Fluctuations in numbers of neophytes, especially *Impatiens glandulifera*, in permanent plots in a west German floodplain during 13 years

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Summary

In wetlands of the middle section of the Rur Valley, western Germany, 80 permanent plots were investigated phytosociologically from 1989 to 2001. Although the primary aim of this programme was not to monitor neophytes, the amount of collected data allows an evaluation of the dynamics of spread at a landscape level. 19 neophytic species have been recorded, the most common ones were Epilobium ciliatum, Impatiens glandulifera, I. parviflora, Bidens frondosa and Senecio inaequidens. There were strong fluctuations in the neophytes' proportions of the total species numbers. Most neophytes did not show a steady increase, but remarkable fluctuations instead. The number of plots which were free of neophytes has decreased slightly during 13 years. For the annual Impatiens glandulifera, extreme fluctuations were recorded, with temporary colonization of reed communities in large quantities in some years, and total regression in other years. These processes are influenced by ground-water tables and river floodings as demonstrated by hydrologic data. In a similar manner, the native perennial Urtica dioica can colonize reeds temporarily. A long-term increase of neophytes at a landscape-wide scale seems to be rather slow. Apprehensions that I. glandulifera or other neophytes could outcompete native species in certain habitats can turn out to be a delusion caused by temporarily large quantities of fluctuating neophytes. There is no reason to expect special challenges for nature conservation resulting from neophytes in the Rur Valley.

Key words: River Rur, ground-water, phytosociology, alien plants, temporary invasion, monospecific stands, *Urtica dioica*, Phragmition.

1. Introduction

Although the spread of neophytes is an outstanding expression of dynamic processes within ecosystems, such processes have not been a target of phytosociological permanent plot studies very often (see Köstler et al. 1991, Bakker et al. 1996, Klotz 1996). Several studies using permanent plots aimed at finding management or control methods against alien invasive species (Adler 1993, Hartmann et al. 1994, Landesanstalt für Umweltschutz Baden-Württemberg 1994, Böcker & Dirk 2002), many others with the same aim did not use phytosociological methodology. There are some studies monitoring neophytes on river banks in Germany, but only few results have been published to date (Brandes 1996, Grote 2001). Further information on the dynamic behavior of neophytes at the scale of individual stands is scatteredly published in phytosociological permanent plot studies which had other primary targets, such as succession in general, or evaluation of different agricultural treatments. Many research programmes, regardless of their aim, have a rather short duration (considerably less than ten years in most cases). There is an apparant lack of long-term studies on the further development of neophyte stands in situ.

Floodplains are known to be rich in alien plants, especially in neophytes (Tüxen 1950, Sukopp 1972, Pyšek & Prach 1993). Natural disturbances (flooding, geomorphologic dynamics) and anthropogenic disturbances (e. g. river management, clearing of forests) in combination with the spatial coherence of riparian corridors are said to be major promoting factors for the spread of new species. In particular, these plants inhabit river banks, but other floodplain habitats often harbour a great number of neophytes, as well.

In 1989 a bio-monitoring project was set up in the valley of the River Rur, a typical western German floodplain, in order to investigate changes in wetlands resulting from lowering of ground-water tables (Kasperek 1998). The core of this project was 100 permanent plots, placed in a variety of vegetation units; its primary aim was not to monitor neophytes. But, because of the great number of permanent plots, a great amount of data on neophytic species resulted, as well as a chance to evaluate dynamics of their spread on a landscape level.

Fig. 1: Sketch map of the study area; in the zoom window, low mountain ranges are indicated with hatching, research area by rectangle.

The main aims of the present study are to ascertain if neophytes are spreading (or receding), and to assess how fast and continuous these processes are. Furthermore, the dynamics of a particular species and its relation to habitat dynamics will be examined exemplarily in order to show that, in certain cases, set-backs in the spread of neophytes are far from impossible.

2. Research area

The River Rur has its source in the geographic area called Hohes Venn, Belgium, and meets the River Maas in the Netherlands after a course of a little more than 200 kilometers. Its middle course is situated in the westernmost part of Germany, in a triangle between the cities of Aachen (Aix-la-Chapelle), Köln (Cologne) and Mönchengladbach (Fig. 1). The climate of this lowland area, about 50 - 125 m above sea level, is influenced by the proximity of the sea, with winters being mild and summers not too warm. Mean values of air temperature are between 9,5 and 10° C (Deutscher Wetterdienst 1989). Because of rain shadow effects, precipitation amounts are rather low, reaching less than 650 mm/a in some parts of the Rur Valley.

In the valley bottom around the town of Jülich where the research area is situated, there are extended wetlands with high ground-water levels. Twelve wetlands around Jülich, with a total area of 5,62 km², have been monitored since 1989, most of them being nature reserves (Kasperek 1998). Originally, 100 permanent plots (PPs) were set up. 80 of these PPs are targeted in this study, because of their continuous data up to 2001. These PPs represent a range of vegetation units typical of floodplains of the western part of Central Europe: forest communities, mainly of the alliances Alno-Ulmion and Carpinion (45 %), reeds and sedge swamps belonging to Phragmition, Magnocaricion and Glycerio-Sparganion (36 %), and other communities in smaller shares, with the spatial density of PPs being 14 per km².

3. Methods

Permanent plots (PPs) were set up according to the phytosociological methods of Braun-Blanquet (Dierschke 1994). Each PP contained homogenous vegetation; plot size was chosen according to the concept of minimum area. The plots were marked off, normally by using permanent wooden poles, and their geographical coordinates were determined (see Kasperek 1998 for details). Vegetation relevés using a cover/abundance-scale with 9 subdivisions (value "2" split up according to Barkman et al. 1964: 399) were done annually from 1989-1995, then every two years from 1995-2001. Selected plots have been investigated annually since 1989. The nomenclature of plant names follows Wisskirchen & Haeupler (1998); classification of species as neophytes, archaeophytes or indigenous species was done according to Rothmaler (1988) and by taking regional literature into account.

Ground-water tables were monitored using metal pipes (with a length of 3 m and a lockable cap) which were installed beside the PPs; monthly measurements were performed with a special plummet.

Table 1: List of recorded neophytes, with number of plots in which they occurred; life form is given according to Rothmaler (1988), with modifications based on the author's observations. (*: these species have been observed behaving exclusively like annuals in the study area.)

Alien species	No. of plots	Life history	Time of arrival in Rur Valley
Epilobium ciliatum	24	annual / perennial*	1970s
Impatiens glandulifera	18	annual	1970s
Bidens frondosa	15	annual	1970s
Impatiens parviflora	12	annual	?
Senecio inaequidens	4	perennial / suffrutex	1970s
Acorus calamus	3	perennial	18th /19th century
Quercus rubra	3	tree	?
Galinsoga ciliata	2	annual	1900-1950 (?)
Cornus sericea agg.	2	shrub	?
Galanthus nivalis	2	perennial	cultivated since long ago
Hesperis matronalis	2	biennial / perennial	1900-1950 (?)
Lactuca serriola	2	annual / biennial	?
Aesculus hippocastanum	1	tree	cultivated since long ago
Chaenorhinum minus	1	annual	? [archaeophyte?]
Fallopia japonica	1	perennial	1900-1950 (?)
Heracleum mantegazzianum	1	biennial / hapaxanth	1980s
Lycopersicon esculentum	1	annual	cultivated since long ago
Mimulus guttatus	1	perennial	1980s
Oxalis stricta	1	annual / perennial*	?

4. Overview of neophytes

Within the 80 PPs, 19 neophytic species were recorded, seven of which occurred in only one PP (Tab. 1). *Epilobium ciliatum* was the most common neophyte. It occurred in 24 plots, mainly located in reeds or sedge swamps; in these communities it could especially be found on patches of open soil caused by flooding. Contrary to most statements in literature, *E. ciliatum* behaved like an annual species in these habitats. The second most common neophytic species was *Impatiens glandulifera*; it almost occurred in one out of four PPs, mainly in reeds and in wet forests with a more or less open canopy (see chapter 5). *Mimulus guttatus* is an example of a species which has been spreading fast in the Rur Valley in recent years; it probably arrived here during the last two decades, but in the present study it was only recorded in one PP. *Galanthus nivalis*, which is not indigenous in this part of Germany, was found in forests even at great distance from villages, and seems to be well-established there.

Most of the listed neophytes are well-established in more or less natural vegetation in the research area, and most of them are widespread in Central Europe as well. About one half of the recorded neophytic species are either annual, or longer-lived species which are able to set fruit in the first year.

None of the PPs in this study was dominated by neophytes. In 18 PPs, neophytes made up 10 % or more of the total species number, at least for single years (Tab. 2). But up and down fluctuation of values was remarkable: there was no PP in which the share of neophytes was 10 % or more over the whole period of investigation. The highest value for a single year / plot was 33 % (one plot with only three species in 1990, one of these being *Impatiens glandulifera*; in later years, species number showed a strong increase, and in some years *I. glandulifera* even vanished

Table 2: Neophytes' proportions of the total species number in PPs per year; those PPs are shown, in which values of 10 % or more (in bold figures) occurred.

PP code	1989	1990	1991	1992	1993	1994	1995	1997	1999	2001
1/3-11	**10,0**	8,3	8,3	7,7	5,9	5,9	5,3	6,3	5,9	4,8
1/3-17	**10,0**	**10,0**	7,7	9,1	6,3	4,2	**11,1**	9,1	**15,4**	7,1
1/4-1	0,0	0,0	0,0	**12,5**	0,0	0,0	7,1	0,0	0,0	0,0
1/5-2	0,0	0,0	0,0	0,0	**18,2**	**12,5**	0,0	0,0	0,0	0,0
1/6-1	0,0	0,0	0,0	0,0	0,0	0,0	**11,8**	8,3	**10,5**	0,0
1/8-6	7,7	0,0	**14,3**	**11,8**	**11,8**	**12,5**	**11,8**	**11,8**	**10,0**	7,7
1/8-11	**16,7**	**14,3**	**12,5**	9,1	9,1	9,1	9,1	9,1	6,3	5,6
1/8-13	5,9	6,3	5,9	6,7	6,3	5,6	5,6	**10,5**	0,0	0,0
2/1-3	0,0	0,0	10,0	**13,3**	7,4	0,0	9,1	8,7	9,1	3,7
2/1-6	0,0	0,0	0,0	3,4	3,0	7,4	3,7	4,2	9,7	**12,0**
2/1-7	0,0	**33,3**	**22,2**	**10,0**	9,1	**13,3**	**14,3**	0,0	8,3	0,0
2/1-8	0,0	0,0	0,0	0,0	7,7	**11,8**	**11,1**	**13,3**	**11,1**	0,0
2/1-9	0,0	0,0	0,0	0,0	**11,8**	5,9	5,9	0,0	5,3	5,9
2/1-11	0,0	**11,1**	5,6	0,0	**10,0**	**12,0**	**13,3**	6,7	**13,5**	6,3
2/1-12	0,0	**14,3**	**12,5**	**14,3**	**16,7**	**17,4**	4,8	**11,1**	9,4	0,0
2/1-13	7,7	7,1	7,7	**18,2**	**14,3**	**17,6**	8,3	10,0	5,9	5,6
2/1-14	0,0	8,7	**10,0**	**11,8**	6,3	**12,5**	4,5	6,3	5,6	9,1
2/1-17	**10,0**	8,3	**11,8**	**20,0**	**11,1**	**9,4**	9,1	**14,3**	**11,5**	**14,3**

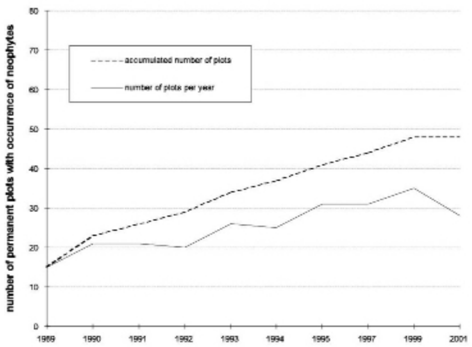

Fig. 2: Number of permanent plots in which neophytes occurred, shown as number per single year, and as accumulated number since 1989 (total number: 80 permanent plots).

out of this plot). In none of the 80 PPs was there a a monotonous increase or a monotonous decrease in the share that neophytes had of the total species number.

65 plots were free of neophytes in the beginning (1989). This number showed a slight trend of decrease to circa 50 over 13 years. Vice versa, the number of plots in which neophytic species occurred increased slightly (Fig. 2). Due to fluctuations, 20 of those 48 PPs in which neophytes occurred in some years were free of neophytes again at the end (2001). 32 out of 80 PPs, i. e. 40 %, remained free of neophytic plants over the whole period of investigation.

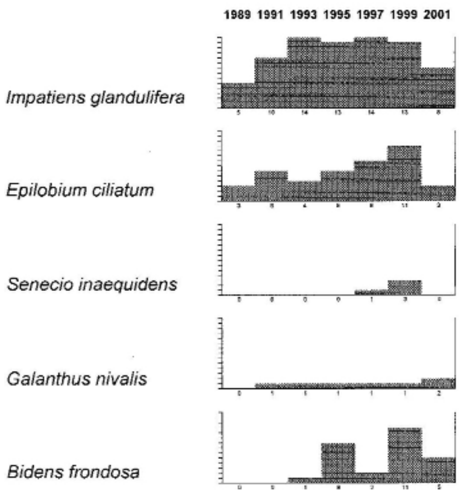

Fig. 3: Number of plots occupied by selected neophytes per year.

These strong fluctuations are elucidated by data on particular non-indigenous species in figure 3. Concerning the number of plots occupied by *Impatiens glandulifera*, an increase in the first half of the period of investigation is clearly detectable, but is followed by a pronounced decrease in the period from 1997 to 2001. *Epilobium ciliatum* is another species with strong fluctuations, reaching a maximum in 1999, then dropping to its initial level. *Senecio inaequidens* appeared in the last years in four different plots, but vanished again from these plots. The species mentioned so far do not show clear steady trends of increase; and there are only very few neophytes which do increase slowly in a more or less steady manner during 13 years, such as *Impatiens parviflora* and *Galanthus nivalis*, both occuring in forest communities. An example of a seemingly stronger increase, but again with pronounced fluctuation, is *Bidens frondosa*, growing mainly in reeds. Obviously, annual species show particularly strong fluctuations in numbers of occupied PPs.

5. Fluctuations in stands of *Impatiens glandulifera*

The tallest annual species of the German flora, *Impatiens glandulifera*, is a concise example of fluctuations in floodplain vegetation. This is shown using data from one PP which has been investigated annually (PP 2/1-11, Fig. 4). It is situated about 100 m away from the river bank in a reed

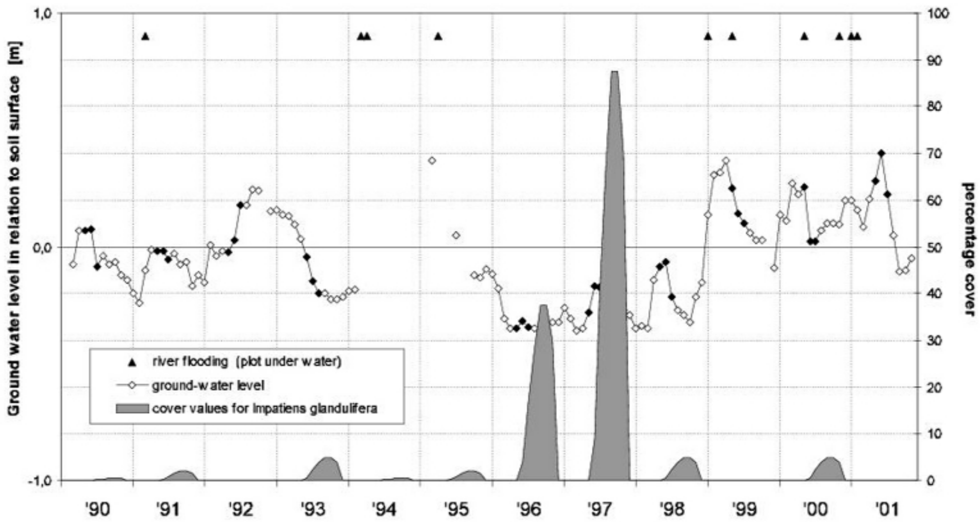

Fig. 4: Ground-water levels and cover of *Impatiens glandulifera* in permanent plot 2/1-11. Cover values are based on relevés once a year, have been transformed according to Fischer (1982), and are visualised schematically, in order to illustrate the seasonal development of the species from April to September. The line of ground-water course shows a gliding mean (for 3 values); data points for March, April and May are in black. Vertical lines meet november values, thus demarcating "hydrologic years".

which was dominated by *Glyceria maxima* in the beginning (relevé no. 4 in Kasperek 1998: 154). In most years, the soil surface is under water for several month in winter. During 13 years, there were highly dynamic developments with distinctive interannual variation in relation to timing and duration of flooding: e. g. in 1996/ 1997 no river floods occurred, there were low amounts of precipitation and low ground-water tables; on the other hand, in 1999/2000 there were several river floodings and high ground-water levels throughout the whole summer.

Of all species in this plot, *Impatiens glandulifera* is the one with the most pronounced fluctuations. In extreme cases, cover/ abundance-values changed from "+" to "5" and back from one year to the next. Similar developments of this species have also been recorded in other PPs with comparable hydrologic conditions. It was not unusual that *I. glandulifera* vanished from plots in which it had previously gained high cover/abundance values.

Water levels in March and April (see grey data points in Fig. 4) showed themselves to be a critical factor determining the "invasion" of *Impatiens glandulifera* in reeds. Germination of the species takes place in March and April (Koenies & Glavac 1979, Beerling & Perrins 1993); ground-water data and observations from the Rur Valley confirm that in this stage the species is particularly sensitive to flooding. Especially the dry years 1996/1997 favoured mass germination of *I. glandulifera*, so that it could temporarily dominate the plot - but this "invasion" was reversible, and in the following years, a typical reed community developed again (Kunze & Kasperek 2001).

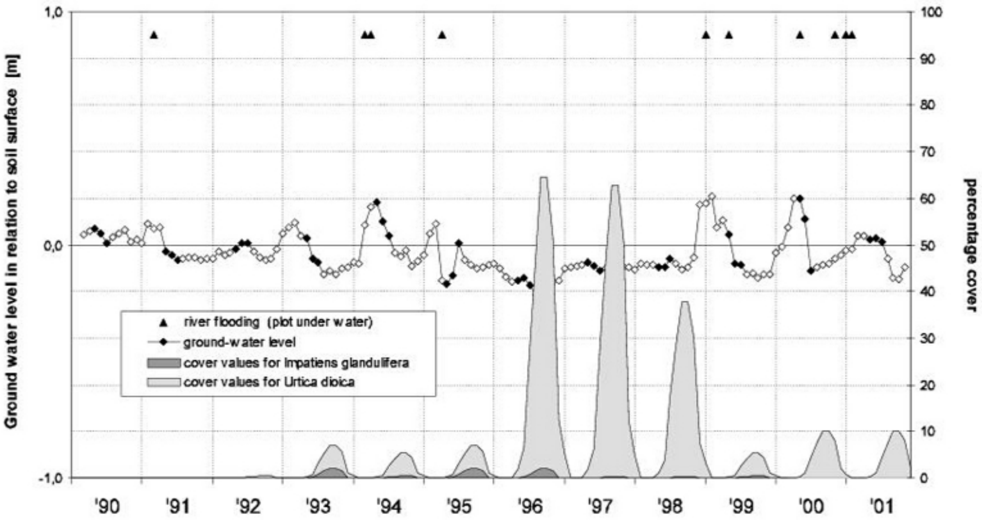

Fig. 5: Ground-water levels and cover of two species in permanent plot 2/1-8.
Cover values are based on relevés once a year, have been transformed according to Fischer (1982), and are visualised schematically, in order to illustrate the seasonal development of the species from April to September. The line of ground-water course shows a gliding mean (for 3 values); data points for March, April and May are in black. Vertical lines meet november values, thus demarcating "hydrologic years".

In some other PPs, which also were situated in reed stands with *Glyceria maxima*, *Impatiens glandulifera* was not able to become a successful "invader", although, at least temporarily, site conditions seemed to be favorable for this neophyte. In these cases, the indigenous species *Urtica dioica* played a similar, antagonistic role as an "invader", reaching high cover-values in drier years (Fig. 5). Between these two species, which are important components of ruderal communities in the study area, competition in the contact zone with reeds seems to be influenced by the amplitude of water levels which is less pronounced in PP 2/1-8, with winter inundation being not higher than 20 cm; this might favour *Urtica dioica* because in this species shoot growth starts early in the year, and a considerable proportion of the above-ground biomass overwinters in some years (Srutek & Teckelmann 1998). Variation in input of diaspores from surrounding vegetation, or late frost could be other factors influencing competition between the two species.

However, with regard to the reed communities under study, the effect of these "invaders" (be they neophytic or indigenous) is reversible: *Urtica dioica* decreased again in wetter years, like *Impatiens glandulifera* in the last example. This type of vegetation dynamics could be termed "temporary invasion"; but the term "invasion" should not be used too extensively, because it is somehow ambiguous, and its use is doubtful in a scientific context because of its judgemental undertone which is, at least subliminally, negative (Kasperek 1999).

6. General Discussion

The study area in the Rur Valley is a typical example of a German floodplain with remnants of natural vegetation and intense anthropogenic changes in other parts. A combination of natural and anthropogenic disturbances is favourable for the occurrence of numerous neophytes in this area. The surface of 80 PPs is only a very small sample of the wetlands under study; nevertheless, out of the twenty most common neophytes which have been recorded within these wetlands (see floristic inventory in Kasperek 1998), 15 occurred inside the PPs. Thus, dynamics of neophytes in the 80 PPs of this study can be taken as a sufficient approximation for the evaluation of processes at landscape level.

The vegetation of numerous PPs in the Rur Valley presented in this paper showed contrasting developments with regard to neophytes. A long-term increase of neophytes at a landscape-wide scale seems to be rather slow, especially when compared to the pronounced short-term changes (non-directional fluctuations) that occur from year to year. The number of plots which were occupied by neophytes has increased slowly over 13 years, but there were partial set-backs. Data on particular species revealed strong fluctuations in the number of plots occupied. Those few neophytic species which are increasing at all do not expand dramatically. Although there are many studies on the spread of single species over large areas (e. g. Conolly 1977, Schulz 1984, Jäger 1986, Pyšek 1991, Radkowitsch 1997), comparable results on the dynamics of neophytes in their entirety within a small research area are lacking. The present study using PPs indicates that there are no dramatic area-wide effects resulting from non-indigenous species in the Rur Valley.

The fact that spread is rather slow or even obscure could mean that in the research area most neophytes have already "found their place", i. e. that they have already reached most of the sites suitable for them. Especially ruderal species with wind-dispersed seeds can be expected to occupy suitable sites within a short time once they have reached the given geographical region via long distance dispersal. On the other hand, for species which are dispersed by water, it might take much longer to colonize the whole floodplain: *Impatiens glandulifera* could be found along the banks of the River Rur almost without any gap for many years (Kasperek 1999), but many suitable sites far away from the river banks were reached by this species only in recent years because lateral dispersal to the edges of the floodplain is slow.

For some species, a further increase can be predicted when considering their biology and their behavior in other parts of Europe. *Fallopia japonica*, for example, has proven to be very persistent once a place has been colonized by the species due to its strong rhizomes and vigorous shoots, and it shows a steady but slow increase along some rivers in Europe (Conolly 1977, Adolphi 1995: 148). Thus, a further spread of Japanese Knotweed can be expected in the floodplain under study, as well.

As shown by the example of *Impatiens glandulifera*, certain neophytic species tend to dominate communities only temporarily: a sudden colonization may be followed by a sharp decrease. Such cases of strong interannual fluctuations with temporary colonization could lead to false conclusions with regard to nature conservation. As stated already by Lohmeyer & Sukopp (1992: 52), the apprehension that *I. glandulifera* could outcompete all other species in certain habitats is due to an illusion

Table 3: Associated floristic diversity in dense stands of four species that tend to dominate communities in the Rur Valley, calculated from all vegetation relevés with dense stands (i.e. cover value of the respective species 75-100 %) published in Kasperek 1998.

Dominant species	Species number per relevé min.	mean	max.	Std. deviation	No. of relevés
Impatiens glandulifera	5	9,8	15	3,7	8
Urtica dioica	6	12,9	24	5,5	21
Glyceria maxima	2	8,5	18	6,0	8
Phalaris arundinacea	1	5,5	9	2,8	6

based on years with large quantities of this neophyte. In fact, there is no evidence for serious negative effects of *I. glandulifera* on native flora and vegetation in the Rur Valley. Numerous vegetation relevés in different vegetation types (Kasperek 1998) show that species richness is not considerably reduced in comparison to stands under the same conditions without this neophyte. In most cases, the indigenous species *Urtica dioica* or *Phalaris arundinacea* would become dominant in the absence of *Impatiens glandulifera*. Cover values of *I. glandulifera* do not have to be higher than 60 or 70 % at flowering time to evoke the delusion of a species-poor stand for observers who do not go inside to do a relevé. But, in fact, the floristic diversity associated with dense stands of this neophyte is in the same range as the diversity associated with dense stands of the indigenous species mentioned (Tab. 3): even if *I. glandulifera* reaches the maximum scale value "5" (meaning that it covers 75-100 % of the studied plot), there are, as a mean value, about ten other species to be found in this relevé.

Some of the indigenous species, in fact, are able to form monospecific stands in the study area (especially *Glyceria maxima* and, more rarely, *Phalaris arundinacea*) – but this does not hold true for *I. glandulifera* in the Rur Valley and other parts of Germany. Many reports of species-poor stands of this neophyte – even in scientific literature – are only based on poor data and seem to lack exact examination of communities . There are no phytosociological relevés with *I. glandulifera* available in scientific literature which have species numbers of only 1 or 2; and in the above-mentioned case of a three-species stand the plot was dominated by *Glyceria maxima*.

It is not only annual species with strong fluctuations that tend to be overestimated in view of their persistence and their effects on communities and ecosystems. An example from the group of perennial neophytes is *Solidago canadensis*. Although it does form dense species-poor stands especially on fallow land and in abandoned gardens (Voser-Huber 1983, Hartmann et al. 1994), long-term observations in the Rhineland have shown that these stands last only a few decades or even shorter, and then are overcome by species of later successional stages (Adolphi 1995: 168). Thus, the occurrence of *Solidago canadensis* may lead to a retarded course of succession, if at all, but available data does not justify apprehensions about serious ecological consequences for flora and vegetation. In the Rhineland, these are not substantially different from consequences of the spread of some indigenous plants, such as *Calamagrostis epigejos*.

In view of the observations on neophytes in permanent plots in this study, there is no reason to expect special challenges for nature conservation resulting from neophytes in the Rur Valley – at least as long as faunistic aspects are not taken into account. Neophytes behave more or less like indigenous species, and vice versa.

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