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Chapter 18

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Functioning of Aquatic Invertebrate Communities in Oxbow Lakes with Various Connection to Riverbed

1. Introduction

Each natural river valley forms a system characterized by meandering or anastomosing river, rich with adjacent places of different depth as well as wetlands, particularly swampy during floods. Such a valley is a mosaic of various ecosystems: oxbow lakes, peat bogs, swampy meadows, riparian forests, alder swamp and oak-hornbeam forests (Puchalski 1999). Among them, oxbow lakes seem to be the most interesting research objects since they are a transitional form between lotic and lentic ecosystems.

2. Division of oxbow lakes and their biological features

Oxbow lake, a subtype of riverine lakes, is an area of water in a curved shape, morphogenetically connected with the main stem of a river (Choiński 1988). They are formed by natural transformations (*natural oxbow lakes*) or artificial straightening to improve navigation or flood alleviation (*artificial oxbow lakes*). Those bodies of water are usually U-shaped by hydrodynamic processes occurring in a riverbed (erosion and accumulation).

Oxbow lakes, due to their specific origin, morphometry and hydrodynamics, should be treated as a separate type of aquatic ecosystems, as opposed to lakes with different, particularly post-glacial origin. While comparing oxbow lakes to other aquatic reservoirs, the following features should be taken into account: distribution, hydrological forms, water trophy and biological characteristics.

In Poland, the share of oxbow lakes in the total number of lakes (> 1 ha) is estimated at the level of 8% (Kondracki 1988), although considerable number of smaller oxbows with area between 0.25 and 1 ha would significantly increase that percentage. Oxbow lakes are the most numerous in the middle course of rivers, both large and small. However, the valleys of large rivers (e.g. Vistula, Warta, Narew) are predominated by natural oxbow lakes while artificial oxbow lakes most often occur in the valleys of smaller rivers (e.g. Słupia, Łyna, Drwęca). The shape and bathymetry are the most distinctive features of oxbow lakes against the background of lakes with different origin. Their morphometric parameters obviously reveal their potamic origin (Glińska-Lewczuk 2009b). The morphometric arrangement usually makes a single, apparently-shaped bend, although older forms have complex structure reflecting the dynamics of fluvial processes- overlapping bends of different age and different level of succession (Leopold, Wolman 1957), (Fig. 1). Considerable number of artificial oxbow lakes does not have that typical curvature. However, the analysis of geologically young and old rivers allows revealing some repeating hydrological and biological patterns.

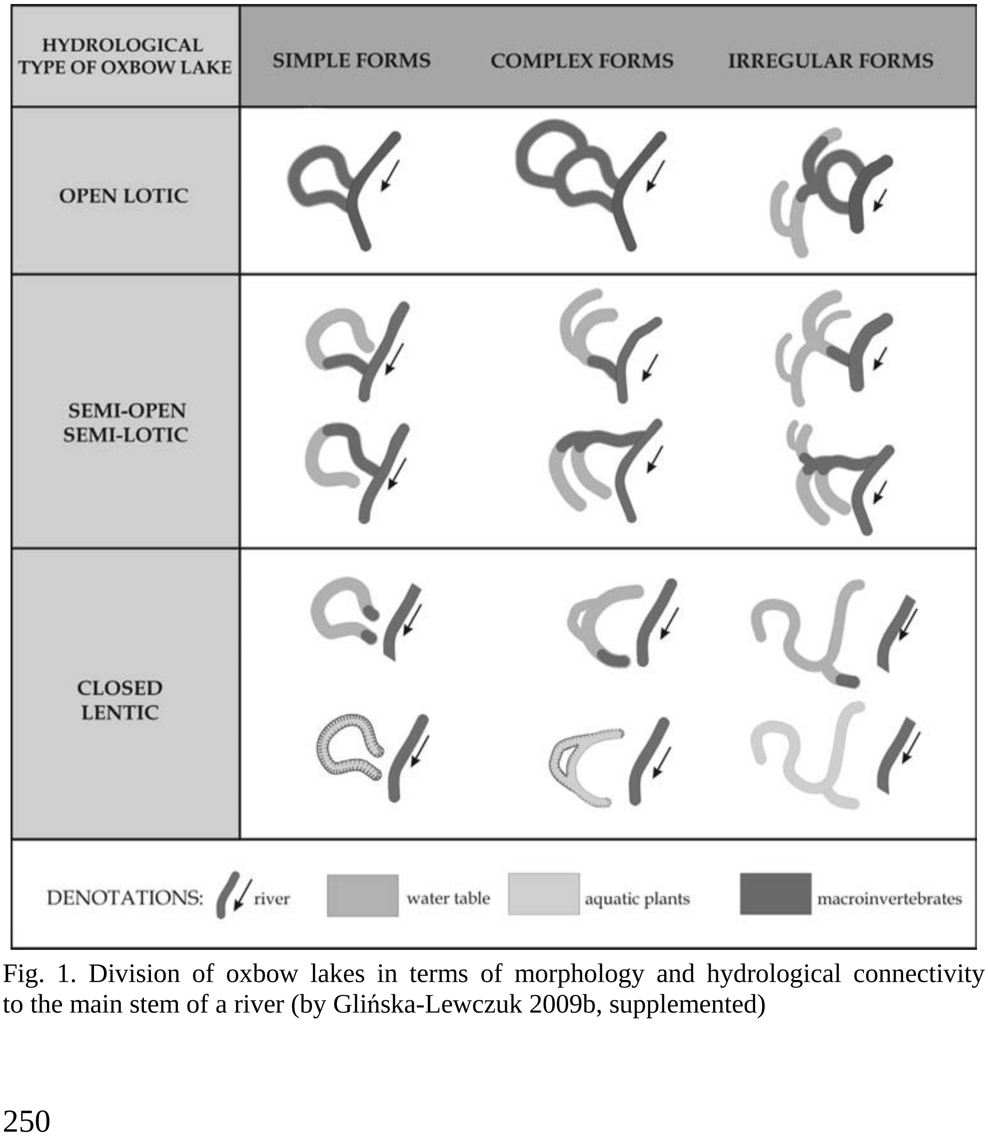

Fig. 1. Division of oxbow lakes in terms of morphology and hydrological connectivity to the main stem of a river (by Glińska-Lewczuk 2009b, supplemented)

Shapes of older oxbow lakes are complex and irregular, while these localized in young-glacial river valleys (e.g. Słupia, Łyna) are usually straight and formed by a single apparent arch. The way of arrangement of complex forms, i.e. made of two or more connected bends, is governed by a rule: the nearer contemporary riverbed, the smaller arches of younger meanders (Glińska-Lewczuk 2009b).

The oxbow lakes are characterized by small width as compared to their length. Unlike other lake types, oxbow lakes usually have no isles, steps, nor bays. These reservoirs have usually smooth bottom with deeper sites at the place of former depressions. The oxbow lake's bottom is made of sediments with a structure corresponding to conditions in which the river worked at the moment of cutting off the main stream. The bottom is covered with organic matter layer, the thickness, level and rate of mineralization of which depend on hydrodynamic conditions in a reservoir. The quicker time of a horizontal water exchange, the slowest sediment increase, namely organic ones, and moderate and coarse-grain material dominates. That forms the conditions preferred by various groups of zoo- and phytobenthos.

Hydrological connectivity between oxbow lake and river is the principle factor influencing the functioning of such an ecosystem. That connection, direct or indirect, depends on hydrological regime which forms the circulation of matter. The period of water refreshment by periodical spates is important in hydrology of river lakes. Moreover, as compared to other natural lake types, they differ with high water level amplitudes, met also in dam reservoirs. Oxbow lakes have usually no surface supply; however, objects that were formed due to hydrotechnical works often function as matter receivers from drainage systems. All those hydrological conditions directly influence the taxonomic structure and dynamics of hydrobiont communities.

Variety of water supplies results in considerable changeability in the quality of oxbow lake waters. Comparing to other genetic types of lakes, oxbow lakes are characterized by higher turbidity as well as larger loads of lithosphere-origin chemicals and nutrients. It is in part associated with small dimensions of the basin as compared to the catchment area, as well as relatively long shore-line contact with a land, from where chemicals are washed out to the oxbow lake's aqueous environment. However, an oxbow water quality mainly depends on the quality of its main river (Lewis *et al.* 2000). The trophy of oxbow lakes directly influences organisms inhabiting such reservoirs.

Biotope of oxbow lakes is a combination of lotic and lentic features. That forms unique habitats assigned to protection within the Habitats Directive Natura 2000 as subtype "Oxbow lakes and small reservoirs" (code 3150-2). Phytosociological indicators of that habitat are submerged unattached macrophytes (*Potamion* and partly *Nymphaeion*), floating attached as well as floating unattached macrophytes (*Lemnetea*). Those unique plant communities in oxbow lakes are accompanied by fauna of equally unique structure (Gallardo *et al.* 2008). Particularly interesting are benthic fauna communities, which condition indicates the ecological state of aquatic ecosystems. Their presence and structure in oxbow lakes depend on the connectivity with the main river (Fig. 1). Benthic fauna is particularly abundant in the contact zone between riverine and oxbow waters while limited hydrological connectivity lowers its density. In cut-off oxbow lakes, which undergo quick succession and shallowing, plants constitute alternative habitat for benthofauna (Strzałek, Koperski 2009). Thanks to "ecological plasticity" some species may survive in anaerobic conditions, which occur in lentic oxbows mainly during summer.

The functioning of wetlands in river basins is directly and indirectly connected to the changes in river water level or flood pulsing (***Flood pulse concept – FPC***) (e.g. Junk *et al.* 1989, Tockner *et al.* 2000).

The concept of interconnections between river valley ecosystems and the river, in respect to the exchange of matter, energy and aquatic organisms through water, was started by Amoros *et al.* (1988, 2002). In turn, Tockner *et al.* (1999b) revealed, that water chemistry and biotic communities are directly influenced by river water level, which reflects hydrological connectivity. Organic matter accumulated in aquatic ecosystems in the area of floodplain is unavailable for organisms inhabiting river. At the same time, rapid increase in water level is destructive for their biocenoses and eliminates most of the flora and fauna representatives in riverbed. The only sources of recolonization are small aquatic reservoirs located in the floodplain (Robinson *et al.* 2004).

Hydrological conditions are a key factor for morphogenetics but also form the environmental conditions of oxbow lakes. They influence water quality and, thus, the biotic communities inhabiting oxbows (Van den Brink, Van der Velde 1991). Limited inflow of nutrients stops eutrophication in cut-off meanders while relatively low content of organic matter favours the predomination of fine grains in bottom sediments. Similar situation is observed, when ground water supply is blocked by fine-grained material covering the bottom of an oxbow lake (loam).

Those relationships are reflected in the average biodiversity of consecutive flora and fauna communities observed in wetlands (Fig. 2). Total biodiversity usually fits the normal distribution but specific groups of organisms differently react to the level oh hydrological connectivity between wetlands and river.

Molluscs and dragonflies reach the highest diversity under limited hydrological connectivity while the remaining communities prefer unlimited contact between an oxbow and its main river. This particularly concerns fish and zooplankton (Gallardo 2009, Ward 1998). Only the diversities of phytoplankton and phytoperiphyton slightly depend on hydrological connectivity.

Irrespective of the fact, that the distinguished hydrodynamic types of oxbow lakes favour the occurrence of specific hydrobionts, those reservoirs are important ecological centres, so called "*hot spots*", on a scale of a river valley or even a region, which form diverse habitats for numerous flora and fauna representatives (Van den Brink, Van der Velde 1991, Ward, Stanford 1995, Bornette *et al.* 1998). Relationships between riverbed and river valley are reflected by complex functions, such as production, decomposition and consumption, which are influenced by systematic floods and oscillations of water level (Sparks *et al.* 1990). According to the "*flood pulse*" theory, alternating periods of floods and streamflow drought favour decomposition and the circulation of nutrients, which increase biological diversity and productivity of ecotones water/land (Zalewski 2006).

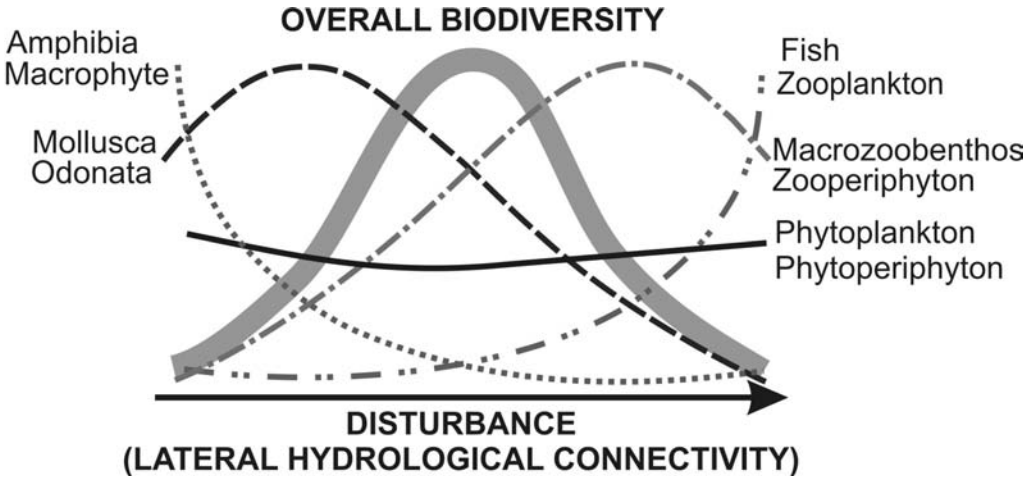

Fig. 2. Changes in the distribution of hydrobiont biodiversity in wetlands along hydrological connectivity (by Tockner et al. 1999b, changed and supplemented)

3. Main factors influencing the structure of invertebrate communities in oxbow lakes

Scientific studies conducted so far have revealed that the following factors influence he taxonomic and functional structures of invertebrates in oxbow lakes:

1. Hydrological connectivity between the river and oxbow lake, which determines the rate of water and matter exchange;
2. Environmental conditions;
3. Presence of vegetation and artificial substrate as habitats for invertebrates.

Hydrological connectivity seems to be the key factor which influences ecological state of an oxbow ecosystem. Differences in surface contact with the main river obviously have impact on taxonomic and functional structures of zoocenoses. Cut-off and eutrophicated oxbow lakes were predominated by Chironomidae or Crustacea (mainly *Asellus aquaticus* L.). In partly open and open oxbows the main component of benthic fauna were Crustacea representatives while in oxbows connected with the main river by melioration ditches the main role played Ephemeroptera larvae. Hydrological connectivity between river and adjacent wetlands reflects in the biodiversity of a river valley. The highest Shannon index (around 1) was recorded for open oxbow lakes and often it was higher than in the main river. In turn, the lowest diversity values were noted in closed oxbows, where the Shannon diversity index usually did not exceed 0.5 (Obolewski 2011). It turns out, that invertebrate diversity slightly increases with increasing hydrological connectivity while the invertebrate abundance has unimodal distribution (Tockner *et al.* 1999b, Ward 1998, Amoros, Bornette 2002, Ward *et al.* 2002, Whiles, Goldowitz 2005, Gallardo *et al.* 2008, Obolewski 2011). The most optimal connection is a partial one – semi-lotic – or alternatively the full contact. Most of the studies conducted so far have revealed that such types of hydrological connectivity favour habitat diversity within one reservoir. As a result, considerable amount of benthic invertebrates appears. Moreover, hydrological connectivity improves environmental conditions in oxbow lakes (Dynesius, Nilsson 1994, Glińska-Lewczuk 2009a).

In semi-open oxbows the highest abundance of macrozoobenthos is usually recorded in the oxbow arms, which are in contact with the main river. A considerable number of taxa are observed in such ecosystems but the total density is low: not exceeding 2000 indiv.m^{-2}. The open oxbow lakes, with moderate flow velocity, the distribution of consecutive invertebrate taxa is more even, however benthic invertebrates tend to group in the oxbow arms. Benthofauna diversity in such oxbows is moderate (around 20 taxa) while density reaches 2000 indiv. m^{-2}. In turn, the benthic fauna in cut-off oxbow lakes is of low diversity; however its abundance can vary considerably, reaching even a few thousand indiv. m^{-2} (Gallardo 2009, Obolewski 2011). Limited water flow (i.e. stable conditions) favours Crustacea, mainly *A. aquaticus* (Obolewski 2011), which domination increases with hydrological connectivity and reaches its maximum at the level of 50%. Therefore, that species can be a treated as **typical of oxbow lakes.**

The influence of floods and flood pulsing in river-wetland ecosystems has been assessed by many scientists (e.g. Boulton *et al.* 1992, Clausen, Biggs 1997, Tockner *et al.* 1999b, Gibbins *et al.* 2001, Sheldon *et al.* 2002, Arscott *et al.* 2005, Robinson *et al.* 2004, Whiles, Goldowitz 2005, Zalewski 2006, Gallardo *et al.* 2007, Reese, Batzer 2007). Hydrological connectivity within a river valley may be treated as a key parameter which influences qualitative and quantitative structure of benthic invertebrates. Regardless of the oxbow-river connection, the abundance of invertebrates in oxbows is usually considerably higher than in watercourses (5-fold in semi-lotic oxbows, 6-fold in lentic and 8-fold in lotic oxbows). Any rapid events within riverbed, which are followed by the elimination of some invertebrate fauna components in the river, can be interacted by organisms inhabiting oxbow lakes. Therefore, the wetlands within a floodplain are "***biological centres***" of recolonization for river valleys.

Different structure, both qualitative and quantitative, of invertebrate fauna has been recorder for river valleys with hydro-power infrastructure, where twenty-four hour oscillations of water level occur. Those fluctuations cause the phenomenon of ***Intensive Flood Pulses Concept*** **(IFPC)** in part of the valley – i.e. repeating rise and fall of water level. That makes the hydrochemical and biological processes more intensive within a floodplain but also disturbs habitat conditions in a riverbed.

One conclusion can be drawn from the examples given above – one of the conditions of stable, biological functioning of river-oxbow system is the maintaining or re-opening of direct hydrological connectivity. Biological differences between three types of oxbow lakes indicate that, apart from hydrodynamic division, there is a need to distinguish **zoocenotic types** of oxbows. Currently, we can only discuss some preferences of invertebrates in terms of hydrological conditions. However, further research should contribute to the knowledge of relationships between zoocenotic communities and hydrological connectivity.

Environmental gradients result from oxbow-river hydrological connectivity. However, due to their diversity, they are discussed as a separate element. Studies conducted so far have indicated the following environmental factors which may influence invertebrate communities: water movement (e.g. Heino 2000, Jeppesen *et al.* 2003), water quality (e.g. Petridis 1993, Woodcock, Huryn 2007), structure and composition of bottom sediments (e.g. Griffith *et al.* 2001, Murphy, Davy-Bowker 2005) as well as the presence of macrophytes (e.g. Carpenter, Lodge 1986, Wissmar 1991).

Oxbow-river hydrological connectivity triggers water movement of different scale and wavy motion, which considerably alter habitat conditions. Intensive water movement prevents the deposition of sediments while stable waters favour the existence of isolated still water pools. Moreover, water flow and waves equalize water temperature and differences in other parameters between consecutive zones of an oxbow environment. They also favour the inflow of food, oxygen and outflow of metabolic products. In terms of water movement, it is clear to divide oxbow lakes into lotic and lentic. More complex situation is observed in semi-open oxbows, which combine the features of both closed and open reservoirs.

Apart from the type of oxbow-river connectivity, the level of connection should be also considered, since it influences the volume of flowing water as well as the velocity and distribution of currents. The strength of currents varies between the oxbow types but also within the same type of such reservoirs. Strong currents occur in open arms of an oxbow lake and in the surface zone. Therefore, habitats differ between lotic reservoirs (favoured by rheophilic organisms), lentic oxbows (preferred by rtheoxenic species) and many intermediate environments. That has been confirmed by the research on invertebrates in a lotic oxbow lake, where fauna more abundantly inhabited the zone of river water inflow **(**Obolewski *et al.* 2009). The more intensive water flow, the higher abundance of benthofauna species, particularly Crustacea, and their biomass, mostly of Oligochaeta, Hirudinea and Crustacea. In case of Diptera larvae, Trichoptera, Ephemeroptera and Mollusca, their abundance and biomass varied considerably. Water flow in the studied oxbow also influenced invertebrates being a part of periphyton. Water movement particularly favoured Nematoda, which feed in many ways and Protista, predominated by sedimentators – Peritricha (Piesik 1992). Suspended material and re-suspended bottom sediments are for them the source of food.

The studies carried out on *floodplain water bodies* have proved that water quality directly and indirectly influence hydrobiont communities (e.g. Wang *et al.* 2007). Flooded wetlands are supplied with nutrients from natural and artificial sources, both external (inflow) and internal (productivity) and their highest content is observed in cut off reservoirs (Tockner *et al.* 1999a). The lack of *flood pulse* increases the rate of sediment deposition and eutrophication. Additionally, anthropogenic influences such as agricultural use and urbanization result in higher trophy of floodplain areas. Sedimentation of heavy particles and their immobility cause that small water bodies and oxbow lakes are so called ecological traps for contaminants migrating within a river valley. Therefore, oxbow lakes are sometimes used as settling basins but the accumulated matter is also a source of food for a wide range of invertebrates. In turn, epiphytic invertebrates, like Peritricha (Protista) and Rotifera (sedimentators), feed on fine particles suspended in water (Piesik 1992). In spite of small size, their considerable density cause that they are able to eliminate most of the suspended matter and improve light conditions in a reservoir. Those processes are intensified thanks to filtrators, represented in periphyton mainly by *Chydrous sphaericus* O.F. Müller.

Water quality has undeniable influence on living organisms and either favours their development or leads to their elimination from aquatic environment. Many studies aim at the assessment of relationships between abiotic factors and macroinvertebrates (e.g. Mallory *et al.* 1994, Sadin 2003, Gallardo *et al.* 2008). More dynamic thermics of water in oxbow lakes, comparing to other aquatic ecosystems, determines the abundance of invertebrate communities. In this aspect, biodiversity in floodplain areas can be closely connected with global climatic changes (Burgmer *et al.* 2007, Zalewski 2010).

Apart from physical factors, habitat conditions of invertebrates also significantly depend on chemical properties of water. The most important influence on taxonomic and functional structure of the discussed communities has been recorded for nitrogen compounds and sulphates (Blumenshine *et al.* 1997, Gallardo *et al.* 2008). Nitrites are soluble compounds, common in riverine waters, and therefore can be used as an indicator of water quality and integrity of aquatic ecosystems (Smith *et al.* 2007). As a transitional form of nitrogen in geochemical transformations, nitrites influence biodiversity and abundance of invertebrate fauna. Their presence is a sign of dynamic changes in floodplain areas. Low oxygen concentration, particularly in lentic oxbow lakes, results in the occurrence of toxic ammonia, which eliminates the presence of most of invertebrate species. At higher oxygen concentration the nitrate nitrogen is formed, which can be assimilated by aquatic plants. In such conditions a rich food base and habitats favourable for invertebrates appear. The role of nitrite nitrogen in the functioning of invertebrate communities indicates the need of better hydrological connectivity in floodplain areas. Another important chemical parameter in oxbow waters is the concentration of sulphates. The lack of oxygen, particularly in wetlands with limited hydrological connection to the main river, causes the transformations of sulphur compounds and hydrogen sulphide appears, toxic for benthofauna. In turn, sulphate ions can be assimilated by vegetation, which favours their development. Then, the atrophy of plants is followed by the release of sulphur in the form of hydrogen sulphide. In lentic and semi-lotic (one closed arm) oxbow lakes that chemical compound appears regularly.

Vegetation and artificial substrates introduced to aquatic reservoirs form habitats for invertebrates. The level of hydrological connection between an oxbow lake and its main river as well as physico-chemical parameters of water influence the development of specific plant communities. Submerged macrophytes and those with leaves floating on water surface are valuable in aquatic ecosystems because they are direct or indirect source of food for numerous fauna representatives (Giere 1993). Moreover, they are a shelter for a large group of invertebrates (phytobenthofauna). Particular role is played by water-soldier (*Stratiotes aloides* L.) with large, dense clumps of leaves, which can often cover the whole surface of a water body (Kornijów, Kairesalo 1994, Lihard 1999, Tarkowska-Kukuryk 2006). The presence of water-soldier and the *Lemnetea minoris* (Tx. 1955) class significantly influence environmental conditions in oxbow lakes by limiting wind mixing and resuspension of bottom sediments. Dense vegetation cover lowers water temperature and pH but also lowers the concentration of dissolved oxygen and blocks out sunlight indispensable in photosynthesis. Oxbow lakes rich with nutrients, supplied by river waters, are ecosystems favourable to the development of vegetation. Water-soldier can effectively assimilate phosphates, which has been confirmed by experiments (Van der Welle *et al.* 2007), and also micro- and macroelements. That accumulation ability is considerable comparing to other macrophytes, e.g. *Chara* sp., *Nitellopsis obtusa* (*Desvaux*) Groves, *Potamogeton pectinatus* L. (Królikowska 1997).

Considering the distinguished three types of oxbow lakes, the most favourable conditions for the development of water-soldier prevail in lentic reservoirs, cut-off from the main river, due to the accumulation of nutrients and the lack of water flow. Benthic macrofauna in oxbow lakes covered with *Nymphaeion* communities is usually poor (Tarkowska-Kukuryk 2010). Sunlight is blocked out by floating leaves which limits the development of phytoplankton and, thus, oxygen production. Such situation leads to the anaerobic conditions in almost whole reservoir and prevents the development of benthic organisms (Kajak 1996). The only habitat which can be colonized by aerobic benthic invertebrates is formed by water-soldier just below water surface (Cyr, Downing 1988, Lodge 1985, Kornijów, Kairesalo 1994, Savage, Beaumont 1997). The migration of water-soldier with epiphytic fauna is presented in Figure 3.

Another reason why benthofauna inhabits that macrophyte is a shelter from predators formed by leaves. Seasonal changes in density and biomass of that group of invertebrates have a unimodal distribution. After floods in early spring, when water-soldier emerges, phytobenthofauna biomass is rather small due to the presence of mostly young individuals. Over the next months (spring and early summer) a decrease in density is observed but accompanied by the increase in biomass. That can results from the attachment of organisms to plant substrate due to trophic dependencies. The dynamics of quantitative characteristics of phytobenthofauna in oxbow lakes is typical of that formation in other natural aquatic ecosystems (Kornijów 1996, Linhart 1999, Obolewski, Strzelczak 2009).

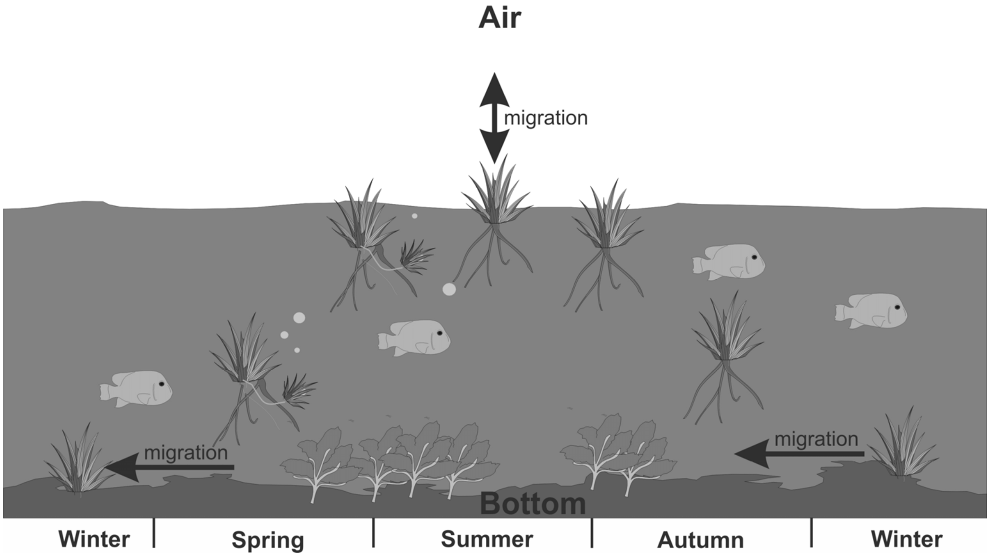

Fig. 3. Migration of water-soldier with epiphytic fauna over a year

The main group of invertebrates which inhabit water-soldier in oxbow lakes are Chironomidae larvae. They live on the surface of leaves and can also mine them. The mining forms reach the highest density and constitute almost 60% of the total invertebrate abundance. The share of Chironomidae larvae and their frequency of occurrence on the surface of leaves decrease (Linhard 1999, Tarkowska-Kukuryk 2006) mostly due to predatory pressure (Prejs *et al.* 1997) and probably because of considerable amount of nitrogen accumulated in water-soldier. Chironomids feeding on plant tissues rich with nitrogen considerably increase their biomass. Another important group of invertebrates are snails represented mainly by six species typical of overgrowing reservoirs with standing waters (Piechocki 2006) - *Lymnaea* sp., *Acroloxus lacustris* L., *Planorbarius corneus* L., *Planorbis planorbis* L., *Anisus* sp. and *Gyraulus albus* O.F. Müller. They significantly contribute to the biomass of epiphytic fauna, reaching even 50% of the total biomass. Snails use macrophytes to move from the bottom zone to the surface. Among other invertebrates an attention should be paid to leeches, represented mainly by *Erpobdella octoculata* L., *Helobdella stagnalis* L., *Glossiphonia complanata* L. and *Hemiclepsis marginata* O.F. Müller as well as trichopterans *Limnephilus* sp., *Ecnomus tenellus* (Rambur) and *Phryganea grandis* L. (Hajuduk, Hajduk 1984, Czachorowski 1995). The highest biodiversity of invertebrates is observed in May.

The above discussion indicates, that the presence of macrophytes in oxbow lakes depends on hydrological connectivity and that macrophytes fulfil two opposing functions. Floating plants change light conditions and water chemistry as well as increase the rate of succession, which eliminates most of benthic invertebrates. On the other hand, macrophytes form habitats for invertebrates and act as a shelter.

4. The role of hydrotechnical treatments in the protection of oxbow lakes

In spite of many important functions of oxbow lakes they are endangered by human impact on rivers and adjacent landscape. A wide range of anthropogenic transformations which started in the middle of XX century was connected with a rapid development of settlement and caused significant changes in river systems (Florek 2008). Dykes and embankments along water courses isolated riverbeds from their valleys and limited the area of systematic floods. The knowledge of biogeochemical processes as well as their climatic and hydrological background should be the starting point for any operations aiming at the restoration of natural systems. That concerns also oxbow lakes as components of natural (meandering) river ecosystems. Hydrological changes in river valleys influence habitats of hydrobionts inhabiting the discussed ecosystems and ecotones. Natural (succession) or artificial (filling up) elimination of oxbow lakes from floodplains decrease the variety of a river valley and, thus, biodiversity. Biological revival of oxbow lakes can be achieved by restoration works which consist in digging oxbow arms, dredging as well as broadening and deepening of those reservoirs. Comprehensive depiction of restoration techniques is presented in Fig. 4.

Unfortunately, those treatments are sporadically applied. Sparse literature on the results and effectiveness of re-connecting oxbow ecosystems with rivers makes any new research valuable (Tockner *et al.* 1999b). It seems that such studies will constitute an important branch of science, joining ecological engineering, hydrobiology, hydrology and fitting in the concept of ecohydrology (Zalewski 2000, 2007, 2010).

In general, oxbow ecosystems enrich floodplain areas and increase biological diversity of river valleys. Their protection should consist in renaturization works applied particularly to oxbows located close to rivers and those, which ecological state is promising for restoration.

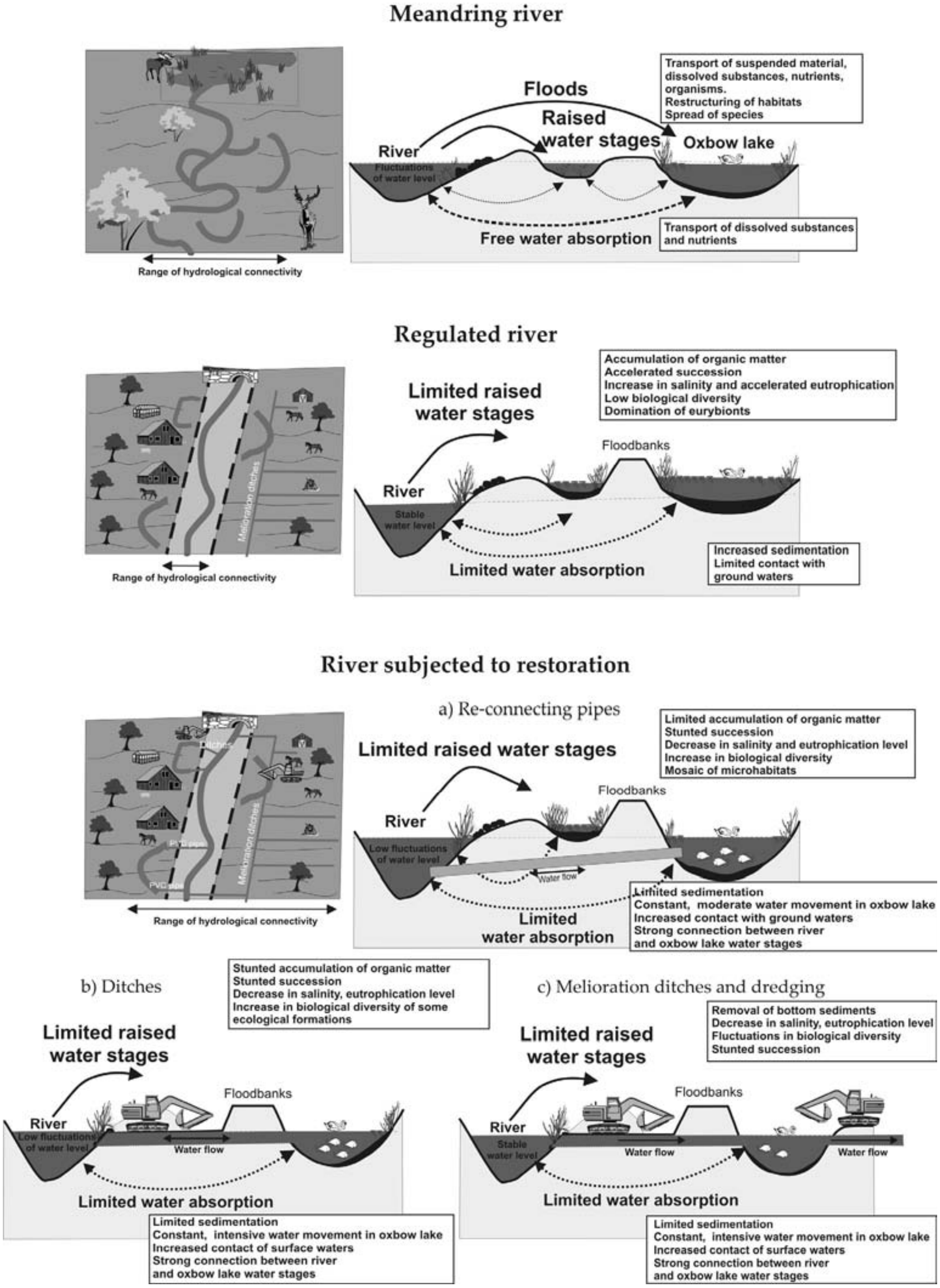

Fig. 4. Functioning of oxbow-river systems in natural/anthropogenically transformed conditions and restoration techniques

5. Conclusions

1. Oxbow lakes are a transitional form between river and lake ecosystems which are important in increasing biodiversity of river valleys and contribute to the recolonization of zoocenoses in riverbed. That role is determined by the following factors: (1) hydrological connectivity and the rate of water exchange; (2) hydrochemical conditions; (3) presence of natural (vegetation) and artificial substrate as habitats for invertebrates; (4) the level of anthropopression.
2. The main factor which influences zoocenoses in oxbow lakes is the oxbow-river hydrological connectivity. Semi-lotic and lotic connections with moderate water flow seem to be the optimal types.
3. Oxbows function as biogeochemical filters and the content of nutrients in their waters increase with limited hydrological oxbow-river connectivity. Dynamic hydrochemical changes in those ecosystems influence invertebrate communities. Dissolved oxygen concentration is the most important for snails while benthic invertebrates in general are mainly influenced by dissolved nitrogen and sulphur compounds.
4. In dependence on hydrological connectivity the presence of vegetation may differently influence invertebrate communities. The lower the level of connection the more important role of macrophytes in forming habitats for invertebrate fauna.

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