Improving degree of conservation of Natura 2000 target species and habitat types through improvement of river connectivity

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MACROPHYTE CONTROL PLAN IN JADRO AND VRLJIKA RIVERS

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REPUBLIC OF CROATIA
Ministry of Environmental Protection and Green Transition

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1. INTRODUCTION

This document has been prepared within the framework of the project Improve River LIFE – Improving the conservation status of target Natura 2000 species and habitat types through improved river connectivity**.** The objective of this plan is to define methods and measures for the control and removal of macrophytes, with the aim of preserving the natural hydromorphology and biodiversity of the Vrljika and Jadro rivers. It is primarily intended for the staff of the Public Institution More i krš but also serves as a model example for other public institutions managing protected areas and ecological network sites.

Macrophytes are a heterogeneous group of organisms that includes vascular plants, mosses, and macroalgae, all of which are associated with aquatic habitats (Lacoul and Freedman, 2006). Macrophytes can be divided into hydrophytes and helophytes. Hydrophytes include species that are completely submerged or float on the water surface. Helophytes are generally rooted in water but grow above the water surface with their aerial parts, such as reeds and cattails (CBS, 2020).

Water flow velocity is a key factor determining the composition of macrophytes in rivers (Franklin et al., 2008). In addition, the occurrence and composition of macrophyte communities are influenced by a range of important abiotic factors, such as substrate type, water transparency and temperature, nutrient levels, watercourse depth and width, seasonal and daily water level regimes, the frequency and duration of floods, and mechanical maintenance of the watercourse (Baattrup-Pedersen et al., 2002; Janauer, 2001). Biotic interactions include competition for light, allelopathy (the effect one species has on another through the production of chemical compounds), and herbivore pressure. Greater macrophyte cover and diversity are observed under low to moderate flow velocities, whereas their development is significantly limited at higher flow velocities (Madsen et al., 2001). Increased flow velocity and discharge, due to stronger drag forces, directly affect mechanical damage to plants and, in some cases, their uprooting (Riis and Biggs, 2003). As flow velocity increases, macrophyte diversity decreases significantly, with only species capable of withstanding strong currents persisting (Kočić, 2013). At the same time, reduced availability of dissolved substances in the water leads to decreased photosynthetic activity and limited nutrient uptake (Madsen et al., 2001).

Although macrophyte vegetation is a natural component of river ecosystems, under certain conditions it can become a significant problem for river functionality and ecological balance. Excessive growth of aquatic plants often creates physical barriers within the watercourse, slowing flow and reducing river velocity. This can result in sediment accumulation, increased risk of local flooding, and habitat alterations (Clarke, 2002).

In the past, local communities regularly removed macrophytes from rivers. These aquatic plants were used as livestock feed, and removal was also carried out to maintain watermills. This practice helped preserve watercourse flow and control vegetation growth. Today, with the abandonment of traditional agriculture, livestock breeding, and other traditional occupations, many rivers no longer receive this type of regular maintenance, leading to uncontrolled vegetation expansion.

Increased macrophyte presence can also negatively affect fish populations, including the endemic softmouth trout (*Salmo obtusirostris*). Although a certain degree of vegetation provides shelter and refuge for juveniles, excessive overgrowth reduces dissolved oxygen levels, disrupts flow, and alters substrate structure, which may negatively affect spawning conditions. Furthermore, habitat alteration and overgrowth may favor invasive species, further disturbing biological balance.

Given the above, it is clear that a systematic approach is required to implement measures aimed at limiting the spread of macrophyte vegetation. The goal of such management should be to preserve natural balance, ensure the functionality of the river ecosystem, and support biodiversity, while also involving the local community and incorporating traditional knowledge in maintaining the river landscape.

Macrophytes are excellent indicators of watercourse eutrophication and represent one of the five biological quality elements used to assess the ecological status of water bodies under the Water Framework Directive (WFD, 2000). According to the Methodology for Sampling, Laboratory Analysis and Determination of Ecological Quality Ratios of Biological Quality Elements (Croatian Waters, 2025), the reference macrophyte community in the Jadro River is a moss community (*Rhynchostegium – Fontinalis* type – RF = *Platyhypnidium – Fontinalis* – PF), characteristic of springs and small to medium-sized fast-flowing mountain and sub-mountain streams on karst substrates. In the Vrljika River, the reference macrophyte community is a herbaceous community (*Berula – Nasturtium* type – BN), characterized by the dominance of emergent-leaved herbaceous species.

In the spring area of the Vrljika River, floating hydrophytes (plants rooted in the substrate with leaves floating on the water surface) dominate, such as large-leaved pondweed (*Potamogeton nodosus* Poir., *Potamogeton* sp.) and *Ranunculus trichophyllus*, which prevail in the middle course. Further downstream, in deeper water, the submerged form of *Berula erecta* becomes dominant. The marginal parts of the watercourse are inhabited by tall emergent vegetation dominated by *Typha latifolia* L., *Sparganium* sp., and *Scirpus lacustris* L. During low water levels, macrophyte vegetation throughout the entire water column is extremely dense and luxuriant, leaving very little open, free water surface (Mrakovčić et al., 2019).

2. CONTROL OF MACROPHYTE VEGETATION IN THE JADRO AND VRLJIKA RIVERS

2.1. IMPLEMENTATION AREA FOR REMOVAL

The removal of macrophyte vegetation, together with the removal of barriers in the watercourse, contributes to restoring the natural balance and creates conditions for the restauration of natural karst river habitats in the Vrljika and Jadro rivers, where they have been degraded due to hydromorphological changes. Through the Improve River LIFE project, the removal of macrophytes is planned over approximately 9.000 m² of riverbed, of which 6.500 m² is in the Vrljika River and 2.500 m² in the Jadro River.

In the Vrljika River, activities are focused on the area around the Opačica barrier (first in sequence) and the Stari vodovod barrier (second barrier), which are located within the Special Ichthyological Reserve Vrljika Spring. Barrier 1, Opačica, is a weir with three sluices and an overflow threshold. Water for irrigation is diverted through the lateral sluice on the left side of the watercourse, while a threshold is present on the right side. Downstream of the barrier, there is a limnigraph of Croatian Waters for continuous water level monitoring. The barrier is located near the Vrljika spring and slows the river flow, allowing significant macrophyte presence, particularly filamentous green algae of the genus *Cladophora*, although over a relatively small area. Upstream of barrier 2, Stari vodovod, water flow is slowed, and the area is marshy. The barrier is 50 m wide and over 2 m high. Sedimentation of organic material covering the riverbed is increased, creating conditions for the growth of macrophyte species indicative of potamalization (flow slowing) and eutrophication. Additional changes caused by anthropogenic impacts include very dense accumulations of filamentous green algae of the genus *Cladophora*, present throughout the spring area, in some locations so dominant that they completely cover the bottom.

In the Jadro River, macrophyte removal activities will be focused on the area around the first barrier, i.e., the Voljak Bridge (Vrilo 1). This barrier creates a narrow throat that promotes excessive macrophyte growth. During low water levels, macrophyte vegetation throughout the entire water column is extremely dense and lush, leaving little open, free water surface.

2.2. MACROPHYTE REMOVAL METHODS

The selected method for removing macrophyte vegetation should be effective and, as much as possible, non-invasive to river ecosystems. Various methods have been developed for macrophyte removal (Hussner et al., 2017).

Mechanical methods include mowing, pulling, raking, floating barriers, dredging, and similar techniques. They can be applied manually or using machinery. If a mechanical removal method is used, it should, whenever possible, be a selective method, such as manual removal, suction dredging, etc. For the removal of aquatic plants in smaller areas, especially densely overgrown ones, manual pulling or removing the entire plant with its roots can be applied. Mechanical pulling and collection can serve as a temporary control for small areas less than 0,4 ha. Suction dredging can be effectively applied in relatively small areas (less than 0,1 ha). Plants are removed along with their roots, which limits both their spread and regrowth. This method can also be species-specific if conducted by divers, and optimal results are achieved on sandy and soft substrates. If a less selective mechanical removal method is used, the method chosen should minimize degradation of the river ecosystem, such as mowing submerged vegetation or removal using raking from a boat. Submerged vegetation mowing is often applied in heavily overgrown areas. Raking is performed using adapted vessels and removes the entire plant with its root system. Removal using other machinery (e.g., excavators) is applied when the above methods are insufficient—such as when plants are deeply rooted, cover larger areas, and removal by cutting, suction dredging, or raking is not sufficient. This type of control removes plant material together with sediment and silt. When removing invasive alien species (IAS), all clothing and equipment used during the process should be thoroughly cleaned to prevent the spread of plant fragments. Removal should also be conducted to avoid leaving any plant parts (e.g., roots, stems) in or near the water.

Chemical methods include the use of herbicides and are not recommended for natural watercourses due to potential negative impacts on fish and other organisms.

Biological methods involve the use of herbivores or altering growth conditions, e.g., shading by planting trees along the banks, to reduce reproductive capacity and density.

In addition to these methods, other approaches that focus on modifying water flow can also be applied (e.g., increasing flow velocity prevents sediment accumulation and overgrowth of the watercourse), modifying growth conditions (e.g., shading by planting trees along the banks), and similar measures.

2.3. TEST REMOVAL IN 2024

Within the Improve River LIFE project, at the beginning of September 2024, the Public Institution More i Krš, in cooperation with the Imotski Water Management Office of Croatian Waters, carried out test macrophyte removal works in the Special Ichthyological Reserve Vrljika Spring. The removal activities were conducted with the permission of the Ministry responsible for nature protection in the area extending from the Utopišće spring to the Stari vodovod barrier within the Special Ichthyological Reserve Vrljika Spring, covering a key section of the river subject to natural changes and challenges in maintaining ecological balance (Figures 1 and 2). The removal activities focused on sections of the watercourse with the densest macrophyte vegetation, specifically around the Opačica and Stari vodovod barriers (Public Institution More i krš, 2025a).

Aquatic vegetation was removed exclusively manually by cutting, according to the permission issued by the Ministry of Environment and Green Transition, without using mechanical or chemical vegetation control methods. Manual cutting, although the most ecologically appropriate, proved to be extremely demanding and time-consuming due to the density and resilience of vegetation in the area. This method requires a large workforce, the removal process is very slow, the available period for removal is short, and it is only feasible in the shallower parts of the river (Public Institution More i krš, 2025a).

Despite intensive efforts and the engagement of a significant number of staff from the Public Institution and Croatian Waters (Imotski), the set objectives were not fully achieved (Public Institution More i krš, 2025a). Due to specific field conditions, inaccessibility of certain parts of the watercourse, and dense, firmly rooted vegetation, manual removal proved ineffective. This prevented achieving the necessary level of riverbed cleaning, and consequently, did not contribute to an increase in water flow or improvement of the river's ecological balance.

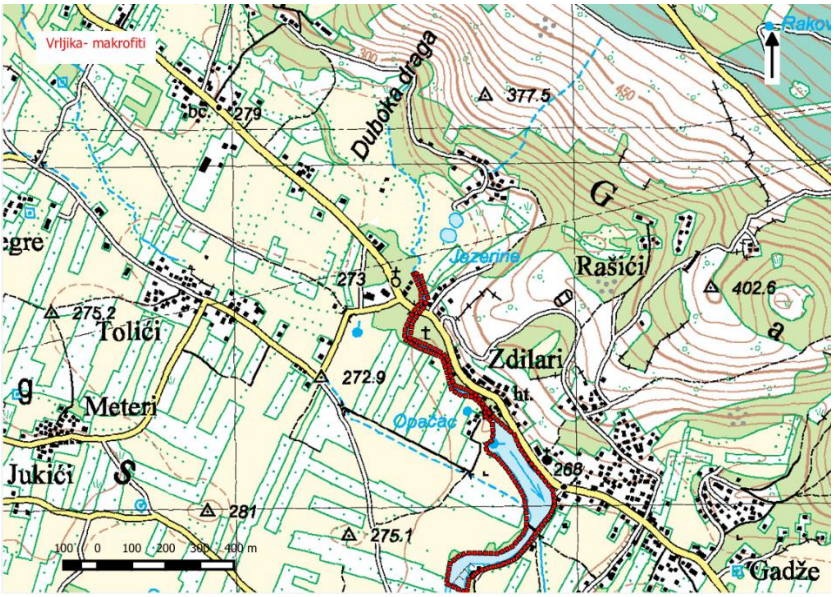

Figure 1. Macrophyte removal area in the Special Ichthyological Reserve Vrljika Spring, 3–4 September 2024 (Public Institution More i Krš, 2025a).

Figure 2. Macrophyte removal in the Special Ichthyological Reserve Vrljika Spring, 3–4 September 2024 (Public Institution More i Krš, 2025a).

2.4. TEST REMOVAL IN 2025

During September 2025, as part of the Improve River LIFE project, macrophytes and silt were removed in a pilot area within the Special Ichthyological Reserve Vrljika Spring, on the sections “from Fabe to the first barrier” (parcel no. 4940, cadastral municipality Imotski-Glavina), in the channel (parcel no. 5253, cadastral municipality Proložac) leading to the mills at Perinuša, including the downstream section of the river (JU More i Krš, 2025b). The works were carried out over an area of approximately 0,8 ha (Figure 3), covering sections of the watercourse with the densest macrophyte vegetation. Special attention was given to areas above barrier 1 (Opačica) and barrier 2 (Stari vodovod), where the densest macrophyte growth was present. Since this is a protected area and part of the Ecological Network, a prior assessment of the intervention’s acceptability for the network was conducted, and permission was obtained from the Ministry of Environment and Green Transition. The removal activities were carried out during low water levels, exclusively using machine-assisted removal from the riverbank, in cooperation with Croatian Waters, and under the professional supervision of the Public Institution More i Krš. Workers did not enter the riverbed, and the machine was equipped with a perforated bucket that allowed water to return to the river during loading.

Figure 3. View of the macrophyte removal area (Public Institution More i Krš, 2025b).

On the section "from Fabe to the first barrier," the natural riverbed of the Vrljika River, approximately 50 m wide, is present. Only vegetation accessible from the left bank was removed, while the right bank remained untouched. To preserve riparian vegetation, access to the riverbed was limited, and cleaning was carried out only in areas accessible to machinery and workers, along approximately 150 m upstream of Opačica (1) (Figures 4 and 5).

The Perinuša channel, on the other hand, was accessible across its entire width due to its narrow form, but longitudinal access was limited by private parcels, walls, and riparian vegetation. This channel is of artificial origin, constructed for watermills. In the past, maintenance was carried out twice a year; after these activities ceased, the channel became so overgrown with cattails (*Typha* spp.) that water flow was almost completely blocked. The channel was cleaned longitudinally between two residential houses and partially at its junction with the main riverbed.


(a)

(b)

(c)

Figure 4. Situation at the site before macrophyte removal (a), during removal (b), and after macrophyte removal (c) in the Vrljika spring section, September 2025 (Public Institution More i Krš, 2025b).


(a)


(b)

Figure 5. Comparison of drone images of the Opačica barrier in March 2023 (a) and after macrophyte removal in September 2025 (b) (Public Institution More i Krš, 2025b).

Macrophyte removal was carried out in a mosaic pattern, with the aim of preserving the majority of the vegetation and maintaining the ecological stability of the habitat. Deposits of silt and sand were removed in a targeted and selective manner in order to expose as much gravel substrate as possible, thereby revitalising habitat suitable for the spawning of softmouth trout (*Salmo obtusirostris*). At this site, it will be possible to monitor the results during the next spawning period of softmouth trout.

A nature protection requirement stipulated that, following the mechanical removal of macrophytes and sediment deposits, the extracted material had to be inspected and any individuals of strictly protected and endemic species returned to the watercourse (softmouth trout, *Delminichthys adspersus*, white-clawed crayfish, makal, basak). These species were not recorded due to the presence of anoxic conditions. Individual specimens of the edible frog (*Pelophylax* kl. *esculentus)* found within the vegetation were immediately returned to the river (Public Institution More i krš, 2025b). The Public Institution More i krš, in cooperation with Croatian Waters and scientific institutions, will continue to monitor results in the pilot area, enabling an objective evaluation of the effectiveness of this measure.

All removed wet biomass was temporarily stored outside the flood-prone area for drainage and drying by an authorised contractor (Figure 6). The material consisted exclusively of several macrophyte species (*Typha* spp., *Mentha aquatica*) and silt. After drainage, it was agreed that the removed biomass would be transported to the Metković Composting Facility.

Figure 6. Removed macrophyte vegetation after loss of water content, 7 October 2025 (Public Institution More i krš, 2025b).

3. RECOMMENDATIONS FOR THE REMOVAL OF MACROPHYTE VEGETATION AND MONITORING OF THE JADRO AND VRLJIKA RIVERS

3.1. SELECTION OF METHOD AND APPROACH TO MACROPHYTE REMOVAL

Based on previous experience in macrophyte removal by the Public Institution More i krš, manual removal carried out in 2024 on the Vrljika River proved to be ineffective, as subsequent monitoring showed only a very short-term effect. Implementation was also highly demanding due to the size of the area and limited human resources (Public Institution More i krš, 2025a). Therefore, the Public Institution More i krš proposed and received approval from the ministry responsible for nature protection to use mechanical methods as a more effective method for macrophyte removal in the Vrljika River. The removal was carried out in cooperation with Croatian Waters, under the expert supervision of the Public Institution More i krš. In certain areas, access for machinery to the watercourse was not possible due to private ownership of adjacent land parcels.

For the removal of aquatic plants in smaller areas, especially those that are densely overgrown, manual uprooting or removal of the entire plant with its root system is recommended. Mechanical pulling and collection of plants may serve only as temporary control on small areas (less than 0,4 ha), while removal over larger areas using this method has proven ineffective. The activity must be conducted carefully to avoid leaving any plant parts (e.g. roots, stems) in or near the water. Manual removal performed by staff of the Public Institution More i krš proved to be very demanding and ultimately insufficiently effective (Public Institution More i krš, 2025a).

If a less selective mechanical removal method is used, the option that causes the least degradation of the river ecosystem should be selected, such as underwater mowing in heavily overgrown areas or removal using vessels equipped with rakes. Raking is performed with adapted vessels and involves removing the entire plant with its root system. Based on experience from September 2024, this method proved unfeasible due to low water levels in the Vrljika River during the removal period (Public Institution More i krš, 2025a). It is important to note that removal is feasible only during low water levels and outside the spawning period of the softmouth trout (*Salmo obtusirostris*). When removing accumulated

silt and macrophyte vegetation from riverbeds and channels, methods and equipment should be carefully selected to minimize disturbance to the channel and riverbed (MESD 2022b).

According to the issued permission, removal is recommended during low water periods in August and early September, under strict supervision of the expert and ranger services of the Public Institution More i krš. During these activities, the entry of machinery into the riverbed and the removal of riparian vegetation are prohibited. If invasive alien species (IAS) such as *Elodea canadensis*, *E. nuttallii*, or *Egeria densa* are removed, special attention should be given to cleaning all clothing and equipment used during removal to prevent the spread of plant fragments (MESD, 2022a). During macrophyte removal, deposits of silt and sand should also be removed where possible to expose as much gravel substrate as possible and thereby revitalize habitat suitable for the spawning of softmouth trout (*Salmo obtusirostris*).

Maintenance works should be carried out in a way that minimizes impacts on nature, taking into account critical periods (spawning, hibernation, nesting). Removal activities should be conducted during the vegetation season, preferably from May to October. The period from December to March is not recommended due to the spawning period of softmouth trout (Mrakovčić et al., 2019) and higher water levels, which reduce removal efficiency.

The use of mechanical removal methods is expected to provide a more long-term solution, while the effectiveness of the measure will be assessed through subsequent monitoring.

3.2. OBTAINING NECESSARY PERMISSIONS FOR IMPLEMENTATION

If the intervention is carried out within the ecological network area, a request for a preliminary assessment of acceptability for the ecological network must be submitted to the competent authority (Ministry/county), including a description or conceptual design of the planned intervention, in accordance with Articles 24–51 of the Nature Protection Act (OG 80/13, 15/18, 14/19, 127/19, 155/23). The intervention may be approved if negative impacts on conservation objectives and the integrity of the ecological network area can be excluded.

In the case of macrophyte removal in the Jadro and Vrljika Rivers, the purpose of the intervention is the restoration of habitat suitable for the spawning of target fish species. As removal works are conducted outside the breeding period of all target species and riparian vegetation is preserved during implementation, such intervention contributes to achieving conservation objectives.

If works are conducted within a protected area (in the case of the Vrljika and Jadro Rivers, Special Ichthyological Reserve Vrljika Spring and Jadro – Upper Course), a permission must also be obtained in accordance with Article 144 of the Nature Protection Act. The ministry responsible for nature protection issues permissions for interventions in strict reserves, national parks, special reserves and nature parks, while the administrative authority issues permission for interventions in natural monuments, regional parks, significant landscapes, forest parks and monuments of park architecture.

For macrophyte removal in the Vrljika River within the Special Ichthyological Reserve Vrljika Spring, nature protection conditions were obtained from the Ministry of Environmental Protection and Green Transition prior to the intervention, and these conditions were respected during implementation.

3.3. PROPERTY-RIGHTS ISSUES RELATED TO RIVER ACCESS

Property and legal issues concerning access to rivers for maintenance purposes represent a complex component of water resource management and environmental protection, as they involve ownership rights, access rights, land use rights, and responsibilities of institutions managing watercourses. The water protection zone (along the river) or water land is considered public property, most often owned by the state or local authorities. However, surrounding land parcels (access plots) may be privately owned, creating challenges for maintenance access. If access passes over private land, the Water Act (OG 66/19, 84/21) allows for the establishment of a right-of-way easement, often without compensation, but with prior notice and minimal disturbance to the landowner. For maintenance purposes, contractors must notify landowners, respect conditions of land use (e.g. avoid damaging crops or fences), and restore the land to its original condition or compensate for any damage. One limiting factor in implementation is the need to harmonize right-of-way easements with landowners, which can be complex and time-consuming.

3.4. CLEANING OF MACHINERY FROM IAS AND DISPOSAL METHODS

During these activities, particular attention should be paid to preventing the spread of invasive species, as they can easily be dispersed by machinery, even through small root fragments. If machinery used for sediment removal or other watercourse activities has been used at sites where invasive species are present, the following steps must be taken:

- All machinery and other equipment must be cleaned of silt and vegetation
- Inspect all machinery and equipment for invasive species (mollusks, snails, plants) and remove them if present
- Wash all contaminated machinery and equipment with high-pressure water (preferably hot pressurized steam)
- Where possible, leave machinery and equipment to dry for at least four weeks before using them in another watercourse (MESD, 2022a)

Extracted plant material should be transported to the bank onto an area protected with tarpaulin. The material should be stored in 1 m^3 construction waste bags until transported to a disposal/destruction site.

Following removal activities, the site should be inspected for several days and any remaining plant fragments in the water or on the bank should be removed. Floating residues near the bank should be collected using nets. Plant material must be transported to a destruction site located outside flood-prone areas. At the disposal site, plant residues should be spread in a layer no thicker than 10–15 cm to ensure rapid drying and plant die-off. In addition to on-site disposal, removed material may be delivered to a composting facility or bioenergy plant (MESD, 2022a).

3.5. POST-REMOVAL MONITORING

Monitoring must be conducted both before and after removal. The first post-removal monitoring should take place at least six to nine weeks after removal during the vegetation season and should include a visual inspection of water surfaces to determine the intensity of macrophyte regrowth. Establishing monitoring stations is recommended.

Macrophyte monitoring enables the collection of data on:

- the extent and intensity of vegetation growth
- species composition (native vs. invasive)
- the impact of vegetation on flow conditions and ecological functions
- effectiveness of previous removal measures

Visual inspections should be conducted regularly after each removal. After each survey, a brief monitoring report with results and photographic documentation should be prepared. The use of aerial drones is recommended to improve site overview before and after removal. The exact monitoring dates, locations, surveyed areas, and relevant cartographic representations should be documented.

Monitoring should be conducted once or twice during the vegetation season for one to five years after the initial removal, depending on population density and removal effectiveness. If excessive regrowth occurs despite previous measures, mechanical removal should be repeated. If no excessive growth is detected, field identification of present species should be conducted, with optional macrophyte sampling. Assessment of ecological status in accordance with the Croatian Waters methodology (Croatian Waters, 2025) is recommended.

3.6. ADAPTIVE MANAGEMENT OF MACROPHYTIC VEGETATION

Macrophyte removal is not a one-time measure but part of a continuous water ecosystem management process based on monitoring, evaluation, and optimization. This approach improves vegetation control, preserves ecological balance, and reduces long-term costs. Effective management requires an adaptive approach based on regular monitoring and analysis of previous measures. Based on current-year results, adjustments in the following period may include:

1. **Adjustment of removal intensity**

   – decreasing or increasing the scope of works depending on vegetation development

2. **Targeted removal of specific species**

   – focusing on invasive species showing expansion tendencies

3. **Adjustment of timing**

   – shifting removal to the vegetation phase when intervention is most effective and least harmful

4. **Selection of removal method**

   – adapting the method (mechanical, manual, diver-assisted) to substrate type, plant density, and terrain accessibility

5. **Integration with ecological status assessment**

   – monitoring results may indicate the need for additional ecological assessments and integration with biodiversity conservation measures

4. CONCLUSION

The Macrophyte Control Plan in Jadro and Vrljika Rivers presents the basic removal methods, previous implementation experience, and specific methods applied in the Vrljika River, adjusted based on field monitoring results.

General guidelines for implementing removal measures are proposed and will be continuously upgraded based on practical experience. The objective is to ensure that the guidelines are applicable and useful to all stakeholders involved in macrophyte management, with particular emphasis on preserving ecological balance and watercourse functionality.

5. REFERENCES

Baattrup-Pedersen A., Larsen S.E., Riis T. (2002): Long-term effects of stream management on plant communities in two Danish lowland streams. Hydrobiologia 481: 33–45.

Clarke, S. J. (2002): Vegetation growth in rivers: influences upon sediment and nutrient dynamics. Progress in Physical Geography: Earth and Environment, 26(2), 159-172.

Croatian Botanical Society (2020): Analysis of Macrophytes of Lake Vrana from 2010 to 2019 within the Project CHANGE WE CARE.

Croatian Waters (2025): Methodology for sampling, laboratory analyses and determination of ecological quality ratios for biological quality elements (in Croatian).

Franklin P., Dunbar M., Whitehead P. (2008): Flow controls on lowland river macrophytes: A review. Science of the Total Environment 400: 369-378.

Guttmann S. (2015): Professional Guidelines – River Management. IPA Programme of the European Union for Croatia, Twinning Light Project EU HR/2011/IB/EN/02 TWL "Strengthening Expert Knowledge and Technical Capacities of All Relevant Institutions for Appropriate Assessment of Plans and Projects for the Ecological Network (Natura 2000)". https://www.haop.hr/hr/publikacije/strucne-smjernice-upravljanje-rijekama

Hussner, A., Stiers, I., Verhofstad, M.J.J.M., Bakker, E.S., Grutters, B.M.C., Haury, J., van Valkenburg, J.L.C.H., Brundu, G., Newman, J., Clayton, J.S., Anderson, L.W.J. i Hofstra, D. (2017): Management and control methods of invasive alien freshwater aquatic plants: A review. Aquatic Botany, 136, 112–137.

Janauer ,G.A. (2001): Is what has been measured of any direct relevance to the success of the macrophyte in its particular environment? Journal of Limnology 60: 33-38.

Kočić, A. (2013): Utjecaj stanišnih uvjeta na dinamiku razvoja makrofita u vodotocima nizinskog dijela Hrvatske. Zagreb, Prirodoslovno-matematički fakultet, Zagreb.

Lacoul, P., Freedman, B. (2006): Environmental influences on aquatic plants in freshwater ecosystems. Environmental Reviews 14: 89–136.

Madsen, J.D., Chambers, P.A., James, W.F., Koch, E.W., Westlake, D.F. (2001): The interaction between water movement, sediment dynamics and submersed macrophytes. Hydrobiologia 444: 71–84.

MESD (2022a): Handbook on the Identification and Management of Invasive Alien Species, Ministry of Economy and Sustainable Development.

MESD (2022b): Handbook for the Implementation of Freshwater Ecosystem Conservation Measures. Ministry of Economy and Sustainable Development.

Mrakovčić, M., Zanella, D., Mustafić, P., Marčić, Z., Ćaleta, M., Horvatić, S., Karlović, R., Vajdić, S. (2019): Study on the Status Review and Valorisation of Softmouth Trout in the Adriatic Basin Region. Interreg – IPA CBC Croatia–Bosnia and Herzegovina–Montenegro, Ri-tour. ISBN 978-953-56977-7-0.

Public Institution More i krš (2025a): Report on Macrophyte Removal Works Conducted in 2024 within the Special Ichthyological Reserve Vrljika Spring.

Public Institution More i krš (2025b Report on Macrophyte Removal Works Conducted in 2025 within the Special Ichthyological Reserve Vrljika Spring.

Riis, T., Biggs, B.J.F. (2003): Hydrologic and hydraulic control of macrophyte establishment and performance in streams. Limnol Oceanogr 48: 1488–97.