Chapter 14

Long-Term Monitoring in Rivers of South Germany Since the 1970s – Macrophytes as Indicators for the Assessment of Water Quality and Its Implications for the Conservation of Rivers

Peter Poschlod, Martijn Kos, Stephanie Roauer, Andreas Seemann, Oliver Wiesmann, Georg H. Zeltner, and Alexander Kohler

Abstract Since 1970 long-term ecological research has been established in several running waters in Bavaria. An emphasis was laid on the record of the macrophytic vegetation. In this chapter we present long-term records from three rivers. The Moosach is situated in the calcareous-rich gravel plains north of Munich. The two soft-water rivers, the Pfreimd and the adjacent Naab, run out from the siliceous bedrock of the 'Upper Palatinate Forest.' Vegetation changes could be interpreted according to water quality changes and confirmed the suitability of macrophytes as water quality indicators, which recently obtained its official acceptance in the new Water Frame Directive of the European Union. The results show that there is a unification of the vegetation losing the extremes especially in the oligotrophic part. However, the regeneration potential of macrophytes is mainly low although in many species it is not yet understood. It is therefore concluded to lay an emphasis on the protection of still oligotrophic sections of a river to maintain the total species pool.

Keywords Long-term monitoring · Running waters · Macrophytes · Southern Germany · Hard water · Soft water

14.1 Introduction

Since a long time running waters were subjected to an increasing influence of chemical and organic load caused by sewage from agriculture, industry, and households with a peak during the 1960s and 1970s. Therefore, long-term ecological studies in running waters to assess water quality have a long tradition since the introduction of the basic principles of the saproby system (*Saprobiensystem*) by Kolkwitz and Marsson (1902, 1908, 1909; see also Kolkwitz, 1950) and the system on the so-called Güte-Klassen, meaning classes of water quality ranking from I to IV by Liebmann (1959, 1960, 1962) later taken over into official DIN standards (DIN 38410 Part 1, 1987; DIN 38410 Part 2, 1990). In these water quality assessment systems macrozoobenthic organisms played the major role as indicators. Kohler established in the 1970s another system based on experiments on the indicator quality of macrophytes that is emerged and submerged aquatic plants (Kohler, Zeltner, & Busse, 1972; Kohler, 1976). His classification system included three classes. At the same time he started the monitoring of rivers in the southern part of Germany, especially in Bavaria in regions of different geology. In this context he studied the river Moosach situated in the largely paludified calcareous gravel plain north of Munich (Kohler, Vollrath, & Beisl, 1971); the river Friedberger Au in the calcareous gravel plain near Augsburg (Kohler, Brinkmeier, & Vollrath, 1974); and the river Pfreimd in the siliceous bedrock of the Upper Palatinate Forest (Kohler & Zeltner, 1974). At this time macrophytes were not incorporated in the abovementioned DIN standards despite the fact that the high value of macrophytes as bioindicators was widely acknowledged. However, with the implementation of the European Water Frame Directive to maintain running waters in good conditions macrophytes were now also 'officially' acknowledged as suitable indicators. Recently, the applicability of macrophytes as

P. Poschlod (✉)
Institute of Botany, University Regensburg, D-93040 Regensburg, Germany
e-mail: peter.poschlod@biologie.uni-regensburg.de

F. Müller et al. (eds.), *Long-Term Ecological Research*,
DOI 10.1007/978-90-481-8782-9_14,

indicators to assess water quality was confirmed again by Schaumburg et al. (2004, 2005) and Bayerisches Landesamt für Wasserwirtschaft (2005).

In this chapter, we present the monitoring scheme and results from the long-term monitoring of two river systems over 30–35 years to (1) show changes in macrophyte abundance and species composition and (2) its relation to environmental changes.

14.2 Study Area

The two systems studied are situated in two different geologic regions representing two extremes, the calcareous-rich river (Moosach) and the soft-water river (Pfreimd; Fig. 14.1).

The Moosach is a tributary of the Isar and runs through the largely paludified gravel plain in the north of Munich parallel to the southern edge of the tertiary hilly land. It drains the large peatlands ‘Freisinger Moos’ and ‘Dachauer Moos’ and crosses afterwards the unpaludified part of the gravel plain. However, throughout its whole length the Moosach is additionally fed by calcareous-rich groundwater. Therefore, it is characterized by the occurrence of indicators for oligotrophic calcareous-rich groundwater such as *Juncus subnodulosus*, *Potamogeton coloratus,* and *Groenlandia densa* (Fig. 14.2). The river Moosach

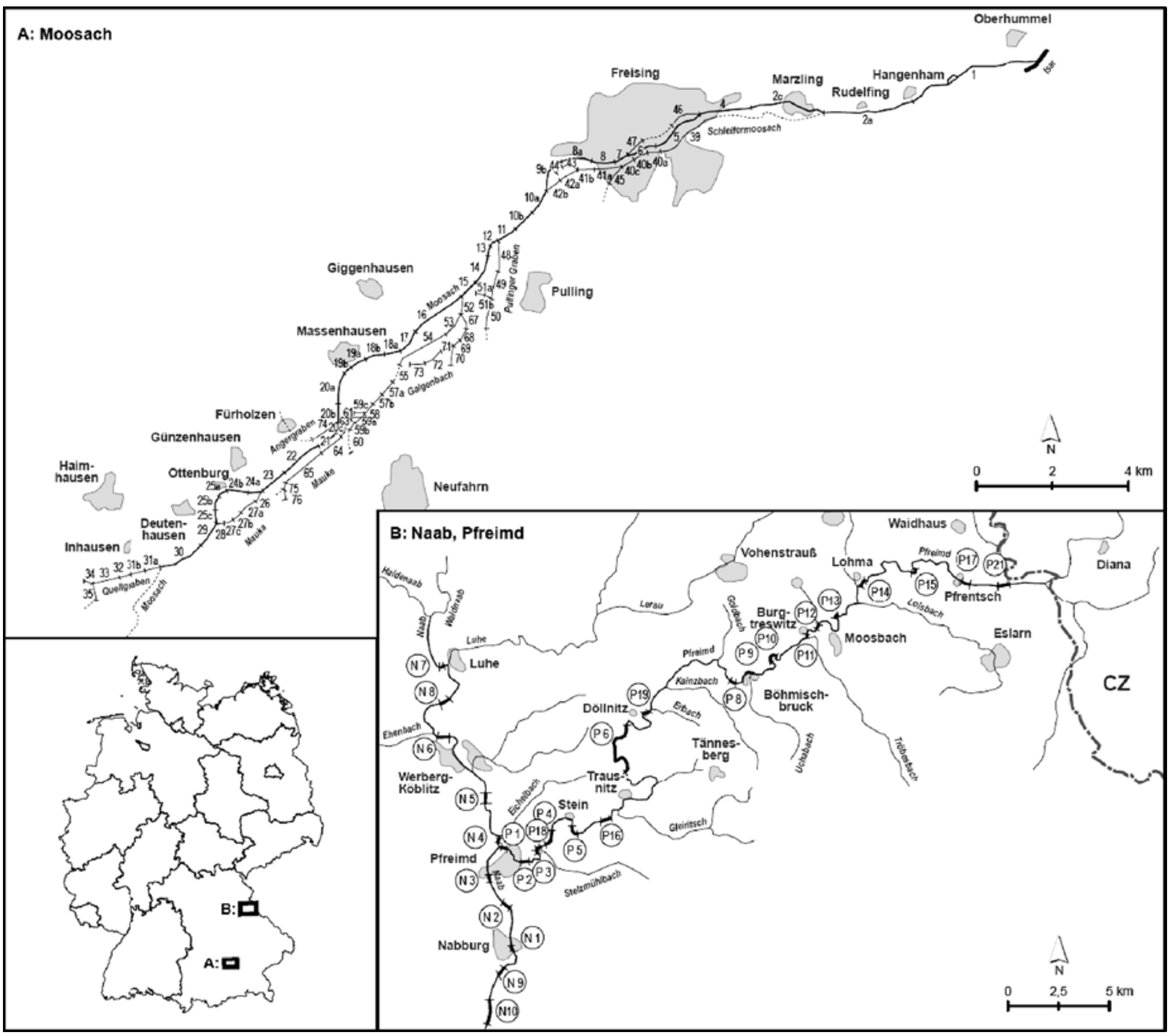

Fig. 14.1 Situation of the studied rivers and their division into monitoring sections

<table>
<tr><th>Species group</th><th>Zone A</th><th>Zone B</th><th>Zone C</th><th>Zone D</th></tr>
<tr><td colspan="5">Calcareous rich water rivers</td></tr>
<tr><td>I</td><td>Potamogeton coloratus, Chara hispida, Juncus subnodulosus, Mentha aquatica</td><td>→</td><td></td><td></td></tr>
<tr><td>II</td><td></td><td>←</td><td>Groenlandia densa, Potamogeton natans, Hippuris vulgaris</td><td></td></tr>
<tr><td>III</td><td></td><td></td><td colspan="2">Callitriche obtusangula, Ranunculus fluitans, Elodea canadensis, Myriophyllum verticillatum, Zannichellia palustris</td></tr>
<tr><td rowspan="2">Indiff. species</td><td colspan="4">Berula erecta, Ranunculus trichophyllus</td></tr>
<tr><td></td><td colspan="3">Agrostis stolonifera, Potamogeton crispus, P. pectinatus, Nasturtium officinale, Veronica anagallis-aquatica</td></tr>
<tr><td colspan="5">Calcareous poor soft water rivers</td></tr>
<tr><td>I</td><td colspan="2">Potamogeton alpinus, Myriophyllum alterniflorum, Ranunculus peltatus</td><td></td><td></td></tr>
<tr><td>II</td><td></td><td></td><td colspan="2">Potamogeton nodosus, P. perfoliatus, Ceratophyllum demersum, Myriophyllum spicatum, Ranunculus penicillatus</td></tr>
<tr><td>Indiff. species</td><td></td><td colspan="3">Hydrocharis morsus-ranae, Potamogeton crispus, Potamogeton natans, Sparganium emersum, Callitriche hamulata, Elodea canadensis, Ranunculus fluitans</td></tr>
</table>

Fig. 14.2 Indicative value of macrophytes of calcareous-rich and calcareous-poor running waters (see Kohler et al., 1971, 1974, 1992; Monschau-Dudenhausen, 1982; Veit & Kohler, 2003; Schaumburg et al., 2005)

is characterized by widths between 2 and 25 m and depths between 0.25 and 1.75 m. Flow velocity is low. Visible depth is relatively high except during floodwater and at the underflow behind Freising. The ground of the river is sandy and stony. Water chemistry measurements during the last monitoring in 2005 (Table 14.1) showed the highest calcium content and the fact that the Moosach was more polluted, especially by phosphate, than the other two rivers. This pollution is due to the localization of the river Moosach in an intensively used agricultural area, in which pasture farming prevails.

The river Naab and the river Pfreimd run partly through the region 'Upper Palatinate Forest' and drain parts of it. The underground of the 'Upper Palatinate Forest' consists of siliceous bedrock.

Table 14.1 Characterization of water chemistry of the studied rivers

	Moosach		Naab			Pfreimd		
Water chemical parameter	1970	2005	1968/1972	1982–1988	2004	1968/1972	1982–1988	2004
pH	7.9	7.0	6.9/6.9–7.5	7.1	7.3	6.9/7.0	7	7.3
Conductivity (μS/cm)	604	530	–	233	280	–	128	170
Ammonium (mg/l)	0.20	n.d.	0.66/0.40–0.92	0.51	n.d.	0.40/0.22	0.11	n.d.
Calcium (mg/l)	115	28	–	–	25	–	–	14
Carbonate (mg/l)	336.6	–	–	–	4.5	–	–	2.7
Nitrate (mg/l)	26.9	26.0	–/8.4–10.0	3.8	11.0	–	2.9	11
Phosphate (mg/l)	0.25	1.10	–/0.31–0.72	0.38	0.44	–	0.10/0.05	0.30

Moosach – 1970 – mean of 8–26 measurements at 14 sites; 2005 – mean of four measurements from June to August 2005 at 14 sites; Naab – 1968 – mean of eight measurements at one site; 1972 – mean of eight measurements at three sites; 1982–1988 – mean of 168 measurements at one site (Kohler et al., 1992); 2004 – mean of measurements in June 2004 at 10 sites; Pfreimd – 1968 and 1972 – mean of eight measurements at one site (Kohler & Zeltner, 1974); 1982–1988 – mean of 168 measurements at one site (Kohler et al., 1992); 2004 – mean of 20 measurements in June 2004 at 20 sites; n.d. = not detectable; – = not measured

Therefore, the rivers are characterized by soft water and by the occurrence of respective indicators such as *Callitriche hamulata*, *Myriophyllum alterniflorum*, *Ranunculus peltatus,* and *Ranunculus penicillatus* (Fig. 14.2).

The river Naab is characterized by widths between 20 and 40 m and depths between 0.25 and 1.5 m. Flow velocity and visible depth are low. The ground of the river is sandy and stony and that of the river-banks muddy. Water chemistry was characterized by relatively high calcium contents affected by confluents from the Jurassic Franconian Alb and low pollution (Table 14.1).

The river Pfreimd is characterized by widths between 5 and 25 m and depths between 0.2 and 1.25 m. As in the river Naab, flow velocity of the river Pfreimd is low as well, but with frequent turbulences. In contrast to the river Naab, visible depth is high. The bottom of the river is stony and sandy, except for the upper reaches, which is muddy. Water chemistry showed the lowest degree of pollution within the studied rivers.

14.3 Monitoring Scheme and Methods

The monitoring scheme in all rivers followed the design described by Kohler (1978). Rivers were divided into sections. The lengths of the sections were defined by prominent and re-detectable features along the river such as houses, bridges, or larger trees. The river Moosach was mapped completely, whereas in the rivers Naab and Pfreimd only the macrophytes of selected sections were recorded. The monitoring in the river Moosach started in 1970 and was repeated in 1979, 1985, 1989, 1992, 1996, and 2005. In the rivers Naab and Pfreimd, it started in 1972 and was carried out again in 1980, 1988, and 2004.

The monitoring program included the mapping of the complete aquatic vegetation, i.e., all plants which had their roots below the water surface between June and August. The abundance of each macrophyte was estimated according to a five-step scale where 1 = very rare, 2 = rare, 3 = common, 4 = frequent, 5 = very frequent. Kohler (1978) explained the procedure in detail, which meanwhile is the standard method for the mapping of rivers according to the European Water Framework Directive (WRRL, 2000).

Water chemical parameters were either measured with an electronic instrument (WTW Multi 340i, pH, and conductivity) or an ion chromatograph was used (Dionex DX 120, calcium, ammonium, carbonate, nitrate, phosphate a.o.).

In this study, data were analyzed with respect to the number of occurrences of certain species with a strong indicator value for water quality. Four classes or zones, respectively, were differentiated following Schneider (2000) and Schorer, Schneider, and Melzer (2000): A = cleanest, unpolluted spring-fed brooks; B = low pollution; C = moderate pollution; D = high pollution. Indicator species were taken from Kohler et al. (1971, 1974) for the river Moosach (Veit & Kohler, 2003) and from Kohler, Lange, and Zeltner (1992) for the rivers Naab and Pfreimd (Fig. 14.2).

A detrended correspondence analysis (DCA) was carried out on the raw vegetation data (PC-ORD 4.0; McCune & Mefford, 1999) to assess the overall development. Sections and species abundances were ordinated, and species were correlated with this ordination to present a bi-plot. For all indicator species we calculated three indices for the first and last year of monitoring, which were the ‘relative range length (L_r)’ and the quantitative indices ‘MMT’ and ‘MMO’ (Kohler & Janauer, 1995).

The relative range length shows the occurrence of a species related to the total length of all mapped sections and is calculated according to the following formula:

$$L_r[\%] = \frac{\sum_{k=1}^{n} L_k}{L_{ges}} \cdot 100$$

where L_r = relative range length, L_k = length of section k, L_{ges} = total length of all mapped sections, k = running index, n = number of sections where the respective species is occurring.

The quantitative indices ‘mean mass total (MMT)’ and ‘mean mass occurrence (MMO)’ quote the dominance of a species related to the total length (MMT) or only to the sections where the species is occurring (MMO). The comparison of both values shows that in case of similar values of MMO and MMT a species is distributed over all monitored sections; in case of high values a species is very frequent and dominant; and in case of high MMO and low MMT values a species is only locally very frequent and dominant. MMT and MMO are calculated according to the following formulae:

$$\mathrm{MMT} = \sqrt[3]{\frac{\sum_{i=1}^{n} M_i^3 \cdot L_i}{L}}$$

$$\mathrm{MMO} = \sqrt[3]{\frac{\sum_{i=x}^{n} M_i^3 \cdot L_i}{\sum_{i=x}^{n} L_i}}$$

where M_i = dominance/frequency of a species in section i, L_i = length of section i, where the species is occurring, L = total length of all sections.

14.4 Results

The water analysis showed changes in all rivers within the long-term study, at least in some chemical parameters. In the river Moosach, calcium and ammonium decreased but phosphate increased. Pollution in the river Naab did not change except for ammonium which decreased and nitrate which decreased from 1972 to 1982/1988 but increased to the former level in 2004. In contrast to these rivers, both nitrate and phosphate increased strongly in the river Pfreimd.

Multivariate analysis of vegetation data shows continuous vegetation changes over time (Figs. 14.3, 14.4, and 14.5).

In the river Moosach, only the first and the last records were compared. Changes are correlated positively with *Callitriche obtusangula* and *Mentha aquatica*. These two species were increasing in contrast to *P. coloratus* and *J. subnodulosus* (Fig. 14.3), which is also shown by the comparison of the 'relative range length' (Table 14.2). This analysis clearly shows a decrease in indicators that point at unpolluted conditions or at low pollution. Even indicators for moderate pollution decline. With the exception of *M. aquatica*, only indicators for high-polluted areas increased such as *C. obtusangula* and *Zannichellia palustris*. Furthermore, a species group which indicates silting processes showed the largest increase of all (Tables 14.2 and 14.3). To this group belong typical reed plants (*Phalaris arundinacea*, *Phragmites australis*, *Iris pseudacorus*) and annual mud plants (*Veronica anagallis-aquatica*, *V. beccabunga*), which promote sedimentation. Some species of this group have established during the monitoring period only.

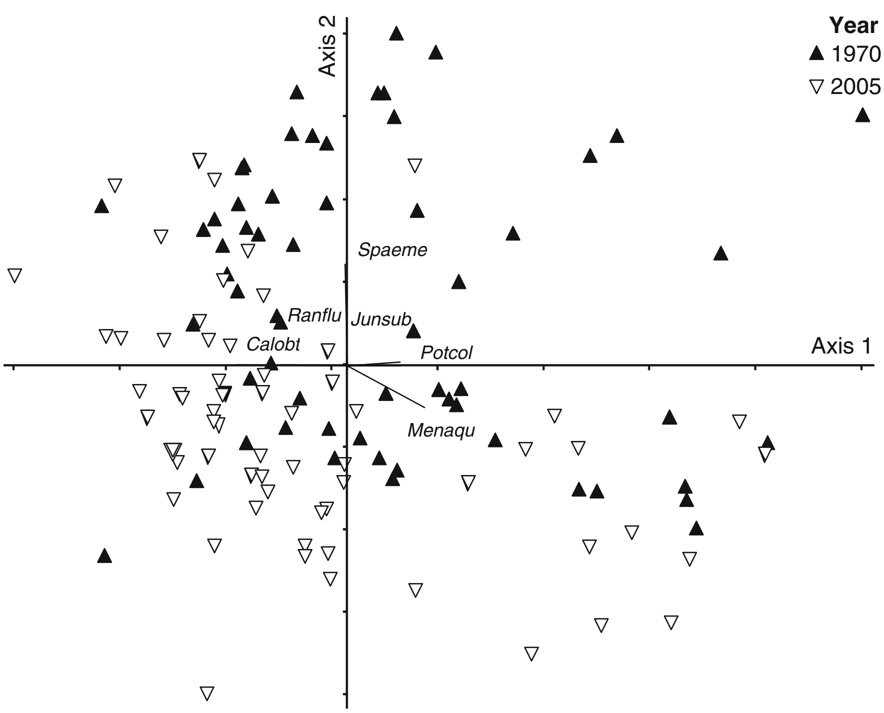

Fig. 14.3 DCA of vegetation data (abundance) of the river Moosach in 1970 and 2005. r^2-value = 0.36. Calobt – *C. obtusangula*, Junsub – *J. subnodulosus*, Menaqu – *M. aquatica*, Potcol – *P. coloratus*, Ranflu – *Ranunculus fluitans*, Spaeme – *Sparganium emersum et erectum*

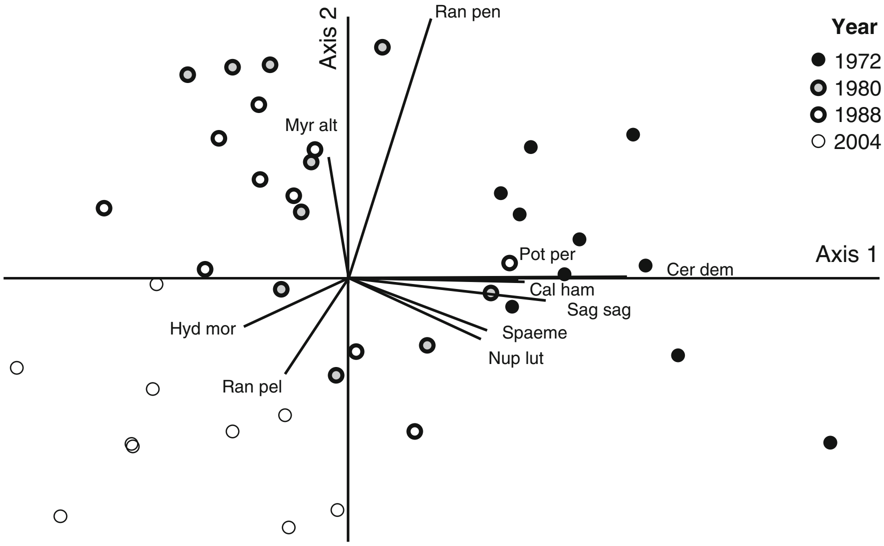

Fig. 14.4 DCA of vegetation data (abundance) of the river Naab from 1972 to 2004. r^2-value = 0.25. Calham – *C. hamulata*, Cerdem – *Ceratophyllum demersum*, Hydmor – *H. morsus-ranae*, Myralt – *M. alterniflorum*, Nuplut – *Nuphar lutea*, Potper – *Potamogeton perfoliatus*, Ranpel – *R. peltatus*, Ranpen – *R. penicillatus*, Sagsag – *Sagittaria sagittifolia*, Spaeme – *Sparganium emersum*

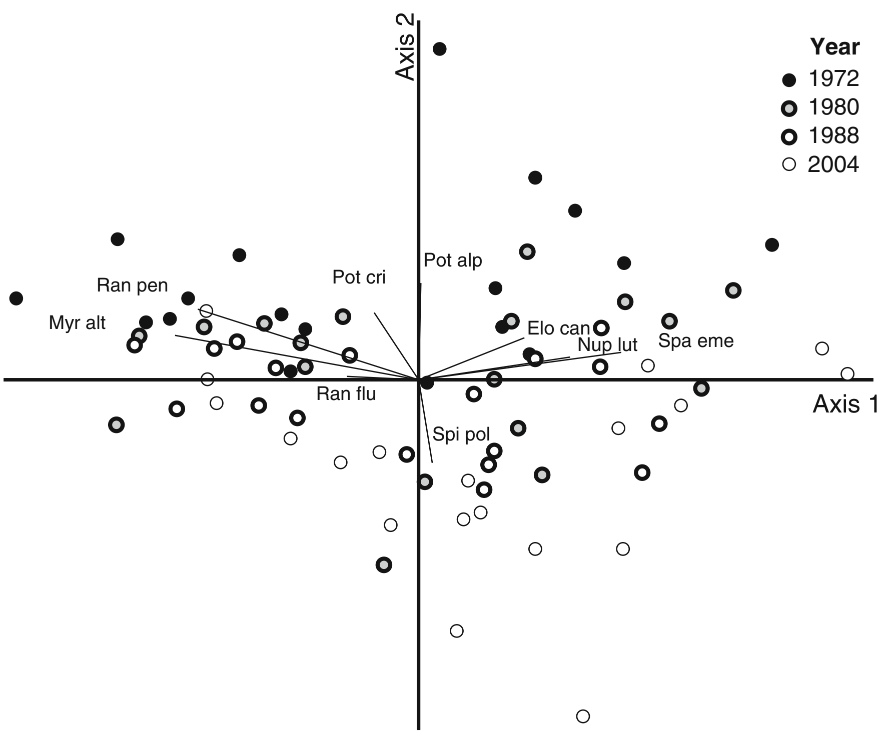

Fig. 14.5 DCA of vegetation data (abundance) of the river Pfreimd from 1972 to 2004. r^2-value = 0.15. Elocan – *Elodea canadensis*, Myralt – *M. alterniflorum*, Nuplut – *Nuphar lutea*, Potalp – *P. alpinus*, Potcri – *Potamogeton crispus*, Ranflu – *Ranunculus fluitans*, Ranpen – *R. penicillatus*, Spipol – *Spirodela polyrhiza*, Spaeme – *Sparganium emersum*

Table 14.2 'Relative range length' (L_r) of water quality (trophy) indicators and their changes in the Moosach from 1970 to 2005

Species	Zone	L_r 1970	L_r 2005	L_r gain/loss (%)
Chara hispida	A	1.47	1.47	0.0
J. subnodulosus	A	4.78	3.10	−35.1
P. coloratus	A	3.10	3.10	0.0
M. aquatica	AB	33.91	70.87	109.0
G. densa	C	16.35	0.00	Extinct
Potamogeton natans	C	11.62	5.05	−56.5
Hippuris vulgaris	C	14.35	8.31	−42.1
Elodea canadensis	CD	47.21	57.26	21.3
M. verticillatum	CD	25.45	4.10	−83.9
C. obtusangula	CD	54.84	83.12	51.6
Ranunculus fluitans	CD	59.25	71.50	20.7
Z. palustris	CD	36.59	61.04	66.8
Agrostis stolonifera	Indifferent	42.01	12.93	−69.2
Potamogeton crispus	Indifferent	20.19	27.23	34.9
Potamogeton pectinatus	Indifferent	5.31	13.99	163.5
Berula erecta	Indifferent	62.09	91.96	48.1
Nasturtium officinale	Indifferent	54.15	33.54	−38.1
Ranunculus trichophyllus	Indifferent	48.42	19.19	−60.4
V. anagallis-aquatica	Indifferent, t	57.31	91.54	59.7
I. pseudacorus	t	0.00	22.40	New
P. arundinaceae	t	44.06	80.76	83.3
P. australis	t	3.63	57.05	1471.1
Typha latifolia	t	0.53	17.88	3273.6
V. beccabunga	t	0.00	28.13	New

Zone A to D – see text; t – indicators for terrestrialization and mud banks; new – species established only during the monitoring period

Table 14.3 Mean mass total (MMT) and mean mass occurrence (MMO) of water quality (trophy) indicators and their changes in the Moosach from 1970 to 2005

		1970		2005	
Species	Zone	MMT	MMO	MMT	MMO
Chara hispida	A	0.74	3.00	0.74	3.00
J. subnodulosus	A	1.58	4.36	1.05	2.90
P. coloratus	A	0.75	2.37	1.32	4.19
M. aquatica	AB	1.96	2.64	2.83	3.81
G. densa	C	1.23	2.25	0.00	0.00
Potamogeton natans	C	1.63	3.33	1.03	2.11
Hippuris vulgaris	C	1.70	3.24	1.26	2.40
Elodea canadensis	CD	1.57	1.93	2.58	3.16
M. verticillatum	CD	0.92	1.46	0.51	0.81
C. obtusangula	CD	3.21	3.77	4.19	4.92
Ranunculus fluitans	CD	3.57	4.09	3.45	3.95
Z. palustris	CD	1.92	2.54	2.15	2.84
Agrostis stolonifera	Indifferent	1.59	2.12	1.07	1.43
Potamogeton crispus	Indifferent	1.28	2.19	1.47	2.51
Potamogeton pectinatus	Indifferent	1.56	4.14	1.88	4.99
Berula erecta	Indifferent	3.58	4.04	4.16	4.70
Nasturtium officinale	Indifferent	1.79	2.11	1.70	2.00
Ranunculus trichophyllus	Indifferent	1.86	2.37	0.90	1.15
V. anagallis-aquatica	Indifferent, t	2.15	2.49	2.75	3.19
I. pseudacorus	t	0.00	–	1.04	–
P. arundinacea	t	1.88	2.35	2.32	2.90
P. australis	t	1.02	2.14	2.19	4.61
Typha latifolia	t	0.17	1.00	0.88	5.05
V. beccabunga	t	0.00	–	1.09	–

Zone A to D – see text; t – indicators for terrestrialization and mud banks

In the rivers Naab and Pfreimd, multivariate analyses showed a general trend correlated with a decrease of most species during the observation period (Figs. 14.4 and 14.5). Exceptions in the river Naab were *R. peltatus* and *Hydrocharis morsus-ranae* (Tables 14.4 and 14.5). *R. peltatus* was first recorded in 1978 and increased strongly until 2004. *H. morsus-ranae* appeared only in 2004, but already in half of the recorded sections. In the river Pfreimd, all indicator species decreased more or less continuously from 1972 to 2004 (Tables 14.6 and 14.7).

14.5 Discussion

Despite the general trend of water quality improvement in rivers throughout Germany (Länderarbeitsgemeinschaft Wasser, 2002) our study showed that only certain water quality parameters improved whereas other did not, especially in the rivers Moosach and Pfreimd. In all rivers ammonium was not anymore detectable indicating that the pollution by municipal sewages has stopped due to the establishment or improvement of sewage treatment plants during the 1970s and 1980s (Schmid, 2003). In contrast to that, phosphate concentrations in Moosach and Pfreimd have increased during the monitoring period, which is contributed by the more intense application of mineral fertilizer in agriculture.

Table 14.4 'Relative range length' of water quality (trophy) indicators and their changes in the Naab from 1972 to 2004

Species	Zone	L_r 1972	L_r 2004	L_r gain/ loss (%)
P. alpinus	AB	0.00	30.34	New
M. alterniflorum	AB	0.00	2.91	New
R. peltatus	AB	0.00	81.55	New
Potamogeton nodosus	CD	55.83	37.14	−33.5
Potamogeton perfoliatus	CD	36.65	0.00	Extinct
Ceratophyllum demersum	CD	92.72	0.00	Extinct
Lemna gibba	CD	21.12	11.89	−43.7
M. spicatum	CD	100.00	100.00	0.0
R. penicillatus	CD	100.00	41.26	−58.7
Spirodela polyrhiza	CD	25.97	50.00	92.5
H. morsus-ranae	Indifferent	0.00	66.44	New
Potamogeton crispus	Indifferent	27.43	22.33	−18.6
Potamogeton natans	Indifferent	30.10	0.00	Extinct
Sparganium emersum	Indifferent	100.00	97.09	−2.9
C. hamulata	Indifferent	94.31	95.68	1.5
Elodea canadensis	Indifferent	39.81	56.07	40.8
Ranunculus fluitans	Indifferent	0.00	7.28	New

Zone A to D – see text; new – species established only during the monitoring period; extinct – species extinct during the monitoring period

This fact has also triggered the higher nitrate concentrations in the river Pfreimd. In conclusion, water quality remained the same or slightly improved in the river Naab but worsened from nearly oligotrophic to mesotrophic in the river Pfreimd and from mesotrophic to eutrophic in the river Moosach. The number of river sections with unpolluted or low-polluted areas continuously decreased in these two rivers since the start of monitoring. This process is correlated with a decreasing number of oligotraphentic species. By contrast, the formerly high-polluted river Naab shows a significant decrease of eutraphentic species. Numerous species indicating lower pollution have re-established since the first record. Surprisingly, one of these species, *R. peltatus*, has established nearly in all sections. However, the contrary trends observed in the studied river systems support the assumption of a tendency toward unification. Currently, we lack more and more the extremes, not only high-polluted but also unpolluted or low-polluted river sections. The last German-wide overview on water quality in rivers assessed by the application of the saproby index showed this trend of unification as well, especially for

Table 14.5 Mean mass total (MMT) and mean mass occurrence (MMO) of water quality (trophy) indicators and their changes in the Naab from 1972 to 2004

		1972		2004	
Species	Zone	MMT	MMO	MMT	MMO
P. alpinus	AB	0.00	0.00	0.67	1.00
M. alterniflorum	AB	0.00	0.00	0.31	1.00
R. peltatus	AB	0.00	0.00	2.74	2.93
Potamogeton nodosus	CD	2.09	2.54	1.20	1.66
Potamogeton perfoliatus	CD	1.85	2.54	0.00	0.00
Ceratophyllum demersum	CD	1.95	2.00	0.00	0.00
Lemna gibba	CD	1.70	2.86	0.49	1.00
M. spicatum	CD	2.08	2.08	2.71	2.71
R. penicillatus	CD	4.56	4.56	1.36	1.83
Spirodela polyrhiza	CD	1.28	2.00	0.79	1.00
H. morsus-ranae	Indifferent	0.00	0.00	0.84	1.00
Potamogeton crispus	Indifferent	1.10	1.69	1.21	2.00
Potamogeton natans	Indifferent	0.00	0.00	0.00	0.00
Sparganium emersum	Indifferent	3.63	3.63	2.63	2.66
C. hamulata	Indifferent	2.61	2.61	1.12	1.35
Elodea canadensis	Indifferent	1.24	1.69	1.62	1.97
Ranunculus fluitans	Indifferent	0.00	0.00	0.42	1.00

Zone A to D – see text

Table 14.6 'Relative range length' of water quality (trophy) indicators and their changes in the Pfreimd from 1972 to 2004

Species	Zone	L_r 1972	L_r 2004	L_r gain/ loss (%)
P. alpinus	AB	13.31	0.64	−92.2
M. alterniflorum	AB	76.86	54.47	−29.1
R. peltatus	AB	87.42	78.38	−10.3
Potamogeton nodosus	CD	0.00	8.21	New
Lemna gibba	CD	0.00	7.30	New
R. penicillatus	CD	92.01	28.92	−68.6
Spirodela polyrhiza	CD	0.00	11.86	New
Potamogeton crispus	Indifferent	29.11	13.23	−54.6
Sparganium emersum	Indifferent	29.57	65.60	121.8
C. hamulata	Indifferent	94.31	79.93	−15.2
Elodea canadensis	Indifferent	13.31	13.87	4.2
Ranunculus fluitans	Indifferent	9.37	10.95	16.9

Zone A to D – see text; new – species established only during the monitoring period; extinct – species extinct during the monitoring period

Table 14.7 Mean mass total (MMT) and mean mass occurrence (MMO) of water quality (trophy) indicators and their changes in the Pfreimd from 1972 to 2004

		1972		2004	
Species	Zone	MMT	MMO	MMT	MMO
P. alpinus	AB	1.25	2.44	0.18	0.00
M. alterniflorum	AB	2.97	1.39	2.17	1.09
R. peltatus	AB	2.59	2.02	2.18	1.21
Potamogeton nodosum	CD	0.00	0.00	0.87	0.00
Lemna gibba	CD	0.00	0.00	0.42	0.79
R. penicillatus	CD	2.77	1.50	2.23	1.99
Spirodela polyrhiza	CD	0.00	0.00	0.49	0.73
Potamogeton crispus	Indifferent	1.66	1.72	1.02	1.45
Sparganium emersum	Indifferent	2.32	2.97	2.25	2.03
C. hamulata	Indifferent	2.41	2.14	2.17	1.71
Elodea canadensis	Indifferent	1.20	2.37	1.03	1.98
Ranunculus fluitans	Indifferent	0.72	1.47	0.67	0.00

Zone A to D – see text

lowland rivers (Länderarbeitsgemeinschaft Wasser, 2002).

Only single species behave opposite to the general trend of their indicator group such as *M. aquatica* in the river Moosach. This may be due to the fact that the occurrence of aquatic plants is affected by a large number of factors in which intensity and interaction are river specific (Schneider, Krumpholz, & Melzer, 2000). Furthermore, although the indicating value of most species is confirmed by other studies comparing water quality and species occurrence (e.g., Schneider, 2000), it was never validated, e.g., by transplantation experiments except for single species during the 1970s (*P. coloratus*, *G. densa*: Kohler et al., 1972).

Therefore, transplantation experiments of especially these indicator species with a different behavior in calcareous-rich and calcareous-poor waters (Fig. 14.2) are still one of the future tasks to better explain changes in certain species.

Today, the indicator group of oligotrophic waters exhibits the largest proportion of extinct and endangered species in Germany compared to any other habitat or ecosystem (Korneck et al., 1998). More than 80% of the 47 vascular plant species restricted to this habitat are listed in the Red Data Book; 4 are said to be extinct. In our systems, *Potamogeton alpinus, P. coloratus*, and *M. alterniflorum* belong to this group of endangered plants, *P. coloratus* and *Myriophyllum* being strongly endangered (Korneck, Schnittler, & Vollmer, 1996).

For this reason, there is an urgent need to know if these oligotraphentic indicator species are also able to re-establish in the case of local water quality improvements. Here we have the largest gaps of knowledge on aquatic plants. The regeneration potential of macrophytes is only poorly studied. Seed or spore (Characeae) bank and dispersal were only studied in more or less polluted rivers (Nilsson, Gardfjell, & Grelsson, 1991; Trottmann & Poschlod in Bonn & Poschlod 1998; Cellot, Mouillot, & Henry, 1998; Boedeltje, Bakker, & TerHeerdt, 2003; Boedeltje, Bakker, Bekker, & VanGroenendael, 2003). The *Chara* species have a high regeneration potential due to a long-term persistent oospore bank. In contrast, macrophytes like *Potamogeton* species seem to have a low regeneration potential taking into account their seed bank persistence which is either transient or short-term persistent (Thompson, Bakker, & Bekker, 1997). Concerning the above-mentioned endangered species no data are available except for *P. coloratus*. Despite the fact that this macrophyte often forms no seeds at all, a small seed bank could be found but in the vicinity of actual stands only (Trottmann and Poschlod, unpublished data). Therefore, it is not surprising that the re-colonization of macrophytes by vegetative propagules, e.g., by fragments, is considerably more relevant than by generative propagules (Capers, 2003). If we assume a transient or a short-term persistent seed bank for the above-mentioned strongly endangered species, at least a few sites of this species have to persist to assure its long-term viability in a river system. Probably this is the case with nearly all macrophytes. Therefore, the protection of oligotrophic conditions including the characteristic species pool should be a main issue in river management strategies to maintain the overall biodiversity for the future. In the case of the presented river systems the areas which should be protected are well outlined. On the one hand two valuable groundwater-fed ditches (Pullinger Graben, Mauke) feed the Moosach (Würzbach, Kohler, & Zeltner, 1997). On the other hand there is an area worth protecting in the upper reaches of the river Pfreimd just downstream the source. That spreading or re-colonization of a species even throughout a whole river system can occur fast is shown by the example of *R. peltatus* in the river Naab (Tables 14.4 and 14.5).

Although no individual of *R. peltatus* was found in 1972, this species had spread out to nearly all studied sections until 2004. For this reason, the study of life history of all indicator species with an emphasis on their regeneration potential is a further important task for the future with the objective of better understanding ecological changes in rivers systems.

Acknowledgments The authors thank all people and institutions who supported and contributed to the studies since the 1970s. In the most recent survey of the rivers Naab and Pfreimd, Julia Engels and Sabine Hartl collected distribution data. Uwe Veit has kindly commented an earlier draft of this chapter. An anonymous referee gave valuable comments that improved the chapter considerably. Sabine Fischer digitalized Fig. 14.1.

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