A6.2 Deliverable - Assessment of the effects of temporal variation on monitoring efforts

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Assessment of the effects of temporal variation on monitoring efforts

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Aims

The aim of action A6 is to deliver a suggestion on monitoring programme for the monitoring of marine biodiversity of shallow photic areas. The optimal timing for monitoring is influenced by the seasonal succession of species as well as by the inter-annual variability of species. The present task deliverable, A6.2 Assessment of the intra-annual timing of monitoring efforts, supports the selection of optimal inter- and intra-annual timing of monitoring. Due to seasonal successional patterns and geographical variation in the length of growing season, both community composition and species abundance can vary substantially over a season (Torn et al. 2006). Due to seasonally narrow time-windows species occurrences could even be completely missed by monitoring. To enhance accuracy of the planned monitoring efforts, both the seasonal and inter-annual variability of species will be investigated using data from the Finnish Inventory Programme for Underwater Marine Diversity, Velmu (Forsblom et al. 2024) and using available monitoring data on algae and vascular plants such as the macrophyte monitoring conducted as part of the Water framework Directive (WFD). This will support the timing of monitoring efforts to be of both optimal timing and time interval.

Intra-annual patterns

Intra-annual patterns in algae have previously been investigated extensively by Ruuskanen (2016), but the data only covers algae. The Velmu programme has carried out inventories of marine vegetation and fauna since 2004, mainly focusing on the summer period (Fig 1). The data has been collected mainly using scuba diving or video methods, with the aim of generally visiting unique locations each time. This makes investigating temporal changes in species annual successional patterns difficult, but identifying some intra-annual patterns for common species is still possible.

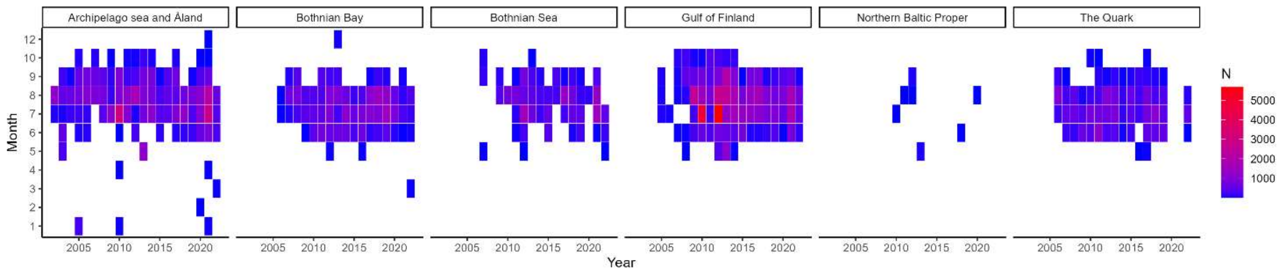

Fig 1. The distribution of the number of observations collected from different sea areas during different months and years.

Successional patterns

To investigate the inter-annual patterns, we divided the observations based on sea areas, and considered only months that had at least 100 observations on species percentage cover available for each species. The data were further split into two depth categories, 0-5m and >5 m deep areas. To calculate median and maximum species cover for each month we used a bootstrap routine, drawing 20 samples without replacement with 100 repeated draws.

We evaluated the intra-annual patterns in percentage cover for 78 species. In half of the considered basin and species combination there were only sufficient information available for one or two months (109). It is possible that these species have their main occurrence within a certain month, but it is not possible to conclusively say from the data. The resampled maximum covers are presented in figure 2 for all species that have sufficient data for four or more months in at least one basin. Some of the species such as *Najas*

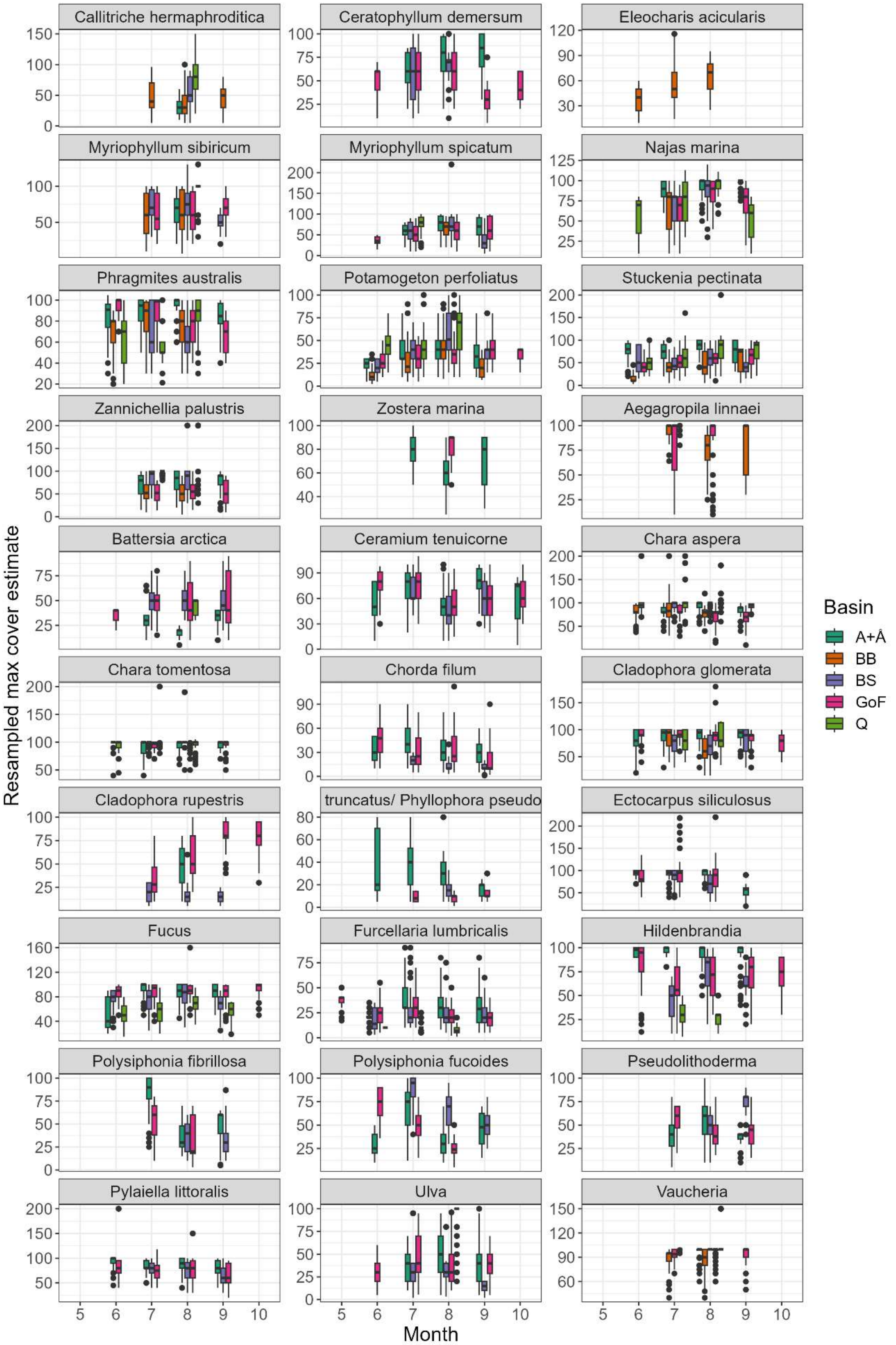

Fig 2. Resampled maximum monthly cover estimates using observations from 0-5m depth. Graph only includes species with at least one basin with four months of data. Basins are A+Å = Archipelago and Åland Sea, BB = Bothnian Bay, BS = Bothnian Sea, GoF = Gulf of Finland and Q = the Quark.

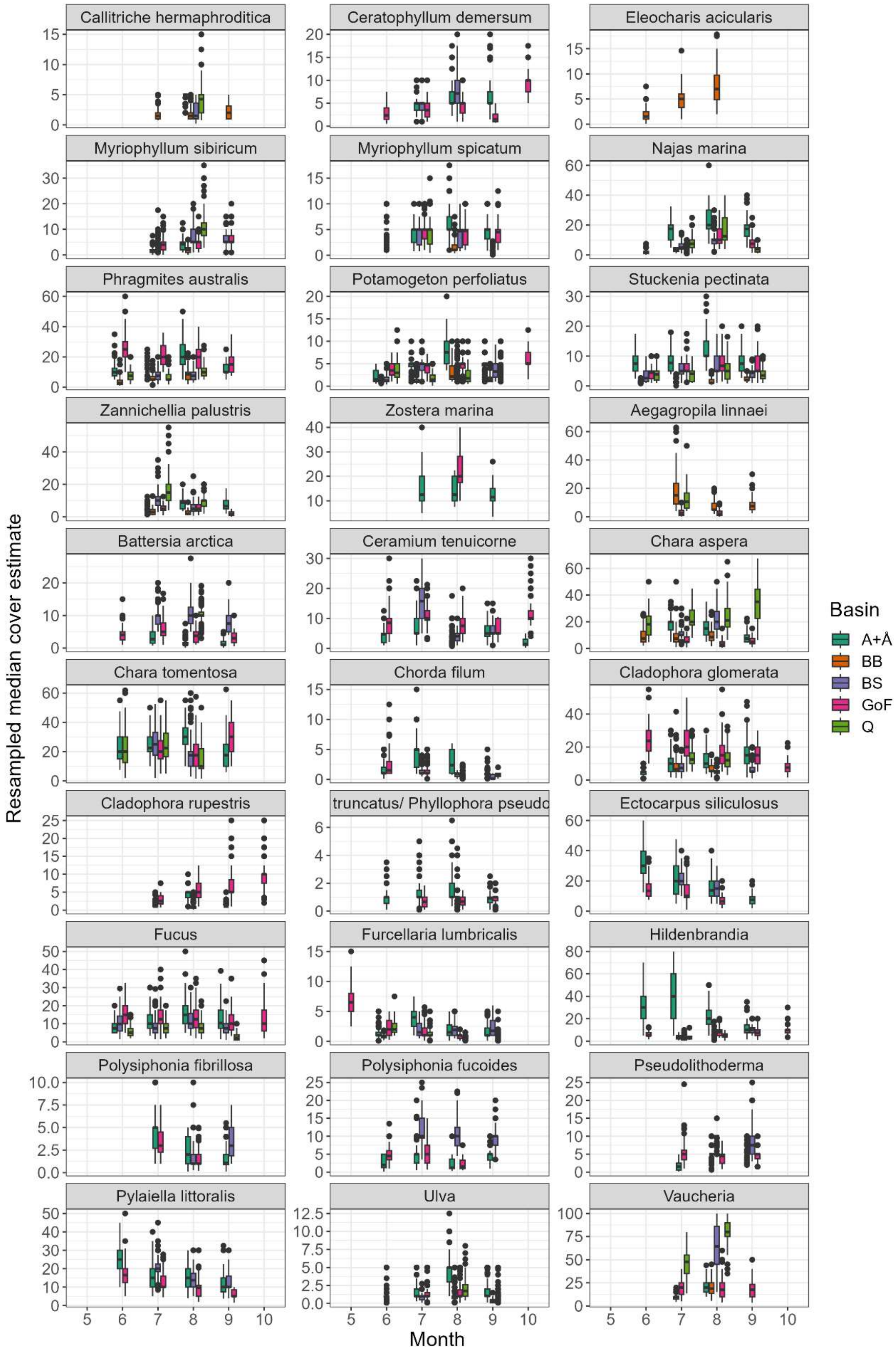

Fig 3. Resampled median monthly cover estimates using observations from 0-5m depth. Graph only includes species with at least one basin with four months of data. Basins are A+Å = Archipelago and Åland Sea, BB = Bothnian Bay, BS = Bothnian Sea, GoF = Gulf of Finland and Q = the Quark.

marina, Potamogeton perfoliatus and *Ceratophyllum demersum,* seem to achieve some form of maximum during the June-July. The resampled maximum cover for *Eleocharis acicularis* and *Cladophora rupestris* increases with month. However, for most species the pattern is variable for all months with observations available. Instead of only assessing cover, assessing biovolume might be another option and offer more detailed results as many species, especially vascular plants, increase in length instead of cover.

Most literature on the successional patterns of submerged aquatic vegetation in the Baltic Sea is limited to local observations at few sites. In the North Sea *Fucus vesiculosus* have been shown to reproduce earlier in higher temperatures in laboratory experiments (Graiff et al. 2017). Also, vascular plants such as *Potamogeton crispus* have been shown to occur earlier in experimental settings (Zhang et al. 2016). Some studies have used remote sensing to map changes in floating aquatic vegetation (Villa et al. 2018) or to identify vegetation from areas during low tides (Légaré et al. 2022).

Missing species

The Velmu mapping programme has predominantly gathered data during the growth season, with an emphasis on July and August. Due to the timing of the mapping effort, some earlier emerging species might be missed. To investigate this, we compared the species observed within the programme to the HELCOM Checklist 2.0 of Baltic Sea Macrospecies (HELCOM 2020). We compared the full species list of macrophytes observed in the Velmu data to the HELCOM check list for the Finnish basins to identify species that could be missing from the data. For the species that were found to be missing we further checked the Global and Finnish Biodiversity Information Facilities repositories for observations in Finnish areas. In total 17 species were identified, but these were either species with all existing Finnish observations located inland, species with no new observations since 1950s and earlier, species only observations from genomic samples (*Chaetomorpha ligustica* and *Pseudendoclonium submarinum*) or as for *Nitella confervacea*, species only occurring very rarely. More in depth work on potentially missing, underrepresented and hard to identify species is carried out in *Action A1*.

Inter-annual patterns

Analysis of macrophyte monitoring data

Identifying inter-annual patterns is important for determining the optimal time interval for monitoring efforts. Ideally the time span is short enough to capture changes but long enough to keep costs low. Inter-annual monitoring data on macrophytes from 2009 to 2023 was analysed from the Quark to Gulf of Finland. Censuses are conducted on a fixed transect in March-November. 18 of the places have been censused during the summer months (June-August) in at least five years (maximum 12 years). Here, we focused on the summer months to avoid confusing inter-annual variation in species composition with seasonal (intra-annual) variation, even though seasonal variation in species diversity, measures as Shannon index, is surprisingly low in the data (Fig 4). The diving transects are located on hard substrates, and therefore the species are mostly perennial macroalgae.

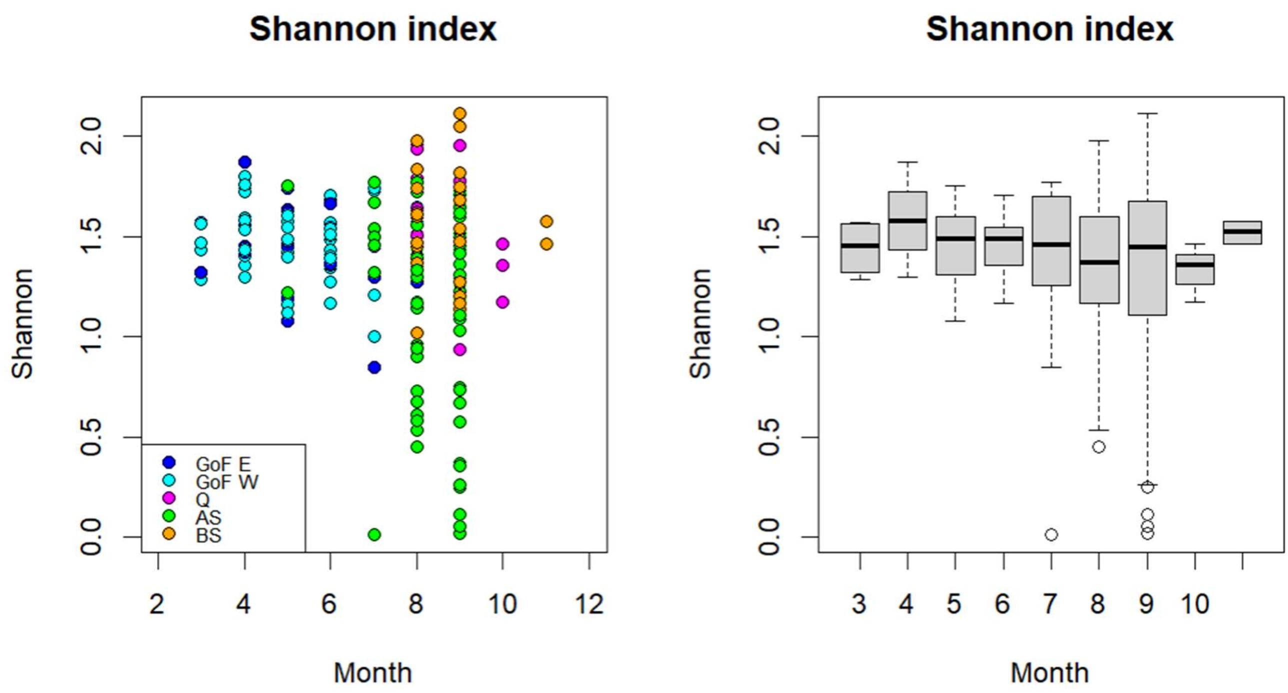

Figure 4. Shannon diversity index per sea area and month. GoF E = Eastern Gulf of Finland, GoF W = Western Gulf of Finland, Q = Quark, AS = Archipelago sea, BS = Bothnian sea. Left: by month and sea area, dots are individual census sites. Right: boxplot of monthly mean index.

Diving transect data on macrophyte abundance that has been collected related to the Water framework directive was analysed from 2009 to 2023. Assessing temporal patterns or potential change from this data set is difficult, because (summer-time) monitoring has been done in different years in different sub basins. It is not possible to reliably disentangle the effects of year and sub basin on the scale of the whole data set because of that. Also, the timing of the monitoring in relation to growing season varies considerably (March-November, Fig.4). Censuses in the Gulf of Finland have usually been done earlier than those in the Archipelago Sea or other sub basins. Unless census month is taken into account, it is possible to falsely interpret phenological patterns as a long-term change or spatial pattern in this kind of data. To avoid this, only data collected between June and September was used in a preliminary analysis and analysis were mostly done for each sub basin separately. The width of the time window is inevitably a trade-off between data quality and sample size.

Ordination for the monitoring data was performed with the function metaMDS in the package "vegan" in R (Oksanen et al. 2022; R Core Team 2022). Abundance data was used instead of presence-absence data, because differences between species communities in the different census sites are more likely to be seen with abundance data. The data was not transformed in any way. Log-transform was tested, but it did not improve the results. Only plants, algae and sessile epifauna were included in the analysis. Using the results from the community analysis, a non-linear (3rd polynomial) model suggests that a change in species composition, measured as NMDS1values that are an output of the ordination, has taken place only in the Western Gulf of Finland (Fig. 5).

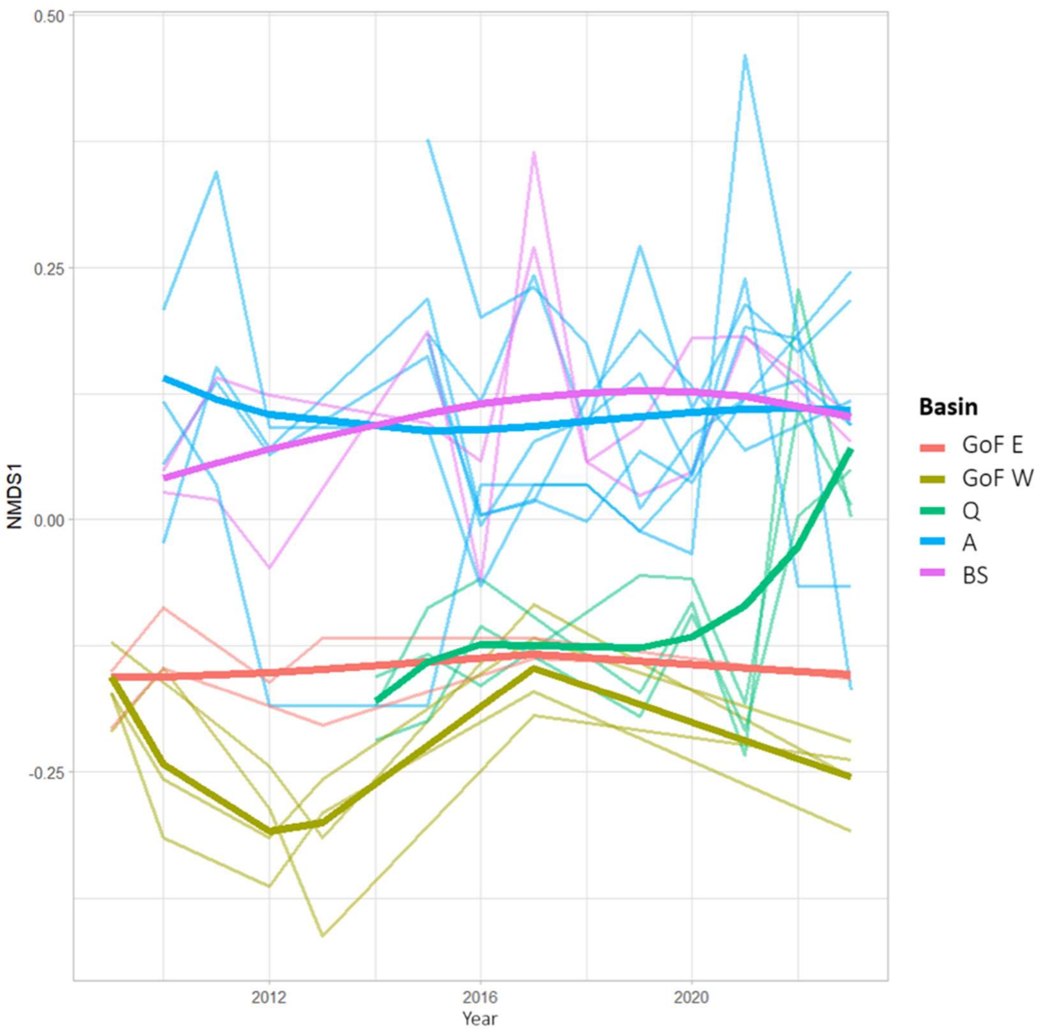

Figure 5. NMDS1, the ordination axis correlated more strongly with year in ordination, as a proxy for community composition, yearly in the different sea areas. Thin lines = individual census lines, thick lines = modeled response per sea area.

Seven diving transects in the Archipelago Sea have all been censused in the same years. This uniform data set was analyzed separately. In this kind of complete data, potential changes in community composition cannot be artefacts of different census lines (or even different sub basins) having been sampled in different years, which is the case on the scale of the whole data set, if focus is only on censuses done in June-September. The data suggests that the species community was statistically significantly different in 2023 compared to other years due to an increase in *Pylaiella* or *Ectocarpus* and a decrease in *Cladophora glomerata* (Fig. 6). Similar analyses of complete data sets from The Quark and the Western Gulf of Finland also suggest that in 2023 species communities differend from previous years.

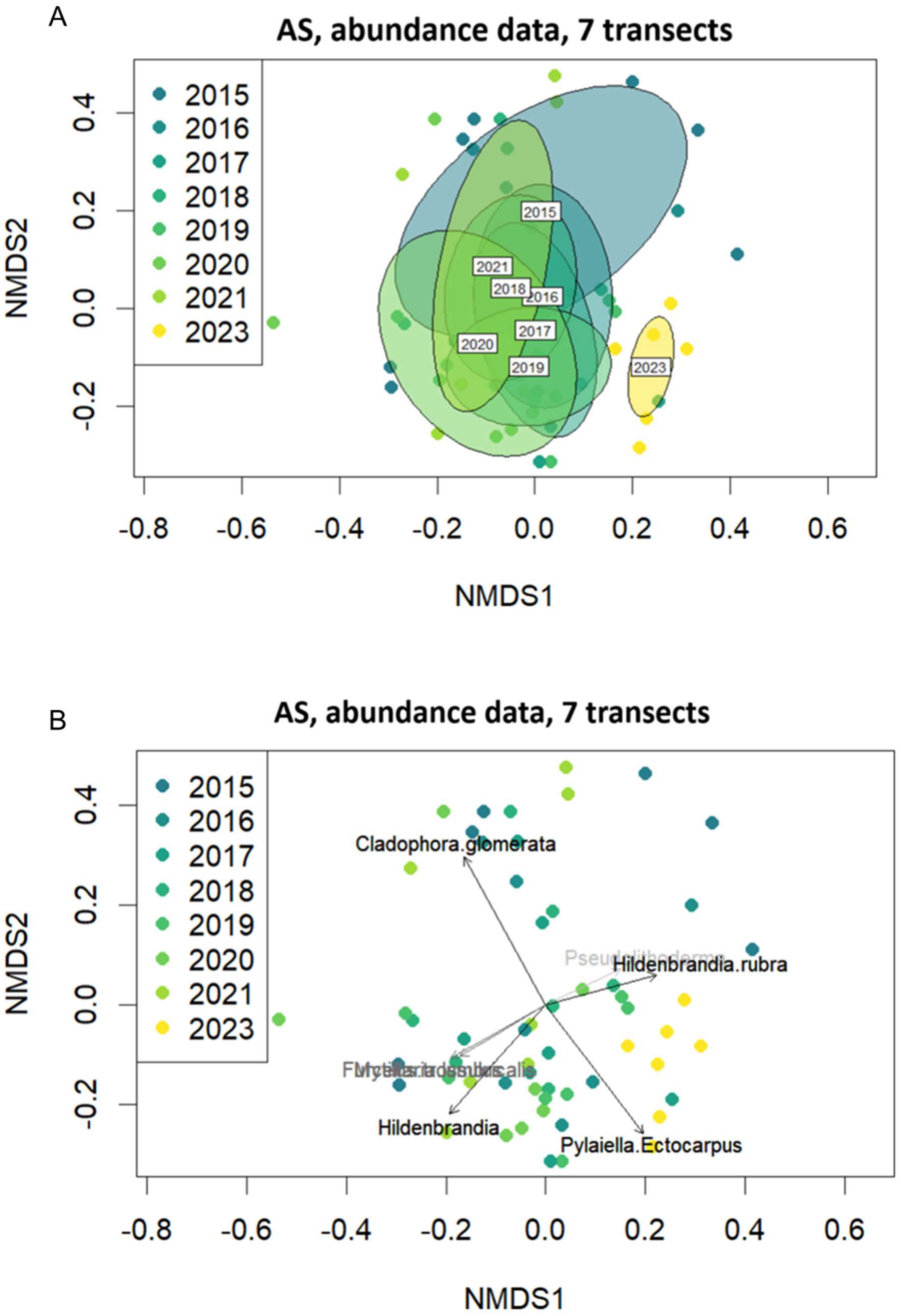

Figure 6 A, B. Ordination for seven transects in the Archipelago Sea. a) Years shown with ellipses based on standard deviation. b) Vectors of statistically significant species shown on top of ordination. Light grey: $p < 0.05$, grey: $p < 0.01$, black: $p < 0.001$.

The small data set from the Archipelago Sea demonstrates how useful complete data is and emphasizes the need to conduct censuses in all the study places in same year and month. Data collected from different places in different years is not useful in a time series analysis, even though it can be useful for studying other questions. For monitoring temporal changes in species communities, the time between consecutive censuses is not as important as the completeness of the time series. In other words, in those years when censuses are conducted, regardless of whether it is every or every *n* years, censuses should be conducted in all census sites. This would produce data that can be used to study temporal changes that can be reliably observed without variation caused by inconsistent or spatially varying sampling.

Potential new monitoring sites should be representative of the sub basin and gamma diversity. In the macrophyte monitoring data set, some diving transects have only three spspecies in some years, whereas others have around 20. These sites with very low species diversity are challenging, because a change is more likely to be observed in a species-rich environment, but still, these are part of the diversity of marine habitats. Some low diversity sites can be included in a study design, but it is important to understand and foresee how that can affect for example ordination plots done from the whole data. In the ordination of the present macrophyte data, the low diversity transects are clearly separated from the rest of the data.

Conclusions and future perspectives

Currently there is very little information available on the intra and inter annual dynamics of macrophyte communities. Using the extensive existing mapping data did not support more in depth investigations into intra-annual variability and successional patterns in the cover estimates of alga or vascular plants. Considering how shifts in species phenology can have broader implications for functioning, this is an important data gap.

Most existing monitoring assessments use data collect every three years and are focused on perennial species. However, data have been collected annually, but due to the focus on perennial species the timing of the collection has been variable over the years and not strictly enforced. Analyzing the most complete time-series and focusing on a narrow sampling window showed that there may have been rapid shifts in the communities. This highlights the importance of monitoring the whole community.

Species diversity, measured as Shannon index does not vary significantly between months when all species are considered. However, annual species might be harder to observe or can be missing if monitoring is done too early. Therefore, it is recommended that monitoring would be done in late summer when most species are easy to observe. A short, fixed time frame also yields data where inter-annual changes are possible to detect reliably. Standardizing the timing is especially crucial for assessing changes in community composition.

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