First publ. in: Aquatic Botany 35 (1989), 1, S. 5-26

'DIE-BACK' OF REEDS IN EUROPE — A CRITICAL REVIEW OF LITERATURE

WOLFGANG OSTENDORP

Limnologisches Institut, Universität Konstanz, Postfach 5560, D-7750 Konstanz (F.R.G.)

ABSTRACT

Ostendorp, W., 1989. 'Die-back' of reeds in Europe — a critical review of literature. *Aquat. Bot.*, 35: 5-26.

Reed decline phenomena have been detected in more than 35 lakes in Europe. About 110 publications and reports, which have dealt with this subject, are evaluated in this paper. The localities and the circumstances that go with the reed 'die-back' are listed. The methods of investigation are discussed. Probable causal factors are grouped into five categories: direct destruction, mechanical damage, grazing, water and sediment quality, lake regulation and related effects. Deficiencies of the present state of research are pointed out.

INTRODUCTION

Nearly 40 years ago Hürlimann (1951) reported a frequent retreat of reed belts around many Swiss lakes. But in the following two decades the phenomenon of 'reed die-back' escaped notice. However, in the 1970s changes in littoral vegetation became obvious, and, encouraged by the early works of Sukopp, Klötzli, Schröder and others (Sukopp and Kunick, 1969b; Klötzli, 1969; Schröder, 1976), many scientists and naturalists tried to find reed decline phenomena in their own working areas. In some lakes, reed retreat was so serious that the yields of professional fishing were at risk. Shoreside sediment instability increased, the disturbance of the deposition–erosion equilibria provoked mud banks and consequently led to hygiene problems. The populations of several bird species decreased in size. Water supply authorities worried about the contribution of reed belts to the self-purification capacity of the lakes. Interpolations which were designed to initiate countermeasures have been presented to state parliaments and to the Federal Parliament of the F.R.G.

Accompanied by a changed awareness of how to preserve natural resources, authorities spent millions of DM to protect the remaining reed stands. However, the success was small. On the contrary, the retreat of the reed belts proceeded on a European scale.

To date, reed decline phenomena have been detected in about 35 lakes and more than 110 publications and reports have dealt with this subject (Table 1). Thus, it is useful to give a critical overview of the present state of research.

SIGNIFICANCE OF LAKE-SHORE REEDBELTS

The beneficial impact of reeds (*Phragmites australis* (Cav.) Trin. ex Steud.) on the diversity and stability of lake-shore ecosystems has been pointed out by many investigations: the high productivity of reeds (c. 1–2 kg dry matter m^{-2} $year^{-1}$) is the food basis for many primary consumers, parasites and secondary decomposers grazing on cellolytic bacteria and fungal mycelia. The food web is completed by fish, birds and mammals. For other species, the reeds form the structural frame for nesting and spawning. Many species living here are endangered by draining and amelioration of wetlands.

Many authors pointed out the high nutrient retention capacity of reeds (for an overview see Ostendorp, 1989). This led to the assumption that reed communities contribute considerably to the 'self purification potential' of polluted lakes or rivers. However, their actual contribution is difficult to quantify.

Valuable information on the utility of reed vegetation comes from waterway engineering and its utilization of natural structures: reed fringes are the best protection against sediment movement and bank erosion. Consequently, *Phragmites* plantations have been widely used to stabilize the shorelines of lakes, rivers, channels and reservoirs (Bittmann, 1953; Bauch and Linke, 1970; Schlüter, 1971). Their successful use in hydraulic architecture confirms their significance under natural conditions.

Healthy reedbelts are a main factor in many landscapes which are dominated by traditional agricultural use. The attraction of such scenery for urban holiday makers is based on the presence of lakes and water-sport facilities, as well as on the natural shore communities. Hence, the function of reedbelts obtains an economic scope: the livelihoods of professional fishermen partially depend on littoral fish species, wild-life reserves attract visitors, the nutrient load of surface runoff from intensively used agricultural areas is diminished by wetland and lakeshore vegetation, bank erosion and, as a consequence, the silting of small harbours, reservoirs, etc., is prevented and waterwork buildings are protected against the wave action of storms and ships. The list of beneficial effects can be continued. The economic value of lakeside reeds can be expressed by the amount of money which must be invested to restore 1 m of reed fringe. At Lake Constance, the waterway authorities spend c. 1000–1500 DM per running metre to create a new reedbed.

The significance of reeds cannot be better demonstrated than by the dieback phenomenon: in many cases the retreat is accompanied by detrimental effects, such as lack of bank protection, disappearance of bird species and a reduction of fish population.

TABLE 1

Reed die-back in Europe and Australia, arranged geographically

No.	Locality	Reed area	Decline	Details of reed regression	Presumed causes	References[1]
1	Bastrup Sø (Denmark)	1912: 7.0 ha	1973: −57%	*Typha angustifolia* and *Schoenoplectus lacustris* retreat also; details unknown	Eutrophication	105
2	Norfolk Broads (Great Britain)	1905: 244 ha	1946: −50% 1977: −80%	retreat 1905–1946: replacement by fenlands and woodlands; retreat 1946–1977: shoreside grazing by coypus and waterfowl	Coypu and waterfowl grazing, increase of recreation activities, increase of boating, increase of nutrient loading	10, 11, 28, 67, 69, 108, 109
3	Gr. Plöner See (F.R.G., Schleswig-Holstein)	-	-	Local retreat only	Summer mowing, ice drifting, mechanical destruction by clusters of filamentous algae (*Cladophora* sp.)	68, 102
4	42 lakes near Neustrelitz and Templin (G.D.R.)	1965: 104 ha	1983: −47%	1935–1960: expansion of reeds; retreat beginning in 1945, since 1973 enhanced decrease; −22.6% by total loss, −24.6% by gap formation within the closed reedbelt	Eutrophication, agricultural and municipal waste water, boating, duck manure, carp farming, recreational activities, artificial rise in water level, summer mowing, wash of filamentous algae, replacement by *Typha angustifolia*	71, 72
5	Gothensee (G.D.R.)	-	-	1971–1975	Grazing by grey-lag geese	39
6	Dambecker Seen (G.D.R.)	-	-	Since about 1960	Grazing by muskrats	39
7	Greifswalder Bodden (G.D.R.)	-	-	Local retreat since about 1960	Grazing by muskrats	39
8	Schweingartensee (G.D.R.)	-	-	Details unknown	Exceptional fluctuations of water level caused by reservoir	39
9	Feldberger Seen (G.D.R.)	-	-	Local retreat only	Wash of filamentous algae; recreation activities; grazing by horses, cattle and muskrats; eutrophication	3, 75

TABLE 1 (continued)

No.	Locality	Reed area	Decline	Details of reed regression	Presumed causes	References[1]
10	Parsteiner Seen (G.D.R.)	-	-	Local retreat only	Eutrophication; wash of filamentous algae; boating and swimming	93
11	Müggelsee (G.D.R.)	-	-	Gap formation 1957–1958	Ice drifting; grazing by muskrats	4
12	Lieps (G.D.R.)	-	-	Beginning in 1973, no reed belts since 1975	Electric fishing	77
13	Havel (F.R.G., West Berlin)	1962: 37.4 km (Lateral extension)	1982: −68%	Lakeside regression; formation of reed-tufts	Wave action by cargo ships; bank erosion; floating rubbish; lowering of water level; wash of filamentous algae; eutrophication; recovery of ammunition; grazing by muskrats, swans and coots, groundwater wells along the shoreline	5, 9, 29, 30, 34, 47, 48, 49, 50, 51, 58, 59, 60, 73, 87, 94, 95, 96, 97, 98, 99, 100, 103, 107, 118
14	Dümmer (F.R.G., Niedersachsen)	-	-	Expansion of reeds up to 1953; lakeside regression	Silting up within the reeds; sapropel formation; eutrophication; replacement by *Typha* and *Glyceria*; compensation of water-level oscillations	22, 46
15	Werra (F.R.G., Hessen)	-	-	Details unknown	Salt loading	8
16	Lake Constance-Untersee (F.R.G., Switzerland)	1954: 379 ha (German territory only)	1978: −23%	Lakeside regression, gap formation in the inner parts	Eutrophication; nutrient loading of the sediments; auto-intoxication of the reeds; rhizome fouling; toxic effects of algae wash; mechanical destruction of reed stalks by filamentous algae; flood disaster in 1965	23, 24, 32, 40, 70, 81, 82, 83, 84, 117

17	Lake Constance-Obersee (F.R.G., Switzerland)	1926: 14.6 ha (Swiss territory only)	1974: −60%	Lakeside regression, gap formation, disintegration of dense reed stands, frequently accompanied by bank erosion	Eutrophication; rhizome fouling; changing of sedimentation processes; compensation of water level oscillations; bank erosion	33, 35, 42, 43, 44, 52, 88, 89, 90
18	Ammersee (F.R.G., Bayern)	-	−60%	Details unknown	Recreational activities, settlements and week-end houses	91
19	Starnberger See (F.R.G., Bayern)	-	-	Details unknown	Recreational activities	111
20	Chiemsee (F.R.G., Bayern)	-	-	Regression of lakeside reedbelts	Recreational activities, mechanical destruction by drifting wood	61
21	Zürichsee (Switzerland)	1850: 90 ha	1979: −94%	1850–1930: decrease by land reclamation (−74 ha); 1950–1979: −11 ha	Eutrophication, land reclamation, lake regulation; wash of filamentous algae	1, 6, 12, 19, 26, 36, 54, 78, 79, 85, 101, 104, 115
22	Greifensee (Switzerland)	1966: 19.3 ha	1984: −24%	Lakeside disintegration of dense reed stands	Eutrophication; lowering of water level; suppression by bushes; bank erosion; recreation activities	17, 41, 80, 104
23	Pfäffiker See (Switzerland)	1954: 28.5 ha	1977: −31%	No specifications	Exceptional high flooding of reed stands caused by reservoir using; lowerings of the average lake level; increase of water-level fluctuations; eutrophication	18, 86
24	Hallwiler See (Switzerland)	1932: 54 ha	1976: −83%	Lakeside retreat	No specifications	45, 104
25	Lake of Lucerne (Switzerland)	-	-	Alpnacher See: regression since 1943; regression in the delta of the Reuß river 1937–1975 (−5 ha); Küßnacher Bucht: 1931 7 km, 1951 1.55 km reedfront	Bank erosion; under-water gravel pits, mechanical destruction	16, 27, 44, 57, 104, 110, 106, 113
26	Bieler See/Lac de Bienne (Switzerland)	1951: 40.8 ha	1968: −18%	Lakeside regression, especially at the spits of the reedbelt; gap formation in the inner parts	Mechanical destruction by wash of floating matter; bank erosion; recreation activities	2, 112

TABLE 1 (continued)

No.	Locality	Reed area	Decline	Details of reed regression	Presumed causes	References[1]
27	Neuenburger See Lac de Neuchâtel (Switzerland)	-	-	Lakeside disintegration of dense reed stands	Eutrophication; destruction by wave action; bank erosion by lowering of the average water level	20, 76
28	Murtensee Lac de Morat (Switzerland)	-	1977: 95.6 ha	Conspicuous 'stubble fields' of the former reed belt; formation of reed tufts	Destruction by boating and by landing places for boats	53
29	Elfenau (in the city of Berne) (Switzerland)	1938: 1.03 ha	1979: −86%	1914–1960 expansion of reeds, regression since 1968	Grazing by coots	74
30	Thuner See (Switzerland)	1936: 11.3 ha ('Gwattlischenmoos' only)	1975: −6%	Lakeside regression; expansion only local	Grazing by coots	38, 92, 104
31	Lake of Geneva (Switzerland)	1942: 17 ha ('Les Grangettes' only)	1982: −76%	Lakeside regression; gap formation; disintegration of dense reed stands	Eutrophication; trampling; mechanical destruction by drifting wood and by drifting rubbish; enhanced wave action by under-water gravel pits; bank erosion	13, 14, 15, 16, 55, 56 62, 63, 64, 65, 66
32	Nesyt Fishpond (Czechoslovakia)	-	-	No specifications	Grazing and nesting of grey-lag geese	37
33	Lake Balaton (Hungary)	c. 1980: 2600 ha	-	Since 1929 expansion of reedbelts; since c. 1980 retreat; thinning of dense reed stands	Eutrophication; waste water loading; massive growth of *Cladophora* (filamentous alga)	25
34	5 lakes in the Masurian lake district (Poland)	1958: 39 ha	1982: −71%	Reduction of the width of the reed belt as well as of the length of the reed covered shoreline	Direct destruction, recreational activities, eutrophication, introduction of the grass carp	114, 116
35	Gippsland Lakes (Australia)	-	-	No regression up to 1903; enhanced decrease since 1922	Oversalting (inflow of marine salt water); import of European carp	7, 21

[1] References: 1, Amann (1966); 2, Amann-Moser (1975); 3, Barby (1967); 4, Barthelmes (1959); 5, Begemann et al. (1982); 6, Binz (1980); 7, Bird (1961); 8, Blab (1984); 9, Blume et al. (1976); 10, Bonham (1983); 11, Boorman and Fuller (1981); 12, Brockmann-Jerosch (1934); 13, Bruschin (1975a); 14, Bruschin (1975b); 15, Bruschin (1975c) 16, Bruschin and Klötzli (1977); 17, Burgermeister (1978); 18, Burgermeister and Lachavanne (1980); 19, Burnand (1980); 20, Buttler et al. (1985); 21, Calder and Ducker (1979); 22, Dahms (1974); 23, Dienst (1986); 24, Dienst (1987); 25, Dinka (1986); 26, Fehlmann (1915); 27, Gamma (1935); 28, George (1977); 29, Grosch (1978); 30, Grosch (1980a); 31, Grosch (1980b); 32, Grünberger (1978); 33, Grünig (1975); 34, Hiller (1978); 35, Hirscher (1987); 36, Hürlimann (1951); 37, Hudec and Šťastný (1978); 38, Ingold et al. (1985); 39, Jeschke (1976); 40, Jüttner and Schröder (1982); 41, Keel (1985); 42, Klötzli (1969); 43, Klötzli (1973); 44, Klötzli and Grünig (1976); 45, Koeppel and Maurer (1981); 46, Krause (1948); 47, Krauss (1979); 48, Krauss (1982); 49, Krauss (1984); 50, Krauss and Latsch-Oelker (1986); 51, Krauss and Lenk (1986); 52, Krumscheid (1987); 53, Lachavanne (1979); 54, Lachavanne and Perfetta (1985); 55, Lachavanne et al. (1975); 56, Lachavanne et al. (1976); 57, Lachavanne et al. (1985); 58, Landesbeauftragter (1983); 59, Markstein (1981); 60, Markstein and Sukopp (1980); 61, Melzer et al. (1986); 62, Moret (1978); 63, Moret (1979); 64, Moret (1980); 65, Moret (1981); 66, Moret (1982); 67, Moss (1979); 68, Ohle (1940); 69, O'Riordan (1979); 70, Ostendorp (1989); 71, Pries (1984); 72, Pries (1985); 73, Raghi-Atri and Bornkamm (1979); 74, Reber (1979); 75, Richter (1983); 76, Roulier (1983); 77, Ruthenberg (1977); 78, Schanz (1980); 79, Schiess (1979); 80, Schmid (1980); 81, Schröder (1973); 82, Schröder (1976); 83, Schröder (1979); 84, Schröder (1987); 85, Schröter (1932); 86, Schwilch (1963); 87, Siebold (1983); 88, Siessegger (1980); 89, Siessegger (1985); 90, Stark and Pier (1987); 91, Steinberg (1977); 92, Stüssi (1978); 93, Succow and Reinhold (1978); 94, Sukopp (1963); 95, Sukopp (1971); 96, Sukopp (1973); 97, Sukopp and Kunick (1969a); 98, Sukopp and Kunick (1969b); 99, Sukopp and Markstein (1981); 100, Sukopp et al. (1975); 101, Thomas (1972); 102, Utermöhl (1982); 103, Westphal (1980); 104, Wildi (1976); 105, Wium-Andersen (1974); 106, Gamma (1951); 107, Ripl et al. (1987); 108, Moss (1983); 109, Boar and Crook (1985); 110, Arbeits gruppe Reussmündung (1984); 111, Köpsell (1987); 112, Iseli and Imhof (1987); 113, Lachavanne and Klötzli (1984); 114, Szajnowski (1983); 115, Schanz (1980); 116, Krolikowska (1979); 117, Dienst and Stark (1988); 118, Landesbeauftragter (1988).

Lack of bank protection. Sandy banks of the Havel Lakes (Berlin) have become heavily eroded by ship-induced waves; trees and bushes are washed out from underneath and uprooted. The same phenomena are visible at the Gippsland Lakes (Australia), Lake Constance and some Swiss lakes. In some instances, the remains of Neolithic and Bronze-Age lake-dwellings, which were formerly covered by sediments for 3000–6000 years, have been destroyed (Keel, 1985; Schlichtherle and Bürgi, 1986). But the relationship between reed die-back and erosion is mutual: bank erosion may be a cause (see Table 2) as well as a consequence (e.g. Lake Constance-Untersee: Ostendorp, 1989).

TABLE 2

Causes for reed decline phenomena (excerpt from Table 1)

	Causal factor	No. of locality (see Table 1)
Direct destruction	Land reclamation	21
	Recreational activities	2, 4, 9, 10, 18, 19, 22, 26, 28, 31, 34
	Summer mowing	3, 4
	Electric fishing	12
	Recovery of ammunition	13
Mechanical damage	Wave action (cargo ships, winds)	13, 27
	Floating rubbish	13, 31
	Drifting wood	20, 25, 26, 31
	Wash of filamentous algae	3, 4, 9, 10, 13, 16, 21, 33
	Drifting ice	3, 1
	Under-water gravel pits	25, 31
Grazing	Geese, swans, coots, coypus, muskrats, grass carp	2, 5, 6, 7, 9, 13, 29, 30, 32, 4, 34
	Horses, cattle	9
Water and sediment quality	Eutrophication (in general)	1, 2, 4, 9, 10, 13, 14, 16, 17, 21, 22, 23, 27, 31, 33, 34
	Sewage disposal	4, 33
	Duck manure, carp farming	4
	Silting, sapropel formation, nutrient enrichment of sediments	14, 16
	Auto-intoxication of *Phragmites*, rhizome fouling	16, 17
	Toxic effects of algal wash	16
Lake regulation and related effects	Lake regulation (in general)	20
	Compensation of water level oscillations	5, 14
	Artificial rise in the water level	4, 8
	Artificial drawdown of water level	13, 22, 23, 27
	Bank erosion	13, 17, 22, 25, 26, 31
	Flood disaster	16, 23
Others	Suppression by bushes	21
	Replacement by *Typha* and/or *Glyceria*	4, 14
	Salt loading	15, 35

The disappearance of bird species. The loss of reed-covered areas is followed by a decrease in the number of birds or bird species. A breakdown of Great Reed Warbler populations (*Acrocephalus arundinaceus* (L.)) occurred at the Havel Lakes (Westphal, 1980), the Bruchsee near Templin (G.D.R.) (Pries, 1984), the Lieps near Neubrandenburg (G.D.R.) (Ruthenberg, 1977) and at Lake Constance (Orn. AG Bodensee, 1983). The retreat of lakeside reeds is thought to be a main factor (Leisler, 1989). Other species, such as the Little Bittern (*Ixobrychus minutus* (L.)) and the Crested Grebe (*Podiceps cristatus* (L.)) are affected to a lesser extent (Sukopp and Kunick, 1969b; Begemann et al., 1982; Orn. AG Bodensee, 1983).

Reduction in the size of fish populations. The changes in fish populations in the Havel Lakes are clearly related to the regression of reed belts and submerged vegetation. Formerly, species like pike (*Esox lucius* L.), tench (*Tinca tinca* (L.)), carp (*Cyprinus carpio* (L.)) and rudd (*Scardinius erythrophthalmus* (L.)) were very abundant but became reduced to only 3% of the standing fish stock (Grosch, 1978, 1980a,b). However, alterations in fauna caused by vegetational changes in the littoral zone have not been thoroughly examined in other lakes.

Other parts of the littoral community are affected as well, such as the partial extinction of the submerged vegetation (Norfolk Broads (Gt. Britain), Havel Lakes, Dümmer (F.R.G.) etc.) or the die-back of riparian forests (Havel Lakes). Other aspects, such as benthic zoocoenoses, the food web, water chemistry, microbial activity and the 'self-purification potential' have not yet been investigated.

DOCUMENTATION OF REED RETREAT

Methods

Reed retreat phenomena have been documented by: (1) comparing a temporal sequence of maps or aerial photographs; (2) monitoring the development of permanent squares within or at the border of the reed belt; (3) mapping the 'residues' of the die-back process, e.g. the stubble fields.

In some cases the critical evaluation of historical sources and oral information from naturalists, farmers and fishermen may also be informative.

In most cases aerial photographs have been used to describe changes in the extension of the reed belt (Dahms, 1974; Amann-Moser, 1975; Grünig, 1975; Grünberger, 1978; Reber, 1979; Boorman and Fuller, 1981; Koeppel and Maurer, 1981; Moret, 1982; Keel, 1985; Schmid, 1986; Iseli and Imhof, 1987; Krumscheid, 1987; Stark and Pier, 1987; Ostendorp, 1988, Localities 1, 2, 14, 16, 17, 21–24, 26–31, see Table 1). This method is well suited to: (1) quantify changes in total reed-covered area, even if the landside border of the reedbelt is not well defined; (2) identify and distinguish lakeside regression and the formation of 'aisles', gaps, etc. in the inner parts; (3) identify some of the causes, e.g. landing places for boats, bathing places, footpaths, washes, reed-cutting areas, etc.

Field observations, combined with infra-red aerial photographs, allow us to distinguish between *Phragmites*, *Typha*, *Schoenoplectus* and *Carex* stands. The precision of aerial photographs is low if short-term changes are considered: taking into account that a reed stalk may be bowed down in one case and straight up in another, a 0.5–1 m difference between two reed-front borderlines is not significant.

The permanent-square technique is better adapted for investigating short-term changes. Unfortunately, this method has rarely been used (Moret, 1978; Dienst, 1986; Hirscher, 1987; Krumscheid, 1987; Stark and Pier, 1987; Dienst and Stark, 1988). With this technique it is possible to: (1) ascertain reed-regression or reed-progression phenomena from one year to the next, simply by counting the stalks within the square; (2) discover changes in the stand structure (thinning, invasion of other plant species, decrease in culm height, etc.); (3) make detailed observations on the nature and severity of reed damage and its presumable causes (algal wash, erosion, mechanical damage, parasite attack, grazing, etc.).

To find a correlation between the changes in stalk number and the severity of a certain damaging factor, might be the first step in limiting the variety of possible causes. As an example, Hirscher (1987) found a significant positive correlation between the 'degree of severity' of mechanical damage by waves and drifting matter and the decrease of stalk density at Lake Constance–Obersee.

If aerial photographs are not available and permanent-square monitoring is too time consuming the mapping of 'stubble fields' might be helpful: at Lake Constance–Untersee the bases of dead reed stalks persist for more than 20 years (Ostendorp, 1989). If the remains are submerged, even at periods of low lake level, diving can become necessary (Melzer et al., 1986).

Results

In most cases, aerial photographs are the best documentation of reed-belt changes, but most of them are not older than 20 or 30 years. On the other hand, early changes may date back to before the Second World War (localities, 2, 17, 22, 24, 29, 30) or even before the beginning of the century (localities 1, 21). Hence aerial photographs are often of too recent age to record the 'pre-decline' status of the reeds. From lakes without a sign of reed decrease (e.g. Björk, 1967) we can conclude that a healthy reed belt is a homogeneous, dense or sparse stand with no gaps in its inner parts, with an evenly formed lakeside borderline without aisles, shaping a uniform fringe or large lobes, stalk length decreasing gradually at the lakeside border, but all stalks of one stand of similar height; at the landside edge the reeds are replaced by sedge or woodland communities or by unfertilized grasslands.

With these properties of healthy reed stands in mind, it is often easy to discover reed decline phenomena.

Aerial photographs and maps show that reed belts are affected at their lakeside edge as well as in the inner parts and their landside margins. At the landside edge, reeds are repressed by many human uses, such as land reclamation, wetland draining, the construction of weekend houses, bathing beaches, landing sites for boats, etc. Consequently the reeds are destroyed. Gap formation may occur in the inner sections. The gaps can be recolonized by the Phragmitetum or can be replaced by other communities (Lake Constance: Typhetum angustifoliae, Scirpetum lacustris, Phalaridetum arundinaceae, nitrophilic communities, Klötzli and Züst, 1973; Ostendorp, 1989). In other cases, gaps may persist for more than 20 years. This led to the conclusion that at least some of them could be of natural origin (e.g. in the Neusiedler See, Burian, 1971; Zwicker and Grüll, 1985). As a consequence of the lakeside die-back the formerly evenly shaped fringes look frayed or torn apart. Reed-tufts, single culms or nothing but stubble fields are the remains, often accompanied by erosion of the banks. The 'post-decline' edge has been a mid-stand before; hence the stalks are uniformly tall up to the very borderline.

No reports have appeared yet on the alterations that take place in the properties of the stand structure (e.g. stalk density, average length and diameter of stalks, distribution of stem types) at the beginning of a die-back process. However, marked changes are reported in the course of the reed die-back at the Havel Lakes (Sukopp et al., 1975; Sukopp and Markstein, 1981) and at Lake Constance (Ostendorp, 1989).

IN QUEST OF CAUSAL FACTORS

Many factors have been regarded as being detrimental to reed growth, but it has been difficult to demonstrate whether they actually harm *Phragmites* or not. The literature frequently presents lists of possible causal factors (e.g. Pries, 1985), but only little information is given on the share each factor has in the total deficiency (Sukopp et al., 1975; Sukopp and Markstein, 1981; Ostendorp, 1989). Few assumptions have been made on the mechanisms which finally lead to the die-back of single shoots or rhizomes (Klötzli and Grünig, 1976; Schröder, 1976, 1979, 1987; George, 1977; Grünig, 1980; Moss, 1983; Ostendorp, 1989).

The factors listed in Table 2 may be summarized in five groups.

(1) Direct destruction by land reclamation, recreational activities, summer mowing, etc. Causes and consequences are obvious and do not need research. However, they call for a change of consciousness in the land owners, authorities and politicians.

(2) Mechanical damage by waves and floating matter. Wind-generated waves

are a constituent factor of the natural environment of the reed. What has made waves threatening to *Phragmites*, is that: (a) wave action on shore is increased by underwater gravel pits (i.e. wave energy loss by friction on the littoral bottom is lowered; (b) wave action is increased by bank erosion in front of the lakeside reed edge (i.e. breakers are now close to the reed front); (c) wave action is intensified by floating matter such as drifting wood (which formerly was picked out of the mountain streams; Kiefer, 1972; Grünig, 1980; Table 2), drifting rubbish (put in by careless activities or by polluted streams), or filamentous algae (massive growth in the littoral zone caused by lake eutrophication). Other mechanical factors such as drifting ice, electric fishing, recovery of ammunition, etc., are not considered here.

(3) Grazing by coypu (*Myocastor coypus* (Molina)), muskrat (*Ondatra zibethicus* L.), mute swan (*Cygnus olor* (J.F. Gmelin)), and grass carp (*Ctenopharyngodon idella* Valenciennes) may seriously threaten reed stands. These animals do not belong to the original fauna of western Europe, they were introduced at the beginning of the century (muskrat, mute swan), in the 1930s (coypu) and in the 1960s (grass carp). Hence, reed damage by these species is clearly a consequence of alteration of the fauna by man. The detrimental influence of coots (*Fulica atra* L.) (and other waterfowl) is connected with high population densities and also with discontinuous reed stands which allow an extensive penetration of swimming waterfowl. Grey lag geese (*Anser anser* (L.)) are the only autochthonous grazers that harm healthy reeds seriously. Increased damage may be forced by restricted natural grazing habitats (draining and alteration of wetlands); thus, the remaining swamps will suffer the detrimental effects caused by overcrowded goose populations. It should be mentioned that no report demonstrates a causal relationship between attacks by parasitic fungi or insects and the decline of lakeside reed belts. However, it is true that in drier habitats *Archanara* (Lepidoptera, Noctuidae) or *Rhizedra* (Lepidoptera, Noctuidae) can cause noticeable decreases in stalk numbers (Van der Toorn and Mook, 1982).

(4) Eutrophication and sewage disposal. Klötzli was the first to postulate "that — indirectly — the pollution of our lakes is mainly responsible" for reed decline (Klötzli 1971, p. 109). He considered a high level of available nutrients in the soil and in the swamp water to have a negative influence on the sclerenchyma of the stalk wall, the reed thereby no longer being able to withstand the forces of waves and washes. Schröder (1976, 1979) presented a model that showed the reed decline at Lake Constance as being a consequence of increased stalk density, reduced mechanical stalk stability and enlarged flotsam of filamentous algae — all these factors having been intensified by eutrophication. As a consequence, the water exchange between the reedbelt and the pelagic water would be reduced, and finally the reeds would die back owing to anaerobic conditions in the sediment–water interface and the formation of toxic, reduced substances like methane, hydrogen sulfide and ammonia.

However, these theories do not fit the reality; they contrast with many field observations and with experimental data. A detailed critique of the 'eutrophication concept' has been published by Ostendorp (1989). 'Normal' eutrophication processes in lakes should be distinguished from heavy pollution by sewage disposal, fish farming or duck manure. It may be possible that the remains of animal feed, faeces or the animals themselves could impair the growth conditions for *Phragmites*. However, detailed data are lacking. Eutrophication leads to an increased growth of submerged macrophytes and filamentous algae, which may be washed against the reeds. Hence, the enhanced mechanical damage is related to eutrophication in some way. There is also some experimental evidence for the chemical effects of algal material: Schröder (1987) and Ostendorp (1989) demonstrated that toxic substances may originate from decaying algal mats, but they failed to prove a detrimental effect on *Phragmites* in the natural environment (see also Jüttner and Schröder, 1982). Therefore, the poisoning of reeds by algae is still an unproven concept and should be treated with scepticism.

(5) Alterations of the water budget and the lake level. The great majority of European lakes have been regulated at last since the beginning of the century. This includes drops and rises of the mean lake level as well as more subtle alteration of the range between which annual high and low water levels fluctuate. Circum-alpine lakes often undergo high water levels in the early growing period of *Phragmites*. Especially in lakes used as reservoirs, water-level oscillations may vary in a quite unnatural way. The influences on lakeside reed stands are complex: (1) Extremely high water levels in the early growing season (May–July) may lead to an inundation and thereby to the death of a large portion of the stalks (Schwilch, 1963; Rodewald-Rudescu, 1974, pp. 113–114; Jeschke, 1976; Ostendorp, 1989). (2) A drop of the mean water level can cause severe bank erosion owing to enhanced breaker action on the shoreline. Thus, a greater amount of energy in the waves and breakers can reach the reed front (Binz, 1980; Ostendorp, 1989). The damage may be intensified by floating matter. (3) If the former outermost reed front was in equilibrium with the ambient chemical and physical conditions, a rise of the water level may disturb this balance. In order to stay in this equilibrium of factors a new reed front establishes itself at a higher level and closer to the shore. However, the factors which make the reed stalks and/or rhizomes die are unknown; but there are some indications that an altered oxygen supply can affect the health of the rhizomes (Yamasaki, 1984).

There are some other factors which have been regarded as being responsible for the reed decline (Table 2). However, the displacement of *Phragmites* by bushes or by other helophytes like *Typha* or *Glyceria* (Locations 4, 14, 22) should not be considered as a causal factor but rather as a result of the changed conditions in which the interspecific competition takes place. Enhanced nutrient supply, increasing sedimentation rates, changes of the water regime, or alterations in the way wetlands are managed may give other species a competitive advantage.

INDIVIDUAL CAUSES VS. GENERAL CAUSES

Many authors (e.g. Klötzli and Grünig, 1976; Schröder, 1979, 1987; Grünig, 1980; Pries, 1985) claim that there are general causes for reed decline phenomena in Middle Europe, i.e. distinct factors which act in most lakes in a similar way and lead to comparable results. However, one must notice that there are many 'individual' causes that are specific for one or a few lakes or for definite circumstances (Table 2): electric fishing, recovery of ammunition, drifting ice, grazing by horses and cattle, duck manure, fish farming, flood disaster and salt loading.

On the other hand some of the factors given in Table 2 are widely spread over European lake shores: (1) lake shores are often subjected to intensive use for recreational purposes which imply that more or less extensive damage to littoral vegetation will occur; (2) they are commonly affected by waste-water inlets and by the runoff from farmland, as well as by eutrophication effects in the pelagic water, e.g. mass developments of filamentous algae; (3) the water level of many lakes has been altered in the last two centuries; however, the consequences (bank erosion, etc., see above) are not well examined.

Hence, one may describe the reed decline as a function of: (1) the proximity to large cities; (2) the intensity of use of the littoral zone; (3) the application of fertilizers in the surrounding farmlands.

CALL FOR FURTHER INVESTIGATIONS

If it is true that there are 'general causes' for reed die-back phenomena, large areas of reed would be endangered, even in lakes where up to now no reed regression has been observed. In this case the efforts to protect reed belts and to re-naturalize devastated shore sections should not be restricted to a simple repair of very local damages. Protection measures must take into consideration littoral changes as a whole, eutrophication problems as well as wave action, erosion of the banks, agricultural use in the hinterland, changes of the water level and of the submerged vegetation, pressure of land use and recreational requirements, etc. Further, one has to realize that the lake and its littoral zone form a historic subject which has often undergone human impact since prehistoric times. Further research is needed: (1) to understand the complexity of detrimental factors for reed growth; (2) for planning and performing successful countermeasures. Some of the more important fields of investigation are discussed below.

Improved documentation of reed belt changes

Aerial photographs provide much valuable information about vegetational changes in the littoral zone. Hence, their development should be monitored every 5 or 10 years. At the same time, field observations and experiments should be performed, e.g. stand structure measurements at die-back sites and progression sites or at sites with different damaging factors (Dienst, 1986, 1987; Ostendorp, 1989; Stark and Dienst, 1989). Aerial photographs can give some indications of the causal factors such as breakdown of stalks by wave action or by wash, nature of the wash (timber, rubbish, filamentous algae, etc.), erosion, deposition of mudbanks, footpaths, summer cutting, etc. Correlations between the increase or decrease of reeds and a series of factors like exposure to winds, inclination of sublittoral floor, proximity to settlements, boat landing sites or waste-water inlets, distance to navigation routes, etc. can be easily evaluated with the aid of aerial photographs.

Effects of lake eutrophication and sewage disposal

Reed decline phenomena are not restricted to polluted lakes but also occur in mesotrophic lakes like Parsteiner See (G.D.R.), Lake Constance–Obersee and Lake Lucerne (Switzerland). On the other hand *Phragmites* can exist without any sign of harm in hypertrophic lakes and waste-water treatment plants with pelagic nutrient concentrations up to 6.0 mg P l^{-1} and 10 mg N_{anorg} l^{-1} (Tscharntke, 1983). Up to Klötzli (1971) nutrient enrichment was regarded as beneficial for reed spreading (Hürlimann, 1951; Bittmann, 1953; Neuhäusl, 1965, pp. 33–36, 39; Sukopp and Kunick, 1969a, p. 290). Hence, the role of lake pollution in die-back is an unsolved problem, though there have been many efforts to elucidate the relationship:
(1) the stand structure, culm morphology and stem-wall anatomy (Sukopp et al., 1975; Raghi-Atri and Bornkamm, 1979; Bornkamm and Raghi-Atri, 1986).
(2) the mechanical properties (bending stiffness, breaking strength, etc.) of the stalk (Raghi-Atri and Bornkamm, 1980).
(3) the physiology and chemical composition of the reed (Overdieck and Raghi-Atri, 1976; Raghi-Atri and Bornkamm, 1979; Bornkamm and Raghi-Atri, 1986; Dinka, 1986).
(4) sediment and water properties (Schröder, 1973, 1979, 1987; Dahms, 1974; Raghi-Atri and Bornkamm, 1979; Reber, 1979; Boorman and Fuller, 1981; Boar and Crook, 1985; Dinka, 1986; Ripl et al., 1987).
(5) the formation of toxic substances (Jüttner and Schröder, 1982; Schröder, 1987; Ostendorp, 1989).

But no clear-cut results could be presented. This might be due to shortcomings of the experimental design and the fact that in many cases no other factors have been investigated at the same date, locality and circumstances. For a detailed critique see Ostendorp (1989).

Consideration of landscape history

It is usually supposed that all the factors which led to a recent reed decline are of recent origin and that they can be detected by studying the ambient conditions. However, this is not the case, at least in some lakes, because the response of reeds to changed conditions or to a damaging event can be retarded: *Phragmites* rhizomes can act as a 'buffer' against unfavourable as well as against good conditions:
(1) the progression of lakeside reed in the Neusiedler See (Austria) is a delayed response to the silting of the southwestern part of the lake, to the lake regulation and to the eutrophication since the end of the 19th century (Weisser, 1973);
(2) the reed decline in Lake Constance–Untersee between 1965 and 1978 was the after-effect of a single event in 1965: a flood disaster from June to July combined with a storm on 16 June and a hailstorm on 26 June (Ostendorp, 1989). It was not until the beginning of the 1980s that the lakeside reed front recovered and expanded anew (Dienst, 1986; Stark and Dienst, 1989). The effects of the factors mentioned cannot be studied except by historical documents (photos, newspaper articles, water mark records, data of the local weather stations, etc.).

One can expect that the change of landscape over more than 100 years (deforestation, change of agricultural use, construction of mill dams, diverting and damming of rivers, draining of swamps, the trend towards water sports and landscape-consuming recreational activities, etc.) would have affected the littoral vegetation partly beneficially and partly detrimentally. Deforestation of lakeshore woodlands is assumed to have had a positive effect on reed propagation by the Bronze Age and in the Roman period (Rösch, 1987). Nowadays the reed belt is often reconquered by bushes and trees. Medieval soil erosion and the construction of mill dams led to flooding of large areas. When steam mills were built, the wetlands were drained for agricultural use and the reeds were suppressed. The intensified and increased exploitation of lakes and their surroundings since the middle of our century may lead to a general degradation of littoral environments.

Understanding the complex environmental changes in the littoral zone of lakes needs a historic perspective (e.g. Markstein, 1981; Moss, 1983). However, the identification of general factors which are responsible for reed decline in many European lakes is under way and needs more scientific work within a framework of multi-disciplinary cooperation.

ACKNOWLEDGEMENT

The author is indebted to Tom Gonser for linguistic corrections.

REFERENCES

Amann, E., 1966. Aktuelles aus der Sicht des Fischerei- und Jagdverwalters. Jahrb. Zürichsee, 21: 115-124.

Ammann-Moser, B., 1975. Vegetationskundliche und pollenanalytische Untersuchungen auf dem Heidenweg im Bieler See. Beitr. Geobot. Landesaufn. Schweiz, 56: 1-76.

Arbeitsgruppe Reussmündung, 1984. Die Reussmündungslandschaft am Urner See. Ber. Naturforsch. Ges. Uri, 12: 1-194.

Barby, R., 1967. Der Bisam (*Ondatra zibethicus*), ein Schädling im Feldberger Landschaftsschutzgebiet. Naturschutzarbeit Mecklenburg, 10: 45-46.

Barthelmes, D., 1959. Ein Fall von natürlichem Gelegerückgang. Z. Fisch. N.F., 8: 551-555.

Bauch, W. and Linke, H., 1970. Röhricht als Uferschutz. In: H. Linke and W. Meissner (Editors), Ingenieurbiologische Bauweisen und Landschaftsgestaltung. Kammer der Technikg, Berlin, G.D.R., pp. 48-63.

Begemann, W., Krauss, M. and Ritterbusch, B., 1982. II. Zwischenbericht der Beratergruppe Projekt 'Havelufersanierung'. Edited by the Senator für Stadtentwicklung und Umwelt, Berlin, 115 pp. + appendix.

Binz, H.R., 1980. Der Schilfrückgang — ein Ingenieurproblem? Jber. Verb. Schutz Landschaftsbild Zürichsee, 53: 35-52.

Bird, E.C.F., 1961. Reed growth in the Gippsland Lakes. Victorian Nat., 77: 262-268.

Bittmann, E., 1953. Das Schilf (*Phragmites communis* Trin.) und seine Verwendung im Wasserbau. Angew. Pflanzensoziol., Stolzenau (F.R.G.) 7: 1-41.

Björk, S., 1967. Ecologic investigations of *Phragmites communis*. Folia Limnol. Scand., 14: 1-248.

Blab, J., 1984. Grundlagen des Biotopschutzes für Tiere. Bundesforschungsanstalt für Naturschutz und Landschaftsökologie, Kilda, Greven.

Blume, H.-P., Hoffmann, R., Molle, H.-G., Pachur, H.-J., Schulz, G., Sukopp, H. and Tigges, W., 1976. Erosion und Abrasion an der Grunewaldseenrinne und am Havelufer. Expert evidence. Edited by the Senator für Bau- und Wohnungswesen, Berlin, 179 pp.

Boar, R.R. and Crook, C.E., 1985. Investigations into the causes of reedswamp regression in the Norfolk Broads. Verh. Int. Verein. Limnol., 22: 2916-2919.

Bonham, A.J., 1983. The management of the wave-spending vegetation as a bank protection against boat wash. Landscape Planning, 10: 15-30.

Boorman, L.A. and Fuller, R.M., 1981. The changing status of reedswamp in the Norfolk Broads. J. Appl. Ecol., 18: 241-269.

Bornkamm, R. and Raghi-Atri, F., 1986. Über die Wirkung unterschiedlicher Gaben von Stickstoff und Phosphor auf die Entwicklung von *Phragmites australis*. Arch. Hydrobiol., 105: 423-441.

Brockmann-Jerosch, H., 1934. Die Bedeutung der natürlichen Ufer des Zürichsees. Jahrb. Zürichsee, 1934: 7-25.

Bruschin, J., 1975a. Protection des rives du Leman entre le Rhône et l'Eau Froide (Commune de Noville). University of Lausanne, 22 pp. + appendix.

Bruschin, J., 1975b. Protection des rives du Leman entre le Rhône et l'Eau Froide (Commune de Noville). Deuxieme rapport préliminaire. University of Lausanne, 21 pp.

Bruschin, J., 1975c. Protection des rives du Leman entre le Rhône et l'Eau Froide. Rapport final. University of Lausanne, 11 pp.

Bruschin, J. and Klötzli, F., 1977. Dragages lacustre et recul des roselières. Proceedings of the XVII Congress Assoc. Int. Recherches Hydrauliques, Baden-Baden, F.R.G., 5 pp.

Burgermeister, G., 1978. Les Macrophytes du Pfäffiker See et du Greifensee. Travail de Diplôme, University of Genèva, 124 pp.

Burgermeister, G. and Lachavanne, J.B., 1980. Les macrophytes du Pfäffiker See. Ber. Schweiz. Bot. Ges., 90: 213-243.

Burian, K., 1971. *Phragmites communis* Trin. im Röhricht des Neusiedler Sees. Wachstum, Produktion und Wasserverbrauch. In: H. Ellenberg (Editor), Ökosystemforschung. Springer, Berlin, pp. 61-78.

Burnand, J., 1980. Die Entwicklung des Röhrichts am Zürcher Ufer des Zürichsees. Jber. Verb. Schutz Landschaftsbild Zürichsee, 53: 53-69.

Buttler, A., Bueche, M., Cornali, Ph. and Gobat, J.-M., 1985. Historischer und ökologischer Überblick über das Südostufer des Neuenburger See. Telma, 15: 31-42.

Calder, D.M. and Ducker, S.C., 1979. The vegetation of the Gippsland Lakes, South-Eastern Australia. In: R.L. Jefferies and A.J. Davy (Editors), Ecological Processes in Coastal Environments. Blackwell, Oxford, p. 651.

Dahms, E., 1974. Ergebnisse geologischer und limnologischer Untersuchungen am Dümmer und ihre Auswertung für die Umweltplanung. Ber. Naturhist. Ges. Hannover, 118: 213-240.

Dienst, M., 1986. Zur Dynamik der Schilffront am Bodensee-Untersee. Natur Landschaft, 61: 137-139.

Dienst, M., 1987. Untersuchungen zur Schilffrontdynamik. In: Naturschutzgebiet Wollmatinger Ried-Untersee-Gnadensee, Jber., 1986, Deutscher Bund für Vogelschutz, Constance, pp. 67-69.

Dienst, M. and Stark, H., 1988. Die Dynamik des Schilffront am Bodensee-Untersee von 1984 bis 1987. Natur Mensch, 29: 3-8.

Dinka, M., 1986. The effect of mineral nutrient enrichment of Lake Balaton on the common reed (*Phragmites australis*). Folia Geobot. Phytotaxon., 21: 65-84.

Fehlmann, 1915. Gutachten zur 'Verordnung zum Zürcherschen Gesetz über die Fischerei' (cited in Schröter, 1932).

Gamma, H., 1935. Die makrophytische Uferflora des Vierwaldstätter Sees und ihre Veränderung in den letzten 20 Jahren. Mitt. Naturforsch. Ges. Luzern, 12: 91-182.

Gamma, H., 1951. Zur Uferflora der zentralschweizerischen Seen und zum Problem des Uferschutzes. Verh. Schweiz. Naturforsch. Ges., 131: 11-25.

George, M., 1977. The decline in Broadland's aquatic fauna and flora: a review of the present position. Trans. Norfolk Norwich Nat. Soc., 24: 41-53.

Grosch, U.A., 1978. Die Bedeutung der Ufervegetation für Fisch und Fischerei, dargestellt am Beispiel Berlins. Arb. Fischerei-Verb., 25: 1-15.

Grosch, U.A., 1980a. Die Bedeutung der Ufervegetation für Fisch und Fischerei: Dargestellt am Beispiel von Havel und Spree im Raum Berlin (West). Garten Landschaft, 1980, pp. 20-23.

Grosch, U.A., 1980b. Die Fischfauna in Berlin (West) am Ende der siebziger Jahre. Rückblick-Status-Prognose-Restitutionsmöglichkeiten. Berl. Naturschutzbl., 24: 560-565.

Grünberger, M., 1978. Der Rückzug des Schilfröhrichts am thurgauischen Bodenseeufer. Amt für Raumplanung, Abt. Natur- u. Landschaftsschutz, Frauenfeld, Switzerland.

Grünig, A., 1975. Lochbildungen im Röhricht — dargestellt anhand des Rückgangs des Schilfbestandes in Altenrhein (Bodensee) von 1926-1974. Diplomarb. Geobot. Inst. ETH Zürich, 66 pp. + appendix.

Grünig, A., 1980. Unsere Seeufer und das Röhricht in Vergangenheit und Zukunft. Jahrb. Ver. Schutz Landschaftsbild Zürichsee, 53: 15-34.

Hiller, H., 1978. Probleme der Ufersicherung in der Röhrichtzone durch ingenieurbiologische Bauweisen — dargestellt am Beispiel der Havel in Berlin (West). Natur Landschaft, 53: 224-227.

Hirscher, A., 1987. Dokumentation der Schilfbestandsentwicklung (Lipbach, Strandbad Friedrichshafen, Eriskircher Ried) Frühjahr Herbst 1986. Report of the Landratsamt Bodenseekreis, Umweltschutzamt, Friedrichshafen, F.R.G., 37 pp. + appendix.

Hürlimann, H., 1951. Zur Lebensgeschichte des Schilfs an den Ufern der Schweizer Seen. Beitr. Geobot. Landesaufn. Schweiz, 30: 1-232.

Hudec, K. and Šťastný, K., 1978. Birds in the reedswamp ecosystem. In: D. Dykyjová and J. Květ (Editors), Pond Littoral Ecosystems. Structure and Functioning. Ecol. Stud., Springer, Berlin, 28, pp. 366-372.

Ingold, P., Hofer, S. and Wieser, R., 1985. Zur Erfolgskontrolle naturschützerischer Maßnahmen am Beispiel der Schilfentwicklung im Naturschutzgebiet Gwattlischenmoos nach dem Aufstellen von Zäunen — eine Zwischenbilanz. Mitt. Naturforsch. Ges. Bern, 42: 37-44.

Iseli, Chr. and Imhof, Th., 1987. Bielersee 1987: Schilfschutz, Erhaltung und Förderung der Naturufer. Schr. reihe Ver. Bielersee Schutz, 2/1987: 1-151.

Jeschke, L., 1976. Veränderungen des Röhrichtgürtels des Seen in unseren Naturschutzgebieten. Naturschutzarbeit Mecklenburg, 19: 49-52.

Jüttner, F. and Schröder, R., 1982. Microbially derived volatile organic compounds in the recent sediment of the *Phragmites australis* bed of the Bodensee. Arch. Hydrobiol., 94: 172-181.

Keel, A., 1985. Der Schilfbestand am Greifensee-Ufer. Report of the Amt für Raumplanung, Fachstelle Naturschutz Kanton Zürich, 12 pp.

Kiefer, F., 1972. Naturkunde des Bodensees. 2nd ed., Thorbecke, Sigmaringen, 210 pp.

Klötzli, F., 1969. Über die Ursachen des Schilfsterbens. Naturschutz Oberschwaben-Bodensee-Hegau, Singen F.R.G., 10: 7-9.

Klötzli, F., 1971. Biogenous influence on aquatic macrophytes especially *Phragmites communis*. Hidrobiologia, Bucaresti, 12: 107-111.

Klötzli, F., 1973. Über Belastung und Produktion in Schilfröhrichten. Verh. Ges. Ökol. Saarbrücken, 1973: 237-247.

Klötzli, F. and Grünig, A., 1976. Seeufervegetation als Bioindikator. Daten Dok. Umweltschutz, 19: 109-131.

Klötzli, F. and Züst, S., 1973. Nitrogen regime in reed-beds. Pol. Arch. Hydrobiol., 20: 131-136.

Koeppel, H.D. and Maurer, R., 1981. Der Rückgang des Schilfbestandes am Hallwiler See. Report of the Baudepartement d. Kanton Aargau, Sekt. Natur u. Landschaft, Aarau, Switzerland, 3 pp. + appendix.

Köpsell, B., 1987. Belastung der Erholungsgebiete am Starnberger See: Wahrnehmung und Bewertung durch Anwohner und Naherholer. Diplomarb. Geogr. Inst. TU München, Munich, 230 pp.

Krause, W., 1948. Die Röhrichtbestände des Dümmers im Oktober 1947. Report of the Zentralstelle für Vegetationskartierung des Reiches, Stolzenau, F.R.G., 7 pp. + appendix.

Krauss, M., 1979. Zur Nahrungsökologie des Bläßhuhns *Fulica atra* auf den Berliner Havelseen und der Einfluß von Bläßhuhn und Bisamratte *Ondatra zibethicus* auf das Schilf *Phragmites communis*. Anz. Ornithol. Ges. Bayern, 18: 105-144.

Krauss, M., 1982. Ist es für das Havelröhricht bereits 5 nach 12? Berl. Naturschutz-Blätter, 26: 32-35.

Krauss, M., 1984. Abschlußbericht 1984 für das Projekt 'Havelufersanierung', Senatur für Stadtentwicklung und Umwelt, Berlin, 48 pp.

Krauss, M. and Latsch-Oelker, J., 1986. Wellenberuhigung — Ein Weg zur Reduzierung des Röhrichtrückgangs an den Ufern der Havel in Berlin (West). Landschaftsentw. Umweltforsch., 40: 545-551.

Krauss, M. and Lenk, C., 1986. Abschlußbericht 1985 für das Projekt 'Havelufersanierung', Senatur für Stadtentwicklung und Umwelt, Berlin, 51 pp. + appendix.

Krolikowska, J., 1987. Reed (*Phragmites australis* (Cav.) Trin. ex Steud.) growth under conditions of increasing eutrophication of Lake Mikolajskie. Ekol. Pol., 35: 209-217.

Krumscheid, P., 1987. Dokumentation des Bestandsentwicklung der schützenswerten Uferschilfbestände im Bereich des Bodenseekreises. Landratsamt Bodenseekreis, Umweltschutzamt, Friedrichshafen, F.R.G., 57 pp.

Lachavanne, J.B., 1979. Les Macrophytes du Lac de Morat. Ber. Schweiz. Bot. Ges., 89: 114-132.

Lachavanne, J.-B. and Klötzli, F., 1984. Ufer- und Wasserpflanzen. In: P. Stadelmann (Editor), Der Vierwaldstätter See und die Seen der Zentralschweiz. Luzern, pp. 121-138.

Lachavanne, J.B. and Perfetta, J., 1985. Les macrophytes du Lac de Zurich. Beitr. Geobot. Landesaufn. Schweiz, 61: 74 pp.

Lachavanne, J.B., Choulat, Ch. and Munteanu, A., 1975, 1976. Evolution de la basse plaine du Rhône, Objet Naturel d'Importance Nationale. Bull. Tech. Suisse Rom., 1975/18, 1976/1: 17 pp.

Lachavanne, J.B., Jaquet, J.-M., Juge, R. and Perfetta, J., 1985. Zustand, Erhaltung und Schutz der Ufer des Vierwaldstätter Sees. Expert evidence. Bundesamt f. Forstwesen u. Landschaftsschutz and the Bundesamt für Umweltschutz, Berne 109 pp.

Landesbeauftragter für Naturschutz und Landschaftspflege, 1983. Veränderungen des Röhrichtbestandes der Berliner Havel 1962-1982. Inf. Berl. Landschaft, 4/12: 4 pp.

Landesbeauftragter für Naturschutz und Landschaftspflege, 1988. Veränderungen des Röhrichtbestandes der Berliner Havel 1962-1987. Inf. Berl. Landschaft, 9/31: 4 pp.

Leisler, B., 1989. Grundlagen für den Artenschutz des Drosselrohrsängers (*Acrocephalus arundinaceus*): Lebensraumansprüche und mögliche Gefährdungsursachen. Schr. reihe Bayer. Landesamt Umweltschutz.

Markstein, B., 1981. Nutzungsgeschichte und Vegetationsbestand des Berliner Havelgebietes. Landschaftsentw. Umweltforschung, 6: VI+205 pp.

Markstein, B. and Sukopp, H., 1980. Die Ufervegetation der Berliner Havel 1962-1977. Garten Landschaft, 1980: 30-36.

Melzer, A., Harlacher, R., Held, K., Stirch, R. and Vogt, E., 1986. Die Makrophytenvegetation des Chiemsees. Informationsber. Bayer. Landesamt Wasserwirtsch, Munich, 4/86: 210 pp.+appendix.

Moret, J.-L., 1978. Influence des ouvrages de protection sur les roselières de la region des Grangettes. University of Lausanne, 24 pp.

Moret, J.-L., 1979. Les Grangettes — objet naturel d'importance nationale. Les roselières lacustres. University of Lausanne, 27 pp.

Moret, J.-L., 1980. Les Grangettes: A propos de la regression des roselières lacustres. University of Lausanne, 91 pp.+appendix.

Moret, J.-L., 1981. Les Grangettes: carte des roselières lacustres 1976/77-1981, Secteur Villeneuve-Grangettes. University of Lausanne, 11 pp.+appendix.

Moret, J.-L., 1982. Evolution des roselières lacustres de la région des Grangettes entre 1976 et 1982. Bull. Soc. Vaud. Sci. Nat., 76: 185-195.

Moss, B., 1979. Alarm call for the Broads — An ecosystem out of phase. Geogr. Mag., 52: 47-49.

Moss, B., 1983. The Norfolk Broadland: experiments in the restoration of a complex wetland. Biol. Rev., 58: 521-561.

Neuhäusl, R., 1965. Vegetation der Röhrichte und der sublitoralen Magnocariceten im Wittingauer Becken. In: R. Neuhäusl, J. Moravec and Z. Neuhäuslova-Novotna (Editors), Synökologische Studien über Röhrichte, Wiesen und Auewälder. Vegetace, CSSR, A1: 13-177.

Ohle, W., 1940. Rohrverluste in unseren Seen durch Eiskegel-Bildung. Natur Volk, 70: 19-27.

O'Riordan, T., 1979. Alarm call for the Broads — Signs of disaster and policy for survival. Geogr. Mag., 52: 50-55.

Orn(ithologische) A(rbeits)G(emeinschaft) Bodensee (1983). Die Vögel des Bodenseegebietes (Avifauna Bodensee). DBV, Laudesverb. Bad. Württ. (Editor), Constance, 379 pp.

Ostendorp, W., 1989. Schilfrückgang am Bodensee-Untersee. Ursachen — Gegenmaßnahmen. Rep. Limnol. Inst., Univ. Konstanz, 770 pp. (in press).

Overdieck, D. and Raghi-Atri, F., 1976. CO_2-Netto-Assimilationsraten von *Phragmites australis*-Blättern bei unterschiedlichen Mengen an Stickstoff und Phosphor im Nährsubstrat. Angew. Bot., 50: 267-283.

Pries, E., 1984. Verlauf, Umgang und Ursachen des Röhricht-Rückganges an uckermärkischen

Seen und seine Auswirkungen auf Rohrsängerbestände. Naturschutzarbeit Mecklenburg, 27: 3-19, 72-82.

Pries, E., 1985. Allgemeine Ursachen des Röhrichtrückganges. Naturschutzarbeit Mecklenburg, 28: 69-74.

Raghi-Atri, F. and Bornkamm, R., 1979. Wachstum und chemische Zusammensetzung von Schilf (*Phragmites australis*) in Abhängigkeit von der Gewässereutrophierung. Arch. Hydrobiol., 85: 192-228.

Raghi-Atri, F. and Bornkamm, R., 1980. Über Halmfestigkeit von Schilf (*Phragmites australis*) bei unterschiedlicher Nährstoffversorgung. Arch. Hydrobiol., 90: 90-105.

Reber, U., 1979. Ökologische Untersuchungen in der Elfenau unter besonderer Berücksichtigung des Schilfrückganges. Lizenziatsarbeit Zool. Inst. Univ. Berne, 117 pp.

Richter, W.M., 1983. Veränderung der Bestände von *Phragmites australis* im Breiten Luzin bei Feldberg (Mecklenburg). Acta Hydrochim. Hydrobiol., 12: 601-607.

Ripl, W., Santoz-Perez, S. and Wöbbecke, K., 1987. Limnologische Untersuchungen zum Schilfrückgang und zur Erhaltung des Röhrichts. Rep. Inst. Ökol. TU Berlin, 79 pp.

Rodewald-Rudescu, L., 1974. Das Schilfrohr *Phragmites communis* Trin. Die Binnengewässer Vol. 27, 302 pp.

Rösch, M., 1987. Der Mensch als landschaftsprägender Faktor im westlichen Bodenseegebiet seit dem späten Atlantikum. Eiszeitalter Gegenwart, 37: 19-29.

Roulier, Chr., 1983. Contributions à l'étude phytosociologique des groupements végétaux non boisés de la rive sud du Lac de Neuchâtel. Bull. Soc. Frib. Sci. Nat., 72: 75-126.

Ruthenberg, H., 1977. Zu Veränderungen in der Vogelwelt des Naturschutzgebietes Nonnenhof. Falke, 24: 16-22.

Schanz, F., 1979. Blütenpflanzen und Algen der Seeufer. In: N.N., Der Zürichsee und seine Nachbarseen, Zürich, pp. 88-112.

Schanz, F., 1980. Die Entwicklung von Schilfbeständen am unteren Zürichsee 1979/80 an Beispielen. Vjahrsschr. Naturforsch. Ges. Zürich, 125: 393-406.

Schiess, H., 1979. Gedanken zum Naturschutz an Zürich und Obersee. Jber. Verb. Schutz Landschaftsbild Zürichsee, 52: 11-37.

Schlichtherle, H. and Bürgi, J., 1986. Gefährdete Ufersiedlungen am Bodensee. Arch. Schweiz, 9/1986: 34-41.

Schlüter, U., 1971. Lebendbau. Ingenieurbiologische Bauweisen und lebende Baustoffe. Callway, Munich, 97 pp.

Schmid, P., 1980. Landschaftswandel und Nutzungskonflikte am Greifensee-Ufer. Diplomarb. Geogr. Inst. ETH Zürich, Zürich, 80 pp.

Schröder, R., 1973. Die Freisetzung von Pflanzennährstoffen im Schilfgebiet und ihr Transport in das Freiwasser am Beispiel des Bodensee-Untersees. Arch. Hydrobiol., 71: 145-158.

Schröder, R., 1976. Der gegenwärtige Zustand der Schilfgebiete des Bodensee-Untersees. Rep. Inst. Seenforschung Fisch., Langenargen, F.R.G., 27 pp.

Schröder, R., 1979. The decline of reed swamps in Lake Constance. Symp. Biol. Hung., 19: 43-48.

Schröder, R., 1987. Schilfsterben am Bodensee-Untersee. Beobachtungen, Untersuchungen und Gegenmaßnahmen. Arch. Hydrobiol. Suppl., 76: 53-99.

Schröter, C., 1932. Die Flora des Zürichsee und seiner Ufergelände. Jahrb. Zürichsee, 1932: 87-129.

Schwilch, E., 1963. Landschaftspflegeplan Pfäffiker See. Diplomarb. Inst. Landespflege Landschaftsgestaltung TH Hannover, Hannover, 132 pp.

Siebold, G., 1983. IV. Zwischenbericht der Beratergruppe Projekt 'Havelufersanierung', Bereich Limnologie, Senatur für Stadtentwicklung und Umwelt, Berlin, 34 pp.

Siessegger, B., 1980. Bayerischer Bodensee-Uferplan. Grundsätze zum Schutz der Flachwasserzone des Bodensees. Rep. Inst. Seenforschung Fisch., Langenargen, F.R.G., 117 pp.

Siessegger, B., 1985. Flachwasserzonen des Bodensees. In: Landesanstalt für Umweltschutz Baden-Württemberg (Editor), 10 Jahre LfU, Karlsruhe, F.R.G., pp. 129-135.

Stark, H. and Dienst, M., 1989. Dynamics of lakeside reed belts at Lake Constance (Untersee) from 1984 to 1987. Aquat. Bot., 35: 63-70.

Stark, H. and Pier, A., 1987. Die aktuelle Bestandssituation des seewärtigen Schilfröhrichts am überlinger See (Kreis Konstanz) im Winter 1986/87. Report of Deutscher Bund f. Vogelschutz Konstanz (Editor), Constance, 26 pp.

Steinberg, Chr., 1977. Die Bedeutung des Röhrichts an Gewässern. Garten Landschaft, 1977/8: 498-503.

Stüssi, B., 1978. Einfluß des Bläßhuhns (*Fulica atra*) auf die Entwicklung des Schilfbestandes im Naturschutzgebiet Gwattlischenmoos. Lizenziatsarb. Ethol. Stn. University Berne, Berne, 48 pp.

Succow, M. and Reinhold, A., 1978. Das Vegetationsgefüge eines jungpleistozänen Klarwassersees und seine Belastung — eine Studie mit Hilfe von Farbluftbildern. Limnologica, 11: 355-377.

Sukopp, H., 1963. Die Ufervegetation der Havel. Expert evidence by the Senator Bau- und Wohnungswesen Berlin (Editor), Berlin, 40 pp. + appendix.

Sukopp, H., 1971. Effects of man, especially recreational activities, on littoral macrophytes. Hidrobiologia, Bucaresti, 12: 331-340.

Sukopp, H., 1973. Conservation of wetlands in Central Europe. Pol. Arch. Hydrobiol., 20: 223-228.

Sukopp, H. and Kunick, W., 1969a. Die Ufervegetation der Berliner Havel. Natur Landschaft, 44: 287-292.

Sukopp, H. and Kunick, W., 1969b. Veränderungen des Röhrichtbestandes der Berliner Havel 1962-1967. Berl. Naturschutzbl., 13/37: 303-313, 13/38: 332-344.

Sukopp, H. and Markstein, B., 1981. Veränderungen von Röhrichtbeständen und -pflanzen als Indikatoren für Gewässernutzungen, dargestellt am Beispiel der Havel in Berlin. Limnologica, 13: 459-471.

Sukopp, H., Markstein, B. and Trepl, L., 1975. Röhrichte unter intensivem Großstadteinfluß. Beitr. Naturkd. Forsch. Südwestdtschl., 34: 371-385.

Szajnowski, F., 1983. Biotic structure and processes in the lake system of R. Jorka watershed (Masurian lakeland, Poland), XI. Biomass and distribution of emergent macrophytes. Ekol. Pol., 31: 793-800.

Thomas, E.A., 1972. Schilfbestand wird Autoparkplatz der Stadt Zürich. Vjahrsschr. Naturforsch. Ges. Zürich, 117: 381-383.

Tscharntke, T., 1983. Klärteiche — Feuchtgebiete in einer ausgeräumten Kulturlandschaft. Natur Landschaft, 58: 333-337.

Utermöhl, H., 1982. Die Vernichtung von *Phragmites* durch *Cladophora* im Großen Plöner See. Arch. Hydrobiol., 95: 487-490.

Van der Toorn, J. and Mook, J.H., 1982. The influence of environmental factors and management on stands of *Phragmites australis*. II. Effects of burning. frost and insect damage on shoot density and shoot size. J. Appl. Ecol., 19: 477-499.

Weisser, P., 1973. Die Verschilfung des Neusiedler Sees. Umschau Wiss. Tech., 73: 440-441.

Westphal, D., 1980. Bestandsentwicklung und Brutbiologie des Teich- und Drosselrohrsängers (*Acrocephalus scirpaceus* und *arundinaceus*) der Berliner Havel. Ornithol. Ber. Berlin (West), 5: 3-36.

Wildi, O., 1976. Geobotanische Bestandesaufnahme der ALA-Reservate. Bericht zu den Vegetationskarten mit besonderer Berücksichtigung der Veränderungen in den letzten Jahren sowie Vorschläge für Schutz- und Pflegemaßnahmen. Expert evidence, Schweizerische Gesellschaft Vogelkunde Vogelschutz, 143 pp.

Wium-Andersen, S., 1974. Quantitative changes in the higher vegetation in Lake Bastrup Sø caused by eutrophication. Bot. Tidsskr., 69: 64-68.

Yamasaki, S., 1984. Role of plant aeration in zonation of *Zizania latifolia* and *Phragmites australis*. Aquat. Bot., 18: 287-297.

Zwicker, E. and Grüll, A., 1985. Zu den räumlich-zeitlichen Beziehungen zwischen Schilfvögeln und ihrem Lebensraum. Teil I. Wiss. Arb. Burgenland, 72: 411-445.