# Assessment report on overall applicability and technical sustainability

**LiveLagoons project report**

2021

This report is prepared within the implementation of project LiveLagoons „The use of active barriers for the nutrient removal and local water quality improvement in Baltic lagoons", No. STHB.02.02.00-LT-0089/16, a cross-border coopeeration project of the Interreg South Baltic Cross-border Cooperation Programme 2014-2020

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http://www.balticlagoons.net/livelagoons/

# Contents

# Executive Summary

AFWs are an innovative variant of a constructed treatment wetland that allows non-land-based water treatment in water bodies that are too deep for plants to grow and under fluctuating water levels (Grosshans et al., 2019). Nutrient-rich water is treated by bacteria (biofilms) attached to the plant roots performing nitrification/denitrification (release of N2 gas), biological breakdown, and detoxification. Roots and installation themselves enhance particle retention. As a result, increased water clarity, reduced algae, and cyanobacteria growth, as well as reduced nutrient levels, could be achieved. In addition, floating wetlands provide habitats for aquatic and terrestrial fauna. In recent decades the commercially available floating mats (e.g. BioHaven®, Biomatrix®, AquaGreen® or Beemats®) are increasingly applied as a technique to create artificial wetlands for diffuse pollution treatment, water quality improvement, and biodiversity habitat creation. Various types of floating vegetation platforms increasingly available on the market (e.g. Aquascape, Velda, SiboFluidra, EkoWyspa) suggest many types of floating substrates adapted for small ponds and gardens.

Live Lagoon project is dedicated to studying AFW environmental impact on the natural coastal eutrophic waters to assess its potential for nutrient removal. In addition, habitat creation and coastal protection function of AFW was under focus.

Thanks to the LiveLagoons project floating macrophytes islands have been adapted to coastal conditions and deployed in three South Baltic locations: Curonian Lagoon (Juodkrante) and Klaipeda city,Lithuania, Szczecin Lagoon (Wolin National Park –Łunowo Marina and closed branch of Stara Świna), Poland and Darss-Zingst-Bodden-Chain (Born), Szczecin Lagoon (Vogelsang-Warsin) and Warnow estuary (Rostock), Germany. Our goal was to use the fact that plants' roots remove nutrients from the water, thus limiting algal growth and improve consequently the water improving its transparency and, quality, and limiting algal growth. In that way, we could contribute to healthier and cleaner environments in heavily eutrophicated lagoons.

The nutrient removal capacity of the island is the sum of nutrients accumulated in the aerial biomass (stems and leaves) and underwater biomass (roots), nitrogen loss by microbial activity, phosphorus uptake by microorganisms, and sedimentation. The nutrient removal capacity of AFW in the natural open water systems is nearly impossible to estimate. Therefore we selected a simple methodology for estimating nutrient content in the harvested plants, although the aerial biomass could contribute only ~10% of nutrient removal while the rest is accounted for by the root-associated microbial community.

The total plant harvest from 24-28m$^2$ island could reach ~70-90kg of fresh weight. This amount of plant biomass contained ~290-590g of N and ~18-38g of P. While multiplied by a factor of ×10 the total nutrient removal capacity of a single island could be estimated as a maximum of 5,9kg N and 0,38kg of P annually. This rough amount of P is equivalent to P content in ~63m$^3$ of treated household effluent. One island's annual function could cover a footprint of a single household (producing 15m$^3$ wastewater per month) for 4-5 months only. For a larger impact, a higher AFW area is needed.

Even though the nutrient removal capacity of the island is very low compared to the anthropogenic inputs into the coastal systems reaching thousand tons annually, it provides value for biodiversity and ecosystem services for the society. Floating islands or wetlands constitute offer an ecological and efficient option for local water improvement.

However, one should be aware that the islands have a very local water quality improvement impact. Floating islands tend to be most effective directly behind point-sources, e.g. at outlets of aquaculture effluents or drainage stations. Due to mixing in lagoons some positive nutrient removal effects can be noted only in enclosed areas, like marinas or enclosed small bays. However, in all possible locations increase of biodiversity is visible.

AFW serves as a new habitat for birds. It could be a resting place in winter or migration season, nesting hunting, or a lurking location in summer. In the underwater part of the island, the shelter is provided for juvenile fish, even protected species such as eels. AFW planted with some exotic and ornamental plant species provides aesthetic value in urban environments.

This report generalises on two other publications delivered by the LiveLagoon project: ‘Nutrient removal capacity of floating installations’ and ‘Best practice Guidelines for installation and maintenance of floating islands and nets’.

# Overview of installations

Experimental floating structures were placed in five locations, where net and different island designs were tested.

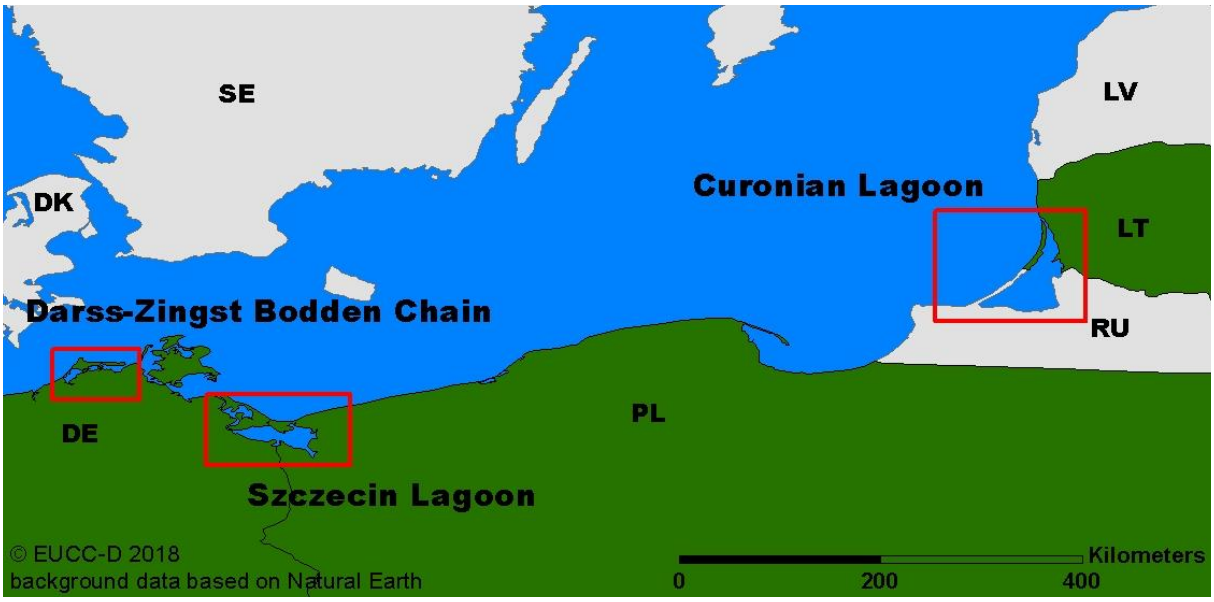


Fig. 1. Island and net instalation sites in the SE Baltic Sea.

The net barrier was installed closing the basin between two piers in the **Nida in the Curonian Spit NP** in May 2018. The net was planted with *Salix* spp. and *Phragmites australis*.

The first floating islands in Germany were installed in **Born at the Darss-Zingst Bodden Chain** (Born) in May 2018 with our cooperation partner – the Federal State Institute of Agriculture and Fishery MV. The islands are located directly behind the outlet of an aquaculture pond (sturgeon cultivation). The first islands were made out of stainless steel mesh filled with reed stems..

A modified new island made out of thermowood was installed in Born in April 2019.

In Poland and Lithuania Biomatrix 3D – Matrix Islands of size: 3.45 m x 6.9 m and a total of 23.9 $m^2$ (**Wolin NP, Juodkrantė Gintaro bay**) and 28 $m^2$ areas (Juodkrantė 14km) were installed in May 2019. The Wolin NP island is located in the marina.

The third floating island in Germany was installed within a drainage channel close to the beach in **Vogelsang-Warsin in the Szczecin Lagoon** in December 2020.

The third island in Lithuania was installed in the **Klaipeda city** center (Jonas Hill water reservoir) in June 2020 using the same Biomatrix 3D design, but different plant assemblage including non-native species.

# Technical constraints and requirements

## Location of the floating island

Climate, salinity and hydrology influence the plant choices, the type of anchoring and the shape of the island, but these environmental factors do no limit the choice of installation sites per se. Floating islands can be adapted to almost all coastal environments. However, limitations regarding suitable sites exist and depend inter alia on legal requirements and social acceptance. Therefore, prior to installations, research regarding site selection needs to be carried out. The purpose of the island will also determine the location. You may already have a specific spot in mind, for example a coastal lagoon suffering from excessive nutrient loadings, an urban pond needing environmental remediation or artificial river banks in need for an aesthetic upgrade Most of the locations were either in protected ebmayments of larger water bodies. More details on location selection were presented in the *Best practice Guidelines* prepared by the LiveLagoons project partners.

## Tested floating island designs

In the LiveLagoons project we used 6 different floating island and one floating net designs (examples below). The most robust were the commercially available islands provided by the BIOMATRIX WATER

**Wolin National Park, Poland**

Matrixes made of recycled and UV-resistant hollow plastic (HDPE) pipes, covered with coconut coir fiber and fastened using a plastic (PP) mesh

**Juodkrante, Lithuania**

Matrixes made of recycled and UV-resistant hollow plastic (HDPE) pipes, covered with coconut coir fiber and fastened using a plastic (PP) mesh

**Nida, Lithuania**

A custom-made floating net with mesh size > 11 cm, 200 m length and 1 m height, placed at 1 m depth

**Klaipeda city, Lithuania**

Matrixes made of recycled and UV-resistant hollow plastic (HDPE) pipes, covered with coconut coir fiber and fastened using a plastic (PP) mesh

**Born, Darss-Zingst-Bodden-Chain, Germany**

Made of a stainless steel mesh which is filled with dry reed stems and hollow stainless steel buoys to enhance the buoyancy effect

**Born, Darss-Zingst-Bodden-Chain, Germany**

Floating matrix is made out of thermowood. With this thermally modified spruce wood the durability and buoyancy is enhanced

**Vogelsang-Warsin, Szczecin lagoon, Germany**

Floating matrix is made out of thermowood. With this thermally modified spruce wood the durability and buoyancy is enhanced

**Rostock, Warnow Estuary, Germany**

Two islands, one made out of glass gravel framed in xylitol and basalt nets, the other one made out of thermowood. Both plastic-free.

matrices made of recycled and UV resistant plastic (HDPE) tubes covered with coconut coir fiber and fastened using a plastic (PP) mesh. However the excessive use of platics lead to search for more alternatives, which were presented by stainless mesh and thermowood constructions tested in Germany and more ecologically friendly matrices, where plastic (PP) mesh was replaced by inox wire mesh and coconut fiber was partly replaces by a local reed dried stems.

# Installation of the floating islands and planting experiences

## Experiences from Germany

First floating islands in Germany were installed in Born at the Darss-Zingst Bodden Chain in May 2018 with our cooperation partner – the Federal State Institute of Agriculture and Fishery MV. The islands are located directly behind the outlet of an aquaculture pond (sturgeon cultivation). The first islands were made out of stainless steel mesh filled with reed stems. They were planted with a pre-cultivated coir mat with a variety of native emergent macrophytes: *Lythrum salicaria, Bolboschoenus maritimus, Iris pseudacorus, Carex acutiformis* and *Schoenoplectus lacustris*.

FIGURE 2: INSTALLATION OF FIRST FLOATING ISLAND IN BORN, MAY 2018.

Most floating island designs use polyethylene, polypropylene, polyurethane or polyvinyl alcohol foam to ensure the buoyancy. Our aim for the German case study site was to develop an artificial polymer free island. However, buoyancy of the first floating islands was not sufficient. A modified new island made out of thermowood was installed in April 2019. Buoyancy of this island is still sufficient and vegetation is thriving (Figure 3).

FIGURE 3: INSTALLATION OF THERMOWOOD ISLAND IN BORN, APRIL 2019.

Based on our success-story with the thermowood island in Born, we installed another floating island in Vogelsang-Warsin at the Szczecin lagoon (Figure ). This coastal municipality repeatedly suffers from high loads of E.Coli bacteria at their bathing site. Studies in rivers and urban ponds showed that floating islands are not only capable of reducing excess nutrients but also bacterial contamination. Whether this also works in coastal waters is now being tested within the LiveLagoons project. A floating island with Carex acutiformis, Carex acuta, Lythrum salicaria and Iris pseudacorus was installed within a drainage channel close to the beach in December 2020. Impact monitoring will be carried out together with the local environmental agency.


FIGURE 4: INSTALLATION OF ANOTHER THERMOWOOD ISLAND IN VOGELSANG-WARSIN, DECEMBER 2020

Two more floating islands were installed in Rostock in summer 2021. The islands are located in the a local recreational park in a sheltered bay off the Warnow estuary with salinities around 8.5 PSU and a water depth of up to 1.5 m. At this site, frequent visitors can appreciate the beauty of a floating wetland that adds dashes of colour into the monotonous reed bed with the purple *Lythrum salicaria* or the yellow *Iris pseudacorus*. We will monitor how the macrophytes cope with these different environmental conditions (e.g. higher salinity) and make comparisons to the other study sites.

FIGURE 5: THERMOWOOD ISLAND IN IGA PARK, ROSTOCK, JULY 2021.

# Experiences from Poland

In the end of vegetation season on the 18th of September, 2018 some planted specimens have been removed from the net for more detailed observations in the laboratory, estimation of biomass and taking samples for nutrient content analysis (Fig. 7).

For the localisation of floating island in Poland, the Łunowo Marina on Wicko Lake, was chosen (Figure 6). The marina area is located in the Szczecin Lagoon within the Wolin National Park. The installation was conducted in April 2019 (Figure 6).

**Figure 6: Łunowo Marina on Wicko Lake, localization of the floating island in Poland (From design to blooming floating island)**

**Figure 7: Instalation of the floating island in Wicko Lake (Łunowo Marina), Poland, April 2019**

After the installation and anchoring of the island the native plants were planted. The choice of indigenous plants turned out to be a good one because the spectacular flora grew very quickly (Figure 7).

A ) B) C)

**Figure 8: The growth of the plants on floating island in Wicko Lake (ŁUNOWO MARINA), Poland, a) June 2019, b) July 2019, C) September 2019**

However, each year composition of plants was changing and the most striking feature was domination of Phragmites over other species. Typha was almost not represented in 2021. The same happened to Schoenoplectus of which only 4 stems survived. Instead Convolvulus arvensis started to colonize the island (Fig. 9).

**Figure 9: Colonization with Convolvulus arvensis – Łunowo Marina in Wicko Lake.**

## Experiences from Lithuania

### Floating net installation

The 'net' i.e. custom-made floating rig of 200m length and 1m height was placed at ~1m depth between the two moles in the end of May 2018. Two types of plants and different fixation methods have been used. The common reed (Phragmites australis) was planted in to the cylindrical PVC containers filled in with expanded clay. While single branches of the willow (Salix, ~1-1.2m length) have been fixed directly to the net. The plants were taken from the close coastal area at Juodkrante site and have already developed fresh leaves.

Figure 10: Floating net installation in Nida

Both species survived the waving and water level fluctuation conditions. Within two months Salix stems produced a significant amount of roots , while above ground growth was not significant.

The net has its structure disposed at whole cross-section of the water column. Zebra mussel *Dreissena polymorpha* attached to the rig itself and the plants fixed to the net at ~40cm below water surface, presumably avoiding waving and ultraviolet radiation. Below this depth, 60cm of the willow stem was fully covered with the newly settled zebra mussels. The nutrient content in soft tissues of zebra mussel is ~100.9 mg N/ gDM and 9.3 mgP/gdDM; shell contains ~0.38% of N and 0.45 mg P/g DM (McLaughlan and Aldridge, 2013). Zebra mussel can grow to the end of season and produce ~8 g of DW equivalent to ~8mg of P and 79mg of N.

Fig. 11. Zebra mussel (*Dreissena polymorpha*) attached to willow stem (photo by Ž. Grigaitis).

**Table 2.** The total nutrient removal by underwater production of willow stems and roots of *Phragmites*. N is number of stems and containers fixed to the net.

| Biomass parameter | Nitrogen, mg | Phosphorus, mg | N | Nitrogen, g | Phosphorus, g |
|---|---|---|---|---|---|
| *Salix* | | | | | |
| Roots | 114 | 5 | 100 | 11.400 | 0.500 |
| Mussels | 79 | 8 | 100 | 7.900 | 0.800 |
| Above ground | NA | NA | | NA | NA |
| *Phragmites* | | | | | |
| Roots | 398 | 33 | 100 | 39.800 | 3.300 |
| Above ground | NA | NA | | NA | NA |
| | | | Sum | 59.1 | 4.6 |

## Island type installations

There were four islands installed in Lithuania – two in the Curonian lagoon and two in the Klaipeda city in urban locations.

| | | |
|---|---|---|
| Curonian Lagoon Gintaro | Island area $24m^2$ Producer: Biomatrix Water Installed in 2019 Dominant plant species: *Carex acutiformes, Typha angustifolia* Harvesting in September |  |
| Curonian Lagoon 14km | Island area $28m^2$ Producer: Biomatrix Water Installed in 2019 Dominant plant species: *Carex acutiformes*, other Harvesting in September |  |

| | | |
|---|---|---|
| Klaipeda city | Island area 24m$^2$<br>Producer: Biomatrix Water<br>Installed in 2020<br>A selection of ornamental plants was used |  |

Fig. 12. Island type installations in Klaipeda.

## Plants used in the AFW

Choice of the macrophyte species was dependent on the purpose of the floating island and environmental constrains. In the protected territories only native plants were used.

- Perennial plants (the annual plants will grow spontaneously);
- Species resistant to local environmental conditions, e.g. salinity and climate.
- For nutrient removal choose *Carex acutiformis*, *Typha*, Iris, *Juncus*, *Sagittaria*, *Phragmites*.
- For biodiversity integration of endangered species (e.g. *Iris pseudacorus*)
- For aesthetic enjoyment integration of flowering plants such as *Lythrum salicaria*;
- Herbal collections (e.g. *Acorus calamus*, *Petasitis hybridus*, *P. spurius*, *Valeriana*).

Plants in these installations also divided into four different categories (Table 3), according to their height and size.

**Table 3.** Plants used in the floating installations in the urban islands (Klaipeda City Jonas Hill and Žardės pond islands).

| Latin name | Common name | Origin |
|---|---|---|
| Lower-medium height | | |
| ***Juncus conglomeratus*** | Common rush | native |
| ***Juncus effusus*** | Soft rush | native |
| ***Carex acuta*** | Slender Tufted-sedge | native |
| ***Carex riparia*** | Greater pond sedge | native |
| ***Carex pendula*** | Weeping sedge | native |
| ***Carex acutiformis*** | Lesser pond sedge | native |
| Decorative flowering | | |

| | | |
|---|---|---|
| ***Lysimachia vulgaris*** | Yellow loosestrife | native |
| ***Butomus umbellatus*** | Flowering Rush | native |
| ***Aster tripolium*** | Sea aster | native |
| ***Pontederia cordata*** | Pickerelweed | N. America |
| ***Thailia dealbata*** | Hardy water canna | N. America |
| ***Hibiscus moscheutos*** | Swamp mallow | N. America |
| Decorative foliage | | |
| ***Iris pseudacorus*** | Yellow flag | native |
| ***Carex morrowii*** | Japanese sedge | E Asia |
| High | | |
| ***Glyceria maxima*** | Great Manna Grass | native |
| ***Typha angustifolia*** | Narrowleaf cattail | native |
| ***Typha latifolia*** | Broadleaf cattail | native |
| ***Schoenoplectus lacustris*** | Lakeshore bulrush | native |
| ***Scirpus sylvaticus*** | Wood Club-rush | native |
| *Trees and bushes* | | |
| ***Taxodium distichum*** | Bald cypress | N. America |
| ***Viburnum x burkwoodii*** | Burkwood viburnum | Garden origin hybrid |

In the urban location (Klaipeda city) exotic ornamental plants were selected:

- Exotic ornamental species (e.g. *Iris* cultivars, *Thalia dealbata*, *Pontederia cordata*, *Hibiscus moscheutos*, variegated *Carex* cultivars )
- Trees and ornamental bushes (e.g. swamp cypress *Taxodium distichum*, *Viburnum* x *burkwoodii*).

Fig. 13. Ornamental plant species in Jonas Hill urban island, Klaipeda.

# The total harvest and nutrient removal capacity

After first growth season (2019) the plant biomass was low with exception of Gintaro island. The dence initiall planting resulted in high production of plant biomass. Gintaro island reached its steady state, after three years, in 2021, there was no more increase of the harvest. While, In Curonian Lagoon second island (14km) and Wolin NP biomass of plants increased during all investigation period.

The nutrient removal capacity increased in Wolin NP island significantly in 2021. Table 4 shows nitrogen and phosphorus removal with harvest. It is assumed that annual average plant harvest is 2.3kg/m$^2$. It varied from 0.5 to 4kg /m$^2$ in 2019-2021.

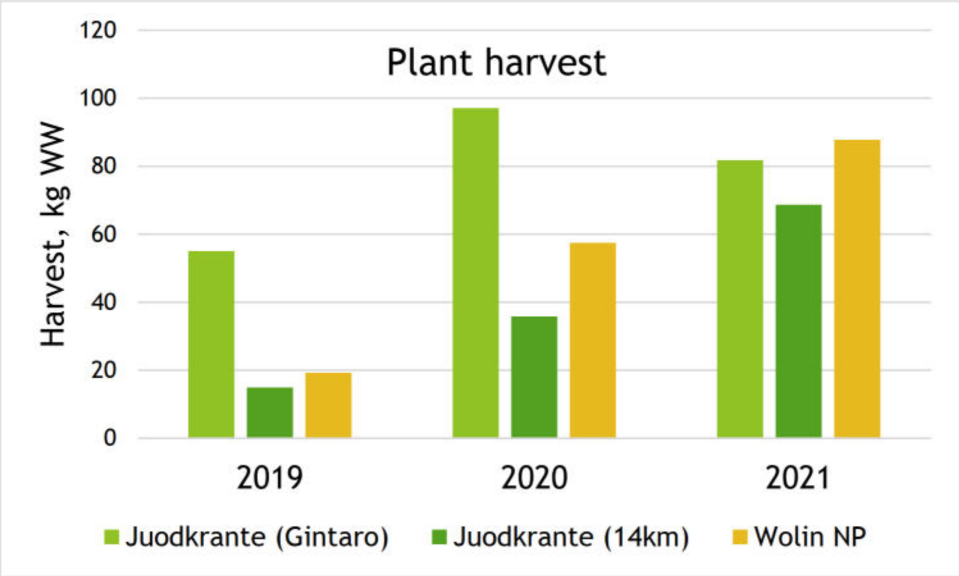


Fig. 14. Plant harvest in the Curonian Lagoon and Szczecin Laggon islands in 2019-2021.

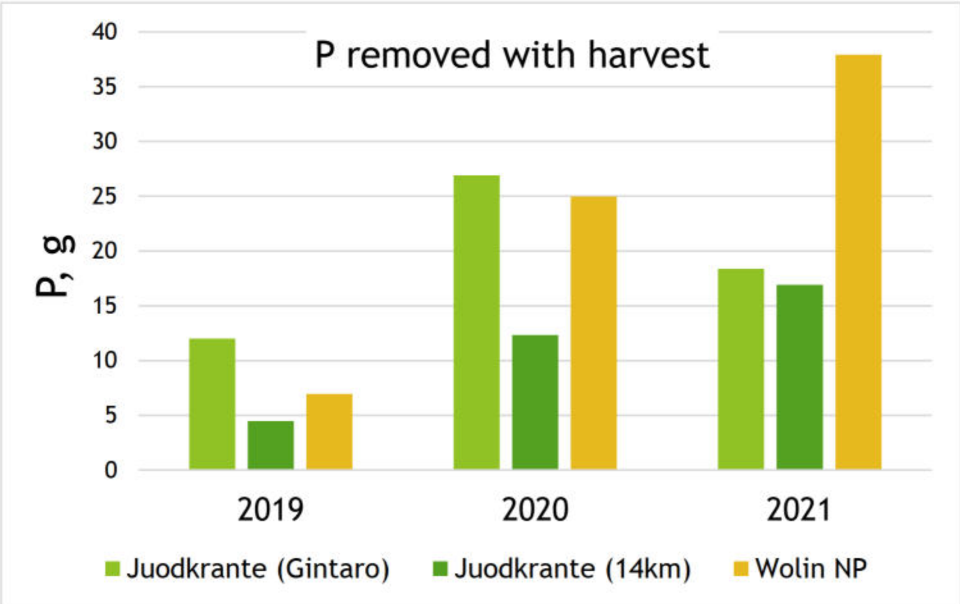


Fig. 15. Posphorus content in total plant harvest in the Curonian Lagoon and Szczecin Laggon islands in 2019-2021.

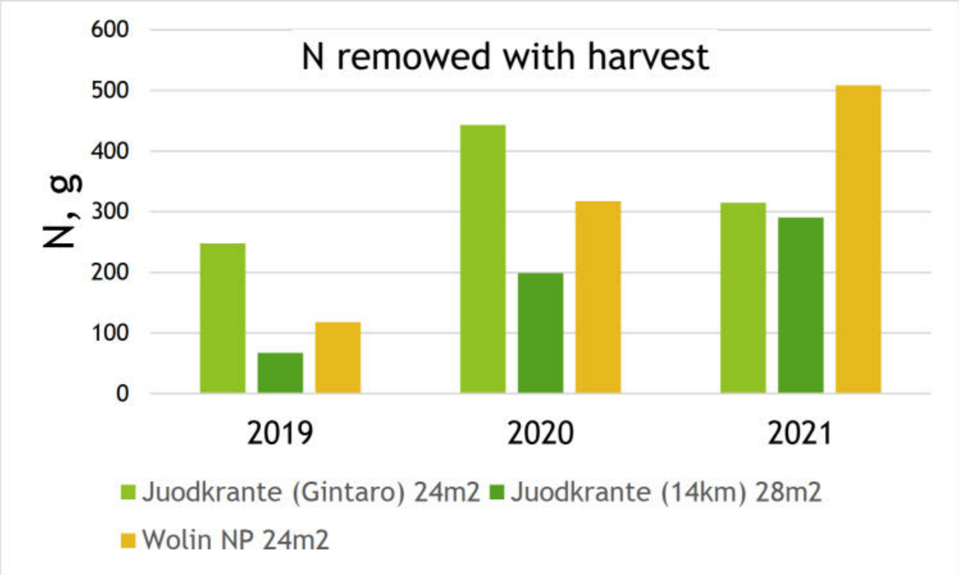


Fig. 16. Nitrogen content in total plant harvest in the Curonian Lagoon and Szczecin Laggon islands in 2019-2021.

Some studies report, that the aerial biomass could contribute only ~10% of nutrient removal while the rest is accounted for by the root-associated microbial community. Therefore, we could assume that the total annual removal of 24 $m^2$ could be ~10x higher ~2-5kg of N and ~160-380g of P.

## Plant succession

In Gintaro island the innitially high density of plants, resulted in a dense grass stand dominated by *Carex acutiformes*, *Typha angustifolia*. Other planted species such as *Scirpus sylvaticus*, *Shoenoplectus lacustris*, *Iris pseudacorus*, *Rumex crispus* become largelly owershadowed and representated by few individuals. There wos no free space for colonization of spontaneous species on Gintaro island. Single sprout of a tree *Alnus glutinosa* was recorded in 2020, but did not survive the next season.

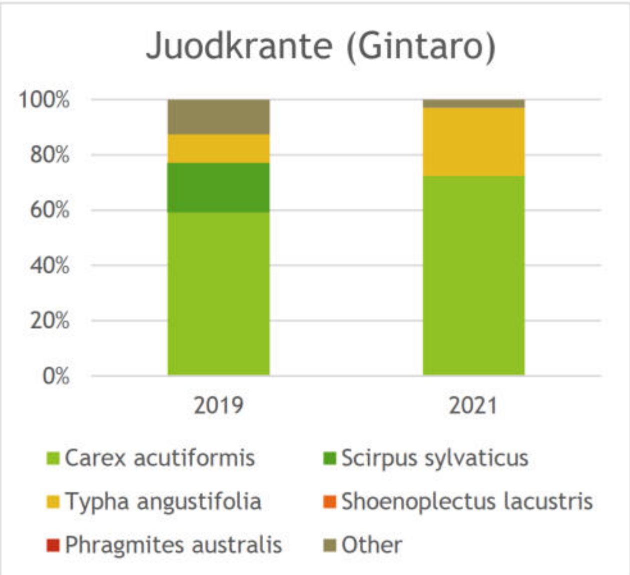


Fig. 17. Harvest composition in Gintaro island (Curonian Lagoon) in 2019 and 2021.

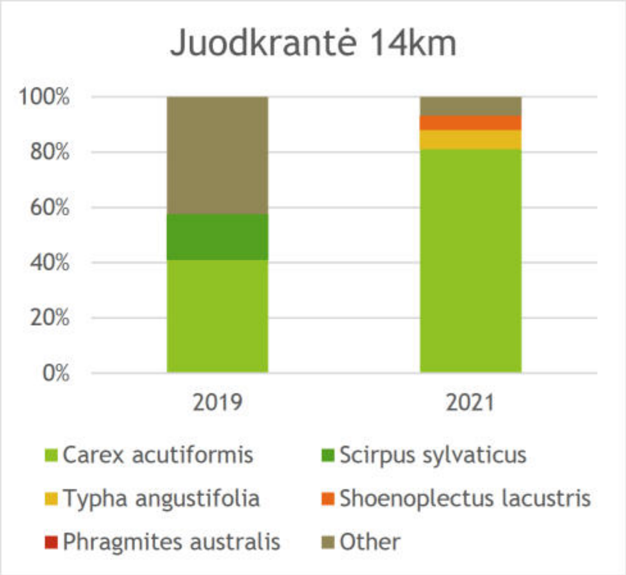


Fig. 18. Harvest composition in Juodkrantė 14km island (Curonian Lagoon) in 2019 and 2021.

In Juodkrante 14km island the innitial plant density was lower and the total island area little higher. Moreower the signficant wave damage resulted in death of some plants. Therefore as a result some open spots on the island occured and where occupied by spontaneous colonists: *Eupatorium cannabinum*, *Rumex palustris*, *Petasites* and many more smaller species. Less dence stand of *Carex acutiformes* resulted in better growth of *Shoenoplectus lacustris*, *Iris pseudacorus*. As result plant diversity on the Juodkrante 14km island was higher than on Juodkrante Gintaro island.

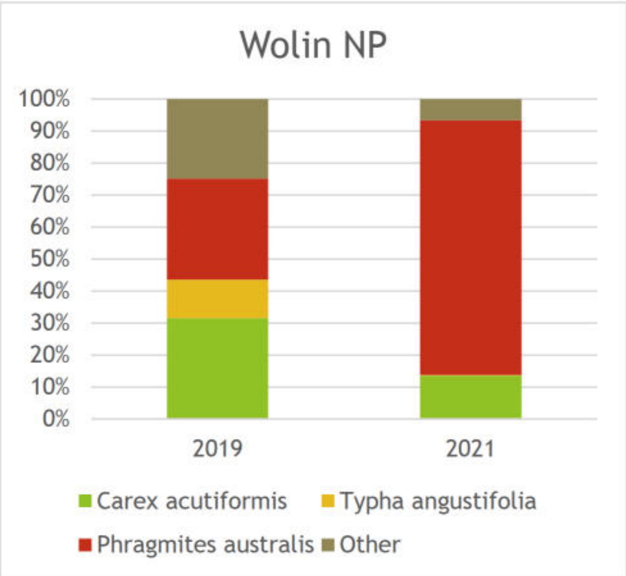


Fig. 19. Harvest composition in Juodkrantė 14km island (Curonian Lagoon) in 2019 and 2021.

In Wolin NP island the macrophyte stand is dominated by *Phragmites australis*. This species grows tall and produces high biomass. However owershading of other species is significant and the owerall plant diversity is low.

It could be concluded that innitial plant species selection, planting density is very important for the final result. But the natural succession should be taken in to account and oweral management goals should be defined in the beginning, whether the island serves as nutrient removal barier or plays an aesthetic role, or biodiversity support function.

Fig. 20. Spontaneous species in Juodkrantė 14km island (Curonian Lagoon) in 2019 after first growth season.

Fig. 21. Spontaneous species in Juodkrantė 14km island (Curonian Lagoon) in 2020 after second growth season.

## Nutrient content in main plant species

The highest nitrogen and phosphorus content was recoreded in *Carex*. It was lower in *Typha* and *Phragmites*, but varied among the islands. In general, all species contained higher P concentration in Wolin NP island, whereas N content in many cases was higher in Juodkrante 14km island.

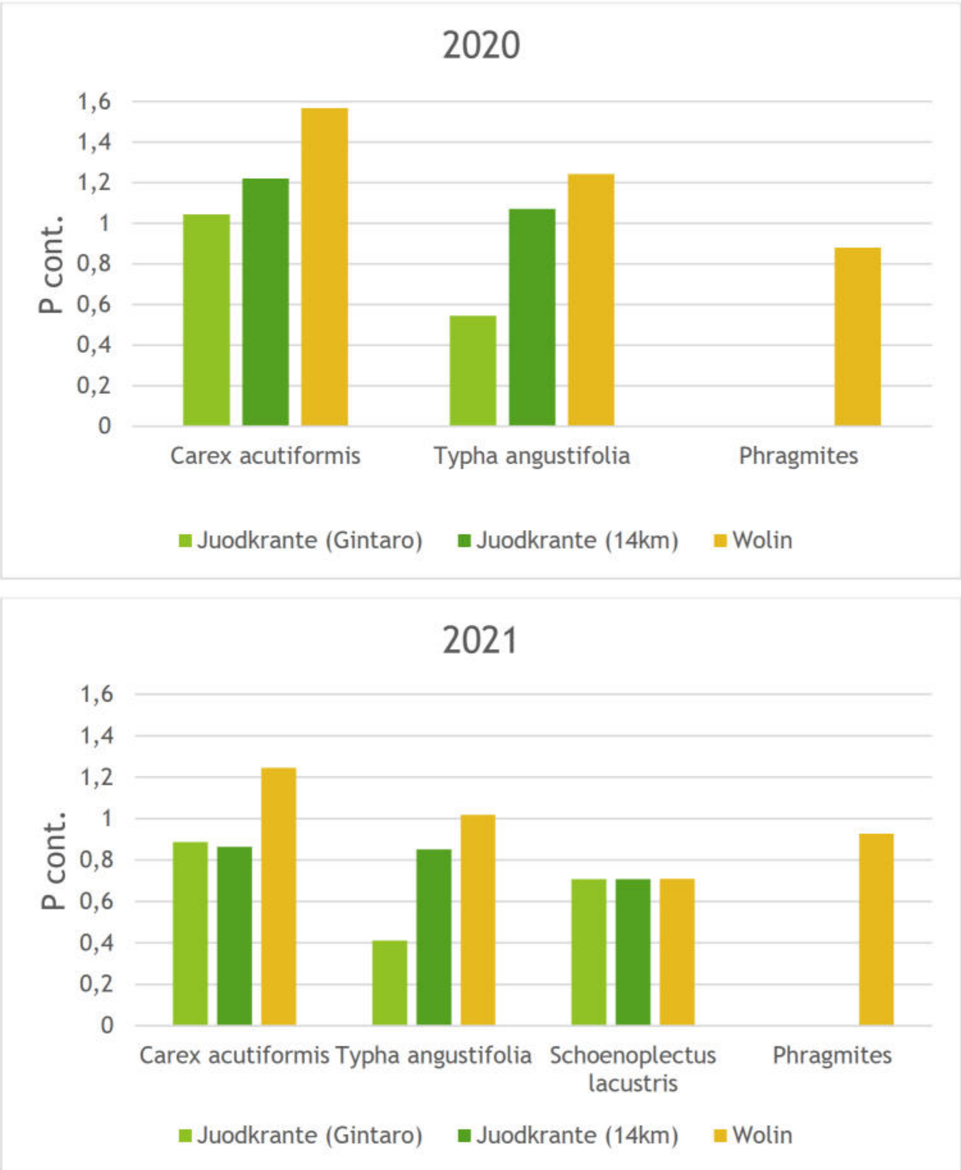


Fig. 22. Phosphorus content (%) in dry plant biomass.

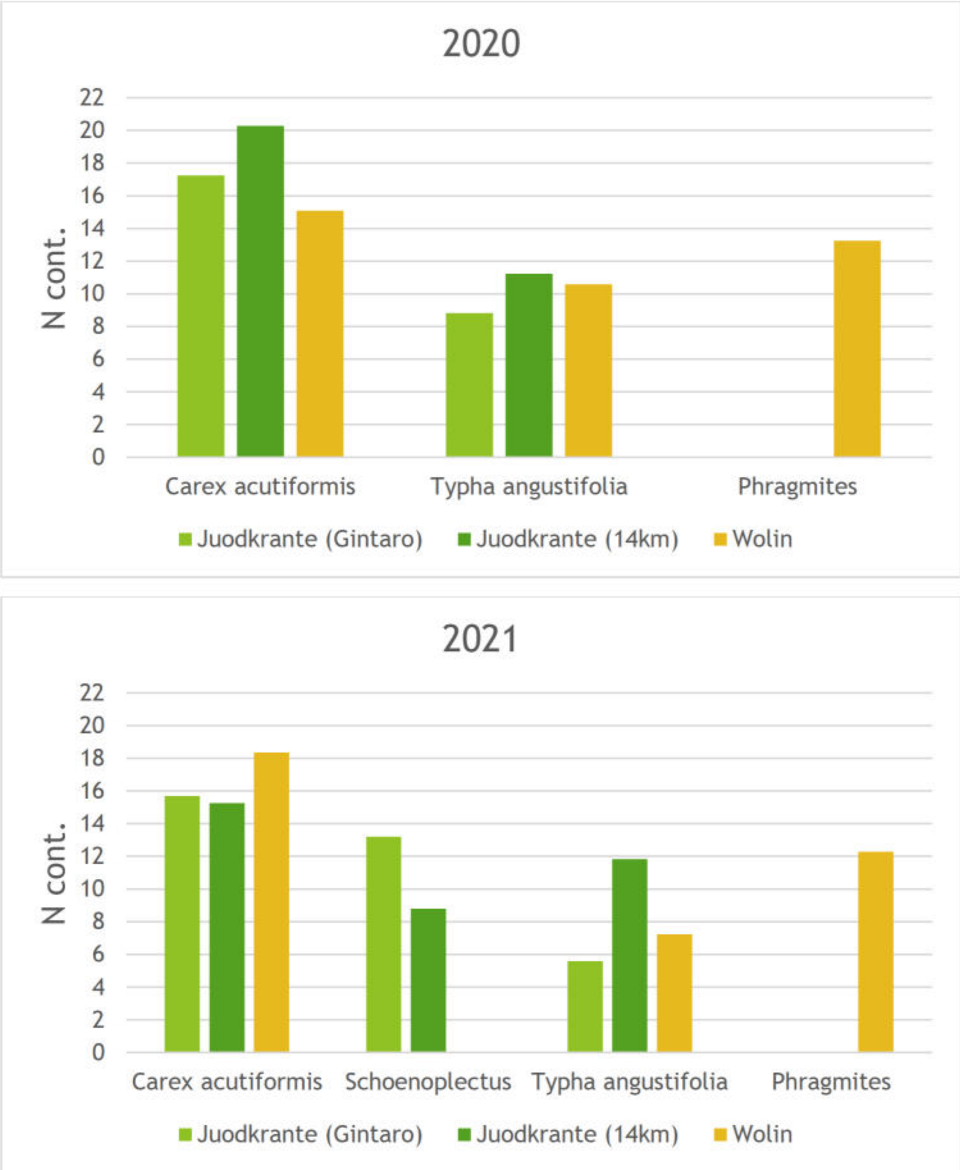


Fig. 23. Nitrogen content (%) in dry plant biomass.

## Harvesting timing

Harvesting time is interesting issue as it takles a trade-off between the aesthetic value and nutrient removal capacity. It is assumed that plants start allocating nutrients from leaves and shoots in to the roots in the early autumn, thuse early harvesting in September is recommended.

As long as Wolin NP island is located in the marine, its aesthetic function is important. We tested nutrient content in green biomass (September/October) and brown biomass in November to investigate late harvesting time effect. Our result show, that in *Phragmites* the nutrient content could be slightly higher in September (2019). In other year (2021) it does not change significantly.

It could be concluded that given priority to aesthetic function of the island the harvesting could be postponed to October or even late November.

Fig. 24. Plant collor change in the early and late autumn Wolin NP island (Szczecin Lagoon).

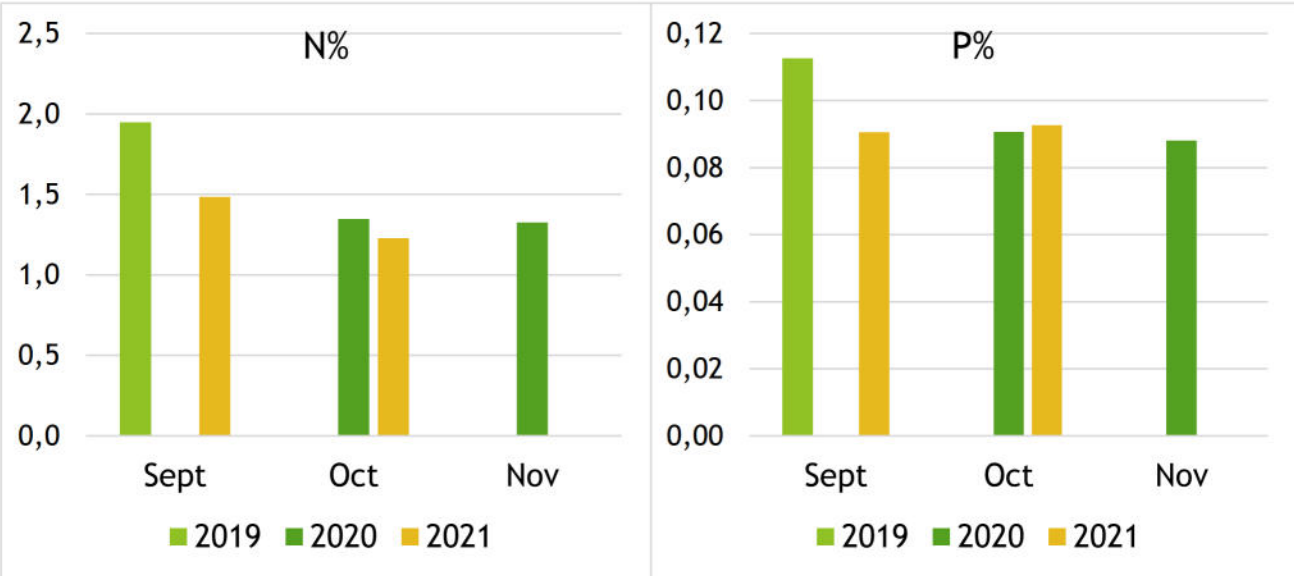


Fig. 25. Nitrogen and phosphorus content (%) in dry plant biomass in autumn.

## Nutrient content in other plant species

Phosphorus content variated from 1.6 gP/kgDW in sea aster to less than 0.4 gP/kgDW in the lakeshore bulrush.

The data presented in figures five and six show variability in the relative content of nutrients both between plant species and between experimental locations. The highest content of both phosphorus and nitrogen was found in the vegetative parts of lesser pond sedge (*Carex acutiformis*). This plant species did show remarkably high biomass increase during the summer. There were significant differences in both nutrient content between different experimental locations, the lowest being recorded for the location in Born, Germany, while the highest was in Lithuania. Total calculated nutrient removal per square meter of an island could be calculated as up to 3,6 gP/m$^2$ and up to 103 gN/m$^2$, which accounts to approximately annual impact of ~100 gP and 2822 gN per annum for a 28m$^2$ island .

All chosen macrophytes grew well under brackish water conditions and fluctuating salinities although C. acutiformis, I. pseudacorus and J. effesus are not salt tolerant according to Ellenberg and Leuschner (2010). Nutrient concentrations differed significantly between plant species (Fig. and Fig. ). Mean phosphorus concentrations ranged between 0.5 g kg-1 dry mass in B. maritimus and up to 1 g kg-1 dry mass in L. salicaria. Mean nitrogen concentrations were between 1.3 % of dry mass in S. lacustris and 2 % of dry mass in I. pseudacorus.

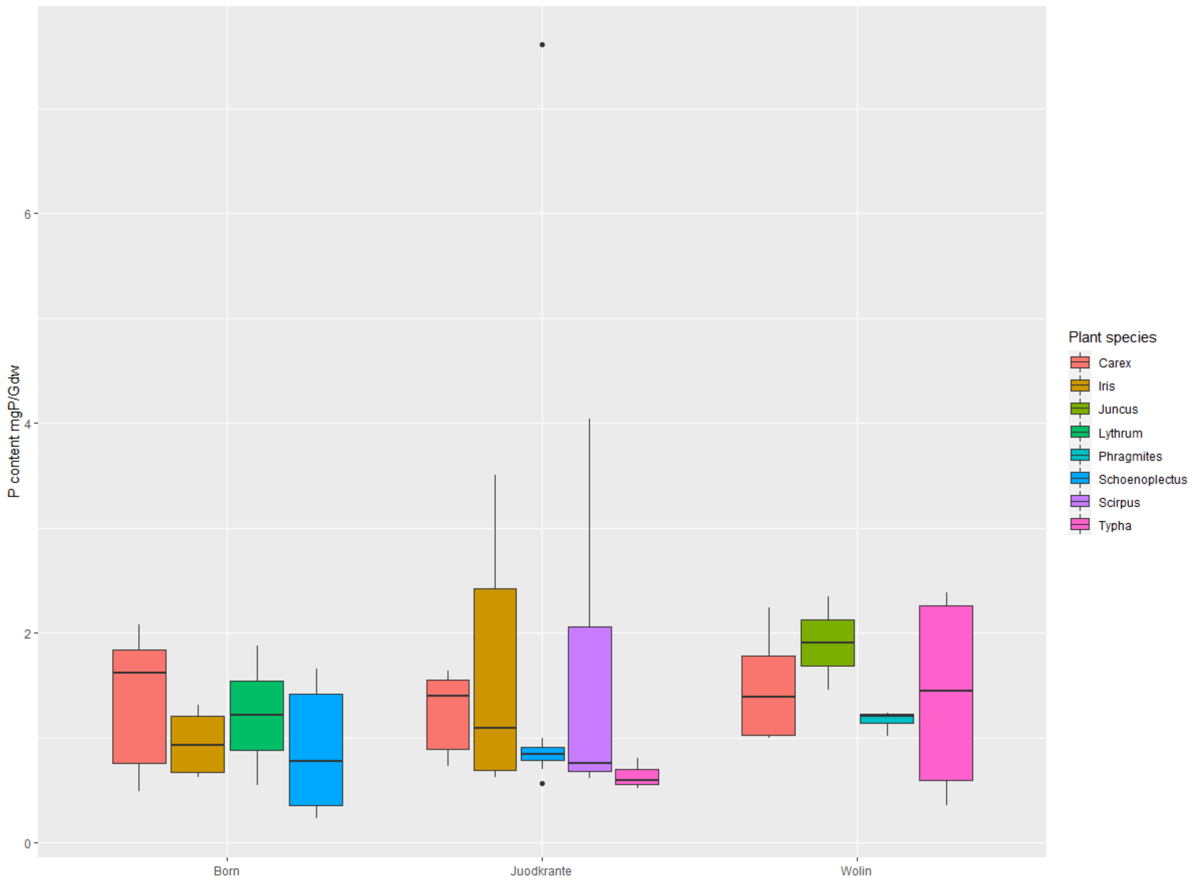


Fig. 26. Phosphorus [mgP/Gdw] in aboveground plant biomass in the eight different macrophytes species during harvest time across different sites.

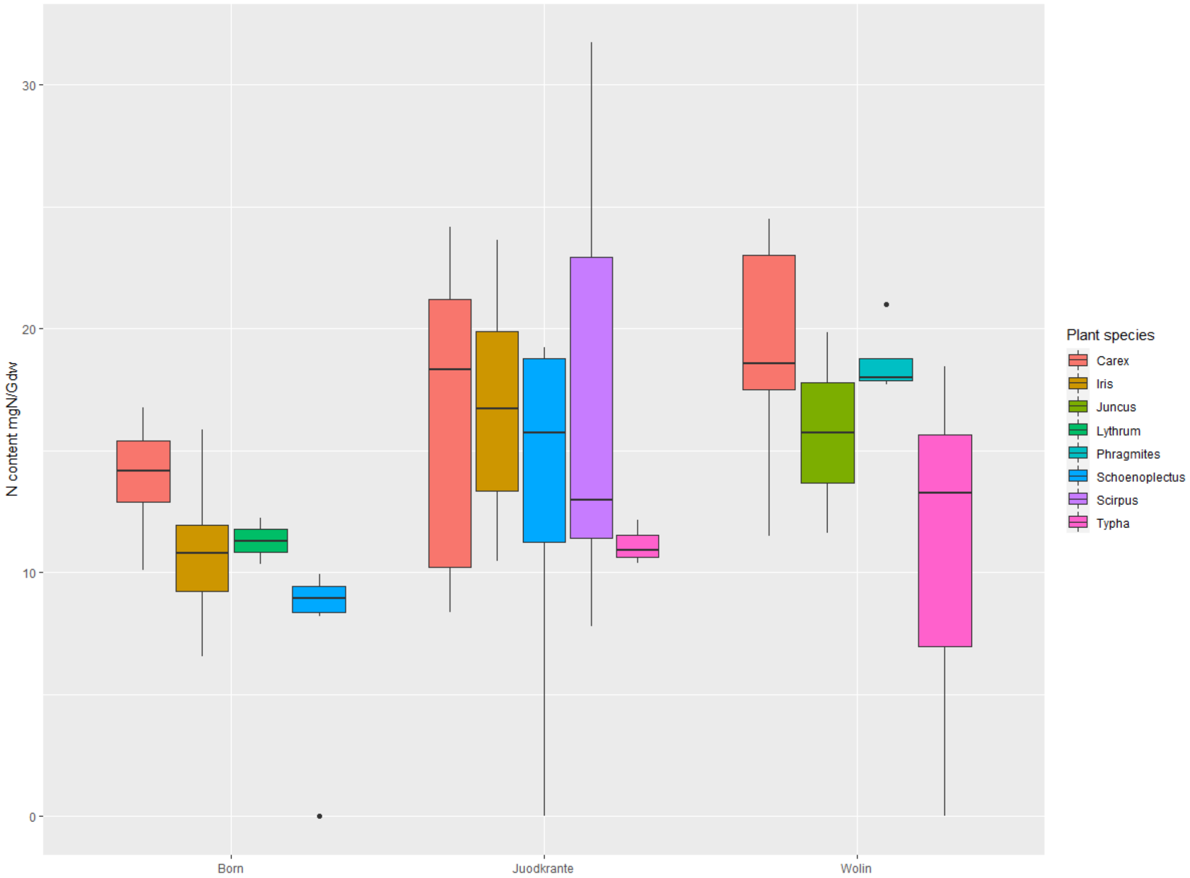


Fig. 27. Nitrogen [mgN/Gdw] in aboveground plant biomass in the eight different macrophytes species during harvest time across different sites.

## Biodiversity impact

In Lithuania, we have assessed the benthic biodiversity beneath te island and a read bed located next to the island.

While the overall taxa number was slightly higher in the reed bed (11 vs. 9), the diversity index H' in the constructed island was triple of that in the reeds (0.5 vs. 1.5) (Fig. 25.).

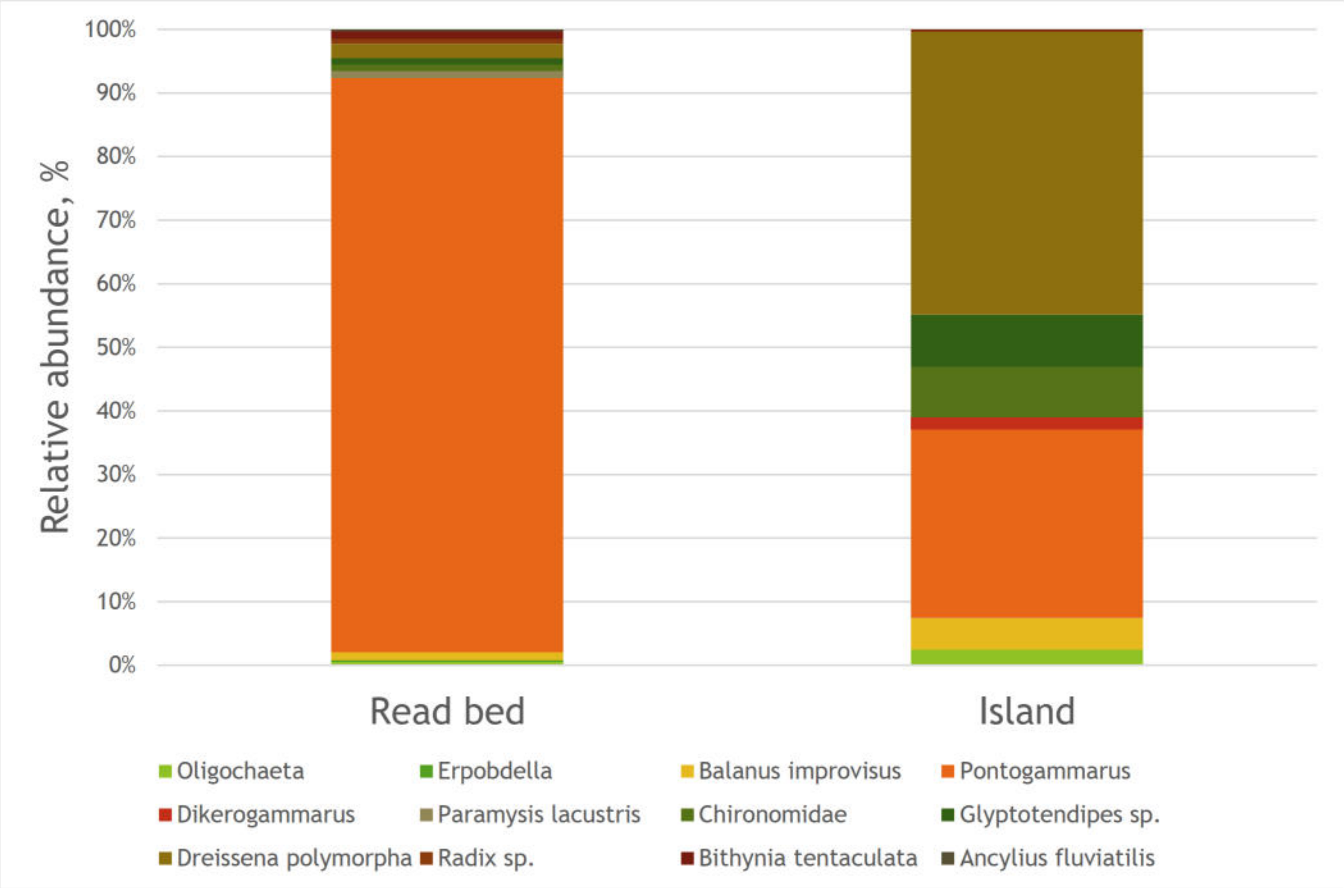


Fig. 28. Relative abundance of benthic and epibenthic species in the floating island and neighboring reed bed.

During the observation period few bird species were pictured on the islands: most common blue-headed mallard (*Anas platyrinchos*), grey heron (Ardea cinerea), great cormorant (Phalacrocorax carbo), mute swan (*Cygnus olor*), gulls.

In the night camera record we also recognised fox hunting otter on the Born island. It suggests, the biodiversity effect of new constructed habitat is significant.

Fig. 29. Birds resting on the island in winter Juodkrante 14km island (Curonian Lagoon). Photo. M. Bružas.


Fig. 30. Grey heron on the island. Record from the camera installed on the island.

Fig. 31. Nest of blue-heded mallard on Juodkrante island.

## Managing urban bird effect

A newly installed and planted island could suffer severe urban bird grazing effect. The instalation of the fence could be an option to manage bird grazing until the plants are rooted, gain hight and volume.


Fig. 32. On May 17 the Klaipeda island was replanted and partially fenced to protect plants form ducks. This picture (June 3) shows that ducks are on the non-protected part of the island, while fenced part of island is more green.

Fig. 33. On June 3 we fenced entire island and replanted the grazed part repeatedly. This picture (June 18) shows that ducks are still on the island, breaking loosely fitted fence, but generally plants grow better.

Fig. 34. Island on July 21 has improved aesthetic view. Plants grow high they are no more vulnerable for duck grazing and there is no free unvegetated spots. There is no more need to control duck grazing and fence could be removed for the rest of the season and winter period.

# Conclusions

In general technical design solutions proved to be adequate and reliable. There were only minor issues with material parts of the islands and the net. However net type design didn't prove effective in provide substrat for growth of plants and significant removal of nutrients. This was partially compensated by the colonisation of the net structure by zebra mussels (Dreissena polymorpha). The increase in total phosphorus content behind the net installation could be attributed to the reduction of water exchange to the lagoon proper. The island type instalations provided multiple benefits for the water quality and biodiversity.

The direct measurements of nutrients accumulated in the plants during the summer gave more concrete results of the nutrient removal, while the actual biomass and subsequently nutrient removal was very different both between different plant species and between locations. The planted islands had a positive effect on the benthic biodiversity comparing to the neighboring reed beds.

Even without biomass removal, remediation occurs on several levels: Plant roots attenuate wave energy and water flow and are consequently able to enhance particle settling and nutrient burial (Pavlineri et a. 2017). Furthermore, the associated microbial diversity impacts denitrification. Some studies even identified macrophyte root-associated denitrification as the main nitrogen removal pathway (e.g. Choudhurya et al. 2019).After harvesting (or not, in decorative cases) the construction could be kept in water year-round, as freezing and thawing cycles do not seem to harm the islands. The floating island could be moved to sheltered area before the water body is covered by ice.

The most important aspect to be taken in to account:

- Installation: permission to install islands in public and private spaces, selection of a suitable location, initial investment
- Support: replanting (due to birds, adverse conditions such as the effects of waves), cutting and removal of biomass in September
- Maintenance: monitoring of the structure, pulling the island into the estuary during the winter, installation / removal of the fence, removal of invasive species, removal of other unwanted species of trees.

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