Contribution to the Knowledge of Plant Diversity in the Malopolska Region

Focus on Invasive Plants in Kraków and Vicinity

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Abstract— **The objective of this paper was to identify plant species around the water bodies and examine the possible impact of alien plants. Sixteen locations were examined referring to the vegetation and alien species in particular. The locations were the areas surrounding anthropogenic water bodies in Krakow and vicinity. Most of them were borrow pits left to the process of natural succession. Only one water body was of natural origin. In all the locations alien species were found. In total, alien species made 20.9% of all species found in these locations, which is slightly less than overall percentage in Poland (27.4%). There were 30 neophyte species found in total, six of them invasive transformers. One species – the bur marigold (*Bidens frondosa*) – was found in nine locations. Three species were found in eight locations: the Canada golden-rod (*Solidago canadensis*,), Canadian horseweed (*Conyza canadensis*) and annual fleabane (*Erigeron annuus*). Most neophytes (16 species), including the four mentioned above were of North American origin. 18 archaeophytes were found. Four species had uncertain status. Most alien species were covering less than 5% of surveyed vegetation plots. Only the cockspur (*Echinochloa crus-galli*) covered more than 50% and the sweet flag (*Acorus calamus*) covered more than 25% (in both cases in one location). In urban areas, alien species are common, usually without making much problem (exceptions are allergy-causing plants), however; in rural semi-natural areas the monitoring is recommended.**

Keywords – vegetation; alien species; water bodies; suburban areas.

I. INTRODUCTION

The paper is based on the authors' work [1] on plant species around the selected water bodies in the Krakow city and the surrounding area. Compared to [1] three more locations were added, including one natural water body. In [1] only artificial water bodies were examined. The present paper provides the list of all the plant taxa found in the studied locations, including the native ones, which was not possible in the previous work.

Water bodies (natural and artificial) attract many plant and animal species, both native and alien. The region of Krakow is not very rich is natural lakes, but human-made water bodies are abundant there [2]. They have various origin, including: borrow pits of various size, made after the exploitation of limestone, gravel, sand or clay, fishing ponds, former decantation ponds, etc. Natural water bodies in the area can be an effect of the karst phenomena or the formation of oxbow lakes [3]. Not knowing the history of a specific water body it is sometimes difficult to say about its origin, because in the process of natural ecological succession and sometimes due to human-made reclamation measures, human-made ponds get covered with vegetation and become inhabited by animal species [4]. Finally, they form semi-natural environment and can contribute to biodiversity of the region. The objective of the study is to examine the vegetation of selected water bodies focusing on the presence of non-native species and the attempt to assess their possible influence on the environment in the area, looking at their abundance and frequency of the occurrence.

Non-native species can be divided into two groups: archaeophytes and neophytes. Archaeophytes are plants which arrived in the area in pre-historic or early historic times and neophytes were introduced in modern times and the usual border date is accepted as ca. 1500 – the beginning of the era of great geographical discoveries [5]. Most archaeophytes in Europe arrived with the agriculture, as weeds growing in the fields and nowadays they make an integral part of the flora, although can also be invasive. Neophytes, however, are usually regarded more dangerous to biodiversity.

Cross-breeds between native and non-native plants are regarded non-native and crossbreeds having a neophyte as one of the parental species are regarded neophytes [5].

Apart from the origin, the degree of naturalization in the environment is important; Pyšek et al. [5] distinguished casual species - alien species that do not form self-sustaining populations and naturalized species (synonym: established species) that form self-sustaining populations for several life cycles. Invasive species make a subset of naturalized species forming self-replacing populations, having the potential to spread over long distances. Tokarska-Guzik et al. [6], after Richardson et al. [7] also differentiated the category of transformers (a subset of invasive plants) for the species which change the character of ecosystems.

In Section II and Figure 1, respectively, the list and map of locations are given. In the same section a short description of every place and methods of studies are provided. In Section III and Tables I-III the results are presented. Section IV provides the conclusions and recommendations for further studies.

II. STUDY AREA AND METHODS

The study on the vegetation taken in the areas of the water bodies in Krakow and vicinity was carried out in summer 2009 (in the case of Bagry and Zakrzówek also 2008). The studied areas are named below. More detail descriptions of the water bodies can be found in [4] [8] [9] [10] [11]. The geographic distribution of the sites is presented in Figure 1. The given below area of the water bodies was calculated by the program Quantum GIS, based on the airborne images of the Central Cartographic and Surveying Resource. The area included:

1. Two borrow pits situated south-east from the centre of Kraków in the area called Płaszów. The area of the bigger pond, called Bagry is 30.1 ha and the smaller one – called Staw Płaszowski (the Płaszów Pond) is 9.0ha. Formed after the exploitation of sand and gravel in 1930s [11]. In Table I, they are marked as BG and SP, respectively.
2. Staw Dąbski (the Dąbie Pond, marked as D), 2.1 ha – situated in Kraków, east from the centre, formed in 1930s after the exploitation of clay - by the Resolution no. XC/1202/10 of the City Council of Krakow the pond was established "Ecologically Useful Area" [12].
3. Zakrzówek (marked ZK) - a borrow pit south-west from the centre of Kraków of 17.0 ha surface, made in 1990s after quarrying limestone [2].
4. The Pond of the Kaczeńcowa Street (KA) – by the Resolution no. XXXI/405/07 of the City Council of Krakow established Ecologically Useful Area – the area is 0.82 ha [13]. The pond is situated in the quarter of Nowa Huta in Krakow. The pond was formed as a result of clay exploitation.
5. Former decantation pond of the Steelworks in Nowa Huta in the region called Kujawy (marked KU), the area of 2.9 ha.
6. Przylasek Rusiecki (PR) – a group of 10-11 gravel borrow pits (the number is changeable, because some water bodies can temporarily be joint or separated), of the total area of 82.19 ha, situated in the eastern part of Kraków, quarter Nowa Huta.
7. Borrow pits in Wola Batorska (WB) – the gravel quarrying is still going on, so the area has been changing. In 2005 it was 13.8 ha.
8. Two borrow pits (exploitation of gravel) of Zabierzów Bocheński (ZB), commune of Niepołomice area of 13.03 ha and 3.43 ha, respectively.
9. The oxbow lake (of the Drwinka River) in Ulesie (UL) – the only natural water body [4] investigated in this paper – 1.0 ha.
10. The fish pond in Zakrzowiec (ZC) - area 1.94 ha - used for commercial angling.
11. Three ponds in the town of Niepołomice – Zamkowa Street (near the castle – 0.1 ha), Mokra street (0.1 ha) and Akacjowa street (0.2 ha). Marked as ZM, MK, and A, respectively.
12. The pond on the border between the localities of Niepołomice, Podłęże and Staniątki (c.a. 0.6 ha), marked as S.
13. Two borrow pits in the Commune of Liszki called Zalew na Piaskach and Budzyń, formerly known as 'Kryspinów' area 24.5 ha and 20.3 ha, respectively. Marked as ZP.

In each location, plots of the area of 10 m^2 were randomly chosen and the plants growing there were identified to the species or – if not possible – to the genus. The plants were listed and identified as native, archaeophytes or neophytes, invasive or not invasive, harmful or not harmful. In the latter case "not harmful" means that harmful effects have not been known. However, the expression "not harmful" may be a simplification, because it cannot be excluded that such effects will be found in the future. To identify the species and define their status literature data from Poland [6] [14] [15] and other countries of Central Europe [5] [16] [17] [18] were used. In most locations the Brown-Blanquet method was applied. The plant cover abundance was given according to the scale:

5 - 75-100%,
4 - 50-75%,
3 - 25-50%,
2 - 5-25%,
1 - <5%, numerous individuals,
+ - <5%, few individuals,
r – solitary, with small cover.

Some more characteristic species were also noted even if found outside the plot. In case of smaller ponds, where it was difficult to mark the plots, only the list of species was given.

III. RESULTS AND DISCUSSION

The results are given in Tables I-III. There were 30 neophyte species found (Table I), which makes 12.0% of all the taxa found. Eighteen archaeophytes (Table II) constituted 7.2% of all the species and four species of uncertain status made 1.6% (Table II). In total alien species constituted 20.9%, which is slightly less than the percentage of alien species in the whole Polish territory, which is 27.4% - 939 out of 2537 species [15]. According to the same study, neophytes (together with casual plants) made 22% of the total number of species. Archeophytes and species of uncertain status constituted 4.5% and 0.05%, respectively, which is less than in the areas studied in this paper. This fact can be explained by the character of sites chosen for this paper, which are rural or semi-rural areas, where species connected with agriculture would be common. Such species are often archaeophytes.

In the studied area there were six species regarded invasive transformers. The most common of them was the bur marigold *Bidens frondosa* found in 9 locations. Three species: the Canada golden-rod *Solidago canadensis*, Canadian horseweed *Conyza canadensis* and annual fleabane *Erigeron annuus* were found in 8 locations. All of them are invasive species. The most dangerous are invasive transformers, able to change the character, condition, form

or nature of ecosystems over substantial areas relative to the extent of that ecosystem [7]. Such species include *Bidens frondosa* and *Solidago canadensis*. Nevertheless, in the study area these species never exceeded 5% of the area. *Conyza canadensis* is regarded invasive weed. *Erigeron annuus* is invasive, but its negative impact on environment is not known.

There were 10 casual species found in the study area, eight of them occurring only in one place and the Mokra street was the most abundant in casual species (4). This was a residential area and some 'exotic' trees (e.g., *Liriodendron tulipifera* and *Catalpa bignonioides*) were planted there. Three casual species were found near the pond at the Zamkowa street, one of them was *Phellodendron amurense* (6 trees planted near the pond), which is rarely grown in Poland. Nevertheless, casual species were also found in less human influenced place, such as Zakrzówek.

The sweet flag *Acorus calamus* is quite common in Poland, although in this study it was found only in one location - Ulesie – the only natural pond studied here. Unlike most alien plants in the study, it was covering a relatively large area of the surveyed plot: between 25 and 50%.

Archaeophytes were represented by 18 species. Four species had uncertain status: one can be archaeophyte or neophyte, depending on subspecies, which was not determined and the origin of three species is still debatable. The most widespread archaeophyte species were *Melilotus albus* and *Setaria pumila*, occurring in 4 locations.

The number of alien species in each location ranged from 1 in Ulesie to 12 in the Zamkowa Street in Niepołomice. Nevertheless, in the Zamkowa and Mokra Street (9 alien species) planted trees distort the real picture. Considering this, the highest number of non-native species would be in Zakrzowiec (9). In that place two locations were examined – one near the pond and the other in the place of the dry pond. In the dried pond an archaeophyte - *Echinochloa crus-galli* was predominant – the plant cover abundance reached 4 in the Braun-Blanquet scale, which makes the highest cover by a non-native species in the whole study. The detail characteristic of the studied sites looks as follows.

A. *Bagry*

The studies in Bagry were carried out on 2/07/2008 by Samalzhan Tleubayeva and Aleksandra Wagner in two locations: (1) – north-western shore of the water body and (2) – northern shore of the water body. Every location included coastal plants like *Juncus effusus*, *Phragmites australis* and *Schoenoplectus lacustris*. In place (1) there was one alien species noticed - *Phalaris canariensis*, a neophyte coming from southern Europe. This was the only alien species among 7 species scored in that place. The 2008 survey in place (2) did not show any alien species, however, more detail survey of 3/08/2009 by Dario Hruševar, Aleksandra Wagner, Uroš Ljubobratović, and Barbara Patuła showed 7 out of 31 alien species, among which 3 (9.7%) were archaeophytes: *Melilotus albus*, *Melilotus officinalis* and *Pastinaca sativa*. The latter was considered native for a long time, but recent studies have shown it was alien [15]. Neophytes were represented by two (6.5%) species: *Acer negundo* and *Robinia pseudoacacia*, both of them classified as invasive transformers. The encountered individuals (one of each species) were young and belonged to the undergrowth. Figure 2 shows the typical vegetation of the northern shore of the Bagry borrow pit.

B. *Staw Płaszowski*

On the western shore, the studies were carried out on 2/07/2008 by S. Tleubayeva and A. Wagner. Eleven species were found, among them two neophytes, none of them invasive: *Oenothera biennis* L. and one of North American ash trees, probably *Fraxinus pennsylvanica*, rarely encountered in natural environment in Poland. The study of 20/08/2009 by D. Hruševar and A. Wagner in the eastern side of the pond showed 22 species, among which the dominant was *Phragmites australis*. There were four (18.2%) neophytes: *Solidago gigantea*, *Solidago canadensis*, *Bidens frondosa*, *Acer negundo* – all of them invasive transformers. There was also a feral cultivar - *Humulus lupulus*. Apart from the plot yet another neophyte was found: *Conyza canadensis*, according to [15] the most common alien species in Poland.

C. *Staw Dąbski (the Dąbie Pond)*

The survey of 07/08/2009 by D. Hruševar, U. Ljubobratović and A. Wagner showed 12 species in the plot in the eastern part of the pond. Significantly dominant was *Typha angustifolia*. There was only one alien species: *Bidens frondosa* L. In other parts around the pond 32 more species were observed, including *Nuphar lutea* – a native species protected by the Polish law – the only place in the city of Krakow where it occurs naturally. There were also three invasive neophyte plants: *Acer negundo*, *Solidago canadensis* and *Erigeron annuus*. The first two are regarded transformer species and the latter is regarded harmless. On the southern part of the pond *Physocarpus opulifolius* was grown. This shrub species has become very popular as an ornamental plant in the green areas of Krakow over the recent 10 years. It originates from North America.

D. *Zakrzówek*

Two surveys were carried out in Zakrzówek – on 18/06/2008 by Samalzhan Tleubayeva, Aleksandra Wagner and Robert Mazur – on the hill in the eastern part of the area and on 13/08/2009, by D. Hruševar, U. Ljubobratović and A. Wagner – in the place slightly further from the previous one. In the first place 17 species were observed, including one archeophyte *Echium vulgare* and one neophyte *Fraxinus pennsylvanica*, usually occurring only as a cultivated plant. In the second place 23 species were present. Among them three alien species were found. One of them was *Lathyrus tuberosus* – an archaeotype, regarded

invasive, but not harmful. Two other species were neophytes: *Juglans regia* – a cultivated tree (originating from Caucasus and Central Asia), now expanding into natural and semi-natural habitats and *Solidago canadensis*, classified as a transformer. None of them was numerous.

Outside the marked area an archaeophyte *Odontites verna* was observed. This is a weed of Scrophulariaceae family. It occurs in the fields and becomes rarer and rarer because of the mechanization of agriculture. It was even included in the Polish Red Book of Plant Species, nevertheless, the exact level of threat is unknown [19].

E. The Pond of the Kaczeńcowa Street

Around the water body 26 species were found, four of them neophyte invasive transformers - North American: *Bidens frondosa*, *Solidago canadensis*, *Robinia pseudoacia* and Asian - *Impatiens parviflora*. The study was carried out on 19/08/2009 by D. Hruševar and A. Wagner.

F. Former decantation pond of Kujawy

The survey carried out on 19/08/2009 by D. Hruševar and A. Wagner showed 15 species, where *Calamagrostis epigejos* was dominating. One of them was archaeophyte - *Melilotus albus* and two invasive neophytes: *Conyza canadensis* and *Solidago canadensis*. Outside the plot one more neophyte species - *Erigeron annuus* was observed as well as 8 native species, including *Centaurium erythraea*, protected by the Polish law.

G. Przylasek Rusiecki

The survey carried out on 25/07/2009 by D. Hruševar, U. Ljubobratović and A. Wagner in two places near the only pond available for bathing: in eastern part of the shore, near the beach and in the northern part – a popular place for angling.

In the first place 39 species were found and the ones occurring in the biggest quantities were *Achilea millefolium* L. and *Melilotus albus*. The latter is archaeophyte and both are characteristic for pastures. The habitats in Przylasek Rusiecki are typically rural despite the fact of being situated in the administrative borders of the city of Kraków. Another archaeotype was *Humulus lupulus*. Neophytes were represented by 3 species: *Erigeron annuus*, *Bidens frondosa* and *Solidago canadensis*. In the second place the most common species was *Euphorbia virgata*. This plant has an uncertain status in the Polish flora. There was an archaeopophyte species - *Melilotus albus*.

Apart from the neophyte plants known from the previous place, i.e., *Erigeron annuus* and *Solidago canadensis*, four more species: *Medicago sativa*, *Conyza canadensis*, *Oenothera biennis* and a tree species: *Populus* × *euramericana* were found.

H. Wola Batorska

The survey was conducted on 19/08/2009 by D. Hruševar and A. Wagner, near the ponds in the eastern part of the water bodies complex. Place (1) was near the bigger pond and place (2) near the smaller pond. In place (1), 36 species were found, among them 7 of alien origin: archaeophytes: *Matricaria perforata*, *Capsella bursa-pastoris* and *Lactuca serriola*, all of them invasive, but usually not harmful. *Panicum miliaceum* was also found. The subspecies was not defined, which in this case, does not allow stating if the plant was archaeophyte or neophyte, but it is invasive. Other alien species included *Phalaris canariensis*, *Acer negundo* and *Bidens frondosa*. In place (2) twelve species were found, including one archaeophyte - *Echinochloa crus-galli* and one neophyte - *Conyza canadensis*. In the area outside the plots, one more neophyte was found - *Picea pungens*. The specimen was in a very poor shape. Probably it was deliberately planted.

I. Zabierzów Bocheński

On 10/08/2009 D. Hruševar, U. Ljubobratović and A. Wagner surveyed two plots in the area: (1) in the central part of the complex – near the beach and (2) in the southern part of the area. In place (1), 34 species were found, where *Bolboschoenus maritimus* in the part near water and *Trifolium repens* – further from the shore were predominant. There was only one neophyte: *Bidens frondosa* and one of uncertain status *Cirsium vulgare*. In site (2), there were 39 species recorded and only one - *Solidago canadensis* was neophyte. There were also *Rumex crispus* – a plant of an uncertain status and *Prunus cerasus* – a cultivated species, in that site occurring as feral. In the water a protected by the Polish law species was found - *Salvinia natans*. Allien species included *Bidens frondosa* and *Conyza canadensis*.

J. Ulesie

The Ulesie oxbow lake is the only natural pond in the area. The survey done on 12/08/2009 by D. Hruševar and A. Wagner showed the occurrence of 14 species in the examined area and 6 more species outside the area.

Only one species was not native. It was the sweet flag *Acorus calamus*, a species originating from Asia (India and China [20] [21]), although also having a subspecies occurring in North America. The date of bringing the species to Poland (accidentally or deliberately as a medicinal plant) is a subject of controversy: several dates are given in literature: 16th century (1557 is the probable date of the introduction to Europe), 1613, 1652 and 1824. It is unclear if the three first dates refer to the cultivated plants or plants growing in the wild [15].

Other sources suggest earlier introduction, during the Tatar invasions (13th century) [20] [21] (the Polish name of the plant is *tatarak*, which suggests connection with Tatars). In that case the plant would be classified as archaeophyte, nevertheless, most sources give later dates of introduction. The plant is invasive, nevertheless not regarded harmful, on the contrary, sometimes used to strengthen embankments [20]. In Ulesie it covered 25-50% of the surveyed plot; the plants were situated very compactly, which is typical of this species [21], but different from non-native plants of other

locations. Other plants included native species, among which *Glyceria maxima* and sedges *Carex* spp. covered between 5 and 25 per cent of the plot. The species dominant in water included *Salvinia natans*, protected by law. Another characteristic species in water was *Stratiotes aloides*.

K. Zakrzowiec

The survey was carried out on 17/08/2009 by D. Hruševar and A. Wagner in two sites. Site (1) was close to the pond and site (2) was in the place of the pond that was dried out several years before the survey. In the site (1) 37 plant species were found. The dominant species was *Phragmites australis* covering more than 75% of surveyed plot.

There were only two neophytes: *Erigeron annuus* and *Conyza canadensis* and one archaeophyte: *Lactuca serriola*. In place (2) 24 species were found. The dominant one was an archaeophyte *Echinochloa crus-galli*.

Other archaeophytes included *Setaria pumila* and *Matricaria perforata* Merat. There was also *Cirsium vulgare*, an invasive plant of uncertain status. Neophytes included *Bidens frondosa*, *Conyza canadensis* and *Erigeron annnus*.

L. Zamkowa Street – Niepołomice

The pond is situated in the centre of the town of Niepołomice, near the Niepołomice Castle. The area was rich in ruderal species, as well as ornamental plants. Altogether, on 5/08/2009 Hruševar and Wagner found 47 species.

Neophytes included herbaceous plants: *Bidens frondosa*, *Conyza canadensis*, *Erigeron annuus*, *Amaranthus retroflexus* as well as trees: 6 specimens of *Phellodendron amurense* (Figure 3), one specimen of *Robinia pseudoacacia* and shrubs such as *Kolwitzia amabilis* syn. *Linnaea amabilis* and *Philadelphus coronarius*. Archaeophytes included: *Digitaria sanguinalis*, *Setaria viridis*, *Setaria pumila* and *Malva neglecta*.

M. Mokra Street – Niepołomice

The survey was carried out by D. Hruševar and A. Wagner on 17/08/2009. There were 31 plants found in the plot near the pond. Archaeophytes included: *Pastinaca sativa* and *Setaria pumila*. Neophytes were: *Erigeron annuus*, *Conyza canadensis* and *Veronica persica*.

The presence of privet *Ligustrum vulgare* could be of anthropogenic or natural origin, but anthropogenic origin was more likely, nevertheless, it was not counted as alien species.

The water body was in the residential area and many non-native species were planted: *Picea pungens*, *Liriodendron tulipifera*, *Catalpa bignonioides*, *Pinus nigra*, *Abies concolor* and *Thuja occidentalis*.

N. The Akacjowa Street – Niepołomice

Around the water body 40 plant species were recorded on 17/08/2009 by D. Hruševar and A. Wagner. There were two archaeophytes: *Lactuca serriola*, *Echinochloa crus-galli* and three neophytes in the area: *Bidens frondosa*, *Robinia pseudoacacia* and horseradish *Armoracia rusticana*. The latter is a cultivated plant, invasive, but not harmful.

O. Staniątki

Near the pond situated in Staniątki on the border with the village of Podłęże and Staniątki on 11/08/2009 D. Hruševar and A. Wagner recorded 11 plant species. The dominant species was native reed mace (cattail) *Typha latifolia* covering more than 50% of the area (degree four in the Braun-Blanquet scale). Alien species included *Bidens frondosa* and *Conyza canadensis*. Six more species were observed out of the plot, including one neophyte – the horseradish *Armoracia rusticana* and one archaeophyte - *Setaria glauca*.

P. Zalew na Piaskach

The place selected for the survey on 31/07/2009 (by D. Hruševar U. Ljubobratović and A. Wagner) was in the area where the pond was shallower and overgrown by macrophytes such as *Typha latifolia* L. There were 40 vascular species and a moss *Sphagnum* spp. There was one neophyte there: *Erigeron annuus*.

The study showed the presence of alien plants, including neophytes in each location. Many of them are invasive, although only in few survey plots they were dominant or even made a significant proportion in the land cover. The most commonly found species (in terms of the number of locations) - *Solidago canadensis* - never covered more than 25% and often less than 5% of the survey plot. This seems to be compliant with an interesting study done by Orczewska [22] suggesting that some native species (such as *Urtica dioica* and *Galium aparine*) can be more dangerous for the habitat than neophytes (such as *Solidago gigantea*). The study also confirms the data suggesting higher presence of non-native plants in human-influenced areas [4], [15]. The lowest number, which was scored in Zabierzów Bocheński and Zalew na Piaskach, places relatively distant from residential areas. The eastern part of the study area (Zabierzów Bocheński) is situated near the Niepołomice Forest, a place with some amount of strictly protected areas, where invasive plants pose serious danger for biodiversity. Fortunately, in that area the influence of invasive species is relatively small (*Solidago canadensis* and *S. gigantea*), nevertheless cannot be neglected. The origin of neophytes is given in Table I. The majority - 18 out of 30 species originated from North America, 5 species come from Southern Europe, 2 from the Caucasus Mts. and 5 from Asia (Central and East).

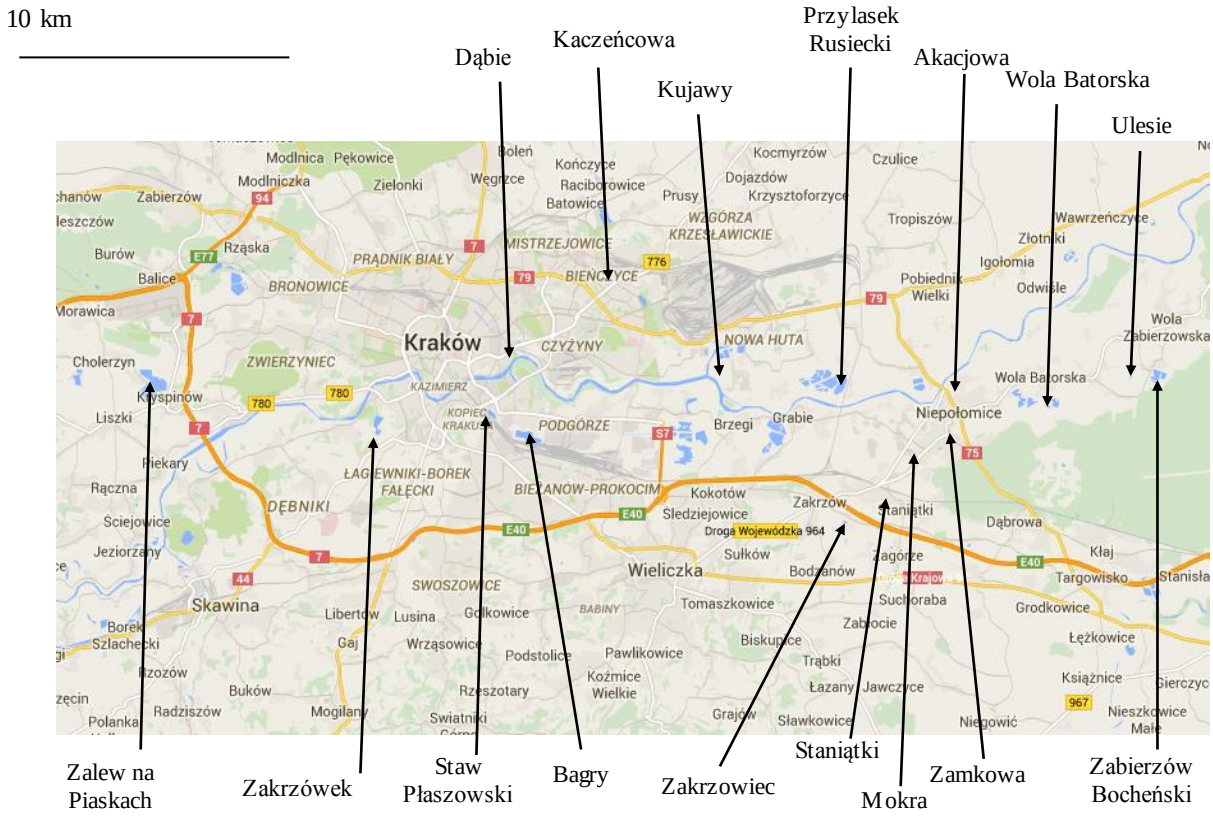

Figure 1. The study area, based on google maps.

Figure 2. *Solidago canadensis*, invasive plant on the grassland above the zone of *Phragmites australis*. The borrow pit of Bagry 8/08/2015, photo: A. Wagner

Figure 3. The pond of the Zamkowa Street – general view, on the top of the photo branches of *Phellodendron amurense*, 5/08/2009, photo: A. Wagner

IV. CONCLUSIONS

In total, 52 alien taxa were recorded for 16 locations near the water bodies in the Krakow region, which made 20.9 per cent of all the species found in the studied area. From that number, 30 taxa are neophytes, and 18 are archaeophytes, the status of four was uncertain. The percentage of alien species was lower than the one found for the whole Polish territory [15], while the percentage of archeophytes was higher. Although alien species occurred in every location in the study area, only two species: the sweet flag *Acorus calamus* and cockspur *Echinochloa crus-galli* reached 3rd and 4th degree of cover, respectively, in the Braun-Blanquet scale. Other species, on surveyed vegetation plots, usually could only be marked by "+".

Among the alien species a particular attention should be paid on invasive transformer species: the ash-leaved maple (*Acer negundo*), black locust (*Robinia pseudoacacia*), Canadian golden rod (*Solidago canadensis*), giant goldenrod (*Solidago gigantea*), bur marigold (*Bidens frondosa*) and small-flowered touch-me-not (*Impatiens parviflora*).

In the residential areas many alien tree species are grown. Apart from two species (the ash-leaved maple and black locust) they are not invasive and most of them can be only sporadically found in the wild.

Further monitoring of invasive plant species is necessary, also because of the perspective of climatic changes. Warming the climate will provide better conditions for the reproduction of southern species so that they could become invasive. The example can be the common walnut (*Juglans regia*), which was found in one location, but, according to literature [11] this species is in the initial phase of invasion, so it is likely to extend its range.

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TABLE I. NEOPHYTE PLANTS IN THE AREA OF WATER BODIES NEAR KRAKÓW

Plant cover-abundance according to the Braun-Blanquet scale: 5 - 75-100%, 4 – 50-75%, 3 -25-50%, 2 – 5-25%, 1- <5%, numerous individuals, + - <5%, few individuals, r – solitary with small cover; * – plant cover was not assessed, only the presence was recorded.

I – invasive, IT - invasive transformer, IW – invasive weed, INH- invasive, harmful effects not detected, NI - not invasive, C-casual.

TAXA	LOCATION																					Invasiveness	Origin
	BG1	BG2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP	
Aesculus hippocastanum L.								*															Balkan Peninsula
Abies concolor (Gordon & Glend.) Lindl. ex Hildebr.																			*				C	North America
Acer negundo L.		r		+	*							r											IT	North America
Acorus calamus L.															3									Asia
Amaranthus retroflexus L.																		*						North America
Armoracia rusticana P. Gaertn., B. Mey. et Scherb.																				*	*		INH	SE Europe & West Asia
Bidens frondosa L.				r	+			*		+		+	+				r	*		*	1		IT	North America
Catalpa bignonioides Walter																			*				C	North America
Conyza canadensis (L.) Cronquist				*					+		1	*				*	+	*	*		1		IW	North America
Erigeron annuus (L.) Pers.		1			*				*	+	+					r	r	*	*			+	INH	North America
Fraxinus pennsylvanica Marshall			2			+																	C	North America
Galinsoga spp.					*																			North America
Impatiens parviflora DC.								*															IT	Central Asia
Juglans regia L.							+																I	Caucasu
Kolkwitzia amabilis Graebn.																		*					C	East Asia

TABLE I. - continuation

TAXA	LOCATION																					Invasiveness	Origin
	BG1	BG2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR 2	W B	ZB 1	ZB 2	U L	ZC 1	ZC 2	ZM	MK	A	S	ZP		
Liriodendron tulipifera L.																			*				C	North America
Medicago sativa L.		+									+												INH	South-Central Asia
Oenothera biennis L.			1								+												NI	North America
Phalaris canariensis L.	1											+												Southern Europe
Phellodendron amurense Rupr.																		*					C	East Asia
Philadelphus coronarius L.																		*					C	Southern Europe
Physocarpus opulifolius (L.) Maxim.					*																		C	North America
Picea pungens Engelm.												*							*				C	North America
Pinus nigra Arnold																			*				NI	Southern Europe
Populus x canadensis Moench											1												NI	Hybrid: Europe and North America
Robinia pseudoacacia L.		r						*										*		*			IT	North America
Solidago canadensis L.		1		+	*		+	*	2	r	r			+									IT	North America
Solidago gigantea Aiton				1																			IT	North America
Thuja occidentalis L.																			*				C	North America
Veronica persica Poir.																			*				IW	Caucasus

TABLE II. ARCHAEOPHYTES AND PLANTS OF UNCERTAIN STATUS IN THE AREA OF WATER BODIES NEAR KRAKÓW

Plant cover-abundance according to the Braun-Blanquet scale: 5 - 75-100%, 4 – 50-75%, 3 -25-50%, 2 – 5-25%, 1- <5%, numerous individuals, + - <5%, few individuals, r – solitary with small cover; * – plant cover was not assessed, only the presence was recorded.

I – invasive, IW – invasive weed, INH- invasive, harmful effects not detected, NI - not invasive.

TAXA	LOCATION																		INVASIVENESS
	BG2	SP2	D	ZK1	ZK2	KU	PR1	PR2	WB	ZB1	ZB2	ZC1	ZC2	ZM	MK	A	S	ZP	
Capsella bursa-pastoris (L.) Medik.									+										INH
Cichorium intybus L.			*																INH
Cirsium vulgare (Savi) Ten.									+	+			+						Uncertain status, invasive, not harmful
Digitaria sanguinalis (L.) Scop.			*											*					
Echinochloa crus-galli (L.) Beauv.									*				4			*			IW
Echium vulgare L.				+	*														
Euphorbia virgata Waldst. et Kit.								3											Uncertain status, not invasive
Humulus lupulus L.		+					+												
Lactuca serriola L.									r			*				*			INH
Lathyrus tuberosus L.					2														
Malva neglecta Wallr.														*					
Matricaria perforata Mérat									+				1						IW
Melilotus albus Medik.	+					1	3	+											
Melilotus officinalis (L.) Lam.	+																		
Odontites vernus (Bellardi) Dumort.					*														Antropophyte, weed
Panicum miliaceum L.									+										Archaeophyte or neophyte, depending on subspecies
Papaver rhoeas L.			*																INH
Pastinaca sativa L.	+		*												*				
Rumex crispus L.											+							r	Uncertain status
Senecio vulgaris L.			*																
Setaria pumila (Poir.) Schult.													2	*	*		*		IW
Setaria viridis (L.) P.Beauv.			*											*					IW

TABLE II. NATIVE PLANTS IN THE AREA OF WATER BODIES NEAR KRAKÓW

Plant cover-abundance according to the Braun-Blanquet scale: 5 - 75-100%, 4 – 50-75%, 3 -25-50%, 2 – 5-25%, 1- <5%, numerous individuals, + - <5%, few individuals, r – solitary with small cover; * – plant cover was not assessed, only the presence was recorded.

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Acer platanoides L.				*							3					r			*				
Acer pseudoplatanus L.																			*				
Achillea millefolium L.			+		+	*		+				+	+		1		*	+	*	*	*		
Aegopodium podagraria L.					*				*										*				
Agrimonia eupatoria L.					*								*										
Agrostis canina L.																							2
Agrostis gigantea Roth												+											
Agrostis spp.					+						1												
Agrostis stolonifera L.												1			1				*				
Alchemilla spp.									*														
Alisma plantago-aquatica L.			*						*					+							*		+
Alnus glutinosa (L.) Gaertner									*					r		r					*		
Alopecurus pratensis L.																			*				
Angelica spp.													+										
Anthemis spp.						*													*				
Arctium lappa L.													*								*	*	
Arenaria serpyllifolia L.										1													
Arrhenatherum elatius (L.) P.Beauv. ex J.Presl et C.Presl					*							r											
Artemisia vulgaris L.			+		*					+	1	2	+		2		1		*		*		
Astragalus glycyphyllos L.										*			+										
Avenula pratensis (L.) Dumort.							2																

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Ballota nigra L.					*																	*	
Berula erecta (Huds.) Coville																					*		1
Betula pendula Roth			r		r					1					+								+
Bidens cernua L.									*														
Bromus hordeaceus L.						*													*				
Calamagrostis canescens (Weber) Roth		1					1																
Calamagrostis epigejos (L.) Roth			4		1			3		4			2	2	2								
Calamagrostis spp.						+					1												2
Calystegia sepium (L.) R. Br.				2	+	+									+		*					1	
Carex spp.															+	2							
Centaurea jacea agg.					*						2	+	*	1	+								+
Ceratophyllum spp.											+			*									
Chenopodium album L.						*							*				*		*				
Cicuta virosa L.													r	1									
Cirsium arvense (L.) Scop.					+			1			+	+		1	1			+	*		*		1
Cirsium oleraceum (L.) Scop.																	r	r					
Cirsium rivulare (Jacq.) All.													r										
Cirsium spp.																	+						
Convolvulus arvensis L.			1	2		*		+			1								*	*			
Crataegus monogyna Jacq.								1								r							
Crepis spp.			r			*	1												*				r
Cucubalus baccifer L.																					*		
Cynosurus cristatus L.																							+
Dactylis glomerata L.				1			2	+				+							*	*			
Daucus carota L.			+			*		+			1	+	*	+	1			+		*			+

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Deschampsia cespitosa (L.) P.Beauv.													*		2				*				
Deschampsia media (Gouan) Roem. et Schult.														+									
Deschampsia spp.																+							
Dipsacus fullonum L.															+								
Eleocharis palustris (L.) Roem. et Schult.																							+
Elymus repens (L.) Gould		2		2											2				*				
Epilobium angustifolium L.					*																		
Epilobium dodonaei Vill.								*		*													
Epilobium hirsutum L.			*		+	r			*		+	+	1	r					*		*		+
Epilobium palustre L.						r									r				*				+
Epilobium parviflorum Schreber											+												
Epilobium spp.																			*			r	
Equisetum arvense L.			+										+				*		*				
Equisetum palustre L.																1							
Equisetum ramosissimum Desf.															*								
Equisetum spp.																					*		+
Eupatorium cannabinum L.						*				r													
Festuca ovina L.							2																
Festuca spp.																			*				
Fraxinus excelsior L.									*														
Galium album Mill.							1																
Galium mollugo L.			1		*																		
Galium spp.														1									+
Galium verum L.							1																
Geranium lucidum L.							2																

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Geranium pratense L.			+		*			1					*										
Geranium spp.																			*				
Glechoma hederacea L.													+						*		*		
Glyceria fluitans (L.) R.Br.									*														r
Glyceria maxima (Hartm.) Holmb.			*													2					*	2	
Heracleum sphondylium L.			+		*						r		+	+	1				*		*		
Hieracium pilosella L.							+																
Hieracium praealtum Vill. ex Gochnat										+													
Holcus lanatus L.											+												
Holcus mollis L.																							+
Hypericum perforatum L.												r					*						
Hypericum tetrapterum Fr.																	r						
Juncus bulbosus L.						*					+										*		1
Juncus effusus L.	2				+									1	1		+		*				2
Lamium album L.																			*				
Lathyrus pratensis L.														+									
Lemna minor L.						*										*							1
Leontodon autumnalis L.					*	*						r	*		1				*	*			+
Ligustrum vulgare L.																				*			
Lolium perenne L.			+		*	*					+	+		3	2		*	+	*	*	*	*	+
Lotus corniculatus L.			+					*										r		*			+
Lycopus europaeus L.			*		1	+			*		+		1	+	+	+	+			*	*		1
Lysimachia nummularia L.									*												*		
Lysimachia vulgaris L.													1										
Lythrum salicaria L.						*					1		+		+		+	r		*		r	+
Malva sylvestris L.						*													*				

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Matricaria perforata Mérat													+										
Medicago falcata L.			1		*			1				+											
Medicago lupulina L.						*				*								1		*			+
Mentha aquatica L.									*								1						
Mentha longifolia (L.) Huds.																	*			*			
Mentha x verticillata L.													+	+									
Milium effusum L.				1																			
Myosotis spp.													+										
Myriophyllum spicatum L.														*			*				*		
Nuphar lutea Sibth. et Sm.						*																	
Ononis arvensis L.					*																		
Ononis natrix L.								*															
Petasites albus (L.) Gaertn														+	+		*		*				
Peucedanum palustre (L.) Moench							1																
Phalaris arundinacea L.		3		3																			
Phleum pratense L.					*	+					+	+		+	1						*		
Phragmites australis (Cav.) Trin. ex Steud.	2	2		2	5	*		1			+	+	2	1			5			*		*	
Pimpinella spp.					*																		
Pinus sylvestris L.										*													
Plantago lanceolata L.				1		*					+				1					*	*		+
Plantago major L.	1			1		*	1	1			+	+			2		*	1		*	*		+
Plantago media L.														2									
Poa annua L.						*									+						*		
Poa pratensis L.							2																
Poa trivialis L.															1			+					
Polygonum aviculare L.													*				*		*				

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Polygonum lapathifolium L.											+												
Polygonum mite Schrank					+								+										
Polygonum persicaria L.									*		r							+					
Populus alba L.						*		1		+	+	r											
Populus canescens Moench												+											
Populus nigra L.						r				1													
Populus tremula L.										r													1
Potamogeton spp.																							
Potentilla anserina L.								1	*									+			*		
Potentilla reptans L.			1					1	*						1		*			*			
Prunella vulgaris L.										1										*			
Prunus cerasus L.															r								
Prunus padus L.							+																
Prunus spp.			*																				
Prunus spinosa L.													1										
Quercus robur L.														r	r								
Ranunculus acris L.					*				*						+					*			
Ranunculus repens L.																		+			*		+
Ranunculus spp.														+									
Rosa canina L.								r	*														
Rubus caesius agg.			1					+				+											
Rubus spp.													1										
Rumex acetosa L.					*	*					r	+							*				
Rumex hydrolapathum Hudson																*							
Rumex obtusifolius L.					*																		
Rumex spp.																	*					+	

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Salix alba L.						2					r	2		r						*	*		+
Salix caprea L.					r																		
Salix cinerea L.						r				r	r			+	+								+
Salix fragilis L.					+								1							*			
Salix purpurea L.						r		*			r			r						*			
Salix spp.								r											*				1
Salix viminalis L.													1										
Salvinia natans (L.) All.														*		*							
Sambucus nigra L.			+					r															
Sanguisorba officinalis L.			*										1		+	*							
Scirpus lacustris L.	2		*																				
Scirpus maritimus L.									*					3	1								
Scrophularia spp.																			*				
Scutellaria galericulata L.											r												
Securigera varia (L.) Lassen												1											
Silene latifolia Poir. ssp. *alba* (Mill.) Greuter et Bourdet																						*	
Silene nutans L.			r																				
Solanum dulcamara L.									*														
Sonchus arvensis L.											r												
Sonchus oleraceus L.						*													*		*	+	
Sorbus spp.																				*			
Sparganium erectum L.						*							+										
Sphagnum spp.																							3
Spirodela polyrhiza (L.) Schleiden																*							
Stachys palustris L.							2							+	+				*				

TABLE III. – continued

TAXA	LOCATION																						
	BG 1a	BG 1b	BG 2	SP1	SP2	D	ZK1	ZK2	KA	KU	PR1	PR2	WB	ZB1	ZB2	UL	ZC1	ZC2	ZM	MK	A	S	ZP
Stenactis annua (L.) L.						*																	
Stratiotes aloides L.																*							
Symphytum officinale L.													+										
Tanacetum vulgare L.			1		+	*				1		2	1				+			*	*		+
Taraxacum officinale Weber			+								r	r		1			*			*	*		
Tilia cordata Mill.							+																
Trifolium arvense L.						*											*						
Trifolium campestre Schreber			+																				
Trifolium hybridum L.													*					+					
Trifolium medium L.																				+			
Trifolium pratense L.	1				*	*		+			1		*	1			+	+		*	*	1	+
Trifolium repens L.	1				*	*		1			r	1		3	2		+	+		*	*		+
Trisetum flavescens (L.) P.Beauv.					+								*										
Tussilago farfara L.																					*		+
Typha angustifolia L.					+	5									*		1						
Typha latifolia L.			*						*				1	2	1						*	4	3
Ulmus glabra Huds.																			*				
Ulmus minor Miller									*														
Urtica dioica L.					+				*						1		*		*		*	2	
Valeriana officinalis L.					*																		
Veronica chamaedrys L.						*																	
Vicia cracca L.					*					*		r		+			*						
Vicia cracca agg.			+			*					+		+										