The development of inter-embankment zones – a method of elimination of invasive species

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Abstract: River valleys are one of main kind of habitats, suitable to occupy by alien invasive species. At scale of landscape, the valleys work as ecological corridors caused spread of species, including plants of alien origin. Rules, what applies for design the lands situated on river valley are very strict. There are exclude permanent development and planting of tall trees and high elements of architecture on river embankment and interembankment zone. In Poland the areas are usually unmanaged with except of sporadically cutting of trees and mowing of herbs. In this paper we propose methods of development of such areas. The methods allow to control dynamics of the invasive species.

The study were performed in three wastelands situated in Odra valley, on Lower Silesia region, two in Wroclaw and one in Brzeg. The phytosociological analysis of abandoned areas shows a significant participation of invasive plant species, particularly Solidago gigantea, S. canadensis, Reynoutria japonica, R. sachalinensis and Padus serotina. The environmental conditions of analyzed habitats were described with use Ellenbergs ecological indices. Recreation way of the use was proposed for these areas, as respect the rules of management of river valleys. The basis of choice of species for planting was a potential vegetation. It were mainly low trees and scrubs from Saliceta purpureae class and Molinietalia order for grasslands. As effective method of prevention of development the invasive plant species were proposed mowing of meadows and shading by wide-branchy trees.

Key words: river valleys, invasive species, recreation

Introduction

Through the ages the life of towns has been associated with a river. New settlements were built at the sides of rivers and, in time, these changed into metropolises. The river is one of the most important symbols of the town where it flows. It is a place which is a symbolic connection, banks, people, and ideas, and it is a place where there is a crossing between culture and nature. For a long time people used rivers for their goodness and, simultaneously, to increase the level of civilisation of a region. River valleys have always been a natural centre of human activity: journeys, hunting, fishing, farming and settlements.
Through the centuries rivers were used as a source of drinking water and food, as well as for irrigation, generating energy and transport (Świerkosz 1999). Riverside areas as well as generating favourable conditions for rest and tourism, can be used for walks, sunbathing, and river navigation (cruises) as well as water sports (Wyrzykowski 2002).

River valleys are a exceptional type of complex ecosystem, which characterized itself by a spatial continuity with, simultaneously variability on longitudinal and crosswise section of the valley (Gacka-Grzesikiewicz 2001). There are transitional areas between water and terrestrial vegetation complicated structure. Special character of the river valleys – major participation of wet and damp areas and every years flooding – protect it against human settlement for a long time (Żarska 2005).

Technological progress in the last decades has meant that people more confidently build housing in river valley regions. In towns huge settlements have developed in “big water” areas (Żarska 2005). This has happened despite the fact that, after floods in 1997, an international conference took place, which was dedicated to the problems of flood protection. An “open letter from ecologists to the governments of the Czech Republic, Germany, Poland and Slovakia”, included important demands for landscaping to protect river valleys:

1. The scale of loss caused by a flood is the result of improper management in river valleys. It is possible to limit the losses and, in addition, to preserve the natural values of river valleys.
2. The catchment basin system of river management is necessary, as is planning for protection in all catchment basins at the same time.
3. The preferred method of flood protection is increasing the retention in the whole catchment basin, e.g. by the protection and reconstruction of wetlands, and by differentiation of landscape structures in the valley and the catchments regions.
4. The range of flood areas should outline a range of human expansion with permanent investment (especially building). Attempts to overcome these limitations lead to degradation of the environment and danger to the health and life of the people.

The valleys performs also a function of migration ways for different groups of organisms. For that reason the riparian vegetation are the most exposed at infiltration of plants of alien origin. It is a serious threat to functioning of these ecosystems, valuable for nature protection and economical reasons (Planty – Tabacchi et al. 2001). The most destructive influence make the invasive plants, which are characterized by major competitiveness and ability to displace the native species. Invasive species are, beside fragmentation and degeneration of natural habitats, one of most important threat of biodiversity in global scale (Byers et al. 2002).

Riverside areas are, for many reasons, the most attractive locations in towns. For this reason, in the last centuries the cities have turned to their rivers, where they have built attractive public areas, parks, promenades, as well as settlements and public buildings. Waterside areas in the centre of cities are regenerated, and others on the outskirts, like post-industrial areas which are discovered anew, are managed and revitalised.

The development and planning of the landscaping of river valleys, particularly in areas of great natural interest, should be a result of compromise where both ecological and hydro-technical aspects should be considered (Żarska 2005).

The rules of the management of river valleys are closely connected with balanced development principles, and the most important of these are:

- to retain possibilities for the regeneration of natural resources,
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- not to cross the borders determined by environmental resistance,
- to protect the biological diversity (Gacka-Grzesikiewicz 2001).

According to the Water Law Act of 18 July 2001, in the areas directly endangered by floods, it is forbidden to do any work or action, which could make it difficult to protect the area from floods, and in particular:

1. to make water equipment and buildings,
2. to plant trees and shrubs, with the exception of wicker plantation for water regulation and vegetation, which is an element of the biological development of river valleys or used to strengthen the banks,
3. to change landform features, store materials or do other work, with the exception of work connected with the regulation and keeping of water and the seashore (Art. 83).

To ensure water tightness and stability of flow embankment it is forbidden:

1. to drive into embankments and along the top of embankments by car, horse and driving animals, with the exception of places designed for this,
2. to cultivate or plant trees and shrubs on an embankment and at a distance less than 3 metres from the base of the embankment,
3. to dig the embankments, to ram in poles, to put up signs without authorisation,
4. to build or dig wells, ponds, holes or ditches at a distance less than 50 metres from the base of the embankment,
5. to damage turf and other reinforcements (Art. 85).

It is important to fit the management of the river to the specific character of the river’s inter-embankment zones.

**Material and methods**

This project was performed in three abdomen sites in area of geomorphological valley of the Odra river. Site 1 was placed between embankment of Odra river near to Wroclaw city centre (fig. 1).

![Fig. 1. Site 1, 1a – inflooded, 1b – flooded](image1)

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Site 2 was located also in Wroclaw, but in suburban area in interembankment of Dobra river, small tributary of Odra (fig. 2).

Site 3 was placed in interembankment of Odra at area of Brzeg Dolny.

The vegetation of the study areas were evaluated on basis phytosociological relevés, the trees and shrubs were a subject of an additional detailed inventory. For each species a constancy was calculate as a frequency of presence in relevés of particular sites. The relevés were clustered into group with similar species composition, next the groups were classify into particular classes of plant associations according Braun-Blanquet approach. For each relevé calculated were: the Shannon-Wiener index and average values of Ellenberg indicators (Ellenberg et al. 1992). The clustering and computation were done with Juice software (Tichý 2007).

The analysis of vegetation was a basis for the planning and management of the described sites. The development projects for the inter-embankment zones consider the potential vegetation of these areas, and their function as an ecological corridor.
Results

The vegetation was classified into 5 classes of plant associations: grassland (*Molinio-Arrhenatheretea*), ruderal (*Artemisietea vulgaris*), reed-beds (*Phragmitetea*), woodland clearings (*Epilobietea angustifolii*) and woodland edges (*Rhamno-Prunetea*). The percentage of area covered by each association in studied sites was presented in Fig. 1.

![Fig. 4. The percentage of plant associations in study sites.](image)

The sites 1 and 3, placed inside of Odra embankment, in the area of towns reveal considerable participation of ruderal communities (*Artemisietea*). In Wrocław (site 1), frequent were also vegetation considered as woodland edges (*Rhamno-Prunetea*). In site 2, placed in suburban area, along small river, most common were grassland (*Molinio-Arrhenatheretea*), whereas vegetation of forest clearings (*Epilobietea angustifolii*) were absent.

The recognized 5 plant associations differ with respect to its biodiversity and habitat conditions. The vegetation with the highest species number was those classified as *Rhamno-Prunetea*, whereas with lowest species number – those from *Phragmitetea* class. The species number is correlated with values of Shannon-Wiener index (Table 1). The ruderal associations indicate open habitats, the grasslands and forest clearings associations indicate relatively dry habitats, whereas reed-beds – the moistest and the most fertile (Table 1).

<table>
<thead>
<tr>
<th>Class of vegetation</th>
<th>No of species</th>
<th>Shannon-Wiener Index</th>
<th>Light</th>
<th>Moisture</th>
<th>Soil Reaction</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molinio-Arrhenatheretea</td>
<td>48,2</td>
<td>3,6</td>
<td>6,7</td>
<td>5,2</td>
<td>7,0</td>
<td>5,4</td>
</tr>
<tr>
<td>Artemisietea vulgaris</td>
<td>34,0</td>
<td>3,4</td>
<td>7,1</td>
<td>5,7</td>
<td>6,6</td>
<td>6,6</td>
</tr>
<tr>
<td>Phragmitetea</td>
<td>21,5</td>
<td>2,8</td>
<td>6,7</td>
<td>7,1</td>
<td>7,1</td>
<td>6,7</td>
</tr>
<tr>
<td>Epilobietea angustifolii</td>
<td>34,0</td>
<td>3,4</td>
<td>6,9</td>
<td>5,2</td>
<td>6,6</td>
<td>5,4</td>
</tr>
<tr>
<td>Rhamno-Prunetea</td>
<td>56,0</td>
<td>3,9</td>
<td>6,2</td>
<td>5,6</td>
<td>7,1</td>
<td>6,8</td>
</tr>
</tbody>
</table>
The analysis of vegetation in the tree sites reveal considerable number of neophytes; especially smooth goldenrod (*Solidago gigantea*) which was present in all sites with high constancy (Table 2).

The most frequent tree and scrubs species in all studied sites were: *Salix alba*, *Populus nigra*), *Ulmus leavis*, *Aesculus hippocastanum*, *Quercus robur*, *Robinia pseudoacacia*, *Fraxinus excelsior*, *Crataegus monogyna*, *Cornus sanguinea* and *Corylus avellana*.

### Table 2. The invasive species and its constancy in each study site

<table>
<thead>
<tr>
<th>Species</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Solidago gigantea</em></td>
<td>II</td>
<td>IV</td>
<td>III</td>
</tr>
<tr>
<td><em>Solidago canadensis</em></td>
<td>III</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td><em>Myrrhis odorata</em></td>
<td>III</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td><em>Clematis vitalba</em></td>
<td>II</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Symphoricarpos albus</em></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heracleum Sosnowskyi</em></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td><em>Echinocystis lobata</em></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td><em>Robinia pseudacacia</em></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Quercus rubra</em></td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Reymoutria japonica</em></td>
<td>I</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Discussion and conception of development

The potential natural vegetation of studied sites are hardwood floodplain forest (*Ficario – Ulmetum minoris*) and, close to river, softwood floodplain woods (*Salicetea purpureae*) (Szczęśniak 2005). However, centuries of exploitation and management of the valley caused total transformation of observed vegetation. Its habitats were captured by ruderal vegetation prone to spread of invasive species.

Basic concept of plans of development is introduction of native trees and shrubs species, typical for potential vegetation as: *Salix purpurea*, *Salix alba*, *Salix triandra*, *Salix viminalis*, *Alnus glutinosa*, *Populus alba*, *Populus nigra*, *Populus xcanescens*, *Ulmus glabra*, *U. laevis*, *U. minor*, *Acer campestre*, *Fraxinus excelsior*, *Cornus sanguinea*, *Viburnum opulus*, *Rosa canina*, *Euonymus europaeus*, *Padus avium*, *Ribes spicatum*, *Humulus lupulus*. The goals of reintroduction of these species is both enrichment of local flora, as well increase of shading by trees and shrubs canopies. It was observed that increase of shading lead to elimination of invasive species, especially light-demanding *Solidago* sp. (Szymura and Wolski 2006). As a method of conversion of ruderal plant assemblages into more valuable, from point of view of nature conservation, is mowing. The mowing should be applied two times per year in case of patches of *Solidago*, whereas other, rarer species will be removed mechanically.

The way of developing particular sites also takes into account the demands of the local inhabitants. On site 1, situated close to the city centre, the proposal was to establish sports fields. A result of observation was that the investigated area was very often visited, so the aim of the development was the planning of recreation areas, which are attractive for inhabitants and are aesthetically-pleasing picnic places. The proposal for the fields, which included a football pitch, a beach volleyball court and a fitness trail, should encourage the local
The development of inter-embankment zone planning aims to provide inhabitants with leisure activities in the fresh air. The fields could be used for everyday recreation, as well as for sports training. Native species were chosen for planting to avoid disturbing the landscape. It was proposed that low plants, specific to the area, should enhance the landscape and make visited places more attractive, such as picnic and recreation areas.

The vegetation project also included herbal plants. It was planned to sow grass and dicotyledonous plants, reducing invading species. On the basis of habitat conditions, the proposed species were: Leucanthemum vulgare, Papaver rhoeas, Centaurea jacea, Tanacetum vulgare, Vicia cracca, Alopecurus pratensis, Festuca pratensis, Phleum pratense, Poa pratensis. The existing paths provide the best information about communication, where paths should be planned. The paths formed the most popular areas, connecting the paths leading to the planned piers. The paths were planned to access courts and pitches. The surface of the paths, both existing and planned, was hardened to maintain their natural look.

The small amount of architectural elements in the project will supplement the functionality of the area and confidence for visiting people, as well as increasing aesthetics and tidiness.

The woody piers are planned to create a friendly place for anglers and prevent groin destruction.

The planned fitness trail will be for running and jogging with exercises on equipment placed on the route. The aim of the fitness trail is to do leisure activities in the fresh air in natural surroundings, increasing resistance to bacteria, as well as comprehensively improving fitness. The elements of the fitness trail are simple, such as slalom, balance beam, diagonal beam for exercises, beam for somersaulting a tree trunk, hurdle for jumping, and beams for press-ups. They will be made of impregnated pine wood.

The football pitch will have a turf surface, and the beach volleyball court will have a sand surface.

![Fig. 5. Example of inter-embankment zone planning – site 1](image-url)
The site 2, placed in suburban areas, was projected as areas for family rest. The project increase recreational values of site as well as adapt it to suspect increase number of visitors. Established were systems of routes for bicycles, foot tourist as well as for horse riding. Generally site were dividing into three zones: playground for child, the family rest zone and the sport zone. It make possible multifunctional utilization of single site.

The zone for the children’s playground includes the central point of the meadow. It will be equipped with a sandpit, a tower with a slide, see-saws, swings and a complex made up of a tower and a shack connected with a moving bridge, a net in the shape of a cone, and a merry-go-round. The children’s playground will comply with the requirements of EU regulations (EN 1176, EN 1177), which concern playground safety (Beltzig 2001).

The family rest zone will be a snug area, where the visitors will be able to relax in deckchairs or on blankets put on the grass.

The sport zone will allow enthusiasts to play beach volleyball, badminton and petanque, and competitions will be held on fields prepared especially for this.

The beach volleyball pitch will be covered with fine-grain sand, without stones and other elements which would be dangerous for the safety of the competitors. The area for playing petanque will consist of six fields. An individual playing field will be 15 metres long and four metres wide. Two of the six fields will have a turf surface, two will be covered with gravel, and two with sand. The fields for playing badminton will have a turf surface.

The project will include utility buildings, a car park and other small buildings. Within the area it is planned to sow a mixture of turf grasses (Festuca rubra 50%, Lolium perenne 40%, Poa pratensis 10%). Numerous trees and shrubs of native species will be planted. Plants which are suited to the habitat will be selected on the basis of numbers indicated. The trees and shrubs will add an additional factor – shadow, which will limit the number of invasive plant species.

Paths will be marked out for horse riding, cycling, and walking. All of the important points of the project area will be connected. Paths should be harden and mowed 6 tome for growing season.

The site 3, projected is as areas for recreation and additionally (according investor demands) social and art events.

There are a few criteria which will be a basis for the conception of the development of this area. The first aim is the creation of an interesting place where open-air painting can be organised. It is important that the surroundings around the ferrymen’s building are tidy, and that valuable trees and shrubs are planted there. The next task is to plan parking places and shelter for passengers and to plan the small elements such as lamps, waste bins and bicycle stands, as well as mark out the paths and places for anglers. An avenue will be filled in by new trees. The landscape of the river valley will give the impression of being natural, not influenced by garden design, and the proposed plants should highlight this impression. Using the residential trees and analysis of potential vegetation, there are proposed species which are growing, or will be growing, naturally, if they are allowed to develop. Considering the widespread area of the study site, the project will include mainly the trees which are dominant within the meadow’s plain, and the shrubs will be limited to the neighbourhood around the ferrymen’s building. The proposed species are native plants, which are deeply rooted in the consciousness of the local inhabitants, and which do not give the impression of being an alien element in the landscape.

The biodiversity of meadow communities has decreased because of invasive plant species, so the area will be sown with grass species which were selected on the basis of conditions in the habitat. In the area of wet meadows sowing is not planned because this will help to reduce the spread of the invasive plants,
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which flourish in wet, soft ground where there is little resistance to trampling. The other meadows are resistant to trampling and may be used as recreation areas. *Arrhenatheretalia* communities are very attractive, with numerous abundant flowering species. These communities are valuable elements of the landscape, so it is important to eliminate the invasive plant species and sow grasses which are suitable for the habitat. There plants were selected: *Alopecurus pratensis*, *Festuca pratensis*, *Festuca rubra*, *Phleum pratense*, *Arrhenatherum elatius*, *Poa pratensis*.

The projects, are suit to rules of management of interembankment areas, not decreasing its flooding – prevent function. The application of potential vegetation, suited to periodical flooding, reduce the probability of flood damage. Additionally the proposed infrastructure is relatively resistant to water influence.

**Acknowledgement**

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