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MACROPHYTES AND MACROINVERTEBRATES INTERACTIONS

Summary: *Macrophytes are an important component in aquatic ecosystems due to which there is the presence of a large number of macroinvertebrates, and therefore their interaction is very important. Macrophytes and macroinvertebrates research in rivers, lakes and reservoirs is not only of scientific imp ortance but it is important for management and conservation of aquatic ecosystems. In addition to the physical and chemical conditions, each state of the water system is characterized by a particular species or group of organisms, so-called bioindicators. Aquatic habitats are among the most sensitive habitats, which are also under a very strong influence of anthropogenic factors, which is why it is very important to do research and determine the diversity of plant and animal species. The quality of freshwater ecosystems is variable because many products that occur as a result of human activities end up in the water, as well as others that are emitted into the air or land, through a variety of processes end up in aquatic ecosystems. The aim of this paper is to present some research that indicates the importance of interaction between macrophytes and macroinvertebrates.*

Key words: *macrophytes, macroinvertebrates, water purification*

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INTRODUCTION

Water is the most widespread substance in nature and is divided into: surface water, ground water and atmospheric water. The composition of surface water is very different because of specific physical, chemical and biological processes that occur in them. Surface waters are subject to change, but not to just those changes that are the result of geological aging, but also to those, especially at the present time, that are caused by human activities. The quality of freshwater ecosystems is variable because many products that result from human activities end up in the water, as well as other products that are emitted into the air or land, through a variety of processes end up in aquatic ecosystems. Water quality is determined on the basis of the examination of its physical, chemical and biological characteristics (Stevanovic and Janković 2001, 126).

To consistently classify surface water is difficult based only on one of the criteria. Thus, the water can be classified based on the amount of nutrients and intensity of the primary production criterion on: oligotrophic (poorly productive and poor in nutrients), eutrophic (very productive and rich in nutrients) and dystrophic (poorly productive, poor, in a certain sense "dying" waters , rich in humic acids, with sparse vegetation and plankton).

Biological processes play an important role in maintaining the balance of aquatic ecosystems. In addition to the physical and chemical conditions, each state of the water system is characterized by a particular species or group of organisms, so-called bioindicators.

According to adaptation to different conditions of life in some parts of the aquatic environment there are different adaptive or life forms. Aquatic organisms usually contain a wide range of life forms, including:

– Bottom organisms (benthos) - flat and ring worms, mollusks, crustaceans, and insects;
– Free-floating organisms (bacterioplankton, aquatic mushrooms, phytoplankton and zooplankton);
– Plant and animal species attached to floating objects (periphyton);
– Organisms on the surface of the water (neuston);
– Animal species that are actively moving through the water (nekton) and
– Plants (macrophytes)

Aquatic habitats are among the most sensitive habitats, which also endure a very strong influence of anthropogenic factors, which is why it is very important to do research and determine the diversity of plant and animal species.
The fact is that the man has always faced the challenges of survival of the human species (Ilić and Praća 2012, 15). The aim of this paper is to present some research indicating the importance of interaction between macrophytes and macroinvertebrates.

1. AQUATIC MACROPHYTES

Aquatic plants include a complex group of different types of adaptive plants that inhabit the various water basins. Some authors classify all aquatic vascular plants, aquatic moss and macroscopic algae under the name of aquatic macrophytes. However, in terms of the size, aquatic plants are divided into a microphone (microscopic algae) and macrophytes, which include more plants and multicellular algae from among *Charales*. In addition to *hara*, macroalgae *Cladophora*, peat moss and ferns are also included.
Macrophytes of aquatic ecosystems, based on their structure and adaptation to the environment, or on the basis of the situation in the water, appear in three forms of life: helophyte, hydrophytes and amphyphytes. basic features of aquatic plants are submerged surfaces of leaves was increased when their small volume, heterofilija, mechanical elements have a central position, intercellular cavity are highly developed, reduction of the root system and the vegetative propagation (Stevanovic and Janković 2001, 140). Basic features of aquatic plants are: submerged surfaces of leaves which increases when they have small volume, heterophylia, mechanical elements have a central position, intercellular cavities are highly developed, reduction of the root system and the vegetative propagation (Stevanovic and Janković 2001, 140). Emersal macrophytes can be found in the shallow littoral zones, to about 1 m depth. Plants with floating leaves are commonly located at depths of 1 to 3 m, and submerged plants grow from the coast to the photic zone border and rarely exceed a depth of 10 m. Thanks to ecophysiological adaptations of aquatic plants intensive photosynthesis of submerged leaves, which is caused by abiotic conditions and

the depth at which the plant is located, is enabled. The most intensive photosynthesis happens in plants which are located directly below the water surface. Submerged plants that inhabit the relatively small area of aquatic ecosystems adapt to the reduced amount of solar radiation, while the floating plants are exposed to very intense radiation at the surface of the water basin. At great depths under low illumination we can find only primary aquatic plants, and algae that are characterized by the presence of complementary pigments that allow them to provide sufficient amounts of solar energy wavelengths that can reach those depths (Stevanovic and Janković 2001, 160).

Depending on the conditions of water and air environment, transpiration can be very intense with floating and emersive leaves. (Stevanovic and Janković 2001, 178). Like all primary producers, these plants respond to water quality in which they are growing, and therefore they are good indicators of the state of the surface waters. The distribution of aquatic macrophytes depends on many factors, such as temperature, light, water, chemical composition, pH, water depth, type of substrate, water velocity and water regime (Weisner 1993, 94; Krischik et al., 1999). Aquatic macrophytes have multiple positive role, in addition to contributing to the healing of the water pane, to the reduction of the flow and enlightenment of water biotope and thus to distorting of the basic environmental qualities. The importance of aquatic plants is multiple (Janković 1985, 112). Their role is reflected in the production of biomass, the production of oxygen and the creation of a specific structure of aquatic vegetation. Macrophytes are an essential component in many aquatic ecosystems. This is reflected in the ecological role, because the plants (taking the algae into account) are primary producers in the aquatic environment, the first link in the food chain and thus all other forms of life in the aquatic environment depend on the plants.

In addition to providing food for fish, invertebrate and waterfowl they also represent places for fish spawning, as well as shelter for fish and invertebrate which tare then involved in food chains (Krischik et al., 1999). It also created a large number of microhabitats necessary for animal species. Their surface area in the roots, stem and leaves inhabit numerous life forms, sessile bacteria and algae, phytoplankton and zooplankton, invertebrate, whether or not attached to the surface of plants, then different species of fish, amphibians and reptiles, aquatic birds and mammals. It also created a large number of microhabitats necessary for animal species. Their surface area in the roots, stem and leaves inhabit numerous life forms, sessile bacteria and algae, phytoplankton and zooplankton, invertebrate, whether or not attached to the surface of plants, then different species of fish, amphibians and reptiles, aquatic birds and. Nitrifying and non-nitrifying bacteria community are developed on them, depending on whether their area is on the light or in the dark as well as many other forms (Kim 2004, 120). They are perfect as a basis for the development of periphyton which is very important for macroinvertebrates.

2. AQUATIC MACROINVERTEBRATES

Aquatic macroinvertebrates (aquatic invertebrates) are a group of organisms that inhabit the bottom (sediments, detritus, macrophytes, filamentous algae) of the freshwater ecosystems throughout their life or part of their life cycle. The size of these organisms is 200 to 500 micrometers. Fauna of the bottom (benthic macroinvertebrate community) belongs to the aquatic zoocenoses alongside with plankton, periphyton, and nekton and neustonic organisms. These organisms play an important role in the flow of energy and the cycling of matter. They also have wide application in biomonitoring of aquatic ecosystems. Abiotic factors in aquatic ecosystems, expressed through the hydromorphological and physico-chemical characteristics of aquatic habitats, significantly affect the structure of benthic macroinvertebrates communities. Out of the physical and chemical factors, the most significant are the temperature; the concentration of dissolved oxygen, and the related values of oxygen saturation; pH value of water; concentration of organic matter and more.

Out of the hydromorphological parameters, the structure of benthic communities is affected primarily by the type of substrate, water velocity (in current ecosystems), water regime and other. All these factors act synergistically on the benthic macroinvertrebrates, and each type has ecological valence in boundaries of which, for a given parameter, certain species survives.

The types of macroinvertebrates that inhabit flowing water are characterized by a certain adaptive traits- they are generally slow moving and some are sessile. In order to achieve such intimate contact with the substrate, with the aim of preventing sailing away, many species have dorsal-abdominal parts flattened (eg. *Plecoptera* and *Ephemerpoptera*). Some species besides having dorsal-abdominal parts flattened also secrete mucus (*Turbellaria*), and thus are even more tightly tied to the substrate. Species that live in the strongest currents have special bodies for acceptance (*Diptera*) or special cornice hook on end of the body (*Diptera*). Larvae (*Trichoptera*) that live under rocks, knit special hunting nets for catching food and some species have homes of grains of sand and small pebbles, which because of the weight cannot be carried away by the water flow. The amount of dissolved oxygen is of particular importance in the aquatic ecosystem. Adaptation of benthic macroinvertebrates on the variation of environmental factors ran in different directions. Due to intensive bacteriological degradation in the organically laden waters, a drastic reduction in the amount of oxygen in the water can happen, which results in the appearance of species that can survive in water with little oxygen, such as hironomida larvae (*Diptera*) and olygochaete of the family (*Tubificidae*). These species in their body fluids possess a special kind of hemoglobin, whereby which they can bind enough oxygen for their needs even if there is a small amount of oxygen in the surrounding environment. Species (*Turbellaria*) do not have any special adaptation of the respiratory organs, because they receive oxygen through the body surface, and crabs and insects whose body surface is hard and thus makes it impossible to breathe through the skin, have a special respiratory-gills.

3. MACROPHYTES AND MACROINVERTEBRATES INTERACTIONS

Species and population composition, or density of the individuals per area unit are uniform in stable aquatic environment, whereas major and minor variations may occur seasonally. These communities respond to change of the environment by changing the structure of the community. Bottom fauna communities react to changes in the environment, particularly on water quality changes under anthropogenic influence, and therefore they can serve as a bioindicator of the status of the aquatic systems. It has been shown that macroinvertebrates change the structure of their community in

the following cases: organic overload and toxic-chemical pollution.
Macrophytes are an important component in aquatic ecosystems due to which there is the presence of a large number of macroinvertebrates, so that their interaction is very important. Research of macrophytes and macroinvertebrates in rivers, lakes and reservoirs is not only of scientific importance, but it is important for management and conservation of aquatic ecosystems. Based on numerous studies of systematic affiliation it can be concluded that the largest share of the macrophyte macroinvertebrates belongs to the species from the class *Insecta.*
Aquatic insects are the rich and groaning group of organisms inhabiting different types of aquatic ecosystems, from small areas of temporary (ephemeral) standing water (eg. Puddles), to springs, streams, large lakes, and major rivers. In lentic, or standing water, aquatic insects appear at the bottom of deep lakes, alongside vegetation, as well as in the open water. In lotic or flowing waters, they appear under rocks, fallen leaves and the remains of plant material, or crevices of tree trunks, buried in sand or sediment where they live sedentary lifestyle or crawl. Aquatic insects are an important component of aquatic food chains. They shred organic material, and they also feed on collapsing parts of fungi, bacteria, and dead animals. By assimilating these substances, disassembling the large pieces into the smaller ones, aquatic insects produce energy and nutrients that become available to other invertebrates and vertebrates (eg. Fish, birds). Regardless of their importance in aquatic ecosystems, only a few representatives spend their entire lives in water (*Coleoptera*). The largest number of aquatic insects linked to the aquatic environment through the larval stage, whereas their adult stages are terrestrial (*Ephemeroptera, Plecoptera, Odonata, Trichoptera, Diptera*). Typical ie. “Normal” responses from the community of aquatic insects (along with other macroinvertebrates organisms) to any change in the physical and chemical factors of water environment are as follows:

a) When the content of sediments in the water biotope grows, the relative abundance of certain species of *Ephemeroptera* and *Trichoptera* larvae that feed by filtering food also grows.
b) When the content of dissolved oxygen in the water decreases, the number of Insect larvae that contain hemoglobin increases (*Chironomidae*).

c) With increasing temperature of the water, the number of larvae *Plecoptera* decreases.
d) Inflow of pesticides in the aquatic environment affects the reduction of species diversity.
e) If intake of organic matter in the aquatic environment (manure or waste from farms) increases, it will increase the number of just a few species, with a simultaneous decline in species diversity.

Numerous studies were conducted which prove that the presence of macroinvertebrates is larger and density of population is higher in the presence of macrophytes in comparison with the aquatic ecosystems where macrophytes are not present. Aquatic macrophytes settlements are the habitat of a large number of invertebrates in relation to places with no vegetation both in terms of species and in terms of total biomass (Popijač 2003).

Gerrish and Bristow (1979) examined the connection between macroinvertebrates and macrophytes. Their research was based on monitoring and comparison of the presence of macroinvertebrates on natural plants *Myriophyllum exalbescens* , *Potamogeton* and *Vallisneria americana* and artificial suurfaces which are in appearance reminiscent of *Potamogeton richardsonii*, in two different periods (June and July 1974). There was no significant difference in the density of population on natural plants and artificial surfaces. According to the results of the analysis conducted in the month of June, it can be seen that the highest presence belongs to representatives from *Chironomidae* and *Oligochaeta* on all surfaces. *Oligochaete* were the most numerous on *Myriophyllum*, and their presence on artificial surface is greater than on the natural *Potamogeton* and *Vallisneria.* Unlike *Oligochaeta*, density of population of *Chironomidae* was the largest on the *Potamogeton*, then on the artificial surface, while the lowest density of population is related to *Vallisneria*. Based on the results from the month of July, *Ephemeroptera* population density also increased, and that increase happened on the natural plants. *Chironomidae* population density was lower on artificial surfaces in relation to the natural plants, while *Oligochaeta* population density was greater on artificial surfaces in relation to the natural plants. Based on these results, it can be concluded that macrophytes represent macroinvertebrate habitat and serve as a basis for the formation of periphyton which macroinvertebrates use as a food source.

According to Forster and Schlichting 1965 research it was found that each macrophytes species has certain characteristics that lead to the formation of the periphyton. In Gerich and Bristow studies (1979) it was noted that natural plants and artificial substrates may similarly enforce the colonization of periphyton and macroinvertebrate population density depends on the morphological characteristics of macrophytes.
Marcel and associates in the year 1997 analyzed the relationship between macroinvertebrates and submerged *Charophyta* in two eutrophic lakes Veluwemeer and Wolderwijd in the Netherlands. Biomass, species composition and macrophytes vegetation period influence the composition and density of the population of macroinvertebrates. Based on the research at the end of the 1960s underwater vegetation in the aforementioned lakes was reduced due to eutrophication. During the 70s and 80s species *Potamogeton pectinatus* L. and *Potamogeton perfoliatus* L. appeared, and after the repairment of the lake in 1979, *Charophyta* species appered, and the species of this type were *Chara aspera* in the Veluwemeer lake and Chara contraria and *Chara vulgaris* in Wolderwijd lake (Hosper and Meijer 1986, 184). In the same period there was a decrease in *Potamogeton pectinatus* population density, and the slight increase was recorded in *Potamogeton perfoliatus* population density. After ten years sampling of macroinvertebrates and macrophytes in Lake Veluwemeer was conducted. That survey revealed the presence of 37 species of macroinvertebrates of which the representatives of *Gamaridae* and *Chironomidae* families were the most numerous ones. In further analysis it was found that the samples taken in places where there is a *Potamogeton* the most prevalent were three types: *Einfeldia Dissidens, Cricotopus gr. sylvestris and Sphaeriidae*, while the samples taken where *Charophytes* dominated the most numerous was *Endochironomus albipennis. Charophyta* biomass was significantly higher than the *Potamogeton* biomass species. It was also found that the Charophyta biomass was positively correlated with two types of Gastropoda family (*Valvata picinalis* and *Bitinia tentaculata*) as well as with water insects *Endochironomus albipennis, Chironomus sp., Psectrocladius sp*. While the species *Potamopyrgus antipodarum, Cladotanytarsus sp., Cryptochironomus sp.* are negatively correlated.
Based on the above results, it can be seen that the presence of macroinvertebrates depends on the plant species and their biomass, because it

was determined that there was no significant difference in the presence of macroinvertebrates that are found between *Potamogeton perfoliatus* and *Potamogeton pectinatus*. *Charophyta* vegetation has different morphological characteristics and biomass higher than *Potamogeton* species, which is a favorable habitat for species that feed by scraping periphyton off the aquatic plants such as *Valvata piscinalis* and *Bithynia tentaculata*.

Numerous studies were conducted which served to indicate the importance of macrophytes as habitats and shelter from predators. Hunter and associates (1986) have carried out a comparative study on four cages of the same physical and chemical characteristics (Maine, USA). In two cages due to changes in pH value (increasing acidity) death of fish occurred, while invertebrate population density was significantly higher than in ponds where there was no change in pH value. Invertebrate represent an important link in the food chain of fish. Foe example, *Tinca tinca* (Linnaeus, 1758) is the largest predator of molluscs - moluskivor, it mainly feeds on mollusks but in the absence of it may use the other sources of food (Popijač 2003). Fish that consume mollusks have a significant effect on the density of their population as well as an indirect positive impact on the growth of fouling. Fouling biomass increased in quasi with the fish due to the reduced pressure of mollusks that feed on fouling (by scraping) (Popijač 2003).

In cages with fish, populations of mollusks are rare due to the predation by fish, and in the periphyton community *Diatomeae* and filamentous algae dominate. In cages with no fish where there is a higher number of mollusks, smaller and strongly attached algae dominated in periphyton community.

From previous studies a positive impact of mollusks on the growth of submerged macrophytes and the negative impact of molluscivora fish can be seen. Molluscs by feeding on fouling reduce the fouling biomass which encourages the growth of macrophytes. This is confirmed by many experiments done in shallow cage with fish in Sweden (Popijač 2003). *Tinca tinca* was used as moluskivor, where the biomass of molluscs decreased in this cage and there was an increase in fouling biomass and a significant reduction in the biomass of the dominant macrophytes (*Elodea Canadensis*). Using aquatic plants as a shelter from fish predation is one of the important causes for much richer communities of invertebrates in dense plant settlements, but the other factors are also important. This is evident from the fact that, even when there is no fish, density and diversity of species of invertebrate macrofauna were higher in areas that are rich with underwater vegetation than in areas where there are no plants or where the plants are very rare. Beside the fact that macroinvertebrates use macrophytes as a shelter from predator fish, one of the important causes for much richer macroinvertebrate communities in dense plant settlements is the availability of food. A very small number of macroinvertebrates can consume significant amounts of fresh macrophytes, but decaying plants provide a relatively high quality detritus that representatives of the Isopoda, snails and insect larvae feed on (Popijač 2003). Much more important food source for them is periphyton or fouling layer covering macrophytes. Hoyer and associates (1997) have researched the flow of carbon by comparing the share of stable isotopes of carbon in different organisms through the food chain. Research was conducted in two lakes in Florida, where one lake was overgrown with vegetation, while the second lake had no vegetation. In the lake without vegetation phytoplankton was the carbon source, and it the lake with vegetation periphyton was the carbon source, while macrophytes had only a small share in the food chain.

CONCLUSION

Based on the examination results of many authors presented in this paper, it can be concluded that aquatic plants or macrophytes have multiple significance. They are an essential component of many aquatic ecosystems and the habitat of a large number of macroinvertebrates and serve as a basis for the formation of periphyton which macroinvertebrates use as a food source. Each species of macrophytes has certain characteristics thanks to which it comes to the formation of the periphyton. Based on the results, we conclude that natural plants and artificial substrates may similarly enforce the colonization of periphyton and macroinvertebrates population density depends on the morphological characteristics of macrophytes. Also, dense settlements of plants are important for macroinvertebrates due to the availability of food. A small number uses fresh macrophytes but for the majority high-grade detritus and fouling (that is perphyton on macrophytes) are significant. You can notice a significant impact of fish on macroinvertebrates population density - mollusks, as well as the positive impact on the growth of fouling. Fouling biomass increases in cages with fish, due to the reduced pressure of mollusks that feed on fouling. By researching macrophytes as a habitat and shelter of macroinvertebrates from predators, it was noticed that the density and diversity of macroinvertebrates is higher in areas that are rich in submerged vegetation than in an area where no plants or in the place where the plants are rare.

Macrophytes are an important component in aquatic ecosystems thanks to which there is the presence of a large number of macroinvertebrates, and therefore their interaction is very important. The research of macrophytes and macroinvertebrates in rivers, lakes and reservoirs is not only of scientific importance but it is important for management and conservation of aquatic ecosystems.

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