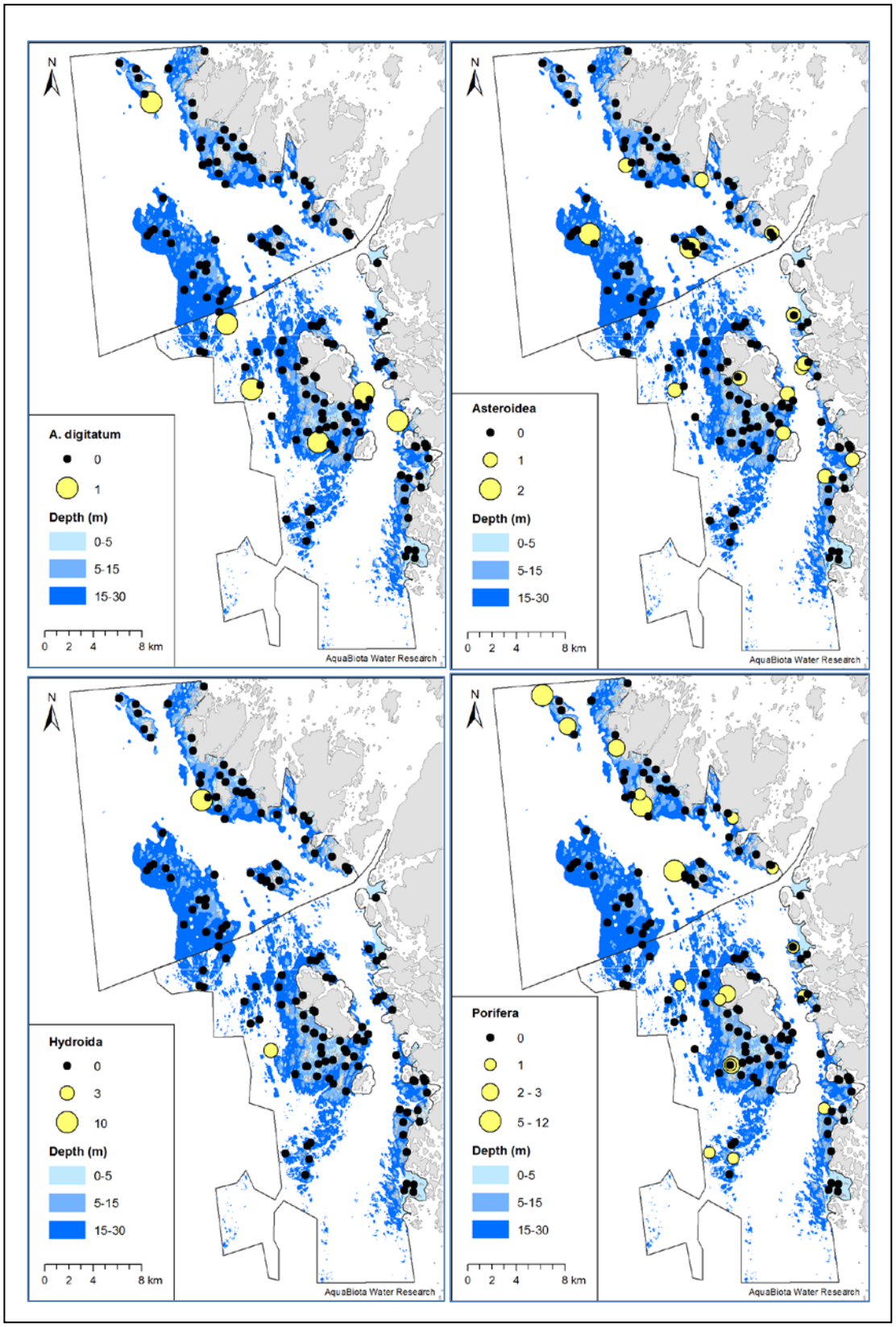
Flora



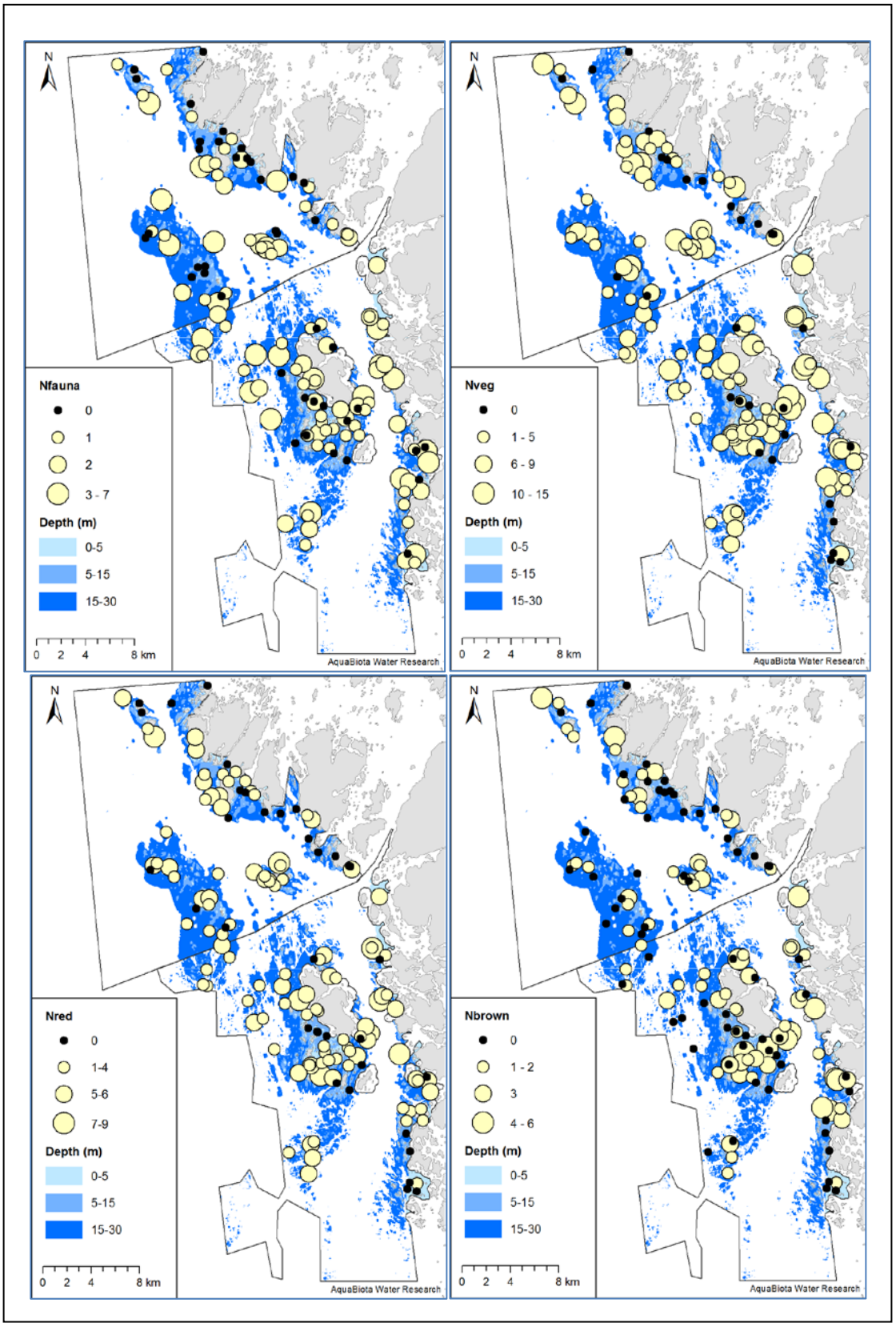

N
Perennial macroalgae
0
1 - 15
17 - 53
55 - 111
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Brown macroalgae
0
1 - 17
18 - 47
48 - 98
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Filamentous algae
0
1 - 5
6 - 11
13 - 55
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Kelp
0
1 - 12
14 - 39
42 - 77
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research

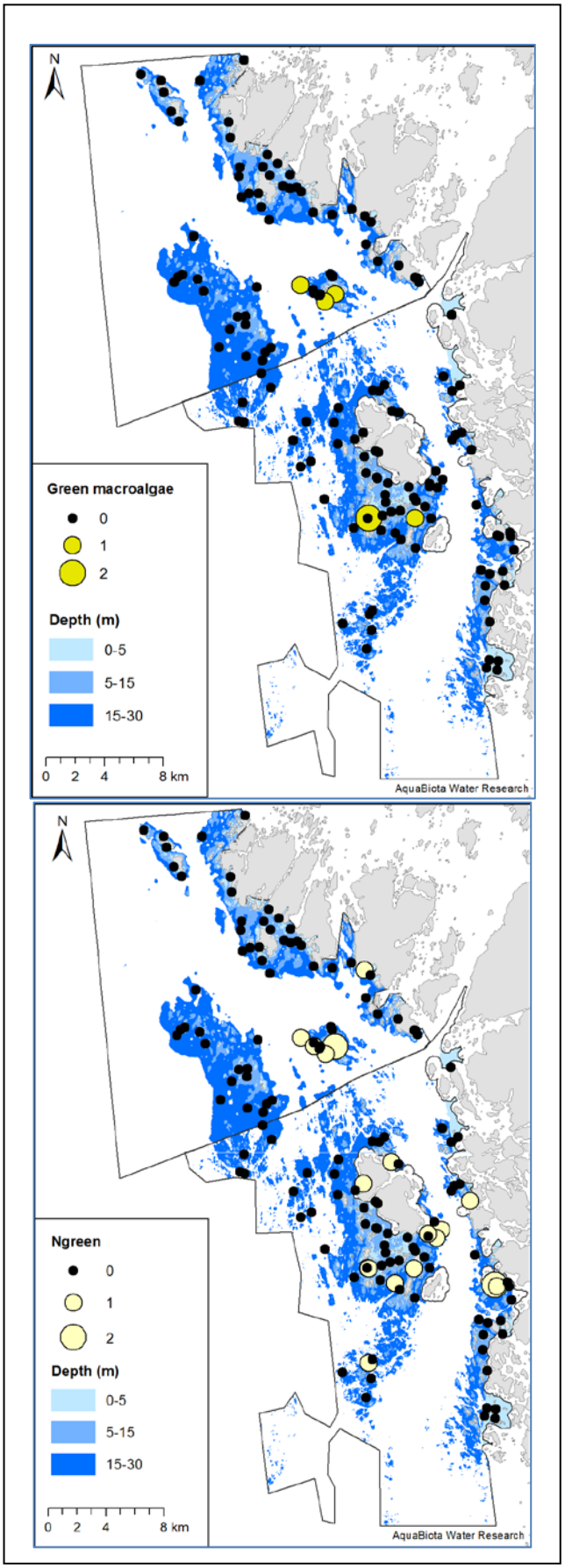

N
Red macroalgae
0
1 - 24
25 - 45
48 - 87
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Encrusting algae
0
1 - 6
7 - 23
24 - 77
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Loose-lying algae
0
1 - 2
3 - 9
10 - 65
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Zostera
0
16
34
87
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research

Fauna


N
A. digitatum
0
1
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Asteroidea
0
1
2
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Hydroida
0
3
10
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Porifera
0
1
2 - 3
5 - 12
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research

Diversity


N
Nfauna
0
1
2
3 - 7
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Nveg
0
1 - 5
6 - 9
10 - 15
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Nred
0
1-4
5-6
7-9
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Nbrown
0
1 - 2
3
4 - 6
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research


N
Green macroalgae
0
1
2
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research
N
Ngreen
0
1
2
Depth (m)
0-5
5-15
15-30
0 2 4 8 km
AquaBiota Water Research

About project Hav möter Land

Climate, water, spatial planning together

Hav möter Land translates to Sea meets Land. Our project brings together 26 organisations from Sweden, Norway and Denmark. We work together on climate, water and spatial planning for the Kattegat and the Skagerrak.

Our results are useful for decision makers, planners, researchers and managers of natural resources.

Climate change alters the conditions for our life and livelihood here. We obtain collective knowledge for collective preparedness.

Municipalities, regions, universities and governmental agencies work together in the project.

Join in on www.havmoterland.se.

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Buskerud fylkeskommune
Falkenbergs kommun
Fylkesmannen i Aust-Agder
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Nøtterøy kommune
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Sotenäs kommun
Telemark fylkeskommune
Vestfold fylkeskomune
Västra Götalandsregionen
Århus Universitet

Video or dive? Methods for integrated monitoring and mapping of marine habitats in the Hvaler-Koster area.

This pilot study has evaluated alternative drop video techniques and diving observations in terms of taxonomic resolution, precision and cost.

The report further gives recommendations regarding sampling design and the expected effort required for a certain precision is given using a specific drop video technique.

Lastly the report highlights how monitoring and predictive mapping may be integrated by providing examples of species distribution modelling using various sampling designs.

The overarching purpose was to evaluate methods for monitoring and mapping of habitat supporting benthic flora and fauna in the Skagerrak and Kattegat.

Hav möter Land

The project Hav möter Land brings together 26 municipalities, regions, universities and governmental agencies from Sweden, Norway and Denmark. We work together on climate, water and spatial planning for the Kattegat and the Skagerrak. Our results are useful for decision makers, planners, researchers and managers of natural resources. Climate change alters the conditions for our life and livelihood here. We obtain collective knowledge for collective preparedness. The European Union is helping to finance the project.

www.havmoterland.se

Hav möter Land

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

Interreg IV A
ÖRESUND – KATTEGAT – SKAGERRAK