Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute

METSÄHALLITUS
FORSTSTYRELSEN
MEAHCIRÁĐĐEHUS

Ålands landskapsregering

A6.3 Suggestion on monitoring programme for piloting

19.12.2025

NATURA 2000

BIODIVERSEA
for marine nature

LIFE20 IPE/FI/000020 LIFE-IP BIODIVERSEA

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Suggestion on monitoring programme for piloting

Louise Forsblom[1], Ari Laine[2], Charlotta Björklund[3], Jaakko Haapamäki[1], Maija Häggblom[3], Mikko Impiö[1], Ari-Pekka Jokinen[1], Essi Keskinen[2], Joni Koskikala[2], Pekka Lehtonen[2], Lasse Kurvinen[2]

[1]Finnish Environment Institute (Syke)
[2]Metsähallitus Parks and Wildlife Finland
[3]Government of Åland

Aim

The aim of action A6 is to deliver a suggestion on monitoring programme for the monitoring of marine biodiversity of shallow photic areas. Especially these areas, representing high diversity of both vegetation and associated fauna, mostly lack operative monitoring. Whereas the *Finnish inventory programme for underwater marine diversity*, Velmu, and other projects have extensively surveyed marine biodiversity and collected over 200 000 observations, very little information on temporal changes of shallow photic areas exist. This document presents the biodiversity features for which pilots have been carried out within the context of actions A6 and C4 to date as well as a road map for which pilots will be prioritized going forward until the end of the project. This document will especially focus on monitoring approaches where there are plans for practical pilots that include fieldwork conducted as part of action C4. In addition to this piloting road map, there are two deliverables focusing on remote sensing-based methods and environmental DNA, respectively. These will include more in-depth descriptions and analyses on how these technologies can be used to support monitoring, as well as some additional habitats such as coastal reed beds. The current piloting of selected methods will test their feasibility and finally contribute to the main product of this action, a suggestion for national operational monitoring of key features of shallow habitats, to be presented in 2029.

Selecting pilots

The initial selection of species and habitats for piloting was done during a joint workshop carried out in 2023 with participants from the Finnish Environment Institute, Parks and wildlife Finland, the Government of Åland (Ålands landskapsregering) and Åbo Akademi University. Participants also included representatives from the indicator development action (C5). Some of the key observations from the workshop included that monitoring should target habitats, but be developed as to also allow monitoring of changes in community composition. It was also decided that monitoring of nonindigenous species is outside of the scope of this action as there are separate monitoring programs targeting them.

Other work within the action conducted to support the development of the pilots have included, compilation and digitizing of existing historical monitoring data, as well as assessments of spatiotemporal patterns in biodiversity. Key observed identified challenges have included, lack of available cohesive temporal data, as well as gaps in our understanding of intra-annual patterns. The large gradients in environmental conditions along the coast, influencing the community composition, also mean that target habitats and species can substantially differ between sea basins.

The pilots that have been carried out have contained some of the key habitats, under water vegetated communities including macroalgae, eelgrass and charophytes, found in lagoons and coastal areas, as well as reefs dominated by blue mussels. The pilots are all listed in Table 1. The next section contains descriptions of the individual pilots, as well as plans for completing them. The level of detail varies depending on the stage of piloting.

Table 1. Overview table of the targeted habitats and methods used in piloting.

Habitat or community	Target variable	Method	Pilot status
Coastal lagoons	Community composition, Functionality	Diving / snorkelling + temperature loggers	24 lagoons in Eastern Gulf of Finland and southern Bothnian Sea have been sampled in 2023 and 2025.
Vegetation in the Bothnian Bay	Community composition	Diving	Existing temporal data from 1993, 2007, 2010 and 2017. Transects repeated in 2025.
Zostera marina / SAV	Extent, depth limit, height	Remote sensing (drone, aerial and satellite images), acoustic methods (side scan and down scan), field validation	Initial piloting was conducted in 2024-2025, including drone, side scan and down scan echo sounding, and video-based surveys. Satellite based mapping of SAV extent has been piloted.
Charophytes	Extent, depth limit, height	Remote sensing (if possible drone, aerial and satellite images), acoustic methods, field validation	High precision acoustic sonar scanning on two exposed charales sites in Bothnian Bay/Gulf of Bothnia.
Fucus habitat	Extent, depth limit, height	Remote sensing (drone, satellite images), acoustic methods (down scan) field validation	Drone field mapping has been piloted on different sites in 2023, 2024. Satellite based mapping piloted for test area in Bothnian Sea
Fucus associated invertebrates	Community composition	Epifaunal scuba sampling, Fucus weight	Repeated data collection planned for sites with historical data starting in 1968-1971 and repeated in 1981-1983 and 1986.
Sandbanks	Community composition	Infaunal scuba sampling	120 samples collected in 2024.
Reefs	Extent, community composition of epibiota, blue mussel community structure and biomass	ROV images and video, scuba sampling of blue mussels	Testing of ROV methods in 2024 and initial data collection in 2025 at two reefs in the Gulf of Finland.
Benthic habitats	Condition	AI-video interpretation	Using existing videos and new video transects to assess habitat quality.

Links to policy

The monitoring described here links to various monitoring demands at from global to national scale. Examples of relevant policies include **global**: CBD (Convention on Biological Diversity) A.2 Extent of natural ecosystems, Ramsar Reporting status of Ramsar Sites, assess and monitor the extent and condition of all types of wetlands*, **European union:** HD (Habitat directive) 1150 structure & function, range, area, MSFD (Marine Strategy Framework Directive) D1C5, D6C3, D6C5, WFD (Water Framework Directive) Ecological status, NRR (Nature Restoration Regulation) Annex 1 1150, Annex II, EA extent, state of type, Natura area site assessment (Nata), **HELCOM**: Monitoring program Habitat-forming species and substrates, softbottom flora, softbottom fauna **National:** Red List of Ecosystems Criteria A, B, C, D flads, gloes, Red List of Species, Nature conservation act 18§ monitoring of: species and habitats (included above), PA ecological status. Occurrence and status of protected habitat type *shelter Chara meadows* and *Zostera marina*, Water act 11§ Occurrence and status of habitat type *flad^*, PA site management (HKS etc).

Coastal lagoons

Aim

Currently, there is no long-term monitoring of the lagoons and their associated macrophyte communities in Finland. In some instances, lagoon vegetation has been mapped in consecutive years (e.g. Kvarken Flada project), but this only covers a three-year period at maximum. Findings show that vegetation in lagoons can vary greatly between years and even between the summer months. Long term monitoring of lagoons will help in identifying trends in the state of the habitat and help in understanding lagoon ecology. This is particularly important as lagoons are important nursery areas for fish, and they can include threatened habitat types such as sheltered charophyte meadows (Kotilainen et al. 2018).

Pilot description

The goal is to build a network of monitored lagoons around the Finnish coast in different development stages on the flad-glo succession and affected by different levels of anthropogenic pressure. This will be piloted by conducting monitoring in a pilot group of coastal lagoons.

The pilot groups were randomized from lagoons that had been mapped during the 2023 Velmu field campaign and two areas were chosen for the pilot, Sea of Bothnia and Eastern Gulf of Finland. This will enable a temporal comparison between 2023 and 2025. The lagoons were first grouped into four groups by two variables: if there is a dredging inside the lagoon or not and if the threshold was in natural state or not. Three lagoons were randomly chosen in each group (dredged inside - dredged threshold, not dredged inside - dredged threshold, dredged inside - not dredged threshold and not dredged inside – not dredged threshold) totalling 12 lagoons in each area and summing up to 24 lagoons.

The mapping of vegetation was conducted at approximately the same time as the reference point from 2023 using methods described in the Velmu method guide (Parks and Wildlife Finland and Finnish Environment Institute 2024). Three temperature loggers were deployed at each monitored lagoon to track temperature fluctuations inside the lagoon and the difference between the inside of the lagoon and the sea area outside (Fig. 1). Two loggers were placed inside and one outside.

Depending on the results from the temporal comparison, the pilot might be expanded to 1) new areas or 2) by collecting data from the lagoons at a third time-point. The mapping of vegetation will be conducted at approximately the same time every year with the date of the 2023 mappings as a reference point. Three temperature loggers will be deployed every year between approximately April and October in each monitored lagoon to track temperature fluctuations inside the lagoon and the difference between the inside of the lagoon and the sea area outside. Two loggers are placed inside and one outside. The condition in the lagoons will be measured using indicators developed for macrophytes in C5.

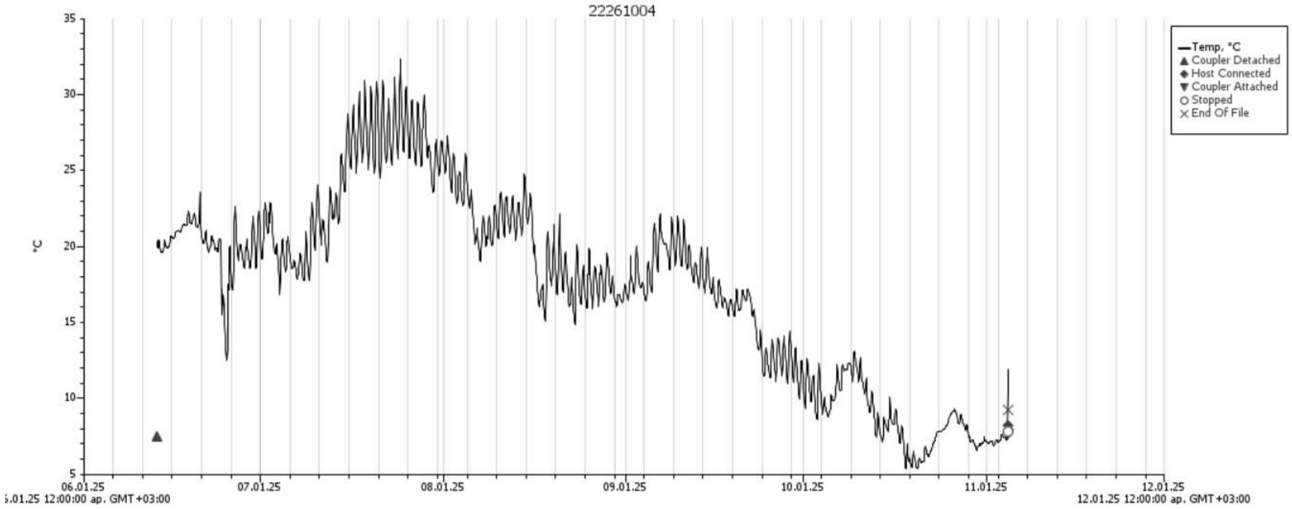

Figure 1. Temperature development during the season for one of the sampled lagoons.

Vegetation in the Bothnian Bay

Aim

Long term regular monitoring of rocky algal areas has been conducted since the early 1990s in the Gulf of Finland and the Bothnian Sea and, to some extent, also in the Kvarken archipelago. These monitoring efforts have mainly concentrated on bladderwrack (*Fucus vesiculosus*) and red algae (Rhodophyta), both of which are almost completely absent from the Bothnian Bay due to lack of sufficient salinity. Because of this, there is a need to expand the monitoring to all marine areas surrounding the Finnish coast.

To gain some information about the long term changes in the vegetation in the northernmost part of the Bothnian Bay, this pilot for monitoring programme will repeat underwater vegetation studies done in the Bothnian Bay National Park in 1994 and again in 2007 (Leinikki and Oulasvirta 1995; Yliniva and Keskinen 1995). This will be the third time for these same transects to be monitored. Aim of this pilot is also to develop statistical analysis for detecting change in dive transect data to evaluate its use as a monitoring method.

Pilot description

Bothnian Bay National Park (Perämeren kansallispuisto) was founded in 1991. Nowadays it is also a Natura 2000 SAC area FI1300301.

The park’s underwater nature was quite unknown at the time. In order to get some information about the underwater flora and fauna, underwater species and habitat mapping took place during field seasons 1993 and 1994. During that time, for example 15 scuba transects were dived within the park area ranging from about 70 m to 214 m in length (one transect 550 m). Bottom substrate was recorded during the whole dive and species of flora were estimated from 0,5 x 0,5 or 1 x 1 m squares (1-9 samples per point) between varying distances.

In 2007, 12 of these dive transects were repeated as accurately as possible at the same places. Since there were no coordinates or other clues where the transects started, except for the drawings on the map, the places are approximate. In the year 2007, all transects were decided to be 200 m long. All transects were dived so that approximately 2 m on both sides of the transect were evaluated for all species of flora and the bottom substrate. Every 50 m a 1 x 1 m sampling site was carefully examined for all species and their % coverage and bottom substrate % coverage.

The missing 3 transects were dived 2010 and 2017, but only as 100 m transects instead of the original 200 m transects. The last missing 200 m transect can be covered with drop-video points from year 2010.

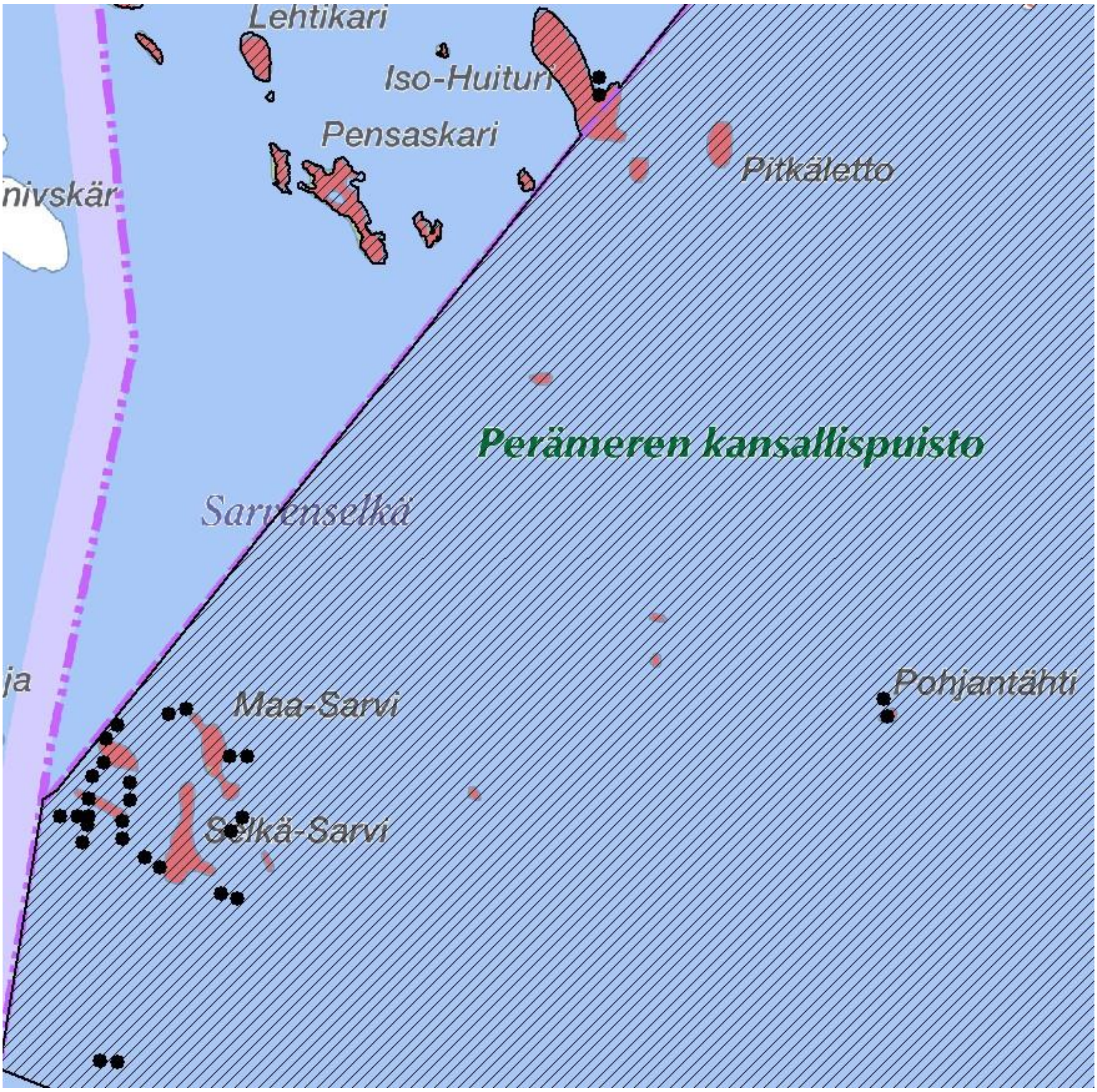

Figure 2. The transects repeated in 2025.

During the field season 2025, all 15 original transects were revisited again (Fig. 2). This time the coordinates were the same as were used in 2007, 2010 and 2017. All transects are 200 m long and were assessed with the same method as has been used for all Finnish national underwater inventories since 2004 (Parks and Wildlife Finland and Finnish Environment Institute 2024). Species and bottom substrate coverage were estimated from a 4 m^2 sampling area according to Velmu methods.

Collected data will be analysed using statistical multivariate methods following commonly used practices presented by Clarke et al. (2014). A special question in analysis will be application of transect data, which represent different depth and vegetation zones. As the collected data is from relatively small geographical area it is also expected that the data analysis will help in estimating the correct monitoring effort for detecting changes.

Zostera marina

Aim

Eelgrass (Zostera marina) meadows are considered as key habitat in the Northern Baltic Sea. They provide important shelter and nursery grounds for fish, and they have an important role in carbon sequestration and storage (Röhr et al. 2016). The extent and state of eelgrass meadows in the Baltic and Western Sweden have been reported to collapse drastically during last decades due to changes in water quality and habitat loss due to construction (Moksnes et al. 2018). In Finnish coast evidence of trends of eelgrass dynamics has been scarce (Boström et al. 2022) but it has been estimated that 30 to 50 % of the eelgrass meadows have vanished due to deteriorated water quality in the Northern Baltic. Consequently, the state of eelgrass meadows is considered vulnerable according to the latest red list of habitats assessment Kotilainen et al. 2018). Recently, to improve and speed up the conservation status of eelgrass meadows, they were included to the list of protected habitats by the revised national Nature Conservation Act. Establishing robust methodology to identify and monitor eelgrass meadows and their dynamics is highly needed to evaluate the state of eelgrass meadows in the Finnish coast. We are planning to test monitoring approaches on eelgrass extent and eelgrass lower growth limit dynamics by means of remote sensing methods.

Pilot description

Extent

Our aim is to test different optical remote sensing datasets in order to find the most feasible methodological set up for eelgrass extent monitoring. Our test site, Kolaviken, is located in Hanko peninsula close to the city of Hanko. Kolaviken is known to host large mixed meadows of eelgrass and other vascular underwater vegetation. Kolaviken is well suited for piloting methodologies as the meadow is large and in good condition. It is one of the top locations for eelgrass on the Finnish coast. Monitoring eelgrass dynamics only in Kolaviken may not reflect the overall trajectory of the state and trend of eelgrass meadows in Finnish coast and it is likely that monitoring efforts developed needs to be piloted also elsewhere.

In summer 2024, we tested the potential of drone imaging, aerial photography and satellite imagery in monitoring the extent of eelgrass.

Aerial photographs provide a feasible dataset for eelgrass extent monitoring. The operational national aerial photograph program will provide images with approximately 3-year interval nationally. The spatial resolution of these images is 50cm. With this resolution, it is possible to model submerged aquatic vegetation (SAV) extent that can be later modelled to eelgrass extent with ground truth samples. Furthermore, historical aerial images may give valuable information on the development of SAV and eelgrass growth (Fig x). On the other hand, aerial photographs are snapshots. NLS program is not designed to monitor vegetation and therefore the image acquisition time is not optimal for vegetation surveys.

Limitations of aerial photographs are related to water quality and weather conditions.

European space agency's Sentinel 2 satellites provide 13 spectral band optical sensor coverage with 2-3 day interval in the Finnish coast. The program is operational and would be very beneficial to integrate some of the monitoring elements to Sentinel satellites. The spatial resolution is 10-20m. While the resolution will not resonate to species level there is growing evidence that Sentinel images can be used to monitor SAV dynamics (Fig X). In addition, commercial very high resolution (VHR) satellite images may be used to observe the finer scale vegetation fragmentation that is not visible in the coarser spatial resolution.

- ➔ We will use combination of the optical remote sensing products above to create SAV model in Kolaviken. To move from SAV cover to eelgrass and other species cover, we will sample the SAV area and conduct detailed vegetation survey on each sample spot. We will introduce video transects with accurate location to collect vast amount of observation in feasible time.
- ➔ We aim to repeat the study at the Kolaviken site during 2026 to identify changes in extent compared to the initial pilot (collaboration with the Luontotietoinfra).

Identifying the lower growth limit

Capturing the lower extent of eelgrass only aerial satellite or drone based remote sensing is not possible due to the optical water properties in Finnish waters. Eelgrass has been reported to be sensitive to deterioration of water quality. Often the changes in the environmental conditions are seen by shift or structure change in the lower growth limit (LGL). Our aim is to define the LGL of eelgrass in Kolaviken bay by combined use of side scan and down scan sonar imaging and develop a suitable temporal interval for monitoring changes in eelgrass LGL. In summer 2024 we ran tests on feasible ways to map LGL of eelgrass using side scan sonar images (fig x). The LGL is possible to be detected from the imagery. To validate the species we conducted video transects along the LGL (fig x). The underwater video camera location was linked to on board portable GPS receiver with a RTK correction. This way we were able to create locationally very accurate video transects.

- ➔ We will continue monitoring the LGLt of eelgrass in Kolaviken. In summer 2025 we will add down scan imaging with GPR-RTK level accuracy to the methodology to better understand the physical structure of the LGL. We will also conduct accurate video transects to evaluate the species structure of the LGL. The aim is that after 2025 we will have a detailed baseline of the LGL for monitoring.

Charophytes

Aim

Exposed charophyte meadows are found throughout the marine areas along the Finnish coastline (Kotilainen et al. 2018). Among the perennial habitat types characterized by vegetation rising from the seabed, charophytes form an important group that provides essential habitats for many other species, including invertebrates, benthic organisms, and fish. In the northern Bothnian Bay, exposed charophyte meadows, which can occur in abundance in some areas, have been assessed as Near Threatened (NT) in evaluation the second assessment of threatened habitat types in Finland (year 2018). Both large-scale construction projects planned or underway, as well as small scale pressures including dredging, pose a threat to the vegetation communities of shallow coastal waters, especially when combined with eutrophication and pollution. To properly plan conservation actions it is important to monitor changes in spatial extent and condition of charophyte dominated habitats over time.

Among the exposed habitat types of the Bothnian Bay, charophyte meadows are especially suitable for many monitoring approaches. These habitats can be used to monitor the occurrence, condition, and spatial extent of charophyte vegetation over time.

The marine area of the Bothnian Bay is characterized by relatively low water transparency due to the input of humic substances from large rivers (see Secchi depth maps and references). As a result, optical remote sensing methods—such as aerial and satellite imagery—are not well-suited for detecting charophyte meadows on deeper sandy bottoms.

The lower growth limit of charophyte vegetation could be an important indicator of charophyte condition, as the maximum depth is expected to be tied to water clarity, which in turn reflects broader eutrophication trends in the area. Charophyte meadows typically occur on exposed sandy and gravel substrates. These plant communities help stabilize the seabed by binding sediment and reducing erosion—similar to the function of seagrass meadows. However, constantly shifting sands can lead to rapid changes in growth conditions leading to changes in habitat extent.

Pilot description

No previous monitoring has been conducted specifically on exposed charophyte meadows. However, the Velmu has been mapping marine biodiversity and valuable habitats along the Finnish coastline since 2004. This dataset provides a solid foundation for selecting suitable charophyte sites and planning a pilot for a monitoring program.

The Bothnian Bay is particularly well-suited for monitoring exposed charophyte occurrences due to the abundance of these meadows in shallow, sandy marine areas.

The monitoring method will be piloted at two exposed marine sites during the 2025 field season. One site will represent a relatively undisturbed charophyte community, with minimal turbidity caused by riverine input or human activity. The second site will be located closer to the coast, where anthropogenic pressure is higher. Both sites will be selected to minimize the risk of disturbance from pack ice.

The primary method for delineating the charophyte meadows will be the use of a high-precision echo sounder (RTK). The sonar data and species composition at each site will be verified using drop-video transects and point observations with RTK-level accuracy. Additional species verification may be conducted through diving surveys or by using a rake sampler (e.g., Luther rake).

We will pilot an analysis of spatiotemporal changes in the extent of Charales meadows using NLS aerial photographs in exposed habitats of the Bothnian Bay. The approach includes modelling the distribution of submerged aquatic vegetation (SAV), which can later be refined to estimate Charales extent using ground-truth samples. Using data tied to precise geographic coordinates, it will later be possible to monitor changes in vegetation at the sites—for example, shifts in the lower growth limit and/or qualitative changes in species composition.

Fucus habitats

Aim

Bladder wrack, *Fucus vesiculosus* (hereafter *Fucus*) is an important habitat forming species, supporting a wide array of invertebrate species and the only large macroalgal species in Finnish waters. *Fucus* is sensitive to eutrophication and experienced substantial declines in the 60 and 70s in the Baltic Sea. The lower depth limit of bladder wrack has been monitored as part of water quality monitoring, but there is currently no monitoring that focuses on the distribution and habitat extent of *Fucus*. Due to the complex optical water properties, monitoring the extent of the habitat using earth observations and drones is only feasible to the depth of 3-5 metres. Monitoring the extent thus requires a combination of techniques combining remote sensing and acoustic approaches.

Monitoring of only *Fucus* is not enough to capture the associated invertebrate community. This has been recognised, and the monitoring of invertebrates has been recently set up as part of the MSFD monitoring. However, to capture changes that might already have occurred with the introduction of nonindigenous species such as the mud crab (*Rhithropanopeus harrisii*), we need to have an understanding of the baseline. Identifying some of the invertebrates to species level, such as small gammarids, using traditional microscope-based counting can be very time consuming. Molecular techniques have the potential of streamlining the sample processing in the future.

Pilot description

Habitat extent (drone + acoustics)

Mapping Fucus beds has been piloted using different spatial resolution remote sensing instruments and acoustic methods to find methods that could 1) estimate the area of Fucus beds including the lower growth limit, and 2) provide regional scale estimates.

In the Ulko-Tammio area, the occurrence of bladderwrack (*Fucus vesiculosus*) stands was surveyed using side-scan sonar. In 2024, 42 vegetation transects were conducted by diving to validate aerial photographs and acoustic data. The resolution of the side-scan sonar was insufficient for delineating the areas covered by bladderwrack, so the sonar data was used to interpret the bottom substrate suitability for it. The mapped area covered approximately 34 hectares, of which 15 hectares were digitized as suitable for bladderwrack. The data also confirms bottom substrate suitability horizontally near the dive transects and below the current lower growth limit. The depth limit for bladderwrack will be determined using available depth models and vegetation transects.

In November 2025, testing of bladderwrack depth limit determination was carried out using a high-resolution echo sounder and HD video transects. A total of 33 precision transects were surveyed, and for 29 of them, bottom substrate and vegetation were verified in shallow sections using video. The videos were HD quality, and live footage was transmitted to the surface via Wi-Fi.

Additionally, the high-resolution sonar data recorded during the 2025 season will be compared with the 2024 dive transects. Species verification will be based on video footage, which confirmed the presence and coverage of bladderwrack along the transects. After this, the suitability of the method for bladderwrack monitoring will be assessed.

Fucus associated invertebrate community

To understand the changes in invertebrate communities over time the pilot focuses on revisiting sites that have historical data. *Fucus* epifauna has been sampled periodically at five locations near Tvärminne zoological station between 1968 and 1986 and four locations from 1968 to 1970 (Pentti Kangas 1980). The number of samples and the sampling frequency vary between years and sampling sites. Seasonal sampling data are available from five sites between 1981 and 1983 (Jouko Rissanen personal communication). We used the original species identification forms and printouts and digitized the species observations, subsequently depositing the data in the national database for benthic macrofauna.

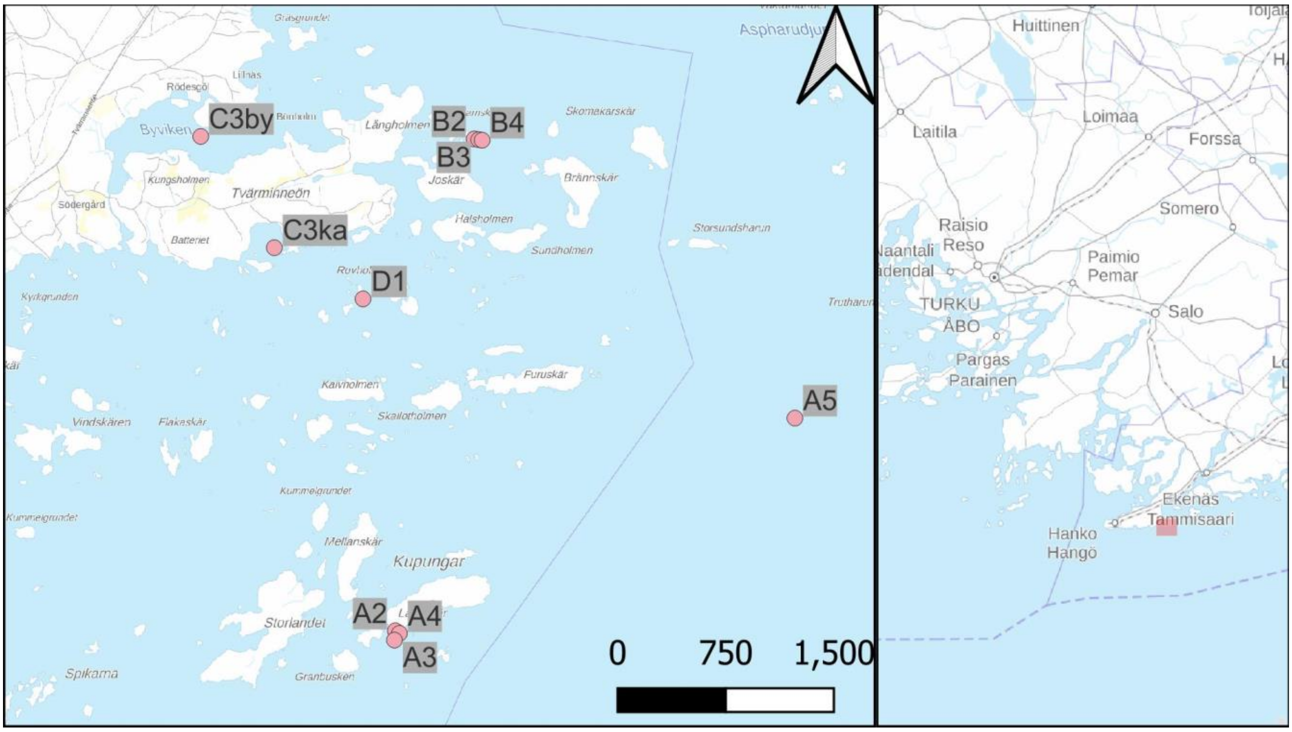

Figure 3. The locations that are planned to be resampled in 2026.

To capture the temporal change in the area, the aim is to resample the sites during 2026 (Fig. 3). Initial field visits were conducted to assess the sites in 2025 for availability of bladderwrack for sampling. If possible, we will also assess the usability of molecular tools to supplement the species identification.

Sandbanks

Aim

Shallow sand banks can be covered by vegetation but are typically bare in both exposed and deeper areas. These habitats are biologically characterized by invertebrate infauna. Separate monitoring will be piloted for sandbanks covered by eelgrass but their extent and coverage is relatively limited geographically. In order to develop monitoring non vegetated sandy bottom, infauna sampling has been included in the action. Data analysis and interpretation of variability in sandbank communities can be tested and evaluated by application of data analysis methods used in operational soft bottom macrofauna monitoring.

Pilot description

During the field season 2024, 120 benthic invertebrate samples (60 in the Bothnian Bay, 42 in the Archipelago Sea and 18 in the Gulf of Finland) were taken from sandbanks and/or sandy areas around the esker islands (Fig. 4A). The aim was to get one sample from the shallowest, middle and the deepest areas on a 100 m scuba transect line on sandbanks but since not all modelled areas turned out to be sandbanks, samples were also taken from sandy esker islands. Three single samples were strived to be taken from each transect but sometimes there was so little sand that all 3 samples could not be taken from the same transect.

The sampler was a 8 cm diameter plastic tube, operated by a scuba diver, or in some cases, a person in a survival suit standing in shallow water (Fig. 4B). The tube was pushed into the sand to the depth of at least 10 cm. Rubber caps were used for sealing the sample of sand, which was later flushed to a sample vial with 80 % ethanol so that in the end 50 % of the sample volume was ethanol. Samples were stored for analysing until 2025.

Further 60 samples were taken during the field season 2025 from the Archipelago Sea and the southern Bothnian Sea and analysed for species composition with the 2024 samples.

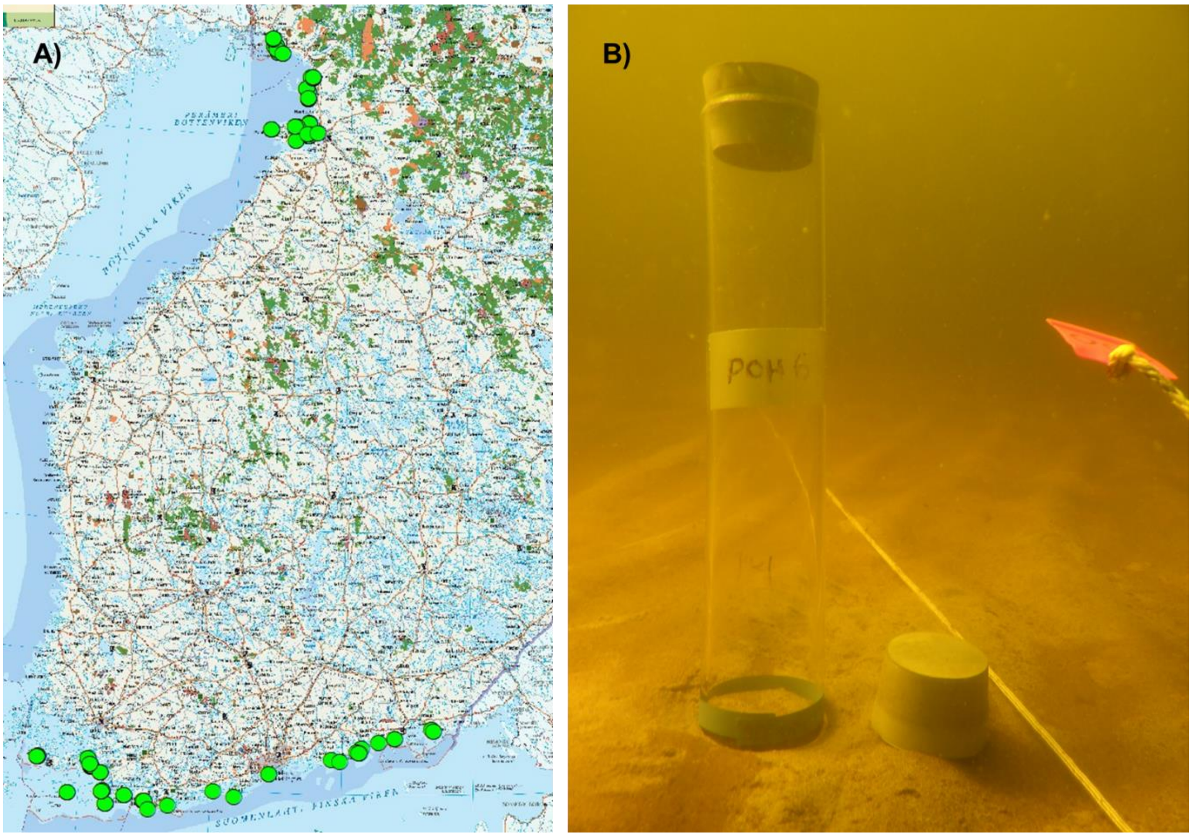

Figure 4. A) Map showing the 2024 sampled sandbanks and B) the sampler during one sampling event (Sara Karvo / Parks and Wildlife Finland).

Samples were analysed to species or genus level during 2025. Collected data will be analysed using statistical multivariate methods following commonly used practices presented by Clarke et al. (2014). Results will be used to evaluate monitoring efforts needed for sandbank habitats.

Reefs

Aim

Reefs are widely distributed and a common and dominant hard bottom habitat in especially outer archipelago and innermost open sea areas, covering about 2450 km2 in Finnish waters. In exposed conditions macroalgae are often scarce and reefs are typically dominated by attached invertebrate epifauna, consisting of suspension feeding mussels, barnacles, and cnidarian, poriferan and bryozoan species. Especially blue mussel (*Mytilus trossulus*) may occur both in high abundance and biomass in reefs extending from central Gulf of Finland in the east to Quark archipelago in the north. The dense mussel beds host several other invertebrate species, support high diversity. By their high filtering capacity blue mussels may contribute significantly to both nutrient and organic matter circulation and has been suggested to even control phytoplankton blooms in coastal zone (Norling and Kautsky 2007, Koivisto and Westerbom 2010). Reefs also support demersal fish communities and can be important feeding sites for several bottom feeding sea birds like eider and long tailed ducks.

Reefs are currently not being monitored, and the aim here is to develop a monitoring method describing changes in epifauna extent and community composition, focusing on changes in blue mussel community structure and biomass. In addition to salinity changes, reef epifauna may respond to changes in eutrophication status and to the observed increasing temperatures, linked to climate change.

Pilot description

To test methods for reef monitoring, video surveys with ROV and the acquired UWIS under water positioning system has been done in 2024-2025. Field tests were done at two reefs located in central and eastern Gulf of Finland. Based on this experience a method to be piloted for reef monitoring has been developed.

Reef epibiota extent and species composition will be studied by high resolution video imaging with ROVs. Two to four vertical transect will be established at each reef, extending from ca. 40 m to the top of the reef. If possible, the transects will be placed radially to opposite directions from the top of the reef. ROV imaging will be combined with high precision under water positioning using UWIS equipment. For optimal placing and representativity a depth model and substrate map will be needed for each reef to be monitored. Already existing data from Velmu inventories and mapping by Geological Survey Finland will be used to model the physical environment. In addition to biota, the amount of fresh sedimentation on hard surfaces will be estimated from video materials. Other environmental characteristics (salinity, temperature, amount of chlorophyll-a and turbidity) will be derived from other ongoing monitoring activities.

For monitoring of blue mussel community structure and biomass, samples will be collected by scuba diving. Community characteristics will be derived from length measurements of the mussels and converted further to biomass estimates. Automatization of length measurements is being developed based on machine learning assisted image analysis. In action C5, an indicator for recruitment success and stability of the mussel population is being developed.

In 2026, three outer reefs located in the Gulf of Finland will be sampled with the above-described method to pilot monitoring of reefs. In 2027, same reefs will be revisited and depending on experience from the previous year and resources, monitoring can be extended to other sea areas also.

Benthic habitat condition

Aim

Eutrophication is usually assessed based on the depth distribution of indicator species or by pelagic measures such as nutrient concentrations of broader areas. As habitats are fragmented, these broad scale pelagic variables do not directly inform the condition of underwater species and habitat types (Forsblom et al. 2025). Here the aim is to develop automated methods for assessing habitat condition of underwater habitat types. This is particularly relevant considering the monitoring needs of the EUs Nature Restoration Regulation.

Pilot description

The aim is to develop automatic assessment of the condition of underwater habitats based on underwater imaging collected using drop down camera equipment. To develop the indicators, we are using video data already collected within the Velmu programme that has already been manually analysed for species composition and eutrophication related variables such as surface sediment quantity. After training of the initial AI-based classification model, we will use newly collected transect data collected as part of the other macrophyte pilots on *Z. marina*, Fucus and Charophytes.

Summary of plans for 2026-2029

The next two years will focus on completing the field work conducted by action C4 connected to the pilots. Of the pilots two have the fieldwork completely completed and are awaiting analyses of the data. The first phase of the lagoon pilot has also been completed and any additional piloting will depend on the results of the analyses conducted in 2026. All other pilots will likely include further data collection before the final assessment of the piloting results during 2028 and 2029. The planned pilot work is briefly describe in the summary table 2.

Table 2. Tentative piloting activities planned for 2026-2028

Habitat or community	2026	2027
Coastal lagoons	**Analyses of collected data.** Second round of pilots to be decided based on analyses	Additional lagoon sampling peding 2026 analysis results
Vegetation in the Bothnian Bay	**Analysis of collected data**	
Zostera marina	**I)** Analysis of collected data **II)** Repeat of pilot to identify temporal change in Kolaviken **III)** Piloting in different conditions	Data analysis continues
Charophytes	**I)** Analysis of collected data **II)** Piloting in different conditions	**I)** Piloting in different conditions **II)** Data analysis
Fucus habitat	**I)** Analysis of collected data **II)** Tentative plans for more piloting in different conditions	
Fucus associated invertebrates	Resampling of historical sites	Analysis of collected data; identifying temporal change in community
Sandbanks	Analysis of collected data	
Reefs	**I)** Analysis of collected data **II)** Piloting in the field	**I)** Additional piloting in the field
Mytilus indicator	**I)** Development together with indicator development in action C5 **II)** Collection of additional data when piloting reefs	**I)** Collection of additional data when piloting reefs **II)** Data analysis

Habitat conditions	**I)** Analysis based on existing videos and transects collected during 2025 **II)** Potential to use additional transects collected in 2026.	

Acknowledgement
We would like to extent our thank you to all who have contributed to the collection and management of the data used in the present work as well as the Finnish inventory programme for underwater marine diversity, Velmu. We would also like to thank the CoastalBioMon project lead by Camilla Gustafsson (Tvärminne Zoological Station, University of Helsinki) for collaboration. We also want to thank Finnish Marine Research Infrastructure (FINMARI) consortium for providing equipment.

References

Boström, C., Bonsdorff, E., Kangas, P., & Norkko, A. (2002). Long-term changes of a brackish-water eelgrass (Zostera marina L.) community indicate effects of coastal eutrophication. *Estuarine, Coastal and Shelf Science*, *55*(5), 795–804.

Kangas, P. (1980). Rakkolevävyöhykkeen makrofauna Tvärminnen alueen saaristossa. *Oulun Yliopiston Eläintieteen Laitos*.

Koivisto, M.E. and Westerbom, M. (2010). Habitat structure and complexity as determinants of biodiversity in blue mussel beds on sublittoral rocky shores. Mar Biol 157: 1463–1474.

Kotilainen, A., Kiviluoto, S., Kurvinen, L., Sahla, M., Ehrnsten, E., Laine, A., Lax, H. G., Kontula, T., Blankett, P., & Ekebom, J. (2018). The Baltic Sea. In T. Kontula & A. Raunio (Eds.), *Threatened Habitat Types in Finland 2018. Red List of Habitats, Part II: the Habitat Descriptions* (pp. 99–183). The Finnish Environment Institute and the Ministry of the Environment 5/2018.

Leinikki, Jouni and Oulasvirta, Panu (1995) Perämeren kansallispuiston vedenalainen luonto. *Metsähallituksen luonnonsuojelujulkaisuja*. Sarja A, No 49. 86 s.

Moksnes, P-O., Eriander, L., Infantes, E. & Holmer, M. (2018). Local Regime Shifts Prevent Natural Recovery and Restoration of Lost Eelgrass Beds Along the Swedish West Coast, *Estuaries and Coasts* https://doi.org/10.1007/s12237-018-0382-y

Norling, P. and Kautsky, N. (2007). Structural and functional effects of Mytilus edulis on diversity of associated species and ecosystem functioning. Mar Ecol Prog Ser 351: 133-175.

Röhr, M. E., Boström, C., Canal-Vergés, P., & Holmer, M. (2016). Blue carbon stocks in Baltic Sea eelgrass (Zostera marina) meadows. *Biogeosciences*, *13*(22), 6139–6153. https://doi.org/10.5194/bg-13-6139-2016

Parks and Wildlife Finland, & Finnish Environment Institute. (2024). *The Finnish Inventory Programme for the Underwater Marine Environment (VELMU) Methodology guide*. https://zenodo.org/records/11576650

Yliniva, Marika and Keskinen, Essi (2010) Perämeren kansallispuiston vesimakrofyytit – peruskartoitus ja näytteenottomenetelmien vertailu. *Metsähallituksen luonnonsuojelujulkaisuja*. Sarja A 191. 66 s.

Deliverable A6.3 Data management plan

The data collected during the monitoring pilots will be deposited into national databases and repositories (Table 3). Most of the species observations will be deposited in either LajiGIS or POHJE databases. Data deposited to LajiGIS and POHJE are publicly available through the Finnish Biodiversity Information Facility (FINBIF) and from the Velmu map service.

Additional environmental variables and derived data such as extent assessments of the habitats, will be made available and distributed either distributed as part of Sykes Downloadable spatial datasets or distributed through Zenodo. All datasets will include metadata that supports the reusability of the data. Selected data can also be shared with the public through the Velmu map service.

Table 3. Description of the data types and intended storage of all new data collected from each of the pilots.

Habitat or community targeted in pilot	**Type of data**	**Planned data deposition**
Coastal lagoons	Species observations and associated data	LajiGIS (https://laji.fi/, https://velmu.syke.fi/)
	Temperature logger data	Zenodo / Downloadable spatial datasets (Syke)
Vegetation in Bothnian Bay	Species observations and associated data	LajiGIS (https://laji.fi/, https://velmu.syke.fi/)
Zostera marina	Species observations and associated data	LajiGIS (https://laji.fi/, https://velmu.syke.fi/), drone images stored to dedicated internal server
Charophytes	Species observations and associated data	LajiGIS (https://laji.fi/, https://velmu.syke.fi/), drone images stored to dedicated internal server
Fucus habitat	Species observations and associated data	LajiGIS (https://laji.fi/, https://velmu.syke.fi/), drone images stored to dedicated internal server
Fucus epifauna	Species observations and associated data	Pohje (https://laji.fi/, https://velmu.syke.fi/)
Sandbanks, invertebrates	Species observations and associated data	Pohje (https://laji.fi/, https://velmu.syke.fi/)
Reef	Species observations, videos	Field observations with Velmu method LajiGIS (https://laji.fi/, https://velmu.syke.fi/) Video data are stored on dedicated internal server by MH.
Mytilus indicator work	Species observations, videos	Field observations with Velmu method LajiGIS (https://laji.fi/, https://velmu.syke.fi/) Video data are stored on dedicated internal server by MH.
Habitat condition indicator	Video	Video data are stored on dedicated internal server by MH.