ICWATER RDI FUNDED PROJECTS BOOKLET

Title of the project: Mass development of aquatic macrophytes - causes and consequences of macrophyte removal for ecosystem structure, function, and services

MadMacs

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Project structure (WPs description):

WP1: project coordination and dissemination. To provide results which are useful for management in an international context, we will ensure a harmonized BACI design across all case studies.

WP2: modelling. (2.1) Based on existing knowledge from literature and project partners, including the key stakeholders, we will develop a general risk assessment tool of macrophyte mass development and associated ecological impacts under multiple pressures, as well as of the effects of macrophyte removal, using causal pathway analyses and a probabilistic approach. (**2.2)** We will then test the model predictions against the macrophyte removal experiments from all case studies (WP3), and improve the model. Stakeholders will be involved to explore the effects of different scenarios (changes in drivers, stressors, macrophyte removal) on the consequences of macrophyte removal using the Bayesian Network relative risk model.

WP3: case studies. We will execute a set of "real-world experiments" in a harmonized BACI design at six case study sites in water bodies in five countries (Norway, Germany (2), France, South Africa, Brazil). Macrophyte removal will be done in collaboration with the key stakeholders, who are responsible for the macrophyte management at the sites. The size of the cleared area will in all cases be ≥ 1000 m^2, i.e. an area which is realistic and relevant for management. The following four exercises will be completed at each study site:

WP3.1: role of macrophytes for the provision of habitats. For all biological quality elements, we will quantify parameters related to ecosystem structure, such as taxonomic composition and species richness, but also ecosystem functions, including response diversity and functional redundancy, to determine the susceptibility of the communities to stress. This will be done at least twice before and twice after macrophyte removal at control and impact areas. Biological components to be measured are phytoplankton, zooplankton, benthic algae, macrophytes, macroinvertebrates, and fish. Harmonization of methods and taxonomic resolution will be monitored by ECOBIO, in tight collaboration with all partners.

WP3.2: effects of macrophytes on carbon and nutrient retention. We will quantify the retention of nitrogen, phosphorus, and carbon before and after macrophyte removal. Temporal retention via assimilation into plant biomass and sedimentation in macrophyte stands will be measured. We will analyse the permanent removal of N by denitrification and of C by emission of greenhouse gases (CO_2, CH_4). We will record diurnal oxygen curves to estimate primary production and the intensity of decomposition; these records will also provide information about the frequency and intensity of anoxia. Along river sections, the net balance will additionally be measured as difference in concentrations between the up- and downstream points.

WP3.3: hydraulic effects of macrophytes. We will quantify the effects of macrophytes on shoreline hydromorphology by analysing the impounding effect of macrophytes as well as their effect on shoreline erosion. We will deploy data loggers to quantify the effect of macrophyte removal on wave height at control and impact areas. We will compare water level – discharge relations from periods with and without macrophytes (before / after mowing, summer / winter). We will analyse the water level – discharge relations for periods of known macrophyte biomass. They will be combined with available elevation models to define flooded areas at various combinations of discharge and macrophyte biomass. These areas and land use data (agriculture, infrastructure, residential areas, etc.) will be combined using GIS to estimate potential impacts of flooding.

WP3.4: effects of aquatic macrophyte removal on ecosystem service provision. The rationale is that (a) before removal during the nuisance stage, the importance of some ecosystem services may have been underestimated, and (b) macrophyte removal will change several ecosystem services. We will apply the services cascade interpretation of Mononen et al. (2016) based on the CICES typology of ecosystem services. This involves an estimate of final services as biophysical flows (e.g. kg/ha/yr) followed by a monetary estimate. The sum of estimated monetary values is an approximation of Total Economic Value (TEV). This two-step approach allows a separate comparison of individual biophysical benefits, as well as an aggregate TEV comparison of the "before" versus "after" situations. Cultural services depend on human appreciation (e.g. perceived nuisance, experienced scenic beauty), and these will vary with local public as well as sectoral stakeholder interests. A survey will be developed early in the project, pre-tested, locally adjusted, translated, and carried out at each of the case study sites with the help of the case-owning MadMacs partners and the key stakeholders. Several provisioning and regulating services will be quantified from the data collected in WP3.1-WP3.3 and from local data (e.g. weed management program costs).

WP4: Synthesis and recommendations for improved management of water courses with dense aquatic vegetation. By performing a meta-analysis of the data generated in WP3, in combination with the Bayesian network (BN) model developed in WP2, we will identify consistent effects of macrophyte presence versus removal, and estimate consequences of macrophyte removal in aquatic ecosystems. This will enable us to directly compare benefits and dis-benefits of macrophyte removal (as quantified within the four tasks in WP3), and generalize the findings. Based on these, we will formulate guidelines for the management of water courses with dense aquatic vegetation ("cookbook"-tool to assess and balance benefits and dis-benefits of aquatic macrophyte removal).

We propose the following case studies:

***Juncus bulbosus* in the River Otra (Norway):** mass development of the native macrophyte *J. bulbosus* is the most serious environmental problem in rivers in southern Norway. Annually, on average 250 000 € are spent on abatement measures, but regrowth is generally observed after few years. The Otra River is subject to hydromorphological alterations, climate change and anthropogenic pollution, and the river is used for recreation and hydropower generation. The stakeholder involved in this case study is "Krypsivprosjektet på Sørlandet" (KPS), a consortium of hydroelectric power companies, Energy Norway, the Norwegian Water Resources and Energy Directorate (NVE), and representatives from Norwegian environmental authorities.

***Elodea nuttallii* in Lake Müggelsee (Germany):** mass development of the non-native species *E. nuttallii* is a challenge in many water bodies in Germany. In Lake Müggelsee, this species has dramatically increased in abundance. The lake is used intensively for drinking water production, navigation, and recreation, and is subject to climate change, anthropogenic pollution, hydromorphological alterations and an invasion of non-native dreissenid mussels. Risks of mowing *Elodea* have so far not been quantified, but could potentially be serious because a switch to a turbid state could affect drinking water production, especially if cyanobacteria should develop blooms. The stakeholder involved in this case study is the Senatsverwaltung Berlin (regional environmental authority).

***Native macrophytes* in the lower River Spree (Germany):** From the mid-1990s, macrophyte vegetation gradually has increased. In recent years, submerged and floating-leafed macrophytes (mostly *Sagittaria sagittifolia*, *Sparganium emersum* and *Nuphar lutea*) attained a wet weight of 700-800 tons in a 30-km river section, of which about 250-300 t are mechanically removed each year. In parallel with the development of macrophyte biomass, the water level rose by 20-50 cm, causing problems for farmers and residents. Mowing the aquatic vegetation impaired water quality in the downstream river sections and of lakes in the Berlin region. This river section is intensely used for recreation, and the Spree is a main source of drinking water for Berlin. The stakeholder involved is the agency responsible for landscape management (Wasser- und Landschaftspflegeverband Untere Spree).

***Ludwigia* sp. in Lake Grand-Lieu (France):** Lake Grand-Lieu is a large lake with extensive beds of floating-leaved macrophytes. Two non-native aquatic plants (*Ludwigia peploides* and *L. grandiflora*) colonized the lake in the 1990s, developing dense mats in the lake and canals and causing problems for biodiversity conservation and for human activities such as fishing and boating. The lake is affected by eutrophication, climate change, hydromorphological alterations and the invasion of the non-native *Ludwigia* sp. Since 2002, 5-10 tons of *Ludwigia* were removed annually. The management of these invasive species is costly and inefficient, because regrowth is regularly observed, and macrophyte removal reportedly enhanced the development of cyanobacteria in the lake, with negative consequences for fishing and on biodiversity. The stakeholder involved in this case study is the Natural Reserve of Lake Grand-Lieu.

***Eichhornia crassipes* in Hartebeespoort Dam (South Africa):** Despite efforts to control, *E. crassipes* remains South Africa's most problematic aquatic macrophyte. Hartebeespoort Dam currently is a hotspot of *E. crassipes* invasion. The plant has been present since the 1970s and was successfully controlled in the 1980s using herbicides. In 2016, however, herbicidal control was halted, resulting in massive plant growth. A steering committee has been put in place to draw up a control plan, but this excludes the use of herbicides, which to many seems to be the only viable option. The dam is subject to serious anthropogenic pollution, climate change, and hydromorphological alterations. The primary use of the dam is for irrigation, as well as for domestic and industrial use. The stakeholder in this case study is the Department of Environmental Affairs: Natural Resource Management Programmes.

***Urochloa arrecta* in the River Guaraguaçu (Brazil):** *U. arrecta* is an invasive aquatic grass which in the last years produced mass developments in several water bodies in South Brazil. One of these is the River Guaraguaçu, a tidal river. The plant biomass affects the use of the river for navigation, jeopardizes environmental quality for tourism and fisheries, and probably affects the diversity of native species. The River Guaraguaçu is in LAGAMAR, a key region for biodiversity conservation in South Brazil harbouring several endangered species. The

river is subject to anthropogenic pollution, climate change, and other invasive species such as catfish which may benefit from the dense *U. arrecta* beds. Management of *U. arrecta* has not yet started, but is under discussion. The stakeholder involved in this case study is the Instituto Ambiental do Paraná, the environmental agency responsible for managing the area.
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