Biodiv. Res. Conserv. 21: 63-72, 2011

BRC
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DOI 10.2478/v10119-011-0010-1

Translocation of *Nuphar lutea* (L.) Sibth. & Sm. from the A2 road near Nowy Tomyśl (Poland) into alternative sites

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Abstract: A translocation of *Nuphar lutea* (L.) Sibth. & Sm. was made from its primary location in Prądówka, situated in the path of the construction site of the A2 motorway, into replacement biotopes. All rhizomes were taken out of the water and used to prepare cuttings. These were divided into three approximately homogeneous groups. Each group was introduced into different replacement water bodies with environmental conditions that resembled those of the biotope in the Prądówka site. Two of the water bodies were fish ponds. A third was a so called 'ecological water body' (settling pond, settling basin) that collected fall effluents delivered from the surface of motorway. The results of the examination of the physical-chemical features of water and bottom sediments from the Prądówka peat pit, two fish ponds and four settling basins are presented in the article. Biological and autecological features of the species *Nuphar lutea*, which are significant from the aspect of the growth of the seedlings within the alternative sites, have been discussed. A year after translocation it was observed that in the case of fish ponds, 83% and 75% of the introduced plants survived, while in the settling basin only 50%. A conservation project was undertaken by the investor in order to compensate for the negative effects of the A2 motorway within the area of the European Ecological Natura 2000 Network.

Key words: autecology, biodiversity conservation, contamination of environment, environmental compensation, Natura 2000

1. Introduction

A translocation of the yellow water-lily, *Nuphar lutea* (L.) Sibth. & Sm. was made from its natural location in the Prądówka peat pit into alternative sites. The purpose of the treatment was to maintain the gene pool of this plant, protected in Poland since 1983. It is a structural element of *Nymphaeo albae-Nupharetum luteae*, a habitat consisting of natural eutrophic lakes with the *Nymphaeion* or *Potamion* type of vegetation (Natura 2000 – 3150 code), within the European Ecological Natura 2000 Network. The translocation was made in order to compensate for the disturbance of its original habitat due to the construction of the A2 motorway in the area of the Wielkopolska Voivodeship.

The Prądówka peat pit was situated along the route of the A2 motorway (at 93+300 kilometre). It also was located within two areas of Natura 2000 – PLB080005 The Pszczew Lakes and The Obra River Valley, and PLH 080002 of the same name. The investor – the General Directorate for National Roads and Motorways – was therefore obliged to translocate the protected species according to the imperative formed in the decision of the Regional Director of Environmental Protection in Poznań.

The translocation of the yellow water-lily was made according to the implementation project, prepared on the basis of general guidelines set out in 'A detailed project and a schedule of activities planned on the basis of natural compensation, necessary for the assurance of the cohesion and proper functioning of the Natura 2000 network at the section of the A2 motorway between Trzciel and Nowy Tomyśl (92+533 km – 107+900 km)' (Wojterska *et al.* 2010). Guidelines referring to the translocation of plants, as suggested by experts on plants

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from the Species Survival Commission (SSC) in the International Union for Conservation of Nature (IUCN) were also included (Makomaska-Juchiewicz 1999).

The permission of the Regional Director of Environmental Protection in Poznań, under certain conditions, was released for the destruction of the Natura 2000 – 3150 natural habitat in Prądówka, and also for the translocation of the yellow water-lily into alternative habitats. The first condition was the division of *Nuphar lutea* into three groups of plants, the second one involved relocation to water bodies in which the environmental conditions were in accordance with the autecological scale of this species and which were also similar to those that existed in the primal habitat.

The translocation of the yellow water-lily, as part of a natural compensation measure for the adverse effect of the undertaking on the environment, was the first project of this kind attempted in the Wielkopolska Voivodeship, and its implementation was thoroughly documented. As such a translocation had not been attempted before, for practical purposes, it was necessary to create an innovative procedure in order to carry it out effectively. This procedure may be treated as a reliable model for the relocation of an aquatic macrophyte from its native location to a preferred habitat and can be applied in other, similar cases.

2. Material and methods

2.1. Procedure of translocation of *Nuphar lutea* into alternative habitats

In the decision issued by the Wielkopolska Province Governor concerning the environmental considerations of the permit for investment, three settling basins were designated as new potential sites for the water-lily from Prądówka. They had already been singled out in the above mentioned "A detailed project and a schedule (...) of natural compensation" (Wojterska *et al.* 2010). These reservoirs were created as pools constructed at the following kilometres of the A2 motorway: 107+800, 108+430 and 109+400, allotted to the retention of rain water, channelled from the road. The decision also included a condition that 'In the case of inappropriate conditions for the conducting of metaplantation in the recommended water bodies, it is possible to single out other reservoirs'.

A procedure for the translocation of the yellow water-lily to the alternative water bodies was evaluated in accordance with the guidelines stated in the decision of the Wielkopolska Province Governor on environmental considerations of the permit for project implementation as well as to the general guidelines in the project of compensation together with the requirements of the

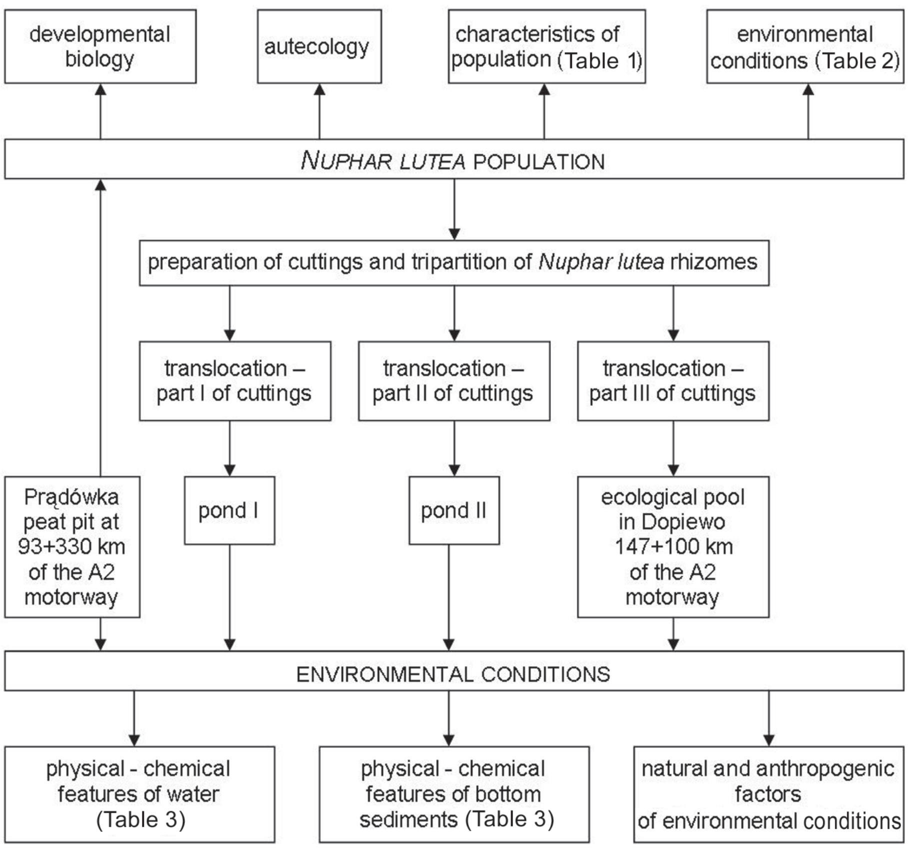

Fig. 1. The procedure of the *Nuphar lutea* translocation into alternative habitats

Species Survival Commission IUNC (Fig. 1). Three main tasks were included in this procedure: (*i*) a study of the structure of the *Nuphar lutea* population in Prądówka, (*ii*) an analysis of a habitat at the natural site of the yellow water-lily, (*iii*) a diagnosis of a natural environment in the alternative reservoirs.

Based on the results of the examination, a method for the preparation of plant material for the translocation was worked out. The results of environmental analysis allowed to single out the potential biotopes. In May 2009, ten water bodies were examined and in seven of them the quality of water and bottom sediments was estimated. Additionally, electrical conductivity, pH reaction and oxygen concentration were measured *in situ*. In the samples of water collected in the field: total phosphates (procedure conducted with the molybdenum method), total phosphorus (after mineralization with sulfuric acid, PN-EN 1189), ammonium nitrogen (with Nessler reagent solution), nitrate nitrogen (with sodium salicylate), nitrite nitrogen (sulfanil acid method), total hardness (wersenian method), COD (with potassium dichromate), total suspended matter (weight method, after filtration on the filters GF/F), chlorophyll *a* concentration (ISO 10260) were determined. The following parameters were analysed in the samples of bottom sediments: total phosphorus content using the molybdenum method after reducing the sample to ashes in 550°C and mineralization with hydrosulfuric acid; the obtained results were demonstrated in mg P/100g of dry mass; total nitrogen after mineralization using the Kjeldahl method in the Kjeltec System apparatus (Tecator), the results were given in mg N/100g of dry mass; organic matter using the weight method after roasting the sample at 550°C (Hermanowicz *et al.* 1999). Water hardness was determined according to the Choiński's classification (1995).

The content of bottom sediments in organic matter was classified according to the recommendations of Dobrzański and Zawadzki (1981). Nomenclature of vascular plants was taken after Mirek *et al*. (2002) and phytosociological system after Brzeg and Wojterska (2001).

2.1. Developmental biology and autecology of *Nuphar lutea*

Nuphar lutea (Nymphaeaceae) is a macrohydrophyte with a thick (up to 10 cm in diameter) and long rhizome, growing horizontally, profusely branching, often forming a dense net. In the top part of the rhizome there are dense, spirally situated leaves and stalks. Significant scars remain after their detachment. Older parts of the rhizome decay quickly. Leaves are floating and submersed. The first type possesses long stalks and a leather-like leaf blade, while the second type has a 'lettuce-like' shape. Adventitious roots may grow both at the upper side and underside of the rhizome. Near the apex of the stalk the roots become more numerous, relatively larger and aerenchymatic. The yellow water-lily reproduces mainly vegetatively. It creates extensive, clonal populations. It roots itself usually at the depth of 0.5-1.5 metres. In some regions of the earth it is categorised among oppressive synanthropic plants, eradicated through mechanical and chemical methods. It is willingly consumed by beavers (Padgett 2007).

The yellow water-lily inhabits slowly flowing or stagnant water, exhibiting significant variation in ecological scale between these ecosystems (Schneider 2007). The species is characterised by a wide ecological amplitude (Szańkowski & Kłosowski 1999). According to Kłosowski (1994), it finds its optimal developmental conditions in water from slightly eutrophic to eutrophic, medium hard (average weighted total hardness 3.7 mval/l, carbonate 2.9 mval/l), and also rich in magnesium (12.5 mg/l on average), sulfate (21.2 mg/l on average) and calcium (46.6 mg/l on average). This plant species can inhabit a hypereutrophic lake (Toivonen & Huttunen 1995), water of quite low transparency. The yellow water-lily is well adapted to prolonged anaerobic conditions. It can also tolerate high water level changes (Pliński & Wnorowski 1993), as well as periodic lack of water (Padgett 2007). Significant changes in the water conditions may become visible in the morphological and anatomical structure of a plant, including the elongation of leaf stalks or diminishment of their diameter (Śpiewakowski *et al.* 1985). It is resistant to changes in the water pH - it can occur in the range from light acidic to alkaline, i.e. 5.9 - 8.2 (Piękoś-Mirkowa & Mirek 2003). Kłosowski (1994) states that the bottom sediments, in which the yellow water-lily is rooted, are of organic-mineral character, high in their content of organic substances (33% on average), with a high level of hydration (79% on average), rich in sodium (1.2 g/kg of dry mass on average) and also in potassium (0.76 g/kg of dry mass on average) as well as rich in magnesium (9.57 g/kg of dry mass on average), calcium (132.7 g/kg of dry mass on average), SiO_2 (0.84 g/kg of dry mass on average), SO_4 (6.27 g/kg of dry mass on average), Cl (1.21 g/kg of dry mass on average), and also of considerably high oxygen demand (108 O_2/kg of dry mass on average). This plant species has also been recorded to be resistant to high concentrations of copper in the sediments (Aulio 1980).

Nuphar lutea can easily colonise new sites, where it can spread spontaneously or have been reintroduced (Kaplan *et al.* 1998). Its success depends on environmental conditions, ranging within its ecological scale (Barrat-Segretain 1996). The yellow water-lily adapts easily to garden cultivation. After two years of planting, one specimen of the yellow water-lily is able to cover the surface of several square meters. This is why it is planted in baskets, which enable gardeners to control its development by cutting rhizomes and roots.

3. Results

3.1. Natural environment and population of *Nuphar lutea* in the Prądówka peat pit

The Prądówka peat pit was situated at 93+330 kilometre of the A2 motorway. It was of a rectangular shape. Its surface accounted for 0.4 ha and its bank line was almost 300 m long. The population of *Nuphar lutea* grew by the southern bank (WGS 84: N 52°19'44.89", E 15°53'38.81") and was in the early phase of its development. The plant bed covered an area of 16 m^2 and consisted of 34 rhizome fragments of 'lettuce-like' underwater leaves differing in size (Table 1). In accordance with the regional division of Poland (Kondracki 2000), the investigated reservoir was situated in The South Baltic Lakeland (Pojezierze Południowo-bałtyckie) subprovince.

The water of the peat pit was characterised by a slightly alkaline reaction, low hardness and slight oxygenation (57%). Electrical conductivity did not exceed 500 µS cm^{-1}. The concentrations of phosphorus and nitrogen were at the medium level. Bottom sediments contained considerable amounts of organic matter (Table 2).

3.2. Environmental conditions in the ecological pools at the A2 motorway

In the decision of the Wielkopolska Province Governor, three ecological pools were designated at the following kilometres of the A2 motorway: 107+800, 108+430, 109+400; as alternative habitats for *Nuphar lutea* from the Prądówka peat pit. A field survey showed that these were the basins with embankments and bottoms laid out with open-work concrete panels. In

Table 1. A characteristic of the rhizome fragments of *Nuphar lutea* brought out from the Prądówka peat pit

	Rhizome fragment		
	Small	Medium	Large
Number	2	14	18
Size */**	25-39cm/ ≤2.4 cm	30-49 cm/ 2.5-3.4 cm	50-60 cm/ ≥3.5 cm
Form	with one not emerged floating leaf reasonably well developed, with primordium of flower shoot	with one not emerged floating leaf weakly developed, without flower shoot	without floating leaf, without flower shoot

Explanation: */** lenght/diameter

The vegetation of the Prądówka peat pit was created by phytocoenosis of the following communities: *Caricetum paniculatae*, *Carici elongatae-Alnetum*, *Eupatorietum cannabini*, *Glycerio-Oenanthetum aquaticae*, *Lemnetum trisulcae*, *Phragmitetum communis*, *Scripetum sylvatici* and *Typhetum latifoliae*. On the edge of the reservoir, within a strip of approximately 50 m in width, *Sedo maximi-Peucedanetum oreoselini* and *Agrostio-Populetum tremulae* were identified. 112 specimens of *Epipactis helleborine* (*Orchidaceae*), a species under strict protection, were encountered in the stenothermal tall herb fringe communities with *Peucedanum oreoselinum* and also under the canopy of *Pinus sylvestris*, in the vicinity of *Populus tremula*. The flora of this water body, analysed with the use of ecological indicator values of vascular plants (Zarzycki *et al.* 2002), and also with regard to phytocoenotic differentiation of vegetation and abiotic conditions, showed that the examined object was a peat pit, that is, a reservoir created as a result of peat exploitation. The littoral vegetation was poorly developed due to the steep banks of the pond basin. In the western part there was a short section with a better developed littoral platform, where reed peat was deposited under the rushes with *Phragmitetum communis*.

none of them there was any water and in the openings of these panels, terrestrial vegetation with the participation of psammophilous species was well developed. Therefore it was necessary to find alternative biotopes. In four water bodies, designated by the investor (110+200, 113+850, 113+960 and 147+100) the quality of water and bottom sediments were analysed (Table 2). In small water bodies (usually shallow and with surface covered with macrophytes) the application of the commonly used method for classification of trophic conditions (e. g. according to Carlson 1977) for lakes causes a multiplicity of interpretational difficulties (Joniak *et al.* 2009). This means that the estimation of the trophic conditions of a small water body is restricted to an analysis of its chemical parameters – phosphorus (TSI_{TP}) and chlorophyll *a* concentration (TSI_{Chl}).

The water of the ecological pool '110+200' was characterised by neutral pH reactivity, high concentration of dissolved mineral compounds, strong development of algae biomass and, at the same time, by very low water oxygenation. Bottom sediments represented mineral type due to a scarce amount of organic matter. The content of nitrogen and phosphorus was low. High concentrations of chlorophyll *a* (93.6 µg l^{-1}) indicated advantageous conditions for photosynthesis, however, much higher concentrations of pheophytin *a* (141.3 µg l^{-1}) suggested the existence of parameters influencing a declination of algae communities. The main reason responsible for such a situation was the very high hardness of water caused by strong salinity. Electrical conductivity considerably exceeded the value of 2000 µS cm^{-1}, typical for coastal reservoirs. Such a high value was a result of a high content of sodium, potassium and magnesium, most probably derived from the rain water runoff from the surface of the motorway, de-iced with salt during the winter.

A feature of the chemism of the ecological pool '113+850' was its very good oxygenation, alkaline reactivity and very high content of dissolved mineral substances. Electrical conductivity reached here a record value of 5710 µS cm^{-1}, which is equal to the level of salinity of the Baltic Sea. The total hardness of water was also the highest here. Bottom sediments contained a scarce amounts of organic matter, while concentrations of phosphorus and nitrogen were high and irrefutably indicated an inflow of water contaminated with these elements. A high content of nitrogen and phosphorus also characterised water of this reservoir. Concentrations of phosphates and ammonium were particularly high, which indicated at least a periodical inflow of strongly contaminated water. Concentrations of nitrates, at a level characteristic of industrial sewage (0.246 mg l^{-1} NO_2), was a sign of the disturbance of biochemical processes. Due to very strong development of algae biomass (concentration of chlorophyll *a* accounted for 812.1 µg l^{-1}), water of this pool contained very high amounts of suspended matter. Another source of suspended matter (mainly mineral) was water flowing in from the pipeline. The final evaluation of the quality

Table 2. The results of habitat analysis in the Prądówka peat pit and ecological pools primarily designated for translocation

Physical-chemical features	93+330 Prądówka peat pit	Location of ecological pools – kilometre of the A2 motorway			
		110+200	113+850	113+960	147+100
Water					
Oxygenation mg l^{-1}	6.5	5.6	12.4 8.4*	12.0	8.4
Oxygen saturation (%)	57	48	107 88*	104	85
pH	7.7	7.3	8.6 8.0*	8.4	8.1
Conductivity µS cm^{-1}	460	2480	5710 640*	2750	740
Phosphates mg l^{-1} PO_4	0.028	0.067	1.594 0.046*	4.774	0.061
Total phosphorus mg l^{-1} P	0.056	0.07	0.567 0.109*	1.487	0.056
Ammonium mg l^{-1} NH_4	0.87	0.69	5.38 0.37*	4.35	0.72
Nitrates mg l^{-1} NO_3	0.79	0.49	0.81 0.53*	3.42	0.77
Nitrites mg l^{-1} NO_2	0.007	0.01	0.246 0.01*	0.736	0.01
Total hardness mval l^{-1}	2.33	19.4	26.5 1.85*	20.8	4.6
COD mg O_2 l^{-1}	82.6	67.2	66.8 45*	138	32.4
Suspended matter mg l^{-1}	9.4	5.6	31 53.2*	97	10.1
Chlorophyll *a* µg l^{-1}	40.5	93.6	812.1 6.8*	31.3	13.6
Trophic conditions of water					
TSI_{TP}	62.2	65.4	95.6	109.5	62.2
TSI_{Chl}	66.9	75.1	96.3	64.4	56.2
Final evaluation (E – eutrophy, H – hypereutrophy)	E	H	H	H	E
Bottom sediments					
Total phosphorus mg P/100 g	45	29.1	73.7 16.6**	14.7	27.8
Total nitrogen mg N/100 g	679	147	413 35.8**	182	95.2
Organic matter %	68	5	4 4**	5	65

Explanations: * – water from the pipeline leaking from the water body, ** – sediments collected at the entry of the pipeline of water flowing out of the pipeline was not bad, especially, when oxygenation and concentration of biogenic compounds are considered. Taking into consideration the time of conducting the examination as well as the general picture of the water and bottom sediment chemism of the reservoir, it should be presumed that it periodically provides water of much worse quality. The fact that the electrical conductivity of water in this pool was high, even though the winter action of motorway cleaning was finished, seems to support this assumption.

The water of the reservoir '113+960' was characterised by features similar to those of pool '113+850', i.e., very good oxygenation (oxygen supersaturation) and slightly alkaline water reactivity. Although the salinity was only half that of the former object the total hardness was high (20.8 mval l^{-1}). Similar values are typical for coastal lakes and are connected mainly with a high concentration of sodium (Choiński 1995). The conditions for the phytoplankton community development were unfavourable in this water body, especially as a result of the restriction of light influx caused by a surfeit of suspended matter. Hence, considerably low concentrations of chlorophyll *a* were found (31.3 µg l^{-1}) along with record high concentrations of the product of its decomposition (pheophytin *a* 1400 µg l^{-1}). The content of phosphates, nitrites and organic compounds, expressed by COD, was very high. This kind of contamination is usually a result of over-fertilising of soils and/or the illegal deposition of liquid manure (Joniak & Kuczyńska-Kippen 2010). The bottom sediments contained a minimal amount of organic matter useful for macrophytes and concentrations of biogenic compounds were also very low.

The ecological pool '147+100' was characterised by a moderate level of water oxygenation and neutral pH. Its electrical conductivity was also moderate, characteristic of water with a higher content of ions of calcium and potassium (Joniak 2009). In comparison with the water bodies described above, phytoplankton development was weaker in this reservoir, however, the conditions for its development were stable, without deteriorating chemical parameters. Mineral compounds of phosphorus and nitrogen occurred in low concentrations, similarly to bivalent cations, generating water hardness. Organic substances occurred in amounts half as low as average, which clearly indicated a load of high significance for oxygen conditions. Bottom sediments were characterised by a high content of organic matter (silting), and at the same time very low resources of biogenic compounds.

The physical-chemical features of water and sediments of the ecological pools designated for the translocation of *Nuphar lutea* differed significantly from those recorded in the Prądówka peat pit. This was a result of a repeatedly higher inflow of mineral and organic contamination, coming from motorway. The main negative effects of their presence were seen in the decrease of water oxygenation and the occurrence of gasses, the products of decomposition of organic matter (methane, hydrogen sulphide). Unstable oxygen conditions, occurring in three of the investigated objects (110+200, 113+850, 113+960), which depended on the seasonal changeability in the abundance of contamination inflow, did not offer any guarantee of a successful outcome for the translocation. This equally concerned the features of water and sediments, whose chemical parameters were far from suiting the autecological scale of *Nuphar lutea*. However, significantly better abiotic conditions and higher stability of the environment occurred in the pool '147+100'. The main virtue of this reservoir was a lack of excess of mineral compounds and, at the same time, high oxygen concentration that would guarantee stable conditions for biochemical decomposition of the inflowing matter. Nevertheless, it should be underlined that this pond did not provide optimal developmental conditions for this plant species.

An analysis of the environmental conditions of six ecological pools, adjacent to the embankment of the A2 motorway, revealed that the yellow water-lily could not be relocated to any of the basins destined to retain water flowing from the paved part of the road. Sewages contain mineral and oil-derivative contaminations, rubber particles from tyre wearing and burning, elements of road vehicles, loose and liquid remains of transported substances, atmospheric fall as well as substances washed away from bituminous mass and salt applied during winter maintenance of the road surface. Waste reaching the ecological pool, i.e., a de facto settling pond, is devoid of mechanical fractions. Hence, water and sediments that are brought in by thawed and rain water from the road route, must be assumed toxic. Furthermore, it was not only the poor quality of water and bottom sediments that excluded any possibility for translocation, but also a small thickness of sediments as well as the way in which the open-work concrete panels were laid out, thereby preventing plants from rooting. A further problem also lay in the periodical removal of sediments along with their vegetation from the water bodies. It seemed that a serious factual mistake had been made with the recommendation in 'A detailed project and a schedule (...) of natural compensation' and in the legal decision of the Province Governor of Wielkopolska, that ecological reservoirs be adopted as alternative habitats for the yellow water-lily.

3.3. Natural environment in the alternative habitats of *Nuphar lutea*

Poor environmental conditions, insuitable for the development of the yellow water-lily, which were recorded in the recommended water bodies led to a search for other aquatic ecosystems. However, in accordance with the article 120.1 of the Act on Nature Protection (Act 2004), alternative sites could have been only water bodies of anthropogenic origin as the introduction of foreign species into the natural environment is forbidden. The article 5 of the above mentioned law does not define the term 'alien species'. In this case, it can refer to the alien species in the sense of its geographical as well as local range. The introduction of the yellow water-lily into any biotop is followed by serious consequences caused by the biology of its development. As mentioned earlier, in favourable conditions it grows intensively and can infest vast areas, and, as a consequence, it can quickly cause changes in biocoenotical relationships. *Nuphar lutea* belongs to a group of hydrophytes with a high annual production of biomass. It provides considerable amounts of organic matter which accumulates, filling a lake basin and leading to its shallowing, therefore accelerating the process of drying out in aquatic ecosystems (Padgett 2007).

After analysing hydrographic maps in relation to the occurrence of aquatic habitats in the neighbourhood of the A2 motorway, as close as possible to the native site of *Nuphar lutea* in Prądówka, in close proximity of the road investment, only two reservoirs of anthropogenic origin were found. Both had formerly been fish ponds near the village of Przychodzko (Zbąszyń commune, Wielkopolska Voivodship), described as pond I and pond II. Aquatic ecosystems of such a type are more and more often used as alternative habitats for endangered species. As a result of geobotanical studies as well as of an analysis of the abiotic features of their water and bottom sediments (Table 3), both water bodies were found to comply with the autecological requirements of *Nuphar lutea*.

The water of ponds represented many common features: very good oxygenation, neutral pH, low hardness and conductivity in the range of 300 µS cm^{-1}. Greater differentiations concerned organic and mineral compounds. The development of algae biomass was weak, which was reflected in low concentrations of chlorophyll *a*. Bottom sediments of both objects were characterised by high and very high content of organic compounds (homogenic organic sediments) with similar resources of nitrogen and phosphorus. Their level of nitrogen concentration was higher than in the near-motorway reservoirs, and, at the same time, typical of mid-forest water bodies of the Wielkopolska region (Joniak *et al.* 2007; Kuczyńska-Kippen & Joniak 2010). Summing up, the quality of water and composition of sediments in ponds I and II was completely different to that found in ecological pools 110+200, 113+850 i 113+960. The fact that both ponds had a favourably high concentration of organic matter and nitrogen in their sediments was of key significance for the yellow water-lily.

Materials available in the National Spatial Information Infrastructure (www.geoportal.gov.pl) showed that pond I and pond II are situated within one geodetic parcel. Their owner has informed that he has no plans to conduct the fishery industry in the ponds and also agreed to the introduction of the yellow water-lily and to the monitoring of the state of its population.

Table 3. Comparison of trophic conditions in the reservoirs finally chosen for translocation of *Nuphar lutea*

Physical-chemical features	Pond I	Pond II	147+100 km Dopiewo
	Water		
Oxygenation mg l^{-1}	11.5	10.6	8.4
Oxygen saturation (%)	118	105	85
pH	8.3	8.4	8.1
Conductivity µS cm^{-1}	322	310	740
Phosphates mg l^{-1} PO_4	0.297	0.474	0.061
Total phosphorus mg l^{-1} P	0.12	0.2	0.056
Ammonium mg l^{-1} NH_4	0.69	2.74	0.72
Nitrates mg l^{-1} NO_3	1.08	1.99	0.77
Nitrites mg l^{-1} NO_2	0.01	0.02	0.01
Total hardness mval l^{-1}	2.72	2.51	4.6
COD mg O_2 l^{-1}	45.6	97.2	32.4
Suspended matter mg l^{-1}	8.5	7.6	10.1
Chlorophyll *a* µg l^{-1}	6.0	4.7	13.6
	Trophic conditions of water		
TSI_{TP}	73.2	80.6	62.2
TSI_{Chl}	48.2	45.8	56.2
Final evaluation		eutrophy	
	Bottom sediments		
Total phosphorus mg P/100 g	79.8	97.5	27.8
Total nitrogen mg N/100 g	2730	2210	95.2
Organic matter %	94	81	65

3.4. Cuttings from *Nuphar lutea* and their planting in alternative habitats

In the case of metaplantation of the yellow water-lily, it would be very good to relocate all the specimens to alternative sites along with the substratum or introduce offspring obtained from seeds into the environment. This would enable the genotypic and phenotypic variation of the population to be maintained and would decisively increase the chances of species survival at the new locations. The three-month period forecast for carrying out the whole project of metaplantation, designated by the investor, was not sufficient to allow the development of seedlings from seeds of the yellow water-lily, coming from its native site. It was also impossible to translocate whole specimens into the replacement water bodies. The population of the yellow water-lily in Prądówka possessed a very complex system of tangled roots, strongly rooted in the bottom sediments.

The translocation process of *Nuphar lutea* was started in the early phenological phase, before the floating leaves emerged on to the surface of water sometimes with one floating leaf developed, and when only several underwater leaves of a 'lettuce-like' shape were present at the tops of rhizomes,. At the beginning of the vegetative season, the plant uses mainly reserve substances profusely stored in fleshy rhizomes and thanks to this it shows a high growth dynamics during this period. The metaplantation was undertaken in May to save reserve substances for the period of adaptation to the new ecological conditions in the alternative water bodies. The yellow water-lily, multiplied from fragments of rhizomes, does not usually produce floating leaves. Removal of whole specimens was therefore given up, and the oldest parts of rhizomes, of little use for preparation of cuttings, were left in the sediments. This approach guarantees a full physiognomy of future clonal specimens. Only those fragments of plants were detached from the bottom and taken out of the water that possessed freshly leaved tops of rhizomes and which were naturally well equipped with adventitious roots.

Cuttings of the yellow water-lily were prepared from the top fragments of ramets, 5-20 cm in length. Older leaves were completely removed from them. Roots were shortened up to 5-7 cm. Soft parts of the rhizome were cut off with a sharp knife. All the cuttings were covered with active coal dust. Each of them was placed in the silt-turf soil, in a bag made of plastic (of a green colour) with a large mesh, which would enable the roots to proliferate and exit the bag. The buds of a plant were placed at approximately 5 cm above the surface of the substratum. Regarding the great fluidisation of the sediments in the peat pit, the native substratum of the yellow water-lily was not taken for filling the bag. Instead, slit-turf soil from a plant bed of *Scirpetum sylvatici* was used. This plant community was the phytocoenosis most closely situated to the population of *Nuphar lutea* and, at the same time, closest to the terrestrial community under which the soil was so compact that after being placed in a bag it would not leak through its mesh holes. Each of the bags with plant cuttings was given a form adapted to the shape of a rhizome. Bags with smaller cuttings were loaded with fine stones of native origin, so as to settle well on the bottom. Stones were placed in such a way as not to touch the rhizomes. Cuttings were placed in water with water level of about 40-60 cm above the bud.

The prepared cuttings were divided into three groups, homogenous in respect to the size of plants and their condition. The purpose of such treatment was to enhance the chances of the species preservation. The division was made based on biometric measurements. One group, consisting of six large cuttings, five of a medium size and one of the smallest, was introduced in pond I (WGS 84: N52°18'0.56", E15°54'34.4"). The second group, of a similar composition, was placed in pond II (WGS 84: N52°17'56.35", E15°54'40.91"). The third group, consisting of six large cuttings and four of a medium size, was put into the ecological pool in Dopiewo (147+100 km; WGS 84: N52°20'59.82", E16°39'30.74").

4. Discussion and conclusions

The translocation of the yellow water-lily *Nuphar lutea* was made from its primary location in the Prądówka peat pit into replacement biotopes. According to guidelines suggested by the Species Survival Commission IUCN, anthropogenic sites which have been created through the process of metaplantation must be published for scientific purposes. Therefore, the present article contains data referring to the created sites of the yellow water-lily, and additionally it outlines the applied procedure for active protection.

The conservation project was a natural compensation for the negative effect of the construction of the A2 motorway. The permission of the Regional Director of Environmental Protection in Poznań included an agreement for the translocation of the yellow water-lily from Prądówka into six chosen ecological water bodies, provided that environmental conditions, after laboratory analyses, were shown to fit within the autecological scale of *Nuphar lutea*. Ecological water bodies are designated to collect waste water from the road surface so it could have been presumed in advance, without any analytical examination, that the physical-chemical parameters of the water and bottom sediments would be far from the optimal developmental conditions of the yellow water-lily. The results of conducted

Fig. 2. Planting of the cuttings of *Nuphar lutea* in the settling basin in Dopiewo, at 147+100 km of the A2 motorway (photograph by J. Borysiak, May 2009)

analyses proved that the selection of ecological water bodies, as alternative habitats was a serious factual mistake.

It may be surprising that the authority of state administration responsible for the management of plant resources decided to undertake the costly and labour-intensive conservation procedures in relation to *Nuphar lutea*, which is quite a common plant and easy to cultivate. However, it should be strongly underlined that natural compensation refers to the maintenance of the genotypes which make up a genotypic bank of the structural element of a natural habitat of Natura 2000-3150, possibly important, from the point of view of long-term survival of this plant in the region of its primary occurrence.

A field examination was carried out one year after translocation to estimate its effectiveness for the active protection of this species. Generally the effects of the treatment were estimated positively. In pond I, ten specimens (83%) survived out of 12 planted, while in pond II nine of 12 (75%) and finally in Dopiewo half (50%). Monitoring of *Nuphar lutea* will be continued. It can be forecasted that the specimens of the yellow water-lily introduced into the two long disused fish ponds will have the greatest chances for permanent settlement. During the translocation process basic parameters referring to the quality of water and bottom sediments were fully in accordance with the autecological scale of the metaplanted species.

It was decided that the third replacement biotope would be the ecological water body (Dopiewo km 147+100), even though its water features and bottom sediments offered developmental conditions far from optimal for the yellow water-lily. Long-term observations of the metaplanted plants will show whether they are able to survive in an artificial ecosystem which is extremely challenging for them. The scientific premises for introducing the yellow water-lily into the ecological water body were based on the results of some studies concerning hydrobotanical sewage treatment plants. They showed that many hydromacrophytes will survive and develop successfully even in very highly polluted waters and bottom sediments. The survival of specimens of the yellow water-lily in Dopiewo (Fig. 2) will depend not only on the level of contamination of this ecological water body by toxic substances in the run-off from the surface of the A2 motorway, but also on the weather conditions.

An analysis of the quality of water and sediments of four ecological water bodies, constructed adjacent to the embankment of the A2 motorway, which retain run-off water flowing off the road, has been made in this article. The results of the analysis should be taken into consideration in reports on the effects of motorways and express roads on the environment.

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